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LIQUID AND GASEOUS OXYGEN SAFETY REVIEW

FINAL REPORT

Vol. IV

JUNE 1972

A. LAPIN
AIR PRODUCTS AND CHEMICALS, INC.
ALLENTOWN, PENNSYLVANIA 18105

Prepared for

AEROSPACE SAFETY RESEARCH AND DATA INSTITUTE
LEWIS RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CLEVELAND, OHIO 44135

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Paul M. Ordin, Program Manager

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16. Abstract

A thorough and detailed study of Air Products and Chemicals, Inc. and Air Products Ltd. practices in the design and use of equipment in oxygen service, was performed. The report includes Liquid and Gaseous Oxygen Safety Review information covering: Material Compatibility, Operational Hazards, Maintenance Programs, Systems Emergencies, and Accident/Incident Investigations and Reports, and a set of references. Areas requiring further research and development for systems involving exposure to oxygen environment have been identified. An index to the Liquid and Gaseous Safety Review Data Forms and a General Index have been included to allow for easy retrieval of the reported information.

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Air Products and Chemicals INC.

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SAFETY – GRAM

Air Products and Chemicals INC.

May 14, 1962
Number 11

Safety Shoes

The following was extracted from the National Safety Council's publication, "Industrial Supervisor."

"My talk today is aimed at the fellows who have never had a bad foot injury. Anyone who has had one knows very well that he wants no more of the same. It's bad enough to smash a toe. That combines the pain of broken bones and bruised flesh. Probably few people realize how important toes are in walking or even in just standing. Anyone who loses a toe or two, particularly a big toe, finds out that it makes a whale of a difference. That foot just doesn't do as good a job. It's more likely to slip or stumble. It tires more quickly--its shoe doesn't fit so well--its spring is gone. The really bad foot injuries are those where the arch is broken. The bones may be broken or the ligaments that hold them in place may be torn, or both. That kind of thing is terribly painful, and a cure comes hard. Nature used a lot of bones and ligaments and muscles in making the human foot. They are all fitted together just so. When that arch is smashed, even the most highly skilled surgeon has a tough job to put the pieces back together so it will work at all. Sometimes he can't. Then the question is: "Shall I drag through life with a practically useless foot, or would a peg foot be better"?"

Why do so many fellows take chances with their feet? There's no way of telling how many do, but it seems like it must be nearly everybody who works--there are so many foot injuries. In 1955, over two hundred thousand workers were temporarily or permanently disabled by foot and toe injuries. Those were only the guys who didn't get away with the chances they took. Some of you may call me on my saying that <u>all</u> those fellows took chances. You'd be right, but only for a very few cases. Except for a few rare happenings, the fellows who got hurt could have avoided it--and very simply. They could have avoided foot injuries mostly by the proper attitude of mind--one might call it safety mindedness aimed at the feet.

What would a workman with that attitude of mind do? First of all, he'd take care that his shoes fit well. He'd wear only good solid shoes, and he'd keep them in good condition. No badly worn soles, no run down heels. He'd have rubber heels, of course. They cushion the jolt of fast walking on hard floors. Next he'd study the foot hazards of his job. What could fall on his feet, and where? On what job might a fumble allow something to drop on his feet? On what work might he get a foot caught under something, for example, in using a pry bar or crow bar? Any chance of having a foot run over by a hand or power truck? The list is almost endless. The point is that almost any job in or about almost every plant, offers some hazard to feet. A foot-safety-minded person would look for these hazards.

Then what would he do? You know the answer as well as I do. He'd go to safety shoes. He'd not wear any other kind on the job. And since safety shoes that fit just as well and look just as good as the unsafe kind are available, he'd wear them all the time, everywhere. Well, not quite--he'd have another pair for dancing and church, and still another kind for bowling. But you get my point. Safety shoes would be standard with him. Some guys are full of excuses for not wearing safety shoes. They surely throw some sour ones. Probably the sourest is to be afraid of that steel toe cap--that it might get smashed down onto their toes. The answer to that one is that anything heavy enough to do that would smash those toes to a pulp except for the toe cap. It's a great toe saver. Anyway, "the proof of the pudding is in the eating." The record books prove that the men who wear safety shoes have practically no foot injuries.

Wear foot protection and keep <u>your</u> feet safe.

This item should be discussed at safety meetings, then posted on the bulletin board. APCI contributes $2 toward the purchase of safety shoes for employees. It is urged that employees take advantage of our safety shoe program.

RESPIRATORY PROTECTIVE EQUIPMENT

1. PURPOSE

This standard establishes the criteria for the selection and purchase of approved respiratory protective equipment.

2. SCOPE

This standard applies at all APCI facilities unless otherwise specified in the facility safety equipment list.

3. GENERAL

Air Products and Chemicals, Inc. activities involve a great many areas where respiratory hazards are present or potentially present; in order to protect personnel from these hazards various forms of respiratory protective equipment are needed. A basis for all respiratory protection is the U. S. Bureau of Mines, and all equipment purchased must meet their specifications.

The following is a guide of respiratory hazards which require protective equipment; they may occur singly or in any combination:

A. NUISANCE DUSTS - Generated by handling materials such as coal, ashes, feed, flour, cement, sawdust, etc., are neither poisonous nor capable of producing fibrous tissue in the lungs, yet are discomforting nuisances to be avoided. They may become dangerous if associated with colds, bronchitis, pneumonia or tuberculosis.

B. PNEUMOCONIOSIS, PRODUCING DUSTS AND MISTS - These convert and degenerate healthy spongy lung tissue into useless fibrous or scar tissue. Silicosis is the commonest type of this disease, caused by mineral dusts and mists containing free silica (sandstone, flint, quartz, chert, or agate). Asbestoses is a related disease from asbestos dusts (serpentine, chrysotile.)

C. TOXIC DUSTS - These are body poisoning dusts originating in the handling of inherently poisonous materials such as lead, arsenic chromium, mercury, or their compounds. Whether inhaled through the nose and lungs or ingested through the mouth and stomach, these dusts dissolve and enter the blood stream to produce injury to many of the organs of the body.

D. MISTS - Mists are wet fog-like oil or water droplets containing toxic or lung damaging particles suspended in them. They may be formed in the process of spray coating with paints, viterous enamels, and glazes. A common and particularly harmful type is chromic acid mist produced by the escaping gas bubbles in chromium plating baths.

Air Products ...INCORPORATED	Originated By: H. W. Smith	Approved: Safety Director W. L. Ball	Date January, 1964

3. GENERAL (Cont'd)

E. METALLIC FUMES OR SMOKES - These are solid particles much finer than dust particles, usually generated by smouldering hot metals or salts, encountered in smelting, refining, welding and similar operations. They are difficult to retain with filters. Fumes should not be confused with true vapors, which are at times misnamed chemical fumes.

F. GAS AND VAPORS - These are molecular particles like those of the air itself. They are about a thousand times smaller than dust, fume and mist particles. They pass through even the best dust or metallic fume filters as easily as the air itself. Therefore, they must be removed by an entirely different mechanism: by surface reaction with specially activated chemicals in the cartridge or canister beds.

4. GUIDE TO RESPIRATORY PROTECTIVE EQUIPMENT

General Classification of Respiratory Protective Devices	Atmosphere in Working Area Contains Normal Concentration of Oxygen (21%)			Less Than Normal Oxygen
	Disperseroid Dust, Fume, and Mist	Gas or Vapor Concentration by Volume		Any Concentration of any Contaminate
	(Quantity Not Critical)	No Greater Than 0.1%	No Greater Than 2%	
Filter Type Respirator (Dust, Fume and Mist)	X			
Chemical Cartridge Type Respirator		X		
Airline Respirator	X	X		
Hose Mask With Electrical Blower	X	X		
Gas Masks		X	X	
Hose Mask Without Blower	O	X	X	X
Hose Mask With Hand-Operated Blower	O	X	X	X
Self-contained Breathing Apparatus	O	X	X	X

X = Safe to use in atmosphere indicated
O = Safe to use but usually not practical

Air Products Incorporated	Originated By: H. W. Smith	Approved: Safety Director W. L. Ball	Date January, 1964

5. FILTER TYPE SELECTOR TABLE - DUST, MIST AND FUME HAZARDS

These units may be either the single or double type, and are to be used in areas where the hazard is moderate and where the prolonged use of the filter mask will not inhibit the users ability to work safely. It must be noted that these filters do not protect against gases, vapors or oxygen deficiency. If in doubt, a self-contained breathing unit should be used.

SYMBOL	CONTAMINANT
N	Nuisance Dust
A	Alkaline Dust
M	Mist
S	Silica Dust
T	Toxic Dust
F	Solid or Liquid Fume
R	Radioactive or Very Toxic

HAZARD	TYPE
Alkalies	A
Aluminum Powder	N
Alundum (alumina)	N
Ammonium Dichromate	T
Antimony Dusts	T
Arsenic Dusts	T
Asbestos	S
Ashes	N
Barium Dusts	T
Barium Peroxide	T
Beryllium Dusts	R
Borax and Boric Acid	N
Brass Dust	N
Brass (zinc) Fumes	F
Brick Dust	N
Cadmium Dusts	T
Cadmium Fumes	F
Calcium Carbide	N
Carborundum	N
Caustic Potash	A

HAZARD	TYPE
Caustic Soda	A
Cellulose (cotton, wood)	N
Cement and Concrete	S
Charcoal (carbon)	N
Chrome Pigments	T
Chromic Acid (mist)	M
Chromium Dusts	T
Clay (kaolin)	N
Coal and Coke	N
Cobalt Dusts	T
Copper Dusts	N
Cotton Lint	N
Derris Powders	T
Diethylene Glycol	M
Drug and Dye Powders	T
Emery Paper Dusts	N
Fertilizers	N
Ferrous Metals	N
Fiberglass	N
Fire Brick	S

RESPIRATORY PROTECTIVE EQUIPMENT

5. FILTER TYPE SELECTOR TABLE - DUST, MIST AND FUME HAZARDS (Cont'd)

HAZARD	TYPE	HAZARD	TYPE
Flint	S	Rosin	N
Flour	N	Rotenone Powders	T
Fluorides	T	Rubber Dust	N
Foundry Dust	S	Salt	N
Grain Dust	N	Sandpaper	S
Granite	S	Sawdust	N
Graphite	N	Selenium Dusts	T
Grinding Wheel Dusts	S	Shellac	N
Gypsum	N	Silica and Silacates	S
Iron Dusts	N	Slate and Shale	S
Iron Oxide Fumes	F	Soap Powders	N
Lead Dusts	T	Soapstone	S
Lead Azide	T	Soda Ash	N
Lead Fumes	F	Sodium Chlorate	N
Leather Dust	N	Sodium Dichromate	T
Lime	A	Sodium Floride	T
Limestone and Marble	N	Sodium Metal	A
Lint	N	Soot	N
Magnesium Dusts	N	Sulfuric Acid Mist	M
Manganese Dusts	T	Talc (crude)	S
Mercury Dusts	T	Tellurium Dusts	T
Metallic Fumes	F	Tetyrl	T
Mica (crude)	S	Thallium Dusts	T
Nickel Dusts	N	Tin Fumes (metallic)	F
Oxalic Acid	T	Tin Dusts	N
Perchloric Acid Mist	M	Trinitrotoluene	N
Phosphoric Anhydride	M	Tungsten Carbide	T
Phosphorus	T	Uranium Dusts	R
Picric Acid	T	Vanadium Dusts	R
Plastics Dust	N	Welding Fumes	F
Portland Cement	S	Wood Dust	N
Potassium Dichromate	T	Wool Lint	N
Pyrethrum	T	Zinc Dusts	N
Quartz	S	Zinc Fumes	F
Rock Wool	N	Zirconium Dusts	N

NOTE: Filters do not protect against gases, vapors or oxygen deficiency.

Air Products Incorporated	Originated By: H. W. Smith	Approved: Safety Director W. L. Ball	Date January, 1964

5. FILTER TYPE SELECTOR TABLE - DUST, MIST AND FUME HAZARDS (Cont'd)

   A. Approved manufacturers for U. S. Bureau of Mines Approved Respirators

      (1) Willson Products Company

      (2) Mine Safety Appliances Company

      (3) Acme Protection Equipment Company

   B. Approved vendors for respiratory equipment

      (1) Industrial Products Company
      2820 N. 4th Street
      Philadelphia 33, Pa.

      (2) Mine Safety Appliances Company
      201 N. Braddock Avenue
      Pittsburgh 8, Pa.

6. CARTRIDGE TYPE SELECTOR TABLE - GAS AND VAPOR HAZARDS

These respirators are the non-emergency type, and afford protection where there is danger of chronic poisoning after repeated or prolonged exposure to the following gas and vapor hazards. All respirators will be of the dual canister or cartridge type meeting the U. S. Bureau of Mines approval. These respirators are not a substitute for gas masks, airline respirators or local exhaust systems; and must not be used in vapor-concentrations in excess of 0.1% by volume. Should there be the slightest doubt as to the concentration, a gas mask or self-contained breathing unit should be used.

SYMBOL	CONTAMINANT
A	Acid Gases
B	Ammonia
C	Organic Vapors
D	Organic Vapors and Acid Gases
M	Mercury

RESPIRATORY PROTECTIVE EQUIPMENT

6. CARTRIDGE TYPE SELECTOR TABLE - GAS AND VAPOR HAZARDS (Cont'd)

HAZARD	TYPE
Acetaldehyde	C
Acetate Solvents	C
Acetic Acid	D
Acetic Anhydride	D
Acetone	C
Acid Gases	A
Alcohols	C
Aldehydes	C
Alkyl Mercaptans	D
Ammonia	B
Amyl Acetate	C
Aniline	C
Benzine (pet. naphtha)	C
Benzol (benzene)	C
Butadiene	C
Butyl Acetate	C
Butyl Alcohol (butanol)	C
Butyl p-amino phenol	C
Carbon Disulfide	C
Carbon Tetrachloride	C
Chlorex	C
Chlorinated Hydrocarbons	C
Chlorobenzene	C
Chloroform	C
Chlorosulfonic Acid	A
Cleaning Solvents	C
Cresol	C
Cumene	C
Dichloroethyl Ether	C
Dichlorobenzine	C
Dioxane	C
Epichlorohydrin	C
Esters	C
Ethers	C
Ethyl Acetate	C

HAZARD	TYPE
Ethyl Chloride	C
Ethyl Ether	C
Ethylene Dichloride	C
Ethylene Oxide	C
Formaldehyde	C
Furfural	C
Gasoline	C
Hydrochloric Acid	A
Hydrogen Chloride	A
Mercury Metal	M
Methyl Alcohol (methanol)	C
Methyl Bromide	C
Methyl Chloroform (trichloroethane)	C
Napthalene	C
Naptha (petroleum)	C
Nitrobenzene	C
Nitroparaffins	C
Organic vapors-acid gases	D
Paint, thinners, solvents	C
Paraformaldehyde	C
Perchloroethylene	C
Petroleum Vapors	C
Phenol	C
Pyridine	C
Styrene (monomer)	C
Sulfur Dioxide	A
Sulfur Trioxide	A
Tar Fumes and Vapors	C
Tetrachloroethylene	C
Tetrachloroethane	C
Thiophene	C
Toluene (toluol)	C
Trichloroethylene	C
Turpentine	C
Vinyl Chloride	C
Xylene (xylol)	C

6. CARTRIDGE TYPE SELECTOR TABLE - GAS AND VAPOR HAZARDS (Cont'd)

A. Approved manufactureres for U. S. Bureau of Mines Approved Respirators

(1) Willson Products Company

(2) Mine Safety Appliances Company

(3) Acme Protection Equipment Company

B. Approved vendors for respiratory equipment

(1) Industrial Products Company
2820 N. 4th Street
Philadelphia 33, Pa.

(2) Mine Safety Appliances Company
201 N. Braddock Avenue
Pittsburgh 8, Pa.

7. CANISTER-TYPE GAS MASKS

Canister type gas masks are to be used only in atmospheres where the oxygen content is known to be 18% or over. Canister gas masks do not replace the oxygen content in a confined area, they are designed specifically for protection against irritants and contamination which might cause body harm, but in areas or environments in which the oxygen content of the contaminated air is NOT below safe oxygen (18%) limits.

Should limits of oxygen content not be met, a supplied air respirator or a self-contained breathing apparatus should be used. At all times follow the safe operating recommendations supplied with the mask; make sure that the masks fit the users, and that personnel are trained in their use.

All gas masks should be included on a monthly maintenance program, the canisters should be replaced after each use and after one year storage time. Each mask must be inspected for cracks, holes and breaks and be cleaned with an approved cleaning solution as perscribed by the mask manufacturer.

RESPIRATORY PROTECTIVE EQUIPMENT

7. CANISTER-TYPE GAS MASKS (Cont'd)

CANISTER SELECTION GUIDE FOR GAS MASKS

SYMBOL	DESCRIPTION
N	All Purpose
FD	All Purpose
AG	Acid Gas
AMN	Ammonia (amonite)
AGAM	Acid Gases and Ammonia
AMS	Ammonia (silica gel)
CL	Chlorine
CYN	Cyanogen Chloride
HCN	Hydrocyanic Acid and Cyanogen Chloride
HCNCC	Hydrocyanic Acid and Cyanogen Chloride
HCNPS	Hydrocyanic Acid and Chloropicrin
Hg	Mercury Vapor
M	Military
OV	Organic Vapors
OVAG	Organic Vapors and Acid Gases
OAAM	Organic Vapors, Acid Gases and Ammonia

NOTE: The canister column shows an "F" where a toxic smoke or dust filter is required in a canister for proper protection,

"OV" where a chemical for absorbing organic vapor is required,

"AG" where a chemical for absorbing an acid gas is required,

"AM" where a chemical for absorbing ammonia is required,

"Hg" where a chemical for absorbing mercury vapor is required,

"FD" where all-purpose gas and toxic smoke or dust protection is required,

"N" where all-purpose gas protection only is required,

"CL" and "HCN" where a special canister is available.

7. CANISTER-TYPE GAS MASKS (Cont'd)

NAME	CANISTER	NAME	CANISTER
A B H	OV-F	Barium	F
Acetaldehyde	OV	Benzine	OV
Acetic Acid	OV	Benzol	OV
Acetic Anhydride	OV	Benzonitrile	OVAG
Acetone	OV	Benzoyl Cyanide	OVAG
Acetonitrile	OVAG	Benzylamine	OV
Acetylene	OV	Benzyl Chloride	OV-F
Acid Gases	AG	Beta Borane	FD-N
Acridine	OV-F	Boron Fluoride	FD-N
Acrolein	OV	Boron Hydride	FD-N
Acrylaldehyde	OV	Bromoacetylene	OVAG
Acrylonitrile	OVAG-FD-N	Bromine	OVAG
Alcohols	OV	Bromobenzine (mono)	OV
Aldehydes	OV	Butadiene	OV
Aldrin	OV-F	Butaldehyde	OV
Allyl Cyanide	OVAG-FD-N	N-Butanol	OV
Alkyl Isocyanide	OVAG-FD-N	Butane	OV
Allethrin	F-non-toxic	Butanone	OV
Allyl Chloride	OV	Butoxethanol	OV
Allylene	OV	N-Butyl Acetate	OV
Alundum	F	Butyl Alcohol	OV
Amines	OV	Butyl Cellosolve	OV
Ammonia	AM	Butylene	OV
Amyl Acetate	OV	Butyl Nitrite	OVAG
Amyl Alcohol	OV	Cacodyl	OVAG
Amylene	OV	Cadmimum	F
Amyl Nitrite	OV	Camphor	OV
Aniline	OV	Captan	OV
Antimony	F	Carbon Dioxide	AG
Antimony Hydride	N-FD	Carbon Monoxide	FD-N
Arsenic	F-OVAG-FD	Carbon Disulfide	OVAG-OV
Arsenic Fluride	N-FD	Carbon Oxychloride	FD-N-OVAG
Arsenic Trichloride	N-FD-OVAG	Carbon Oxysulfide	FD-N
Arsine	N-FD	Carbon Suboxide	FD-N
Asbestos	F	Carbon Tetrachloride	OV

RESPIRATORY PROTECTIVE EQUIPMENT

7. CANISTER-TYPE GAS MASKS (Cont'd)

NAME	CANISTER	NAME	CANISTER
Cellosolve	OV	Dichloromonofluoromethane	OV
Centonylene	OV	Dichloronitroethane	OV
Chloroacetylene	OV	Dicloropropane	OV
Chlorine	OVAG-CL	Dichlorotetrafluoroethane	OV
Chlorine Dioxide	OVAG-N-FD	Diethylamine	FD-N
Chlorine Monoxide	OVAG	Dimethylamine	OV
Chloroacetone	OVAG	Dimethyl Ether	OV
Chlorobenzene	OV	Dioxane	OV
Chlorobutadiene	OV	Ethane	OV
Chloroform	OV	Ether	OV
Chloronitropropane	OV	Ethyl Acetate	OV
Chloropicrin	OVAG-OV	Ethyl Alcohol	OV
Chlorotoluene	OV	Ethyl Benzene	OV
Chromic Acid	F-AG-F	Ethyl Bromide	OV
Collodion	OV	Ethyl Chloride	OV
Cresol	OV	Ethylene	OV
Cyanide	FD-OVAG-F	Ethylene Oxide	OV
Cyanogen	FD-N-OVAG	Ethyl Ether	OV
Cyanogen Bromide	OVAG	Ethyl Iodide	OV
Cyanogen Chloride	OVAG	Ethyl Nitrate	OV
Cyclohexane	OV	Ethyl Nitrite	OV
Cyclohexanol	OV	Ethyl Silicate	OV-F
Cyclohexene	OV	Formaldehyde	OV
Cyclopropane	OV	Formic Acid	OV
Decane	OV	Freon	OV
D D T	OVAG-F	Furfural	OV
Diacetylene	OV	Gasoline Vapors	OV
Diborane	N-FD	Heptane	OV
Dibromomethane	OV	Heptylene	OV
Dichlorobenzene	OV	Hexane	OV
Dichlorodifluoromethane	OV	Hexylene	OV
Dichloroethane	OV	Hydrazine	AM
Dichloroethylene	OV	Hydriodic Acid	AG
Dichloroethyl Ether	OV	Hydrobromic Acid	AG
Dichloromethane	OV	Hydrochloric Acid	OVAG

7. CANISTER-TYPE GAS MASKS (Cont'd)

NAME	CANISTER
Hydrocyanic Acid	HCN
Hydrofluoric Acid	AG
Hydrogen Cyanide	HCN
Hydrogen Sulphide	FD-N
Iodine	OVAG
Iron Oxide Fumes	F
Isobutane	OV
Isophorone	OV
Isopropyl Ether	OV
Ketene	OV
Ketone	OV
Lacquer	OV-F
Lead Tetraethyl	OV-OV-F
Magnesium Oxide Fumes	F
Manganese	F
Mercury	Hg
Methanol	OV
Methyl Alcohol	OV
Methyl Bromide	OV
Methyl Chloride	OV
Methyl Ether	OV
Methyl Nitrite	OV
Muriatic Acid	AG
Naphtha	OV
Nitric Acid	AG
Nitrobenzene	OV
Nitrogen Dioxide	FD-N
Nitromethane	OV
Nitropropane	OV
Nitrous Oxide	FD-N
Octane	OV
Ozone	OV
Paint-lead	OV-F
Pentaborane	N-FD
Pentane	OV

NAME	CANISTER
Perchloroethylene	OV
Phenol	OV
Phosgene	FD-N
Phosphorus	OVAG-F-FD
Propane	OV
Propyl Alcohol	OV
Propylene	OV
Propyl Ether	OV
Pyridine	OV
Rochelle Salt	OV-F
Selenium	F
Silica Dusts	F
Soapstone	F
Stibine	FD
Stoddard Solvent	OV
Sulphur Chloride	OVAG
Sulphur Dichloride	OVAG
Sulphur Dioxide	AG
Sulphuric Acid	AG-F
Sulphur Trioxide	AG-F-FD
Talc Dust	F
Tar	OV
Teflon	OV-F
Tetraborane	FD-N
Tetrachloroethane	OV
1, 1, 2, 2, Tetrachloroethane	OV
Tetrachloromethane	OV
Toluene	OV
Tribromomethane	OVAG
Trichloroethylene	OV
Turpentine	OV
Uranium (unsoluble)	F
Uranium (soluble)	OVAG-F
Vinyl Chloride	OV
Xylene	OV
Xylol	OV
Zinc Oxide Fumes	F

Air Products ...INCORPORATED	Originated By: H. W. Smith	Approved: Safety Director W. L. Ball	Date January, 1964

RESPIRATORY PROTECTIVE EQUIPMENT

7. CANISTER-TYPE GAS MASKS (Cont'd)

A. Approved manufacturerers for U. S. Bureau of Mines Approved Gas Masks.

(1) Willson Products Company

(2) Mine Safety Appliances Company

(3) Acme Protection Equipment Company

B. Approved vendors for gas mask equipment

(1) Industrial Products Company
2820 N. 4th Street
Philadelphia 33, Penna.

(2) Mine Safety Appliances Company
201 N. Braddock Avenue
Pittsburgh 8, Penna.

8. AIRLINE RESPIRATORS

The U. S. Bureau of Mines has approved the use of supplied air respirators for respiratory protection in any atmosphere not immediately harmful to life, or from which the wearer can escape without the aid of a respirator.

Air line respirators, abrasive blasting helmets and supplied air hoods are termed supplied air equipment, since a source of compressed air is used to supply the wearer with the air he needs for breathing. It is important that the wearer receive clean dry air; this may be accomplished by either filtered plant compressed air systems, or from cylinders.

This equipment should be operated at a mask pressure up to 26 psi, be equipped with an air release valve which will release at 26 psi, and be equipped with a constant flow filter.

A. Approved manufacturers of airline respiratory equipment.

(1) Willson Products Company

(2) Mine Safety Appliances Company

(3) Acme Protection Equipment Company

8. AIRLINE RESPIRATORS (Cont'd)

B. Approved vendors for airline respiratory equipment.

(1) Industrial Products Company
2820 N. 4th Street
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Pittsburgh 8, Pa.

9. SELF-CONTAINED BREATHING APPARATUS

Self-contained breathing units may be worn under any conditions which warrant protection from dusts, vapors, fumes and oxygen deficient atmospheres. These units should be available for rescue, quick entry, work and escape. Selection of the proper unit will depend on the areas of use and the time element involved. At least one extra cylinder should be provided for each unit provided for the facility.

APCI has standardized on both the Scott and Surviv-Air self-contained breathing apparatus; a summary of these units is as follows:

MODEL	WEIGHT LBS.	BREATHING TIME UNDER WORKING CONDITIONS	REMARKS
Scott - 6000-B4A Air Pak	19 1/2	15 Min.	Not U. S. Bureau of Mines Approved
Scott - 6000-A2MS Air Pak	30	30 Min.	U. S. Bureau of Mines Approved
Surviv-Air - 9009-20	8	7 to 10 Min.	Not U. S. Bureau of Mines Approved
Surviv-Air - 9030	25	30 Min.	U. S. Bureau of Mines Approved

NOTE: 1. All Scott Air-Pak's will be equipped with a Scott Low Pressure Alarm Unit. This alarm unit must be specified when ordering.

2. All Surviv-Air Units must be ordered with a case. This case must be specified when ordering.

3. Compressed Air Only will be used for self-contained breathing units. Under no conditions will oxygen be substituted for compressed air.

RESPIRATORY PROTECTIVE EQUIPMENT

9. SELF-CONTAINED BREATHING APPARATUS (Cont'd)

A. Approved manufacturers

(1) Scott Aviation Corp.

(2) Surviv-Air Corp.

B. Approved Vendors

(1) Scott - Southern Oxygen Company
Division of Air Products and Chemicals, Inc.
P.O. Box 5087
Washington 19, D. C.

(2) Surviv-Air - Industrial Products Company
2820 N. 4th Street
Philadelphia 33, Penna.

Air Products ...INCORPORATED	Originated By: H. W. Smith	Approved: Safety Director W. L. Ball	Date January, 1964

Occupational Noise Protective Equipment

1. PURPOSE

This standard establishes the criteria for the selection of personal protective occupational noise suppresant equipment for use in high noise areas.

2. SCOPE

This standard applies to all APCI facilities where there is a need for protection from high levels of occupational noise.

3. GENERAL

The following approved safety equipment shall be provided and used in areas where the occupational noise level exceeds 90 decibels as measured on the "A" scale of a standard sound level meter at slow response, regardless of octave band.

4. NOISE PROTECTION EQUIPMENT

TYPE	MANUFACTURER	PART NUMBER	DECIBEL RANGE OF USE
Ear Plug	Willson Products Co.	EP-100	90 to 110
Ear Plug	H.E. Douglass Eng. Co.	5000	90 to 110
Ear Muff	Willson Products Co.	155-A	110 to 130

Note 1.) - Due to differences in ear structure, some persons may not be able to be fitted with ear plugs. These persons shall be provided with, and use, the 155-A Ear Muff.

Note 2.) - There may be occassions where the decibel level may exceed 130. For these exposures both the EP-100 ear plug and the 155-A ear muff shall be provided and used.

Note 3.) - All of the above safety equipment may be worn with a hard hat or cap without modification.

5. SUPPLIER

All ear protection equipment is being stocked by the Spare Parts Department, and is to be ordered by requisition. The address is as follows:

Air Products and Chemicals, Inc.
Post Office Box 482
Allentown, Pennsylvania, 18105
Attention: Spare Parts Department

Air Products and Chemicals INC.   PUT IT IN WRITING

Date April 7, 1971

To M. H. Halsted Subject Operations Hearing Protection Program

From H. H. Master

cc: W. L. Ball W. J. Scharle
A. W. Mellen H. E. Wynn

Operations Department has been supplying hearing protection equipment as needed or requested for a number of years. Wearing was more or less voluntary and was recommended where believed essential. As equipment sizes increased, the wearing of protection was more necessary, and the program was broadened. With the advent of the Walsh Healy Act and industrial and public awareness of environmental deterioration, the Operations Department program was broadened further and accelerated.

In April, 1970, at your direction, the writer visited Geismar, Lone Star, Los Angeles, and Wharton plants. H. Smith accompanied me to all locations excepting Los Angeles. Sound level surveys were made at each location and safety meetings were held with employees. The Geismar and Los Angeles plants were picked because they were essentially new facilities and initial employee training is instrumental in attaining good compliance. Lone Star was picked because general attitude of employees is good, and Wharton was included as noise levels are high there due to indoor installation of large machinery.

Employee acceptance at test plants was good, and it was decided to proceed with coverage on all plants. Since that time, A. L. Hatley and the writer have had safety meetings at plants in conjunction with other reasons for visiting their locations. 15 of 23 major locations have been covered (see attachment). Nitrogen plants have not been included, primarily because there is no apparent problem. Allentown, Western Electric facility, was surveyed as a typical location, and there was a high reading of 93 dB (A) but at only one spot in the area. All other spots were 89 or less.

Safety meeting material outline included:

1. Reasons for concern - increased public and industrial noises.

2. Sound measurement - explanation of decibel - examples of various levels (whisper, talking, discotheques, average auto, jet plane, etc.)

3. Walsh Healy Act exposure limitations without hearing protection.

4. Parts of the ear and their function - how noise affects them - what can be done if damaged.

5. Plant sound levels - where protection should be worn - limitations of ear plugs and ear muffs.

Air Products and Chemicals INC. PUT IT IN WRITING

Date April 7, 1971

To M. H. Halsted

Subject Operations Hearing Protection Program

From H. H. Master

Since the Company had no compulsory rules on this area, compliance was suggested by "we want you" or "you should" wear hearing protection. The attachment outlines facilities which have had meetings and surveys, and the compliance column rates employee observance of wearing protective equipment as observed by the writer or reported by plant management or A. L. Hatley. Compliance here is based on our instructions to have them wear protection at any location over 90 decibels regardless of the time in the area. Walsh Healy specifies 90 decibels limit for eight hour exposures. It was thought best to have them wear protection at all times in these areas (with the possible exception of pass-through) as no one keeps track of his time and the probability of the future limit being lowered to 85 dB (A) is very likely. Generally, ear plugs are satisfactory, but ear muffs are recommended for venting, defrost and recycling as it is very likely noise levels reach 110 decibels for these operations.

There are a number of complaints against standard ear plugs. Through Safety Department, the writer acquired G.E. Peacekeeper kits which are a silicone rubber material molded to the individual's ear. H. Smith had been checked out on making these plugs and he, in turn, taught the writer. After cleaning and lubricating the ear with mineral oil on cotton swabs, the base material is mixed with a catalyst. It is then worked into the subject's ear and left to set for 20 minutes after which time he has a set of ear plugs custom-made for his ear. The writer has made about 80 sets for employees at Los Angeles, Delaware City, Sparrows Point, Cleveland, Lathrop, and Middletown and general acceptance is good. Only H. Smith and the writer are permitted to make these plugs at this time as we do not want anybody and everybody to do this work on employees' ears.

Operations has had the foresight to educate their employees in this matter. 65% of the major facilities have been covered hoping to get a voluntary compliance. The Safety Standard has now been issued and we will expedite meetings at the remaining locations.

ORIGINAL SIGNED BY

H. H. Master

HHM/lmg
Attachment

Retyped 9/27/72 krs

SUMMARY
OPERATIONS HEARING PROTECTION PROGRAM

Facility	Meetings Attended By	High Reading dB (A)	Compliance
Ashland			
Birmingham	A. Hatley	93	
Burns Harbor	H. Master	109	Good
Butler			
Cleveland	H. Master	103	Fair
Creighton		111.5	
Decatur	A. Hatley	94	Excellent
Delaware City	H. Master	104	Good
Geismar	H. Master H. Smith	114**	Very good
Granite City*	W. Schmoyer E. Sheasby	106	
LaPorte	A. Hatley	97	Good
Lathrop	H. Master	99	
Leechbury			
Lone Star	H. Master H. Smith	106	Excellent
Los Angeles	H. Master	106	Poor
Middletown	H. Master	112	
New Martinsville			
New Orleans	A. Hatley	105	Fair
Pittsburgh		99	
Puerto Rico	H. Master	109	Good
Sparrows Point	H. Master	106	Very good
Weirton		107	
Wharton	H. Master H. Smith	102	Very good

* Impromtu meeting held during visit here when employees and union raised questions. Another meeting would be in order and is planned.

** Mufflers have been added here and new data will be obtained.

OCCUPATIONAL NOISE

1. PURPOSE

This standard establishes the responsibility and describes the procedure to identify and reduce, to acceptable limits, problems concerning industrial noise.

2. SCOPE

This standard applies to all APCI facilities.

3. OBJECTIVE

Revision of the safety and health regulations applicable under federal regulations requires that protection be provided against the effect of excessive noise. The regulations require that feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels below certain prescribed maxima, "Personal Protective Equipment shall be provided and used." In order to provide a uniform program which is compatible with these regulations, the following procedures will be required:

A. Evaluation of APCI facilities for noise exposures, utilizing accepted methods and equipment.

B. Comparison of noise exposure data to noise criteria for identifying noise hazards.

C. The introduction of a hearing conservation program, where necessary, incorporating the following:

(1) Control and reduce noise by engineering methods whereever possible and practical.

(2) Provide personal protective equipment for employees in those areas where noise control is not possible or practical under C (1) above.

4. RESPONSIBILITY

A. The facility manager is responsible for ensuring that all employees under his supervision are protected against the effects of industrial noise as outlined in this standard. It is thus his responsibility to institute plant surveys, institute programs to reduce noise wherever possible, and to require the wearing of protective equipment where noise levels exceed the criteria.

B. The Engineering Department shall be responsible for including in the specifications for all new equipment, a requirement for keeping noise reduced to a level consistent with personal safety and good design.

OCCUPATIONAL NOISE

5. PROCEDURE

A. General Requirements

The maximum steady noise level that an employee shall be exposed to for an 8-hour work day is 90 dB (A). If the noise level exceeds 90 dB (A), the steps listed below shall be taken:

(1) The noise shall be reduced by engineering methods wherever possible or practical.

(2) Where adequate noise reduction is not possible by engineering methods, personal protective equipment as set forth in Safety Standard 627.4.8 shall be provided.

Note 1: Exposure to impulsive or impact noise shall not exceed 120 peak dB (A) Sound Pressure level.

B. Plant Surveys

Noise surveys shall be made of all facilities where industrial noise appears to exceed the criteria. Assistance in making the survey can be obtained from:

(1) Corporate Safety Department,

(2) Workmens Compensation liability insurance carrier, or

(3) A qualified representative of the division involved.

Surveys will be entered on standard equipment arrangement drawings and shall be held as a matter of record in the Corporate Safety Department office. Each instrument shall be calibrated prior to each survey. The calibration method and date shall become part of the survey.

C. Plant Resurveys

Plant resurveys shall be performed whenever a change in the facility's equipment has been made. A request for a resurvey may be made by the facility manager or the Corporate Safety Department at any time.

D. Noise Evaluation Equipment

Noise surveys shall be conducted using a General Radio sound survey meter type No. 1565-A or type No. 1555-A calibrated to the "A" scale at slow response. Only in special cases shall readings be obtained using various octave bands.

OCCUPATIONAL NOISE

E. Personal Protective Equipment

Acceptable personal protective equipment is described in Safey Standard 627.4.8.

F. Definitions

Audiogram - A graph showing hearing loss as a function of frequency.

Audiometer - The instrument for measuring hearing sensitivity.

Decibel - The decibel (dB) is the common unit of measurement of sound pressure. It is 20 $\log_{10}$ of the ratio between the root-mean-square (rms) pressure of a given sound and a reference rms pressure which is usually 0.0002 microbar.

dB (A) - This symbol denotes the decibel reading on the "A" scale.

SAFETY DEPARTMENT
FKKitson/bp
June 25, 1968

STAFFING AND "CHECK-IN" SYSTEMS FOR OPERATING PLANTS

The Safety Department recommends the guidelines listed below be utilized in establishing the controls to provide a means of checking on the condition of personnel who are working alone performing emergency maintenance work, daily plant operation, or weekly plant operations. The guidelines set forth establish the minimum requirements - obviously where a "check-in" system can be established with a nearby Air Products facility, customer personnel, or neighboring industry guard service, such an arrangement shall be made. The hazards inherent in the type of work being performed by the individual shall be the criteria used in determining whether a "check-in" system is required.

1. TYPE OF PLANT

   A. Flammable Gas Plants

   Regularly scheduled plant operations with one man/shift at any plant processing flammable gas must be provided with a positive method of "check-in" by the operator. The frequency of "check-in" may vary with the type of system established but must provide a minimum operator "check-in" once every hour. The plants included as flammable gas plants would be acetylene, hydrogen or other flammable gas cylinder filling plants and carbon monoxide, liquid hydrogen, or LNG production facilities.

   B. Fluorine Production Facilities

   Production of fluorine or transfer of fluorine (liquid or gaseous) into containers shall require two personnel to be present at the facility. A communication system shall be provided, such as "walkie-talkies".

   C. Nitrogen Generating Facilities

   A "check-in" system is not required for one man/shift operations or maintenance of these facilities.

   D. Oxygen Generating Facilities

   A "check-in" system for one man/shift operations is required if routine operations necessitate operation from more than grade elevation or if cryogenic liquid loading operations are performed. The frequency of "check-in" shall be a minimum of once every hour.

   E. Oxygen, Nitrogen, Argon Cylinder Filling Facilities

   A "check-in" system is not required for one man/shift operations.

2. MAINTENANCE WORK

The following guidelines shall be used during maintenance work:

A. Maintenance work on systems containing flammable gases will require the presence of more than one person.

B. Maintenance work on electrical systems:

(1) Work on energized electrical systems with voltages up to 250 volts will require the presence of more than one person. (Under no circumstances are personnel permitted to work on energized circuits with voltages exceeding 250 volts.)

(2) Work on de-energized circuits with voltages of 440 volts or above will require the presence of more than one person (the second person need not be an electrical technician.)

C. Maintenance work other than that described above will not require a second person or "check-in" system; however, the employee must advise the appropriate plant manager (or his representative) of his time of departure to an unattended facility and his time of return from the unattended facility.

3. ACCEPTABLE "CHECK-IN" SYSTEMS

The "check-in" system utilized shall be a reliable method of determining the responsiveness of an individual such as:

A. ADT System;

B. Telephone contact with APCI personnel, customer personnel, or neighboring industry guard personnel;

C. Reliable telephone answering services.

Air Products and Chemicals INC.

PUT IT IN WRITING

Date: February 19, 1971

TO: All Plant Managers

Subject: LOX Pump Safety Barriers

FROM: R. D. Stompler

cc: W. L. Ball
B. J. Berrettini
J. M. Geist
M. H. Halsted
H. H. Master
G. W. Robinson
M. H. Vogel - APL
H. E. Wynn

Attached is a sketch of a typical or suggested safety barrier to be installed on Paul, Carter and Cosmodyne LOX transfer pumps (3600 RPM Ground Pumps). Each plant manager will be responsible for having these barriers constructed and erected, and should report to the writer each completed unit as they are completed. The report should include make, model, serial number, service and location of each unit along with a picture of the barrier. It is expected that this work should be completed in approximately one week after receipt of this memo.

Although no catastrophic incidents have been reported with these slow speed pumps, the potential still exists and the barriers are to be provided in the interest of personnel safety.

ORIGINAL SIGNED BY.

R. D. Stompler

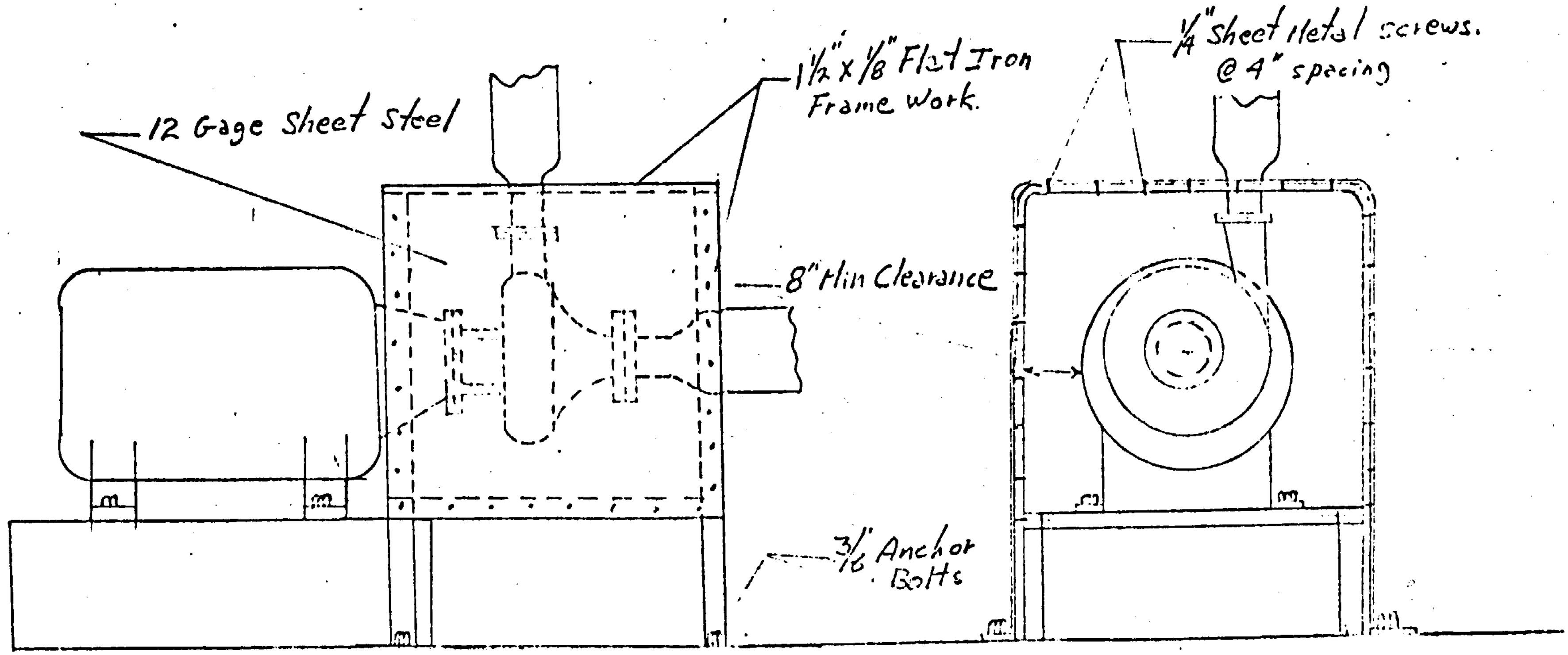
RDS:rsb

Attachment

(Retyped 9/28/72 sba)

Low Speed, Low Head LOX Transfer

Pump Barriers



Notes:

1) Barrier Must NOT Cover Motor.

2) Barrier Must be OPEN at Front, Rear & Bottom.

3) Barrier Must be Anchored Securely

Remarks:

This is a Sketch of a Suggested Low Cost Barrier. Any changes should reflect interest in personnel protection and ease of Installation.

RLB. [illegible]

Bulletin No. 42

Applicable To:

Design Eng. Std. 546.1

I. PURPOSE AND SCOPE

This bulletin incorporates changes proposed for Personnel Protective Shields for Oxygen Systems, Design Engineering Standard 546.1, as contained in B. W. Taylor's memo of July 22, 1971, Subject: Oxygen Standards. The memo is attached.

RWC JMG BWT	R. W. Campbell	9/30/71	DATE: September 30, 1971
	J. M. Geist	9/30/71	
	B. W. Taylor	9/30/71	

Air Products and Chemicals, Inc.

PUT IT IN WRITING

Date: July 22, 1971

TO: R. M. Kroc/W. T. Rector

SUBJECT: Oxygen Standards

FROM: B. W. Taylor*

cc: L. W. Ball*
R. W. Campbell
J. J. Dwyer
J. M. Geist*
M. H. Halsted
G. W. Robinson*
W. J. Scharle*
E. P. Thomas
K. Wilson (APL)

A meeting of those marked * was held on July 21 to reach agreement on modification of APCI standard 546.1 for shields around oxygen compressors. The questions in this area were outlined in my memo of July 19, same subject. Questions and conclusions were as follows:

1. Are single ply shields acceptable around centrifugal compressors?

   The sandwich design must be continued as currently required by the standard to achieve desired time delay prior to burn through of the shield. Compressors with discharge pressure below 50 psig were considered for a single ply barrier. This relaxation was ruled out on the basis that evidence was not available to justify the change at this time.

   Standard 546.1 describes the principles normally requiring placement of the shield approximately 3 feet from the compressor. This dimension may be increased to achieve walkways past piping, etc. The resulting layout in nearly all cases should be within approximately 5 feet of the compressor or 1st elbows off the compressor. Therefore, the standard will continue to require the sandwich design around all centrifugal compressors.

2. Are shields required around reciprocating compressors?

   As a minimum requirement, shields must enclose the cylinders, distance piece openings adjacent to the cylinder and the first elbow of piping connecting to the cylinders. The distance piece housing need not be enclosed. Shields located within 5 feet of the cylinders, distance pieces, or 1st elbows must be the sandwich design as currently required by the standard. Shields outside this 5 ft. boundary may be a single ply design. These requirements apply to reciprocating compressors of all manufacturers and all pressures.

The use of the minimum shielding indicated above or an alternate design totally enclosing the compressor shall be based on economics, accessibility for safety inspections and clearances needed for normal maintenance. The main advantage of close-in shields around Sulzer compressors is greatly improved observation of the distance piece area plus a significantly smaller shield.

During the July 19 meeting, it was agreed that doors may be eliminated if baffles are used in front of each entrance to eliminate line of sight between the compressor and the outside. While this principle applies to either reciprocating or centrifugal compressors, the additional floor space required will usually make it undesirable around the centrifugal units.

3. Are shields required around coolers and piping associated with oxygen compressors?

   It was concluded that the piping and coolers for all pressures are safe without shields if they are kept clean. This area is vulnerable to rusting during the operational phase if a water leak develops into the process stream and corrosive piping materials are utilized. Therefore, the selection of materials and the cost of maintaining cleanliness continue to be very important as indicated by paragraph IVB5 of standard 578.60.1. Plants for APCI operation will probably utilize stainless bonnets on coolers as well as for interstage piping based on total cost.

   However, coolers and piping located in the area under a centrifugal compressor must continue to be enclosed due to the exposure to flames from the compressor area. Additionally, a large number of elbows adjacent to the case are normally located in this area.

Recipients of this memo are requested to carefully consider the above changes and indicate any objections, with justification, by August 1, 1971. A technical bulletin will be published to incorporate the above information in the standard after that date.

B. W. Taylor

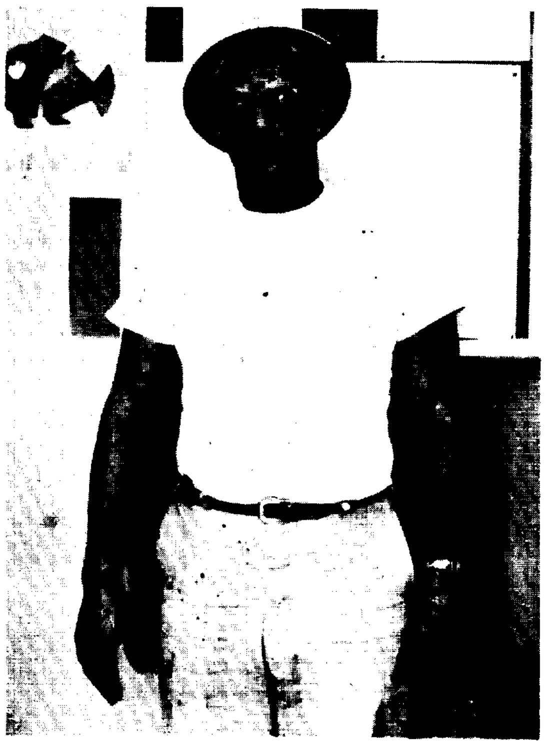
BWT:tas

SAFETY — GRAM

Air Products and Chemicals INC.

August 9, 1963
Number 30

Are Safety Glasses Worth the Cost and Effort?



The two pictures above are the best answer we know of for that question. A shower, first aid to slightly abraided skin from oil and flying particles, and repairs to the safety glasses were much less painful, less time consuming and less expensive, than the medical treatment and possible hospitalization that would have been required if safety glasses had not been used.

These pictures were taken May 29, 1963 at the West Palm Beach facility. Ronnie Hayward had opened the blowdown valve on the HPR oil separator. The line was plugged and the plug broke loose releasing a 500 psi stream into the blowdown opening in the sewer. The escaping gas hitting the sewer and the ground in the area blew sand, oil and sorbead particles back into Ronnie's face. The degree of protection that the safety glasses gave to his eyes is clearly seen in the right hand picture.

SAFETY DEPARTMENT
WLBall/jmf

OUT OF PRINT

OPERATIONS SAFETY MANUAL

Air Products and Chemicals INC.
ALLENTOWN, PENNSYLV...

MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

I. PURPOSE

To establish a st[illegible] procedure for checking and maintaining all portable [illegible] extinguishers at all Operations facilities.

II. RESPONSIBILITY

The Plant Manager or Maintenance Superintendent shall designate a man to be responsible for checking portable firefighting equipment. An alternate to act in his absence or to assist him when necessary shall also be appointed. If possible, these appointees shall have past experience in firefighting and related equipment. If they do not have such experience, every effort shall be made to instruct and train them, making use of such available literature as that issued by the state, by the National Fire Protection Association, and by Air Products and Chemicals, Inc. These men shall always be part of the plant Safety Committee.

If the administration of a particular facility includes a Safety Engineer, then he, working through the employees' supervisors, shall be responsible for directing the maintenance men in the particular job of maintaining portable fire extinguishers. If outside contractors are used because of special equipment required, these maintenance men shall spot check the contractor's work to see that the schedule is maintained.

All operating personnel are responsible for compliance with the general rules of the procedure (see III, B, below).

III. PROCEDURE

A. Scope

Extinguishers covered by this procedure shall include all those approved for company use as detailed in Safety Standard 630.3.2.

Class A Fires - Pressurized water and foam
Class B Fires - Dry chemical (white or purple powder), carbon dioxide, and foam
Class C Fires - Dry chemical and carbon dioxide

B. General Rules

1. All personnel shall observe the following rules:

MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

a. Report the following to the supervisor immediately:

(1). Use of any extinguisher.

(2). Equipment missing from its station. Be familiar with these locations. No extinguisher is to be moved without the supervisor's permission.

(3). Damaged, deteriorated, or malfunctioning equipment.

b. Extinguishers must be readily accessible. Keep the area surrounding it clear and also the aisles leading to it.

c. Keep in mind that portable extinguishers are only "first aid" fire equipment. They can extinguish small incipient fires or check larger fires until more elaborate equipment and professional firefighters arrive at the scene.

2. Supervisors and maintenance men are responsible for the following:

a. Items reported in 1a, above are to be recharged, repaired, or replaced accordingly as soon as practical. They shall be be refilled even if only partly discharged.

b. A station number shall be assigned to each extinguisher. The maintenance and inspection record shall consist of a card fastened to the extinguisher, showing dates of inspection, recharge, or repair. A duplicate record shall be kept in the office, listing this same data and also listing the type of extinguisher, its location, and other pertinent information.

c. Instruction of employees in the use of extinguishers shall be given by demonstration at least every year. This can be done best at the time when extinguishers are scheduled for recharging. These instructions should cover all shifts and, if not all men, enough of them so that there is a good distribution of trained men. The man responsible for the maintenance or the Safety Engineer would be best qualified for this job, and he should explain the fundamentals of firefighting and the use of equipment. Employees should be allowed to get the "feel" of the extinguisher.

MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

C. Maintenance Frequency and Checklists (Minimum Requirement)

1. All Types of Approved Extinguishers

a. Monthly check shall be made as follows:

(1) Be sure that each extinguisher is in its designated area or proper station.

(2) Be sure that the immediate area and aisles are clear so that the extinguisher is accessible.

(3) Be sure that signs and/or painted areas are in satisfactory condition so that marking is conspicuous.

(4) Check for deterioration and damage.

(5) Be sure that directions for use are legible.

(6) Check for hose, nozzle, or orifice obstructions.

(7) Check for tampering. Examine seals and pins where applicable.

2. Pressurized Water Extinguishers

a. Semiannual Check

(1) Perform all items listed on monthly inspection.

(2) Be sure that containers are full.

(3) Check antifreeze solution with a hydrometer where temperatures may drop below 40°F.

(4) Remove, examine, and weigh carbon dioxide cartridges. Replace them if there is a loss of 1/2 ounce or more from the original weight stamped on them.

b. Annual Check

(1) Perform all items listed on the monthly and semiannaul check.

(2) Discharge at least one extinguisher of this type as if at a fire. (See General Rules, B-2C.)

(3) Make a detailed inspection of interior and exterior of container, including gaskets, hoses, screens, etc.

MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

c. Five-Year Check

Have a hydrostatic pressure test of the extinguisher conducted according to NFPA standards by the extinguisher manufacturer, a qualified service agency, or a qualified testing laboratory.

3. Carbon Dioxide Extinguisher

a. Semiannual Check

(1) Perform all items listed on monthly inspection.

(2) Perform a weight check. A loss of 10 percent or more of rated capacity will require recharging.

(3) Make a detailed check of all parts of the appliance.

b. Annual Check

(1) Perform all items listed on the monthly and semiannual check.

(2) Discharge at least one extinguisher of this type as if at a fire. (See General Rules, B-2C.)

c. Twelve-Year Check

Have a hydrostatic test performed by a qualified agency in accordance with the requirements of the Interstate Commerce Commission (Code of Federal Regulations, title 49, parts 71 to 91).

4. Dry Chemical Extinguisher

a. Semiannual Check

(1) Perform all items listed on monthly inspection.

(2) Perform a weight check of the cartridge for full charge.

(3) Perform a weight check of the extinguisher for chemical.

(4) On cartridges that have a gauge, check the gauge for full charge.

MAINTENANCE OF PORTABLE FIRE EXTINGUISHERS

b. Annual Check

(1) Perform all items listed on the monthly and semiannual check.

(2) Make a detailed check of all parts of the appliance.

(3) Discharge at least one extinguisher of this type as if at a fire. (See General Rules, B-2C.)

5. Foam Extinguisher

a. Semiannual Check

Perform all items listed under monthly inspection.

b. Annual Check

(1) Have extinguisher recharged by qualified person or agency.

(2) Discharge at least one extinguisher of this type as if at a fire. (See General Rules, B-2C.)

c. Five-Year Check

Have a hydrostatic pressure test of the extinguisher conducted according to NFPA standards by the extinguisher manufacturer, a qualified service agency, or a qualified testing lab.

IV. RELATED PROCEDURES

V. RELATED FORMS

FIRE PROTECTION

by M. H. Hubbs
Air Products and Chemicals, Inc.

In the selection of a location for air plants the Engineering Department usually has considered the following points:

1. Atmosphere
2. Exposure to hazards from other plants
3. Effects of the plant on the surrounding area
4. Terrain and climate
5. Plant access and communication
6. Fire Protection

We shall discuss the last point "Fire Protection" necessary within air plants.

First it should be explained that a typical 700 T/D plant is being used as an example in this discussion.

The Safety Department works closely with the project and design engineers on the layout of the fire water system, hydrant location and reviews the necessity for sprinkler systems. Lists of first aid fire appliances and other equipment peculiar to fire protection are also drawn up and submitted to Engineering for purchase and installation.

Considerations for fire protection are based on the size of the plant and the known hazardous locations. As certain process features and plant layout affect the fire fighting system, drawings from the Engineering Department are revised by the Safety Department prior to their final approval. Of particular concern at this time is the location of vents and relief valve discharges that may discharge oxygen, and the liquid disposal system with respect to loading areas, operating areas and those locations in the plant where any appreciable quantities of combustibles will be stored or handled. After the general plant layout has been finalized the task of placing the fire protection system begins.

Like most companies, we are obliged by insurance contract to submit certain drawings to them for approval on both new installations and revisions to those now in existance. Their concern, of course, is with building construction, electrical systems, and the adequacy of the fire fighting equipment.

CGA, Air Separation Plant Safety Symposium, Paper and Discussion,
Chicago, Illinois, October 15, 16, 1963, pp. 175-184

ALUMINIZED HEAT PROTECTIVE CLOTHING

1. PURPOSE

This standard establishes the criteria for the selection of aluminized heat protective clothing for entry, proximity and approach to high thermal areas.

2. SCOPE

This standard applies to all APCI facilities where there is a need for entry, proximity or approach thermal protection.

3. GENERAL

The following approved safety equipment is a basis of protection unless, due to the inclusion of other activities, a supplemental list will be necessary. Any changes to this standard require approval by the Safety Department.

4. ENTRY CLOTHING

A. Entry into total Flame

Fyrepel Model 1000-00-09AG - nine layers consisting of three layers of special glass insulation and two layers of Fyretex (aluminized glass fabric). This suit will accomodate a self-contained breathing unit.

B. Ambient Temperature to 1000° (Proximity Suit)

Fyrepel Model 800-00-09AG - five layers consisting of three layers of special glass insulation, one layer of flameproofed cotton and one layer of Fyretex (aluminized glass fabric). This suit will accomodate a self-contained breathing unit.

C. Radiant Heat to 1500° (Approach Suit)

Fyrepel Model 500-00-09AG - three layers consisting of one layer of vinyl coated glass fabric and two layers of Fyretex (aluminized glass fabric). This suit will accommodate a self-contained breathing unit.

D. Miscellaneous Thermal Clothing and Equipment (All Fyrepel)

1. Kool Mitt - Model 640 - 17" gauntlet mitten for 750° service, aluminized backs.
2. Gloves - Model 344 - 13" gauntlet for 300° service, aluminized backs.
3. Boots - Model 650 - 12" height, aluminized glass.
4. Apron - Model 623 - 29" bib type, flameproof lining.

4. ENTRY CLOTHING (Cont.)

D. Miscellaneous Thermal Clothing and Equipment (All Fyrepel)

5. Hood - Model 610 - with heat reflective lens.

6. Rescue Blanket - Model 182 - 6' x 8' size.

7. Fyrumbrella - Model 280 - to be used with fire hose as a heat shield.

5. VENDOR - Kistler Fire and Safety Equipment
122 Turner Street
Allentown, Pennsylvania 18102

TONNAGE AIR SEPARATION PLANT

1. PURPOSE

This standard establishes the criteria for the selection of safety equipment and portable fire extinguishers for a standard tonnage air separation plant.

2. SCOPE

This standard applies to all APCI facilities.

3. GENERAL

The following approved safety equipment is the minimum requirement on tonnage air separation plants constructed following the date of this standard. The quantity and type of equipment required is based upon an operating staff of six (6) men on the day shift and two (2) men per shift on the evening and midnight shift. When the staffing varies significantly from these numbers, this list must be reviewed and revised. Supplemental lists will be required when, because of the inclusion of other activities, additional safety equipment is required. Any changes to this standard require approval by the Corporate Safety Department.

4. FIRE PROTECTION EQUIPMENT

Number Required	Item	Model No.	Vendor
7	CO_2 Extinguishers, 15 lb.	7662-CD-15	Ansul #
8	Dry Powder Extinguisher, 20 lb.	14349-A-20-E	Ansul #
1	Dry Powder Wheeled Unit, 150 lb.	10092-A-150-C	Ansul #

All Ansul extinguishers to be ordered through the Ansul Company, 215 Plank Avenue, Paoli, Pennsylvania, 19301.

Note 1 - Safety First fire extinguishers may be substituted for the Ansul units in areas where repair and servicing is available at APCI IGD Southern area facilities. Safety First extinguishers are available through the APCI Bladensburg, Maryland facility.

Note 2 - All fire extinguishers to be used in outside service will require covers, and must be so stated on the purchase requisition.

5. PERSONAL PROTECTION EQUIPMENT

Number Required	Item	Model No.	Vendor
18	Safety caps, white linear Polyethylene	Bullard 70-802DM	IPCO
12 pr.	Visitor Safety Glasses	VS 3	IPCO
As needed	Employee Safety Glasses		Local Purchase
1	Safety Harness-Parachute Type	Miller 600LN	IPCO

TONNAGE AIR SEPARATION PLANT

Number Required	Item	Model No.	Vendor
1	Safety Belt w/Lanyard (Saf-T-Pak)	Miller 6414-N	IPCO
2 pr.	Wristlets	" 6255-YL	IPCO
2	Chemical Goggles	Willson 303	IPCO
4	Protecto Face Shields - 8"	" V-1-64	IPCO
4	Cover Goggle-Allsafe	Hydron 214	G
2 pr.	High Voltage Lineman's Gloves size 10	13-30612	MSA
2 pr.	Lineman's Leather Protector Gloves	13-38586	MSA
2	Lineman's Canvas Glove Bag	13-37749	MSA
6	Air-Weave Yellow Rain Suits 4 medium - 2 large	900 Series	IPCO
2	Vinylite Chemical Aprons	No. 801	IPCO
1	Scott Air-Pak w/case & alarm	900000-00	APCI*
2	Scott Air-Pak cylinders	100000-90	APCI*
1	Scott Sling-Pak w/case	900002-00	APCI*
1	Scott Sling-Pak Cylinder	10000264	APCI*
2	Fuse Pullers, Pocket Style 1-100 AMP, 600 Volt	FP-3	B.M.
2	Fuse Pullers, Shop Style 60-400 AMP, 600 Volt	FP-4	B.M.
6 pr.	Rubber Boots w/Steel Toe	Local Purchase	
4 pr.	Redmont Chemical Gloves - 14"	19-934	IPCO
6 pr.	Cryogenic Gloves - Welders Chrome Leather Gauntlet	-	APCI
2 pr.	Welders Goggles	-	APCI
2	Flip-Front Welders Helmets	-	APCI

6. PLANT SAFETY EQUIPMENT

Number Required	Item	Model No.	Vendor
1	First-Aid Cabinet	Clearview - 34	IPCO
1	Stokes Stretcher	No. 3	IPCO
2	1/2" Rope - 100' w/5/8" safety snap on end	-	IPCO
1	Stretcher Bridle	Miller 6380	IPCO
3	Fire Blankets #20 w/canister #6	-	IPCO
1	Reel of Poly-rope 1/4" - yellow & black - 25 lb.	-	IPCO
12	Industrial Flashlights - explosion proof - 2 cell	F-81X	S.B.
4	Sipco wall mount Dunking Stations	3-S	IPCO
1	Railroad Car mover - land type (where applicable)	WB-17	A.
2	Railroad Car Wheel chocks (where applicable)	Style A	A.

TONNAGE AIR SEPARATION PLANT

Number Required	Item	Model No.	Vendor
4	Truck wheel chocks - non skid	WB-2H	A.
12	Willson Earmuffs	155-A	APCI**
12	Douglass Sound Sentry	-	APCI**
2	Salt Tablet Dispensers	No. F.C.	IPCO
1	Eagle Safety Plunger Can	P-701	IPCO
1	Eagle oily waste can	906-FL	IPCO
1	Eagle Safety Can - 1 gallon	UL-10FS	IPCO
2	Signs - R.R. Car connected (where applicable)	29-8971	IPCO
12	Signs - High voltage - 10" x 7" 20 gauge	DD-81	R.M.
6	Signs - Folding-double faced - Watch Your Step - 20 Gauge	CH-87	R.M.
3	Signs - No Smoking - 10" x 14" 20 Gauge	DD-134	R.M.
1	Safe Days worked board	No. 506	IPCO
1	Eyewash Bottle #505 w/50 holder	-	IPCO
4	Portable inspection lights - yellow - 15 watt - 50' cord	815-50	IPCO
1	Portable Inhalator - Resuscitator Reviva-Life Dual Butterfly/w case	No. 282M	APCI**
1	Manual Resuscitator - Air-Viva. w/case	No. 9993-950	APCI**
3	Eye Glass cleaning stations	No. 64	IPCO
1	Carton of cleaning tissues	No. 65	IPCO
1	Speakman Combination Emergency shower-eye wash unit (where applicable)	SE-610	IPCO
1	Portable oxygen analyzer-dual range, 0-25 and 0 to 100%, - with dilution valve, green case - complete with leather carrying case and strap	K-2500	G.
1	Oxygen analyzer reactivation kit	514-011	G.
1	Fiberglass probe with 24" hose and Filter	550-013	G.
1	Box of 24 Filter Refills	550-070	G.
1 Doz.	Bar guards-International orange	A-10	G.
2	Guardair Safety Air Gun	57-S	P.
1	Bo's'n's chair - complete	Rose 2165	G.
3	Barrel Rack O_2	621	IPCO

VENDOR KEY

A - Aldon Corp.
3338 Ravenswood Ave.
Chicago, Illinois 60657

TONNAGE AIR SEPARATION PLANT

VENDOR KEY (Cont.)

APCI *	-	Air Products and Chemicals, Inc. 2900 - 52nd Ave. Hyattsville, Maryland 20781
APCI **	-	Air Products and Chemicals, Inc. Spare Parts - Leetsdale
B.M.	-	Bussman Manufacturing Company University at Jefferson St. Louis, Missouri 63107
IPCO	-	Industrial Products Company 2820 North 4th St. Philadelphia, Pennsylvania 19133
MSA	-	Mine Safety Appliance Company 201 North Braddock Avenue Pittsburgh, Pennsylvania 15208
R.M.	-	Ready Made Sign Company, Inc. 12-07 44th Avenue Long Island City, New York 11101
S.B.	-	Stewart Brown Mfg. Co., Inc. 839 Stewart Avenue Garden City, L.I., New York 11530
G.	-	Guardian Safety Equipment Co. 214-16 South 45th St. Philadelphia, Pennsylvania 19104
P.	-	Albert W. Pendergast Safety Equipment Co. 6913 Tulip St. Philadelphia, Pennsylvania 19135

R-5-17-63

AIR PRODUCTS and CHEMICALS, INC.

GENERAL SPECIFICATION

FOR

CLEANING FOR OXYGEN SERVICE

REV.	DATE	APP'D	JOB NO.	MADE BY G. R. Oehmke	Air Products and Chemicals Inc. ALLENTOWN, PA.
E6741	5/15/63		DATE 12/10/59	APP'D	
				SCALE	NO. 550-SD-27A
			GENERAL SPECIFICATION CLEANING FOR OXYGEN SERVICE		

APCI DOCUMENT NO. 99000335

1.0 PURPOSE

1.1 The purpose of this Specification is to establish the degree of cleanliness and preparation for shipment of all compressors, piping and associated equipment in contact with oxygen enriched atmospheres.

2.0 SCOPE

2.1 The cleanliness of all compressors, piping and associated equipment in contact with oxygen enriched atmospheres shall conform to this specification unless the vendor secures written approval from the Purchaser for any exceptions.

3.0 GUARANTEE

3.1 The vendor shall assume full responsibility for the cleanliness of all components cleaned to this specification by themselves and/or subcontractors.

4.0 DEFINITION OF CLEAN

4.1 The word "clean" as used in this specification is defined as being free of all loose, or potentially loose, slag, rust and grit, and completely free of all oil, grease, or other hydrocarbons.

5.0 METHODS OF CLEANING

5.1 Cleaning may be accomplished by any method selected by the vendor, including soaking, scrubbing, or vapor degreasing.

5.2 Chemical cleaning agents may be of any commercially approved grade or type.

6.0 SEALANTS AND THREAD COMPOUNDS

6.1 All sealants and thread compounds in oxygen enriched atmospheres, or used to contain oxygen enriched atmospheres, must be compatible with oxygen.

6.2 The following is a list of typical materials known to be compatible with oxygen. Products other than those listed may be used if approved in writing by Air Products and Chemicals, Inc.

6.2.1 Gaskets -- 1/16" or less thickness, Garlock #900 compressed asbestos.

6.2.2 Pipe Thread Sealants: Teflon Tape -- Permacel, New Brunswick, N.J. - Ribbondope No. 412.
Minnesota Mining & Mfg. Co. - Pipe Thread Sealant No. 48 and 537.
Crane Packing Company -- Thread-Tape.
Fluoro Plastic, Inc. -- Fluoro-Tape #26.

6.2.3 Sealing Compounds: Permatex Company, Inc. - Sealant 1516 (Note: Sealant 1516 is not suitable for containing lubricating oils.)

6.2.4 Stud Lubricants

6.2.4.1 Oils

	Hooker Chemical Co.	Halocarbon Products Co.
Light Oil	FS-5	4-11 & 11-14
Medium Oil	S-30	11-21 & 13-21
Heavy Oil	T-80	10-25 & 14-25

NOTE: The above materials are not to be used with aluminum.

6.2.4.2 Dry Lubricants

Alpha Molykote Corporation:
Molykote Type Z - fine powder
Molykote Microsize - very fine powder.

6.0 SEALANTS AND THREAD COMPOUNDS (Continued)

6.2.5 Protective Wax Coating: Halocarbon Products Corporation - Wax Coating 6-25 & 6-25Z.

7.0 INSPECTION

7.1 Parts shall be considered clean when it is determined acceptable by the following criteria:

7.1.1 When inspected under a bright white light there shall be no loose, or potentially loose, slag, rust, and grit, and completely free of all oil, grease, or other hydrocarbons.

7.1.2 When inspected under ultra-violet (black light) light of a wave length between 3200 and 4000 Angstrom units, there shall be no evidence of hydrocarbon fluorescence.

7.1.3 Wiping with clean white filter paper and inspected under bright white light shall indicate no evidence of vegetable or animal oils (usually not detectable by ultra-violet light inspection).

8.0 PREPARATION FOR SHIPMENT

8.1 All ferrous materials, except pipe, after being cleaned shall be given three (3) applications of protective wax coating to all surfaces. Sufficient time (approximately ½ hour) shall be allowed between coats to permit previous application to become tacky.

Wax may be applied using a clean, standard paint spray gun. Only dry, oil free air or nitrogen shall be used in spraying the protective wax.

8.2 Assemblies such as centrifugal compressors, cylinders, and vessels shall have all openings closed to prevent the entrance of dirt and moisture. Openings shall be closed by covering with clean polyethylene sheet, a gasket, and then a steel plate. Covers for openings less than 18" in diameter shall be a minimum of 1/8" thickness and those over 18", a minimum of 1/4" thickness.

8.0 PREPARATION FOR SHIPMENT (Continued)

8.3 Following cleaning stainless steel, copper alloy or aluminum alloy piping and vessels shall have all openings sealed.

8.4 Ferrous piping and vessels, after cleaning, shall be purged using dry oil free nitrogen, and all openings covered.

8.5 Spare Parts -- All spare parts shall be sprayed with protective wax as described above and sealed in clean polyethylene bags. Bags shall also contain tag stating "Cleaned for Oxygen Service", part name and number.

8.6 All packages, boxes, crates and/or skids containing parts or assemblies which have been cleaned in accordance with this specification shall have a tag "Cleaned for Oxygen Service" attached in a conspicuous place.

AIR PRODUCTS AND CHEMICALS, INC.

GENERAL SPECIFICATION

FOR

CENTRIFUGAL COMPRESSORS

Rewritten April 15, 1965

REV.	DATE	APP'D	JOB NO. 550-SD-16A	MADE BY G. R. Oehmke	Air Products and Chem ALLENTOWN, PA.
28551	4/15/65		DATE April 15, 1965	APP'D [illegible] SCALE	
			GENERAL SPECIFICATION CENTRIFUGAL COMPRESSOR		NO. 550-SD-16A

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ADDENDUM

Revisions to the General Specification shall be listed on this page to facilitate easy identification of changes.

1.0 INTRODUCTION

1.1 Purpose

The purpose of this specification is to establish a set of requirements for centrifugal compressors purchased by Air Products and Chemicals, Inc.

1.2 Scope

When this specification is referenced in the Purchase Order or Job Specification, compressor shall conform to this specification unless vendor secures written approval from the purchaser for any exception. Where conflict between this specification and the applicable job specification exists, the job specification shall govern.

2.0 GUARANTEE

2.1 All equipment furnished shall be guaranteed by the vendor to operate at the conditions set forth in the job specification of the order. The vendor shall assume full responsibility relative to the guarantee of all equipment, accessories, and parts subcontracted by the vendor and furnished under this specification.

2.2 The compressor shall be designed to deliver the required capacity at the pressure listed in the job specification. Brake horsepower at the Design and Guarantee Conditions including gear losses, if any, shall be guaranteed. The compressor shall also be capable of delivering the capacity and pressure at Maximum Volume Conditions when applicable.

2.3 The compressor shall be capable of continuous operation at rated load for a minimum of two (2) years without shut down for maintenance to compressor or auxiliary equipment.

3.0 CASINGS

3.1 Compressors may be of the single shaft in line design or multiple speed integral gear design.

3.2 The thickness of the casing (pressure containing components) shall be suitable for the specified design and test pressures and shall include at least 1/8" corrosion allowance. The hoop stress value at any point shall not be in excess of the values given in the ASME Unfired Pressure Vessel Code, latest edition, for the materials used. Materials for steel castings and forgings and the quality of any welding shall be equal to that required by the code. All welding shall be suitably stress relieved.

3.3 Compressor casings may be cast iron for any gas except oxygen with a temperature any place in the casing not to exceed 350°F.

3.4 Compressor casings containing any gas, except oxygen, exceeding the above temperature limitation, or pressure limitation of the cast iron casing, shall be steel.

3.5 Casings for oxygen compressors shall be cast iron or nickel alloy. Maximum temperature any place in the casing not to exceed 300°F.

3.6 Each casing shall have a securely attached nameplate indicating design operating pressure, design operating temperature, maximum allowable working pressure, hydrostatic test pressure, flow at inlet conditions, and serial number.

4.0 ROTORS

4.1 Impellers may be cast, forged or fabricated. Cast impellers shall be machined all over except internal surfaces. Welding shall not be permitted for repair or balancing. Forged or fabricated impellers shall be assembled with countersunk rivets and rivets shall be ground flush with cover and disc. Assembly by welding shall be permitted on fabricated impellers.

4.2 Individual impellers shall be subjected to a spin test of 115% of rated speed for constant speed machines and 120% for variable speed machines. After spin test riveted impellers shall be inspected for loose or defective rivets. Welded or cast impellers shall be inspected for cracks by use of dye penetrant or magnetic particle method.

4.3 Assembled rotors shall be operated at 110% of normal operating speed in the casing for constant speed machines and 115% of normal operating speed for variable speed machines.

4.4 The assembled rotor shall be dynamically balanced.

4.5 Oxygen compressors shall be provided with stainless steel shafts, impellers and spacers or sleeves.

4.6 Oxygen compressors shall be provided with Monel or bronze alloy rubbing rings or buttons to prevent the impellers from coming in contact with the diaphragms or guide vanes in case of thrust bearing failure.

5.0 AXIAL BALANCE

5.1 Either a balance drum or piston shall be provided, or the compressor impellers shall be arranged to limit axial unbalance. If a balance drum design is used, pressure on one side of the drum shall be piped to the suction end of the compressor. Vendor shall furnish and install the balance line.

6.0 INTERSTAGE SEALS

6.1 Interstage seals shall be provided to prevent internal bypassing of impellers. Interstage seals shall be stationary and replaceable in the field. The seals shall be any non sparking material.

7.0 SHAFT SEALS

7.1 Vendor shall furnish a complete seal system consistent with the applicable sealing requirements. System shall be complete with all necessary solenoid valves, regulating valves, pressure indicators, differential pressure indicators, pressure switches, eductors, and all seal piping, valves and fittings. All utility gas, and vent gas lines shall be manifolded and purchaser shall make one connection to each system. The entire system shall be prefabricated, assembled, and tested by the vendor.

7.2 Casing seals shall be provided where the shaft emerges through the casing to minimize leakage. A small amount of leakage of inert gas or air to the atmosphere will be permitted.

7.3 Casing seals shall be designed to preclude the migration of bearing lubricant into the compressor under any conditions of starting, normal or abnormal operation.

7.4 When required in the job specification, for high purity gas where contamination by atmospheric air is not allowed, vendor shall supply a seal system which shall preclude inward leakage of air under any condition of starting, normal or abnormal operation.

7.5 Oxygen compressor seals shall be designed for zero outward leakage of oxygen and zero inward leakage of air or other sealing medium into the oxygen stream. A buffer gas seal shall be permitted and buffer gas-oxygen mixture may be vented to one common vent connection. All seal piping valves and fittings shall be stainless steel or nonferrous.

8.0 BEARINGS

8.1 Journal bearings and thrust bearings shall be of the precision type and replaceable without scraping or fitting. This requirement is not intended to preclude the use of shims to axially locate rotors. A two directional thrust bearing with replaceable shoes is preferred.

8.2 Bearing housings shall be furnished with covers and it shall be possible to inspect and replace bearing liners without removing the casing top half, or the heads of vertically split machines. Bearing housings shall be furnished with seals to prevent oil leakage.

8.3 Compressors for oxygen service shall have the bearing housings external to the casing and distance piece open to atmosphere shall be provided between bearing housing and the casing. An oil flinger shall be mounted on the shaft to prevent oil migration into the casing seal.

9.0 ADJUSTABLE INLET VANES

9.1 When adjustable inlet guide vanes are required by the applicable job specification the first stage shall have a movable inlet vane assembly. All vanes shall be adjustable and shall move simultaneously.

9.2 Compressors equipped with adjustable inlet guide vanes shall be provided with an air actuated positioner. The operator (positioner) shall have a stall thrust which is approximately two times the friction, plus inertia, plus unbalanced load of the guide vane mechanism. Actuating air shall be available at the pressure specified in the job specification.

10.0 LOW TEMPERATURE MATERIALS

10.1 All materials in contact with gas below minus 20°F shall have an impact strength of not less than 15 foot pounds (ASTM methods of impact testing of metallic materials E23) at the lowest operating temperature.

11.0 CRITICAL SPEEDS

11.1 Compressors having stiff shafts will have the first critical speed at least 25% above maximum operating speed. Flexible shaft machines shall have the first critical between 60 and 70% of rated speed.

11.2 Compressor vendor shall determine that the critical speeds of the driver and gear, if applicable, are compatible with the critical speeds of the compressor and that the combination is suitable for the operating speed range.

11.3 The nodes of torsional vibration shall be at least 25% away from the operating speed or any exciting frequency of the entire driver-gear-compressor train.

12.0 VIBRATION

12.1 Total peak-to-valley amplitude of vibration measured on the shaft adjacent to the bearing shall not exceed the following values:

Maximum Rated Speed RPM	Vibration Inches
up to 4000	0.002
4001 to 6000	0.0015
over 6001	0.001

12.2 For those machines where it is impossible to measure vibration on the shaft, the vibration measured in any plane, any place on the compressor casing or bearing housings shall not exceed 0.0005 inches.

13.0 GEARS

13.1 Separate speed increasing gears shall be of the herringbone type and in accordance with AGMA Standard 421, latest edition. The gear nameplate horsepower rating shall exceed the compressor guaranteed horsepower by 20 percent. The compressor and gear shall use the same lubrication system.

14.0 COUPLINGS

14.1 All couplings required, between the compressor and gear, gear and driver, and for all accessory and auxiliary equipment, shall be furnished by the compressor manufacturer.

14.2 Where parts must be installed or removed over the end of the shaft, a spacer type coupling, with tapered fit, is required.

14.3 If required to permit uncoupled operation, coupling adapters shall be provided.

14.4 Coupling hub to shaft contact area, for tapered bored couplings, shall be a minimum of 80 percent of the total area.

14.5 All couplings 3600 rpm and above shall be dynamically balanced.

14.6 High speed couplings, 4000 rpm and above, shall be continuously lubricated from the compressor lubrication system.

15.0 PROTECTIVE ENCLOSURES

15.1 All open shafts, couplings, gears or other moving machinery must be provided with suitable protective enclosures. This requirement includes the compressor as well as all auxiliary equipment covered under this specification.

15.2 Protective enclosures shall be totally enclosed. The enclosures shall be mounted from vendor's equipment where possible thus requiring no foundation mounts. Enclosure shall be easily removed for maintenance with bolted connections.

16.0 BASEPLATE

16.1 Fabricated steel baseplates shall be provided under all multibody compressor trains and, where practical, under single body and separate gear drive units. The baseplate should be of sufficient length to also support the gear, if applicable.

16.2 Soleplates shall be supplied for all compressors where baseplates are impractical. Soleplates shall also be supplied for all separately mounted equipment.

16.3 Laminated shims shall be supplied under the compressor and gear.

16.4 All hold down bolts (ie. equipment to baseplate or sole-plate) shall be furnished by the compressor manufacturer. Baseplates and soleplates shall be drilled and tapped for hold down bolts.

16.5 Foundation bolts will be furnished by others.

17.0 GAS COOLERS

17.1 All intercoolers required for proper operation shall be supplied by the vendor. An aftercooler shall be supplied by the vendor on all compressors unless deleted in the job specification.

17.2 Unless otherwise stated in the job specification coolers may be manufacturer's standard. All tube bundles shall be of the removable type.

17.3 Maximum allowable pressure drop in water side of coolers shall be 8 psi.

17.4 Rupture discs shall be provided in the shell if gas pressure in the tube exceeds the maximum allowable working pressure of the shell.

17.0 GAS COOLERS (Cont'd)

17.5 Coolers shall be provided with low point drains on both water and gas sides, and a high point vent on the water side. Vent and drain connections shall be provided with valves.

17.6 Vendor shall supply all cooler supports and flexible mounts where required.

17.7 All water piping and valves will be provided by the purchaser.

17.8 Coolers in oxygen service shall be shell and tube design with gas in the tube. Hot side bonnets shall be 300 Series stainless steel. Tubes and tube sheets shall be non-ferrous.

18.0 SEPARATORS

18.1 Condensate separators shall be provided after each intercooler on all wet gas compressors. Condensate separators shall remove a minimum of 90% of the condensed moisture at the separator operating conditions of temperature and pressure. A 3/4" minimum NPT condensate drain connection shall be provided.

18.2 Separator drain piping, drain valves and traps will be furnished by purchaser.

18.3 The aftercooler separator will be furnished by purchaser.

19.0 GAS PIPING

19.1 The vendor shall supply a complete gas piping system from the compressor inlet flange to the final aftercooler discharge flange, including all interconnecting gas piping.

19.2 Drains shall be provided at all low points in the piping system. Minimum acceptable size for all drain connections shall be 3/4" NPT.

19.0 GAS PIPING (Cont'd)

19.3 All piping shall be designed and fabricated in accordance with American Standard Code for Pressure Piping, ASA B31.1, latest edition, Sections 2 and 6.

19.4 All pipe plugs shall be steel except oxygen service where 300 Series stainless steel is required. Plugs shall have hexagon or round heads.

19.5 Pipe sizes of 3/8", 1¼", 2½", 3½", 5" and 7" shall not be used.

19.6 All connections 1½" and larger shall be flanged.

19.7 Vendor shall supply all supports for the piping system with all supports kept within the compressor package.

19.8 All piping shall be fitted, cleaned and assembled at the factory. When necessary to ship loose piping, all sections shall be tagged for easy assembly in the field. Piping shall be thoroughly cleaned, flushed with preservative and tightly sealed.

19.9 Oxygen piping from compressor to coolers shall be 300 Series stainless steel. Piping from the cooler to the compressor may be carbon steel providing the average velocity does not exceed 80 feet per second at normal operating conditions, with the provision that the section immediately adjacent to the compressor for a distance of two (2) feet or two (2) pipe diameters, which ever is greater, shall be 300 Series stainless steel.

20.0 CHECK VALVE

20.1 A low resistance swing type check valve shall be provided by the vendor and shall be of the size required in the job specification.

20.0 CHECK VALVES (Cont'd)

20.2 Check valves of 6" size or larger shall be equipped with a dashpot to prevent slamming the disc against the seat.

20.3 Bodies of check valves for oxygen compressors may be cast iron. At pressures above the limits of cast iron, the body shall be 300 Series stainless steel. Internal parts shall be 300 Series stainless steel. Any lubricant required shall be oxygen compatable and approved by the purchaser.

21.0 LUBRICATION

21.1 A complete lubrication system shall be furnished consisting of oil reservoir, suction strainer, main oil pump, auxiliary oil pump, oil filter, oil cooler, pressure gages, temperature indicators, automatic switches and all piping. Lube system components shall be mounted on console baseplate. The lube system console shall be sufficiently rigid to permit supporting at each corner.

21.2 The oil system shall be sized for adequate capacity to supply the compressor and gear unit lubrication requirements; and when required by the job specification, the drive lubrication requirements, as well. Oil reservoir retention time shall be a minimum of five minutes between normal and minimum oil level based on normal pump capacity. Reservoir shall be fabricated steel of sufficient rigidity to support any top mounted equipment without sagging or vibration. Interior of reservoir shall be cleaned free of scale and foreign material, and the entire inside surface painted to prevent rusting. Clean out and inspection covers shall be provided on the reservoir. Connections shall be provided for filling, drain, vent, main and auxiliary oil pump suction, oil return, low level alarm, and oil level bayonet gage. All connections shall be flanged, gasketed, and extend a minimum of one inch from the reservoir surface. Reservoir bottom shall be sloped at least $\frac{1}{4}$" per foot. Pump suction connection shall be located at the high end of the reservoir and return lines at the low end. A strainer shall be provided in the oil filling connection. A flanged oil

21.0 LUBRICATION (Cont'd)

21.2 (Cont'd)

breather shall be provided and it shall be separate from the oil fill connection. The drain connection shall be a minimum of 3/4" NPT and it shall be provided with gate valve and plug.

21.3 Positive displacement pumps with relief valves for pump protection shall be provided. Unless specified otherwise in the job specification, the main oil pump shall be integrally driven from the compressor or gear and the spare pump shall be electric motor driven. When it is impossible to have an integrally driven main oil pump, an electric motor drive will be acceptable, but the spare oil pump shall then be air motor or steam turbine driven. Pumps shall have suction strainers.

21.4 The auxiliary oil pump shall be of same capacity and quality as main pump and take suction directly from the oil reservoir. A submerged type pump is preferred.

21.5 Pump motor starter and push buttons will be supplied by the purchaser.

21.6 Turbine drivers shall have governors, overspeed trips and be of the brake rim construction. A bypass line and valve shall be supplied around the governor valve.

21.7 Air motor drivers shall be furnished complete with all necessary accessories, including air filters, automatic oil injection devices, as applicable.

21.8 Controls for the spare oil pump shall be so arranged as to automatically start the pump when the oil pressure decreases to a predetermined minimum and shall continue to operate until manually stopped.

21.0 LUBRICATION (Cont'd)

21.9 A shell and tube oil cooler shall be provided. The cooler is to be sized for the maximum cooling water temperature listed on the job specification. Vent and drain connections of ½" NPT minimum shall be provided for both oil and water. Drain shall be equipped with gate valves and vents with globe valves. Tubes shall be 5/8" O.D. 18 B.W.G.

21.10 The oil cooler shall be constructed of the following materials:

Shell	Steel
Tubes	Inhibited Admiralty
Tube Sheets	Non-ferrous

21.11 A full flow, twin oil filter shall be located downstream of the oil cooler, before the bearings. Continuous flow transfer valves shall be provided before and after the filters to allow removal of one filter from service for cleaning. Filters shall be the replaceable cartridge type. Filtration rating shall be 25 micron or less. Bypass relief valves are not permitted within the filter unit. Filter pressure drop shall not exceed 5 psi with new cartridges operating at design system oil pressure, temperature and flow. The filter and filter cartridges must be capable of withstanding full system oil pressure, that is, relief valve set pressure. A line with an orifice and globe valve shall be installed between filters to fill either filter after cleaning. Vent valves of ½" NPT minimum size shall be provided at the high point of each filter and ½" NPT drain connection equipped with gate valves shall be provided at the low point of each filter.

21.12 A bearing header pressure or flow regulating valve shall be installed within the lube oil console to regulate the pressure or flow of oil at the bearings.

21.13 All lubrication piping shall be furnished by the vendor. Piping to be fitted, cleaned and assembled at the factory. When necessary to ship loose piping, all sections shall be tagged for easy assembly in the field. Piping sections shall be preserved and plugged to prevent foreign materials from entering pipe during shipment and erection. Oil piping 1½ inch and smaller shall be schedule 80 minimum seamless steel with welded or flanged connections.

21.0 LUBRICATION (Cont'd)

21.14 When required in the job specification, a low watt density heater shall be provided in the lube oil reservoir. Heater shall be sized to maintain oil at the minimum starting temperature when the compressor is shut down at the minimum ambient temperature specified. Heater shall be provided with a thermostat. Power characteristics for heater elements shall be as specified under auxiliary power and thermostat shall use control power.

22.0 GAGEBOARD

22.1 A fabricated steel 72" high floor mounted gageboard shall be supplied. The front of the panel shall be fabricated of rolled steel plate with all raw edges ground burr-free. All edges shall be finished square to insure tight flush joints, when butted together. Substantial welded in place framing members shall be utilized to provide a rigid, self supporting unit. Top and ends shall be constructed with full depth sheet metal turnback.

22.2 Gageboard shall be finished with two (2) coats minimum DuPont #7 Eye-Ease Light Green #J-276-23707.

22.3 Panel will be mounted on base furnished by others.

22.4 Nameplates shall be supplied on the front of the panel for instrument and service identification. All nameplates shall be laminated black plastic with white core and beveled edges. They shall be 1" high by 3" long minimum, and shall be attached with machine screws and nuts. Lettering shall be minimum 3/16" high characters.

22.5 Gage panel shall contain all gas pressure gages, seal system gages, weight flow controls, anti-surge controls and flow recorder as applicable. All gages and devices shall be flush mounted.

22.0 GAGEBOARD (Cont'd)

22.6 When an indoor installation is specified, the oil pressure gages shall be mounted on the gage panel. For outdoor installation or oxygen service the oil pressure gages shall be located on a separate panel preferably mounted on or adjacent to the lube oil console. In no event shall hydrocarbon oil lines or gages be placed in the same panel or enclosure as oxygen gas lines or gages.

22.7 On gage panels containing electrical apparatus, the back section of the panel containing such apparatus shall be enclosed with bolted covers or hinged sheet metal doors. The complete electrical installation including terminal blocks shall be in accordance with the requirements of the National Electrical Code for General Purpose Installation. Purchaser will supply 115 volt, 60 cycle, single phase AC source or other control power as specified in the job specification with grounded neutral to the panel. Neutral shall be color coded white. Provision shall be made for grounding the entire panel to the plant grounding system.

22.8 Wire shall be type TW, stranded 600 volt insulation, #14 AWG or larger. All wiring to be connected to terminal blocks using pressure type insulated wire terminals, Stakon or equal. In addition to terminal strip identification, each wire is to be tagged at both ends with standard electrical code markings. Wiring and terminals shall be numbered and agree with numbers shown on wiring diagram. All wiring connections between panel terminal blocks and field will be made by others.

22.9 Purchaser will supply instrument air at the pressure specified in the job specification to one connection on the gageboard.

23.0 PRESSURE GAGES

23.1 Flush mounted gages with mounting dimension in accordance with ASA standards, shall be supplied. Flush gages shall have a front flange and a back male connection. The connection shall be ¼" NPT for all pressure ranges up to 800 PSIG and ½" NPT for all pressure ranges from 801 PSIG to 10,000 PSIG. All gages shall be 4½" round dial type with black figures on white background. The case shall be of cast aluminum of solid front construction with rear blowout disc. The crystal shall be plastic. The bourdon tube material shall be phosphor bronze for vacuum and pressures up to 800 PSIG, and beryllium copper from 801 PSIG to 10,000 PSIG. Other metals such as alloy steel, stainless steel, and monel shall be used for special conditions of either service fluid or atmosphere. Socket shall be forged brass or bronze for use with phosphor bronze or beryllium copper tubes, and of the same material as the bourdon tube material for all others.

23.2 Accuracy of 0.5% of full scale (ASA Class AA) required. Gages shall be equipped with a zero adjustment pointer. Gage shall retain calibration when subjected to overpressure as follows:

a. Up to and including 600 PSIG, 30% over range pressure.
b. 601 PSIG to 10,000 PSIG, 10% over range pressure.

23.3 Standard scale ranges shall be in accordance with the following tabulation:

OPERATING LIMITS OF GAGE	GAGE DIAL RANGE
0 - 20 PSIG	0 - 30 PSIG
21 - 65 PSIG	0 - 100 PSIG
66 - 135 PSIG	0 - 200 PSIG
136 - 400 PSIG	0 - 600 PSIG
401 - 650 PSIG	0 - 1000 PSIG
651 - 1000 PSIG	0 - 1500 PSIG
Vacuum -	0 - 30" Mercury
Vacuum - 10 PSIG	30"- 0 - 15 PSIG
Vacuum - 20 PSIG	30"- 0 - 30 PSIG
Vacuum - 200 PSIG	30"- 0 - 300 PSIG

23.0 PRESSURE GAGES (Cont'd)

23.4 When the gage is to be used for oxygen service the face of the dial shall be inscribed, "OXYGEN - USE NO OIL".

23.5 Gages shall be U. S. Gauge, Helicoid, Crosby, Ashcroft, or equal.

23.6 Gas pressure gages shall be provided on the gageboard to indicate the discharge pressure of each intercooler outlet, final discharge, and first stage suction where the inlet is other than atmospheric air.

23.7 Lubricating oil pressure gages shall be furnished up and down stream of the oil filter and at the most remote point in the lubricating oil header.

23.8 On compressors utilizing a diaphragm water cooling system, a pressure gage indicating circulating pump discharge pressure shall be mounted on the gageboard.

23.9 Seal system pressure gages required for proper operation and balancing of the system shall be mounted on the gageboard.

23.10 Differential pressure gages, when required for proper operation and balancing of the seal system, shall be furnished and mounted on the gageboard. Differential pressure gages shall conform to the general requirements of pressure indicators.

24.0 PRESSURE GAGE PIPING

24.1 All pneumatic signal leads, and all direct process connections, where gas is compatable, for pressures less than 1500 PSIG (unless otherwise noted in the job specification), shall be ¼" O.D. x .030" wall copper tubing in accordance with ASTM Specification B68DPH. All tubing fittings for this condition are to be Crawford Fitting Co. "Swagelok."

24.0 PRESSURE GAGE PIPING (Cont'd)

24.2 All direct process connections for pressures 1501 PSIG to 3500 PSIG or where gas is not compatable with copper shall be 3/8" O.D. x .049" wall seamless stainless steel tubing fully annealed in accordance with ASTM Specification A269, TP316. All tubing fittings for this service shall be Parker Appliance Co., 37° flared, stainless steel, "TRIPLE-LOK", in accordance with ASTM Specification A182F316 or A276T316, with inserted Teflon conical seals.

24.3 All panel piping for field connections are to terminate at the rear of the panel on a bulkhead bar. Bulkhead connections for the field shall be ¼" FNPT. All terminal connections shall be identified by a securely fastened engraved plastic nameplate, 1/2" x 3/4". All connections shall be plugged for shipping.

24.4 Process gas and oil pressure piping between compressor or lube oil console and gageboard will be furnished by the purchaser. Vendor shall supply 3/4" NPT connections for pressure gage piping. Seal system gage piping shall be furnished complete by the vendor.

24.5 Pneumatic signal lines between the gageboard and compressor or field mounted control devices will be by the purchaser.

24.6 All pressure gages shall be provided with shutoff valves. Gages mounted on the gageboard shall have the valve located in the rear of the board. Gages operating in excess of 100 PSIG shall have an atmospheric bleed valve between the gage and shutoff valve. Shutoff valves shall be ½" NPT needle type forged steel, Vogt Valve Figure No. 9873, and bleed valves shall be ¼" NPT needle type forged steel, Vogt Valve Figure No. 9871. Oxygen compressors shall be equipped with equivalent stainless steel valves.

24.7 Gage piping or tubing shall be supported and tied down within 18 inches of the gage, 12 inches or less is preferred, if possible. Additional supports every 18 inches are required on tubing runs with continuous tubing rack and tie down construction preferred.

25.0 TEMPERATURE GAGES

25.1 Temperature gages shall be supplied by the vendor as listed below. All temperature gages shall be locally mounted in the piping or vessels with separable sockets allowing gage removal while the compressor is in operation. Gages shall be mounted in accessible positions such that the gage can be easily read from the operating floor level.

25.2 Temperature gages shall be 5" round dial type with black figures on white background, with units in degrees Fahrenheit. They shall be bi-metallic element, adjustable "every angle" type, equal to Manning, Maxwell and Moore, Model 5-6060EH. Connections shall be ½" MNPT.

25.3 Separable sockets shall be 3/4" MNPT with ½" FNPT sockets for the temperature gages. All separable sockets furnished on a particular compressor shall have a pressure rating equal to or greater than the highest pressure encountered on that compressor. Socket well immersion shall be a minimum of two (2) inches in liquid service and a minimum of four (4) inches in gas service.

25.4 Temperature gages shall be provided to indicate the temperature at the following locations:

a. First stage inlet except when gas is atmospheric air.
b. Gas inlet to each inter or aftercooler.
c. Gas outlet of each inter or aftercooler.
d. Cooling water outlet of each inter or aftercooler.
e. Lubricating oil inlet and outlet of the oil cooler.
f. Lubricating oil outlet of each compressor bearing housing.
g. Lubricating oil outlet of each gear bearing housing.

25.5 Where the design of compressor or gear bearing housings does not permit the installation of a thermowell, the well may be omitted provided the temperature sensing point is not in a pressure line. If the design renders it impossible to install dial type temperature indicators, the vendor shall provide thermocouples in each bearing housing and a multi-point pyrometer mounted on the gageboard. Wiring from a common thermocouple terminal block on the compressor or bearing housing to the gageboard will be by the purchaser.

25.0 TEMPERATURE GAGES (Cont'd)

25.6 Temperature indicators installed in the outlet of inter and aftercoolers shall be located in the water piping up stream of the flange.

26.0 ELECTRICAL SWITCHES

26.1 Safety devices shall be supplied and installed by the vendor with the compressor for the services listed below.

26.2 All pressure switches shall be dual switch, S.P.D.T., with independent circuits and adjustment ranges. Switches to be precision snap acting, per NEMA IC-3, rated 15 amperes minimum, continuous, inrush, and break at 50% power factor, 115 volts, 60 cycles. Switches shall have silver contacts, Switches shall repeatedly operate at their set point within plus or minus ½% of span.

26.3 An oil pressure switch shall be provided in the lubricating system sensing pressure at the most remote point in the lubricating oil header. The switch shall be four position device, Mason-Neilen 485 or equal, and arranged to perform the following functions:

a. Actuate alarm circuit on decreasing oil pressure.
b. Start auxiliary oil pump if pressure continues to decrease.
c. Shut down main driver at the minimum safe pressure level.
d. Provide a permissive start contact for main driver.

26.4 A low oil level float switch shall be provided. Device shall be mounted on top of the reservoir. Switch shall be a dual range S.P.D.T. with independent circuits and adjustment ranges. Switch shall conform to the requirements of Paragraph 26.2.

26.5 Compressors in oxygen service shall be provided with a high gas discharge temperature switch following each compressor body before the inter or aftercoolers.

26.0 ELECTRICAL SWITCHES (Cont'd)

26.6 All temperature switches shall utilize remote bulbs with armored capillary tubes. The sensing bulbs shall be in separable wells allowing removal of the bulb while the compressor is in operation. The switches shall be dual switch S.P.D.T. with independent circuits and adjustment ranges. Switches shall conform to the requirements of Paragraph 26.2.

26.7 Low seal gas and high eductor pressure switches shall be supplied as applicable for buffer gas sealing system. Pressure switches shall conform to the requirements of Paragraph 26.2 and shall be mounted within the gage panel.

26.8 Compressors in oxygen service shall be provided with a rotor shift shutdown device. The switch shall have two sets of single pole, double throw contacts. Switch shall conform to the requirements of Paragraph 26.2.

26.9 All switches shall be wired to a common terminal block. Wiring shall conform to the requirements outlined in Paragraph 22.8 and shall be run in rigid conduit. On compressors utilizing a separately mounted lubricating oil console; a separate terminal box will be accepted on the oil console. All wiring between the compressor terminal block and oil console terminal block, if applicable, to the gage board will be made by Purchaser.

27.0 ANTI-SURGE CONTROL

27.1 A control system shall be provided which shall prevent surge when the compression system is subjected to any upset up to and including a reduction of 33% of design flow per second. The reduction in flow may be the result of sudden inlet or discharge throttling.

27.0 ANTI-SURGE CONTROL (Cont'd)

27.2 System shall be complete with all necessary sensing devices, relays and computers. A manual-automatic station shall be flush mounted on the gageboard. The system shall be operable in the automatic mode regardless of the mode of any other compressor control system.

27.3 A flanged, single or double ported bypass valve shall be supplied by the vendor and mounted by the Purchaser. All bypass piping will be supplied by the Purchaser. The bypass valve shall be sized to pass the minimum flow required for stable operation with critical pressure drop at design discharge pressure and/or during startup. Bypass valve operator shall have a stall thrust which is approximately two times the friction, plus inertia, plus unbalanced load of the valve. Actuating air will be available at the pressure specified in the job specification. Valve shall be capable of full stroke in three seconds or less. Maximum valve leakage shall not exceed 0.05% of maximum valve capacity. Loss of actuating air pressure or signal shall cause valve to open.

27.4 Bypass valves for compressors having atmospheric air inlet shall vent to atmosphere upstream of the aftercooler. On all other services the bypass valve will be located downstream of the aftercooler and piped to suction.

27.5 Bypass valves in oxygen service may have cast iron bodies. At pressures above the limits of cast iron the body shall be 300 Series Stainless Steel. Internal parts shall be 300 Series Stainless Steel. Any lubricants required shall be oxygen compatible and approved by the Purchaser. A normally energized three-way solenoid valve shall be mounted on the valve operator. When solenoid valve is de-energized it shall bleed the air from the operator causing the bypass valve to close.

28.0 COMPRESSOR CONTROL

28.1 The control system provided for compressor shall function in either the manual or automatic mode regardless of the mode of the anti-surge system specified in Paragraph 27.0.

28.2 The type of control system shall be as specified in the job specification.

28.0 COMPRESSOR CONTROL (Cont'd)

28.3 The specified control system shall be complete with all necessary sensing devices, relays, computers, recorder and throttling device.

28.4 When a constant weight flow system is specified it shall maintain a constant weight flow with temperature and pressure compensation at the preset value. System shall be complete with manual-automatic station, set point station, recorder, primary element, and throttling device or speed control governor.

28.5 When a constant capacity system is specified it shall maintain a constant discharge capacity at the preset value. System shall be complete with manual-automatic station, set point station, recorder, primary element, throttling device or speed control governor.

28.6 When constant discharge pressure control is specified it shall maintain a constant discharge pressure at the preset value. System shall be complete with manual-automatic station, set point station, primary element, and throttling device or speed control governor.

28.7 When a remote manual control is specified a manual set point station and throttling device or speed control governor shall be provided.

28.8 The primary flow element shall be furnished by the vendor and shall be an insert type Dall flow tube of the size specified in the job specification. Flow tube shall be suitable for installation between 150# ASA Raised Face Flanges. Maximum unrecovered head loss shall not exceed three inches of water column. The flow tube will be installed in the Purchaser's piping following the aftercooler, except for air compressors where the flow tube shall be located between the compressor discharge flange and the aftercooler. Flow tube materials shall be suitable for the maximum discharge temperature.

28.0 COMPRESSOR CONTROL (Cont'd)

28.9 The flow recorder, when required, shall have a range of 0 to 150% of design flow. The chart shall be electrically driven from the control circuit. Chart shall be calibrated in units of cubic feet per hour and the multiplication factor shall be permanently inscribed within the recorder. Recorders for constant weight flow systems shall be temperature and pressure compensated.

28.10 On constant speed machines control shall be accomplished by means of suction throttling. For all gases, except oxygen, throttling by means of adjustable inlet guide vanes is preferred. For oxygen service or where guide vanes are not available, throttling shall be by vendor supplied inlet butterfly valve. Valve will be mounted by Purchaser in inlet piping. Valve shall be suitable for installation between 150# ASA Raised Face Flanges and the valve operator shall have the same stall thrust characteristics as the bypass valve operator.

28.11 On variable speed machines control shall be accomplished by regulating the speed with a pneumatic signal to the air head governor.

28.12 All controls and recorders shall be flush mounted on the gageboard. Relays and computers shall be located within the gageboard. Locally mounted transmitters and other devices shall be grouped and supported on mounting brackets where practical with common connections manifolded.

28.13 Throttle valves in oxygen service may have cast iron bodies. Internal parts shall be 300 Series Stainless Steel. Any lubricants required shall be oxygen compatible and approved by the Purchaser. A three-way normally energized solenoid valve shall be mounted on the valve operator. When solenoid valve is de-energized it shall bleed the air from the operator causing the throttle valve to close.

28.14 Dall flow tubes for use in oxygen service shall be cast iron, bronze, or stainless steel.

29.0 STRAY CURRENTS

29.1 Vendor shall be responsible for analyzing and eliminating all stray currents throughout the complete compressor-gear-driver system.

30.0 TOOLS

30.1 One complete set of all special tools shall be provided. Where more than one unit, up to a maximum of three, is provided at one location, one set of special tools and wrenches per location is acceptable. It shall be the responsibility of the vendor's erector to insure that one (1) complete set of special tools and wrenches is at the location before leaving the site.

31.0 PERFORMANCE

31.1 The compressor shall be tested at full load on the vendor's test stand to verify design calculations and obtain data for actual performance curves. Compressors beyond the capacity of the vendor's drive equipment may be part load tested. Where a compressor train consists of two or more bodies they may be tested individually.

31.2 Compressor shall be operated and data obtained at 120% of rated capacity, rated point, surge point and one point approximately halfway between surge and rated point.

31.3 Data shall be taken to ascertain operating characteristics, vibration, and on flexible shaft machines, the critical speed.

31.4 Lube oil system shall be operated to check the operation of all valves, gages, and pumps. Turbine driven pumps may be operated using air to determine proper direction of rotation.

31.5 Where it is impossible to conduct a full load performance test at the vendor's factory, the compressor may be subjected to a performance test after installation at the Purchaser's discretion. Test procedures will conform to ASME Power Test Code for Centrifugal Compressors (PTC-10). Vendor may witness test. Results of this test will be considered binding relative to compressor guarantee. Any modification required to meet guarantees shall be done by the vendor at no cost to the Purchaser. Any subsequent tests will be performed by the vendor at no cost to the Purchaser.

32.0 PRESSURE VESSELS

32.1 All pressure vessels such as oil coolers, inter and after-coolers, shall be designed and constructed in accordance with the applicable ASME, State, and Local Codes. All vessels within the scope of the codes shall be National Board Stamped.

32.2 All compressor casings shall be hydrostatically tested at one and on-half ($1\frac{1}{2}$) times the pressure it is possible to develop at maximum speed or one and one-half ($1\frac{1}{2}$) times the maximum allowable working pressure, whichever is greater.

32.3 Water passages shall be designed for a minimum operating pressure of 50 psig and hydrostatically tested at 75 psig.

33.0 UNION LABEL

33.1 Gageboard shall bear the label of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitters Industry of the United States and Canada, and manufactured by a company signatory to the panel board and/or gageboard union label agreement.

33.2 All piping within the compressor package 2" and below shall be furnished in random lengths unless required for operational tests in the manufacturer's shop.

33.3 Two copies of a letter confirming that work has been performed in accordance with these requirements shall be forwarded prior to shipment of the equipment to: Purchasing Agent, Air Products and Chemicals, Inc.

34.0 PROPOSALS

34.1 Vendor shall submit three (3) complete sets of proposals. Proposals shall include the following.

34.2 Information:

a. Air Products and Chemicals, Inc. project or reference number.
b. Manufacturer's type or designation.
c. Complete description of offering.
d. Complete description of all accessories.

34.0 PROPOSALS (Cont'd)

34.2 Information (Cont'd)

e. Vendor information pages of the job specification.
f. Price and terms.
g. Delivery.
h. Erection supervision, number of days included in base price, daily rate and overtime rate.
i. Complete list of any exceptions taken to the specifications.

34.3 Characteristic performance curves plotting pressure, brake horsepower at driver coupling, and surge limit versus capacity. Curves shall be plotted using the data provided in the job specification.

34.4 Drawings:

a. Preliminary General Arrangement Drawing including proposed location for all separately mounted equipment.
b. Typical cross section drawing of each casing.
c. Schematic of proposed seal system except air compressors with atmospheric inlet.

34.5 Oxygen compressor proposals shall include a complete tabulation of the materials of all parts that will come in contact with oxygen.

34.6 Spare parts prices for the following items:

a. Spare rotor.
b. Bearings, journal and thrust.
c. Interstage labyrinth or seals.
d. Casing labyrinth or seals.
e. Speed increasing gear rotating elements.
f. Speed increasing gear bearings.
g. Couplings.

35.0 DRAWINGS AND INFORMATION

35.1 Vendor shall submit one (1) reproducible certified drawing of each of the following listed areas. Drawing delivery dates and schedules shall be coordinated at time of purchase and shall be included in the Purchase Order.

35.2 Foundation drawing including:

a. Foundation bolt locations.
b. Foundation bolting for auxiliary equipment.
c. Foundation details.

35.3 General Arrangement drawing including:

a. Total weight.
b. Weight of heaviest part for erection.
c. Weight of heaviest part for maintenance.
d. Location of center of gravity.
e. Space required for removing rotor or impellers and cooler tube bundles.
f. Locations of all piping connections and plugged taps.
g. Size, type and rating of all connecting flanges.
h. Locations of all separately mounted equipment.

35.4 Piping Arrangement drawing, if not included on General Arrangement drawing, including:

a. Process gas piping.
b. Cooling water systems with surge tanks, pumps, etc.
c. Separator drain and local drain valve locations.
d. Pressure gage taps.
e. Seal system piping.
f. Lubrication system piping.
g. Control systems piping.

35.5 Schematic Flow Sheets of:

a. Gas flow.
b. Cooling water flow.
c. Lubrication system.
d. Anti-surge and capacity control system.

Flow sheets shall include all line sizes, pressures, temperatures, flow quantity, pressure vessel design rating, and sensing point of all pressure indicators, temperature indicators and switches. All customer connections shall be indicated.

35.0 DRAWINGS AND INFORMATION (Cont'd)

35.6 Separately mounted inter and aftercooler drawings and TEMA data sheets for all heat exchangers.

35.7 Schematic Wiring Diagram showing all electrical devices, switches and terminal blocks. All wires and terminals shall be numbered.

35.8 Instrument List of all gages, safety valves, switches and control devices. List shall include manufacturer, model, size, range and set point where applicable. List shall be cross referenced with schematic diagrams.

35.9 Equipment lubrication schedule including all auxiliaries.

36.0 REPORTS

36.1 Within two months after receipt of order vendor shall submit three (3) copies of torsional analysis study, listing natural frequencies, operating frequencies and exciting frequencies.

36.2 Within two weeks following shop performance test, vendor shall submit six (6) copies of test report. Report shall include test log sheets, calculated performance curves and typical sample calculations.

37.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS

37.1 Compressor vendor shall supply twelve (12) complete sets of bound Operating and Maintenance Instructions. Delivery date shall be as specified in the Purchase Order.

37.2 Operating Instructions shall be supplied in sufficient detail to instruct a technician in how to prepare the machine for operation (valve and control positioning, lubrication, before-operation checks), how to start the machine (loading, priming, warm up, as applicable), how to operate the machine (normal operating adjustments, pressures, etc., tabulated normal operating conditions), how to shut down the machine (valve and control positioning, etc.).

37.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS (Cont'd)

37.3 Operating Instructions shall include all necessary precautions to be observed to prevent damage to equipment or injury to personnel as a result of failure to observe certain normal operating conditions and procedures.

37.4 Instructions shall include a trouble-shooting table presenting possible troubles that may develop, the probable causes of the troubles, and the appropriate remedies.

37.5 Instructions shall specify the lubricants to be used, the frequency and point of application, and quantity of lubricants required for initial charge.

37.6 Specific characteristic curves of the equipment furnished, marked for the designated operating point, shall be included.

37.7 Maintenance instructions shall be supplied in sufficient detail to indicate to a technician how to:

a. Replace parts subject to wear or failure.
b. Make adjustments to compensate for wear and specify the values and tolerances to be observed in making adjustments.
c. Alter the characteristics of the machine to increase or decrease capacity, pressure, etc.

37.8 Components and special tools shall be adequately illustrated so that construction details and internal workings are described to assist in understanding operation, adjustment, and maintenance procedures.

37.9 If publications are furnished which cover more models of equipment than actually supplied, the vendor shall completely annotate such published material to strike out references, illustrations, and data pertaining to any irrelevant equipment.

37.10 All literature must be certified as accurate and complete. All literature must be revised to incorporate the last change or modification performed prior to closing the Purchase Order and final payment.

37.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS (Cont'd)

37.11 All material supplied by the vendor shall be reproduced in a manner resulting in clear and legible text and illustrations. It is preferred that material submitted be reproduced on 8½ x 11 inch paper with flowsheets and similar items requiring greater length reproduced as 11 inch high foldouts.

37.12 All literature must be marked with Air Products and Chemicals, Inc. equipment Purchase Order number and charge number. In addition, when the Purchase Order requires that the equipment be tagged, the items of literature must also be marked with the tag number. Where one item of literature applies to several pieces of equipment purchased under the same Purchase Order, the literature must be marked with all applicable charge numbers and tag numbers. (The charge number referred to in this requirement is the number appearing in the "CHARGE" column of the Purchase Order.)

38.0 PARTS LISTS

38.1 The manufacturer shall supply twelve (12) complete parts lists of the equipment furnished to this specification including sub-assemblies, attachments, accessories, special tools, and individual parts. Delivery date shall be as specified in the Purchase Order. The manufacturer's part number must provide positive identification of the parts listed. The complete list may be made up of individual sub-assembly lists or bills of material. Any such lists must be identified by a master list so that each part is identifiable as a component of the main equipment. The parts list shall specify the quantity of each item used in the assembly or component.

Common hardware items shall be completely described as to size, length, number of threads, material, finish, type of head, etc. This provision applies whether or not a hardware item has a part number.

38.0 PARTS LISTS (Cont'd)

38.2 Parts lists shall be supported by detail drawings, cross-sectional drawings, exploded-view drawings, or other illustration material identifying each part and keying it to the parts list so that each item in the list can be located on the illustration(s). Items that cannot be procured separately, such as matched sets of gears, pressed fit items, etc., must be clearly noted.

38.3 The complete parts list shall carry notations indicating which items are recommended for spares by the manufacturer.

38.4 A separate price list shall be supplied reflecting current prices for all items appearing on the parts list.

39.0 INSPECTION

39.1 All equipment furnished to this specification, including auxiliaries, shall be subject to inspection by Purchaser's quality control representative. Purchaser's representative shall have full access to all facilities of the manufacturer and its subvendors and have access to all drawings, inspection records, material specifications, and tests to fully determine the quality of material, workmanship, and quality control procedures.

39.2 Vendor shall notify the Chief Inspector, Air Products and Chemicals, Inc. Allentown, Pennsylvania, at least 72 hours prior to hydrostatic tests, piping fabrication, and start of final assembly.

39.3 Shipment shall not be made on any equipment furnished to this specification until approved by the Air Products and Chemicals, Inc. inspector or inspection has been waived by the Air Products and Chemicals, Inc. Inspection Department. Such release shall not relieve vendor of the responsibility to conform to requirements for material, specifications, and workmanship.

40.0 SHIPMENT

40.1 All internal surfaces and all external unpainted surfaces shall be coated with a suitable rust preventative.

40.2 The lube oil system shall be flushed with rust preventative.

40.3 Equipment, including all piping, shall be painted with manufacturer's standard prime coat or with paint specified in the order.

40.4 All major items shall be suitably skidded. All small items shall be wrapped in waterproof paper and boxed. Open pipe connections shall be covered with wood or metal flanges to assure tight seals during transit and field storage.

40.5 All skids and boxes shall be marked with applicable order number, item number and destination.

40.6 All skids and boxes shall be numbered.

40.7 A copy of the packing list shall be furnished to the Purchaser listing contents by skid or box number.

AIR PRODUCTS and CHEMICALS, INC.

GENERAL SPECIFICATION

FOR

RECIPROCATING COMPRESSORS

Rewritten March 9, 1964

REV.	DATE	APP'D	JOB NO. 550-SD-1A	MADE BY J. L. Stolz	Air Products and Chemicals Inc.
E7361	3/9/64	[illegible]	DATE 3/9/64	APP'D J. J. Dunne	ALLENTOWN, PA.
				SCALE	
			GENERAL SPECIFICATION RECIPROCATING COMPRESSORS		NO. 550-SD-1A

APCI DOCUMENT NO. 99000337

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ADDENDUM

Revisions to the General Specification shall be listed on this page to facilitate easy identification of changes.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this specification is to establish a uniform set of requirements for reciprocating compressors purchased by Air Products and Chemicals, Inc.

1.2 SCOPE

All reciprocating compressors purchased by Air Products and Chemicals, Inc. shall conform to this specification, unless the vendor secures written approval from the Purchaser for any exception. Where conflict between this specification and the applicable job specification exists, the job specification shall govern.

2.0 GUARANTEE

2.1 All equipment furnished shall be guaranteed by the vendor to operate at the conditions as set forth in the job specification of the order.

2.2 The vendor shall assume full responsibility relative to the guarantee of all equipment, accessories, and parts subcontracted by the vendor and furnished under this specification.

2.3 All equipment furnished to this specification shall be guaranteed in accordance with the Warranty Clause included in the Purchase Order.

3.0 RUNNING GEAR

3.1 If journal type bearings such as main bearings, connecting rod bearings, crosshead pin bearings, etc., are use, they are to have replaceable shells.

3.2 Crossheads with replaceable shoes are preferred.

3.3 The inside of the compressor crankcase and crosshead housings are to be painted with a paint which is resistant to synthetic lubricants of the tri-aryl-phosphate type (TCP). Hot phosphate treating such as "Parkerizing" is an acceptable substitute for painting.

3.0 RUNNING GEAR (Cont'd)

3.4 On direct connected synchronous motor driven compressors utilizing an outboard bearing, the two piece crankshaft design is preferred. The stub shaft (motor shaft) shall be supplied by the compressor vendor and shipped direct to the motor vendor for assembly with the motor rotor. The stub shaft shall be designed to incorporate the motor collector ring assembly on the end of the shaft.

3.5 Outboard bearings (when supplied) shall include the bearing support pedestal and be suitably insulated between the bearing and pedestal to prevent stray electrical currents. The pedestal shall be separable from the foundation and be designed to facilitate motor removal when the pedestal is removed. Insulation shall be a minimum of $\frac{1}{4}$ inch thick and shall not be painted or otherwise treated such that the insulation value is reduced. Spherically seated oil lubricated journal type bearings with replaceable shells are preferred.

4.0 CYLINDERS

4.1 Compressors above 150 HP shall have replaceable dry cylinder liners. Wet liners on large diameter, low pressure cylinders are acceptable, subject to approval by Purchaser. Liners are not required on lubricated compressors 150 HP and below. All non-lubricated compressors shall be supplied with liners except oxygen compressors, where liners are not permitted.

4.2 Liner hardness shall be a minimum of 240 Brinell Hardness Number.

4.3 Liner bores shall be finished as follows:

Suction Pressure, PSIG	Maximum Roughness (Microinches, rms)
0 - 150	32
150 - 1000	16
1000 and above	8

4.4 Water-to-gas gasketed joints between cylinder heads and cylinders or clearance pockets are not acceptable. External, separate jacket water piping to heads and cylinders is required.

4.5 Each cylinder shall carry a nameplate indicating design operating pressure, maximum allowable working pressure, hydrostatic test pressure, cylinder bore and stroke, and cylinder serial number when applicable.

4.0 CYLINDERS (Cont'd)

4.6 Cylinders being supplied for non-lube operation shall be suitably protected against rusting by hot phosphate treating ("Parkerizing" or equal). Cylinders to be used in other than oxygen service shall be oil dipped ("Lubrited" or equal) in addition to the hot phosphate treatment.

5.0 VALVES

5.1 Compressor cylinder valves are to be easily accessible and capable of being removed without distrubing any piping or other equipment. Valves are to be designed for simple handling and ease of maintenance. Valves installed in lower half of horizontally mounted cylinders shall be provided with holding springs or clips to hold valve in place while installing or removing valve covers. Holding devices shall be designed to eliminate side forces on the valve which prevent proper seating of the valve in the cylinder.

5.2 Valve seat faces shall be arranged in a single, flat plane to facilitate re-lapping.

5.3 Valves and valve parts shall be designed to prevent any part of the valve assembly from entering the swept volume of the cylinder due to failure of the valve or holding device.

5.4 Valve hold-down devices shall be of the single piece construction. Hold-down devices for large diameter valves using more than one hold-down bolt are acceptable; however, the bolts must be used in conjunction with a yoke and must not bear directly on the valves.

5.5 Non-lube compressors shall be equipped with suitably designed valves having self lubricating part- -t points of friction and movement.

5.6 Non-lube valves shall be suitably protected against rusting by hot phosphate treating ("Parkerizing" or equal). Valves to be used in other than oxygen service shall be oil dipped ("Lubrited" or equal) in addition to the hot phosphate treatment.

5.7 Cylinders having only one suction or one discharge valve per cylinder end shall have valves which cannot be installed incorrectly. Oxygen compressors must have valves of this type regardless of the number used.

6.0 PISTONS

6.1 Pistons made of wear resistant materials or provided with suitable wear resistant riding surfaces are preferred. The wear resistant materials may be applied over the entire piston contact area or incorporated as "wear bands" or "rider rings". The wear resistant material shall be softer than the cylinder liner and shall be according to the following schedule:

Service	Material	*Maximum Unit Loading
Lubricated	Babbitt	5 PSI
Lubricated	Bronze	8
Lubricated	Filled Teflon	5
Non-Lubricated	Filled Teflon	3

* The unit loading is based upon 120° arc of contact.

6.2 Wear bands, when used, can be either molded in place or be an assembled part such as with a sectional piston. In either case, the wear band must be held firmly in place and bottom in the piston groove around the entire periphery of the piston. Cold worked or "hammered in" type material such as Allen metal ring~~s~~ are not acceptable.

6.3 Pistons not supplied with wear resistant surfaces shall be surface treated to facilitate run-in during initial operation.

6.4 Aluminum pistons shall have steel inserts in the piston rod attachment area to reduce the unit loading from the piston rod nut and collar. The piston rod and piston shall be designed to prevent creep of the aluminum.

6.5 Pistons to be used in non-lubricated service shall be suitably protected against rusting by hot phosphate treating ("Parkerizing" or equal). Pistons to be used in other than oxygen service shall be oil dipped ("Lubrited" or equal) in addition to the hot phosphate treatment.

7.0 PISTON RINGS

7.1 Lubricated compressor cylinders shall be equipped with bronze alloy piston rings. Where size permits, the rings shall be centrifugally cast.

7.2 Single piece pretensioned rings shall be used where sizing permits and they shall have an angle cut joint. If segmental rings are used they shall be three piece with radially step cut joints employing a bronze alloy expander spring. Where leakage rate is critical with light gases, seal type joints are acceptable.

7.3 Non-lubricated compressor cylinders shall be equipped with self lubricating, filled Teflon piston rings.

7.4 Filled Teflon rings shall be of one piece construction with butt cut ends. If an expansion device is required to expand the piston rings it must be of a material which will not damage the cylinder or piston in the event it comes in contact with the cylinder bore. If segmental rings are required they shall have radially step cut joints. If an expansion device is required it must be as described above.

8.0 PISTON RODS

8.1 Compressors above 150 HP utilizing carbon steel piston rods shall have the piston rods surface hardened to a minimum of 500 Brinell Hardness Number in the pressure packing and oil scraper ring travel area. Compressors utilizing stainless steel or monel piston rods shall have special packing and scraper rings which are softer than the piston rod.

8.2 Piston rods exceeding three (3) inches in diameter shall be undercut in the piston section to facilitate tightening of the piston nut and to allow elastic stretch of the rod to maintain tightness. Tapered piston fits are not permitted.

8.3 Piston rods utilizing thermal lengthwise shrinkage of the rod to insure tightening of the piston nut are acceptable. The vendor is to supply the heater(s) required to loosen and tighten the piston nut.

8.0 PISTON RODS (Cont'd)

8.4 Piston nuts and crosshead nuts shall have positive locking devices to prevent loosening of the nut or rod.

8.5 Compressor handbooks must include proper assembly instructions for thermal or mechanical tightening.

9.0 PISTON ROD PACKING

9.1 Piston rod pressure packing shall be full floating with segmental rings and assembly springs. Coil springs shall be Inconel.

9.2 Lubricated packing rings shall be tinnized bronze or filled Teflon. Filled Teflon rings shall have reinforcing bronze back-up rings.

9.3 Non-lubricated packing shall be filled Teflon with reinforcing bronze back-up rings.

9.4 Packing vents are to be supplied on all compressors handling flammable gas, toxic gas or oxygen. Unless otherwise specified non-vented packings are acceptable on compressors handling air or inert gases. When vented packings are supplied, the vents shall be piped from the packing to a connection on the inside surface of the distance piece housing by the vendor. The distance piece housing shall be drilled through and tapped to 3/4 inch NPT on the outside surface for Purchaser's connection. All distance pieces shall have their packing vent connections at the same relative location.

9.5 Lubricated packing in use at pressures of 1000 PSI and above shall have at least one full cup width pressure breaker ring adjacent to the cylinder.

9.6 Lubricated packing in use at pressures of 1000 PSI and above and all non-lubricated packing shall be water cooled. On compressors with closed jacket water systems the jacket water shall be used and shall be fed from the coolest portion of the system. Provisions must be made to assure adequate water flow through the packing case. The water cooling system shall be supplied by the compressor vendor as an integral part of the cooling water system.

9.7 Oxygen compressors shall have water cooled bronze alloy packing cases completely piped as described above.

10.0 DISTANCE PIECES

10.1 Compressors in service with flammable gas, toxic gas or oxygen shall have a double compartment distance piece. The compartment adjacent to the cylinder and pressure packing shall be gas-tight allowing a slight purge pressure to be maintained. A piston rod oil flinger, sealed to the rod, shall be incorporated in this compartment on non-lubricated compressors.

The compartment adjacent to the crankcase shall be open to the atmosphere except on compressors for outdoor installation where weathertight enclosures with suitable weatherproof vents are required. Oxygen compressors shall have a piston rod oil flinger, sealed to the rod, in this compartment, in addition to the other compartment.

10.2 Compressors in service with air or inert gas where leakage rate is not critical shall have a standard open distance piece. Compressors intended for outdoor installation shall have a standard weatherproof distance piece with suitable weatherproof vents.

10.3 Compressors specified with critical leakage rate shall have multiple distance pieces and oil control devices. The design is at the discretion of the vendor but subject to the Purchaser's review.

10.4 Distance pieces shall have sufficient tapped openings in the housings to permit oil drainage, coolant inlet and outlet, lubricant feed, purge flow, etc., where they are required without requiring connections through the access openings or cover panels.

10.5 Oxygen compressors shall have at least one hinged distance piece cover per housing allowing easy access for internal inspection. The co[illegible] must seal when closed and have retaining devices which are easily opened by hand without the use of tools.

11.0 PISTON ROD OIL CONTROL RINGS

11.1 The crankcase bulkhead shall have full floating segmental metallic oil scraper rings. Compressors with hardened piston rods shall be equipped with tin coated cast iron scraper rings. Compressors with soft rods shall be equipped with scraper rings of a material softer than the piston rod.

11.0 PISTON ROD OIL CONTROL RINGS (Cont'd)

11.2 All compressors equipped with lubricated cylinders shall be designed to prevent carryover of synthetic lubricants from compressor cylinders to the crankcase, and to prevent carryover of crankcase oil into compressor cylinders. Compressors having a distance piece space between the pressure packing flange and the oil scraper case flange which is less than the stroke of the piston shall have extra oil scraper rings. These extra oil scraper rings shall be designed to scrape excess cylinder and pressure packing oil off the rod. The oil from this extra scraper section shall be drained into the distance piece.

12.0 FRAME AND RUNNING GEAR LUBRICATION

12.1 A positive pressure lubrication system shall be provided for the frame and running gear. Horizontal compressors under 150 HP may employ splash lubrication.

12.2 The oil pump for all compressors 1000 HP and above shall be driven by a separate electric motor. Below 1000 HP, frame driven pumps will be acceptable. A manual priming pump shall be provided when frame driven oil pumps are supplied.

12.3 An oil pump suction strainer shall be provided. The strainer shall be either a "perforated-pipe" type located in the compressor crankcase or a "basket" type located in the oil pump suction piping. Either type must be readily accessible for cleaning.

12.4 On all compressors 1000 HP and above, shell and tube type oil coolers shall be provided. Thermostatic control shall be provided to maintain proper oil temperature.

12.5 All compressors using a pressurized oil system shall have oil filters filtering the total oil flow to the bearings. Filters shall be the replaceable cartridge type or cleanable metal edge type. Filtration rating shall be 40 micron or less. Bypass relief valves are not permitted within the filter unit. Filter pressure drop shall not exceed 5 PSI with new cartridges operating at design system oil pressure, temperature and flow. The filter and filter cartridges must be capable of withstanding full system oil pressure, that is, relief valve set pressure. A differential pressure gage with shutoff valves shall be supplied on the filter unit.

12.0 FRAME AND RUNNING GEAR LUBRICATION (Cont'd)

12.6 All lubrication piping shall be furnished by the vendor. Piping to be fitted, cleaned and assembled at the factory. When necessary to ship loose piping, all sections shall be tagged for easy assembly in the field. Piping sections shall be preserved and plugged to prevent foreign materials from entering pipe during shipment and erection. Oil piping $1\frac{1}{2}$ inch and smaller shall be schedule 80 minimum seamless steel with welded connections. Flexible joints, seals, and gaskets shall be suitable for use with synthetic lubricants as well as the normal crankcase oil.

12.7 The system shall be protected by a suitable internal relief valve located in the oil pump and/or by an external relief valve located downstream of the pump in the system piping prior to any shutoff valve.

13.0 CYLINDER LUBRICATION

13.1 It is implied that non-lubricated compressors refer to compressors having no lubrication to the cylinders, valves and packing.

13.2 On lubricated compressors a mechanical force feed lubricator with vacuum type feeds shall be provided for lubrication of compressor cylinders and packings. The lubricator must be driven by an electric motor on compressors 500 HP and above. Below 500 HP, the lubricator may be driven integrally from the compressor. When a separate motor drive is used, an electrical interlock which makes it impossible to start the compressor motor until the lubricator is running will be provided by the Purchaser. When the lubricators are driven integrally from the compressor they must be of the type which can be hand primed before starting the compressor.

13.3 All lubricated compressors must be designed for operation with synthetic cylinder lubricants of the tri-aryl-phosphate type. This includes the lubricator, compressor cylinder assemblies, pressure packing, coolers and any other sections of the compressor coming in contact with the cylinder lubricant.

13.0 CYLINDER LUBRICATION (Cont'd)

13.4 Lubrication shall be provided to each cylinder and packing case in accordance with the following schedule:

Cylinder Bore	Minimum Number of Feed Points	
Inches	Cylinder	Packing
Up to 10"	2	1
10 to 24	3	1
24 to 34	4	1
34 and over	5	1

If desired by the vendor, one of the cylinder feed points may be located in the inlet line; however, each cylinder bore must have a minimum of two feed points spaced a minimum of 90 degrees apart. For cylinders in service 2000 PSI and above, a minimum of two (2) packing oil feeds are required.

13.5 A laminated plastic legend plate shall be attached to the lubricator indicating location of each oil feed, such as first stage upper cylinder bore. The plastic shall be impervious to synthetic fluids.

14.0 COOLING SYSTEM

14.1 A complete cooling water system shall be supplied to provide gas intercooling, gas aftercooling, cylinder jacket cooling, packing cooling and lubrication system cooling. The system shall be complete with all heat exchangers, interconnecting piping, control valves, sight glasses, low point drains and drain valves, high point vents and vent valves. Only one water inlet and one outlet connection shall be provided for the cooling tower water. The cooling water system shall be suitable for operation with cooling tower, nominal back pressure of 20 - 30 PSIG. Open sight flow funnels are not permitted.

14.2 All compressors 1000 HP and above shall be provided with a separate closed jacket water cooling system. This system shall include shell and tube type water-to-water heat exchanger, thermostatic temperature control valve, electric driven water circulating pump, open expansion tank, manual control valves, sight flow glasses, interconnecting piping, low point drains and drain valves. On compressors below 1000 HP the jacket water cooling system may be in series with the

14.0 COOLING SYSTEM (Cont'd)

14.2 (Cont'd)

gas cooling system. Series flow jacket water cooling systems shall include manual control valves, sight flow glasses, interconnecting piping, low point drains and drain valves, and bypass piping for excess intercooler water flow.

14.3 Unless otherwise specified, vendor's standard shell and tube type cooler shall be provided.

14.4 All water cooled coolers are to be machine mounted. Vendor shall provide cooler and cylinder supports. All cooler tube bundles shall be removable. Small pipeline type coolers may be remotely mounted but must include adequate supports.

14.5 Blowout discs shall be provided in the cooler shell if gas pressure in the tubes exceeds the shell maximum allowable working pressure. All blowout discs shall be manifolded by the vendor. Purchaser shall supply one drain connection.

14.6 Maximum allowable pressure drop from intake water manifold to discharge water manifold shall be 10 PSI when parallel water flow system is used for the coolers. 15 PSI is allowable when series flow through cylinder jackets is used on compressors under 1000 HP.

14.7 Interstage pressure drops, through cooler, separator, piping, and bottles, per stage, shall not exceed the following:

$\Delta P = 0.09 \quad P^{0.7}$ where P is interstage pressure in pounds per inch^2 absolute.

14.8 Coolers in use on lubricated compressors or compressors handling wet gas shall be mounted such as to be self draining on the gas side and drain in the direction of the normal gas flow. Any pockets or traps where lubricant or moisture can collect must be provided with a drain valve.

15.0 SEPARATORS

15.1 Condensate separators shall be provided after each intercooler and aftercooler on all wet gas compressors. Condensate separators shall remove a minimum of 90% of the saturated moisture in the gas at the separator operating conditions of temperature and pressure. Vendor's condensate separators shall be provided to meet this requirement unless otherwise specified in the job specification.

15.2 Condensate separators shall have a minimum of 2 hours holdup capacity based upon inlet gas conditions and coolant conditions as specified in the job specification.

15.3 Lubricated dry gas compressors shall be provided with oil separators after each stage of compression to prevent liquid oil carryover. These separators shall be adequate to prevent liquid oil carryover regardless of cylinder lubricant type and feed rate.

15.4 Oil separators shall have a minimum of eight hours holdup capacity based upon vendor's recommended maximum cylinder lubricant feed rate.

15.5 Separators shall be provided with a drain connection and drain valve. Section 17.3 of this specification describes the piping and valve requirements.

16.0 PULSATION DAMPENING

16.1 Adequate pulsation dampening shall be provided to limit pressure pulsations within the compressor system. The allowable peak-to-peak pressure pulsations, expressed as a percentage of the absolute line pressure at that point, are listed below:

Compressor Category	Inlet	Discharge
500 HP and above with atmospheric air inlet	2%	2%
500 HP and above with other than atmospheric air inlet	5%	2%
Below 500 HP	5%	5%

16.0 PULSATION DAMPENING (Cont'd)

16.1 (Cont'd)

The inlet and discharge of the compressor system shall be interpreted as the inlet and discharge piping to and from the compressor. The length of piping considered to be a part of the compressor system shall be equal to one-quarter (¼) wave length of the fundamental compressing frequency. The piping length shall extend upstream from the inlet nozzle of the suction bottle and downstream from the exit nozzle of the final discharge bottle.

16.2 Interstage pulsations shall be adequately dampened to prevent excess vibrations within the compressor package and to assure proper operation of the compressor. Mechanical vibrations of the coolers, piping, separators and surge vessels shall be limited to the following peak-to-peak amplitudes at the corresponding frequencies.

Max. Amplitude	Frequency
.015" @	rotating frequency
.005" @	compressing frequency
.002" @	any higher harmonics

The compressor package shall be interpreted as all of the equipment covered under this specification. The compressor package shall be entirely self contained on its foundation, except for customer connections. No supports to customer's adjoining equipment or buildings shall be permitted. All vibrations as listed above shall be relative to the compressor frame adjacent to the foundation or the frame rails or sole plates. Vibrations in excess of the above amount, which are caused by pulsations, shall be corrected by dampening the pulsations. Mechanical vibrations which are unrelated to pulsations shall be suitably contained by bracing within the compressor package. Bracing must be neat and orderly and not interfere with normal maintenance to the compressor. Excess vibrations related to pulsations of less than five (5) per cent of the absolute line pressure at that point may be braced in lieu of further pulsation dampening.

16.3 Field modifications to reduce pulsations or reduce vibrations shall be entirely the responsibility of the vendor.

17.0 GAS PIPING

17.1 The vendor shall furnish a gas piping package for the compressor, complete from the inlet flange of the inlet manifold or surge bottle to the discharge flange of the final separator following the aftercooler. The piping package shall include:

a. Pulsation dampening system.
b. Gas-to-water inter and aftercoolers.
c. Condensate or oil separators when required.
d. All interconnecting gas piping.

17.2 Low point drains and valves shall be provided at all low points in the piping system. Valves are to be equipped with removable seats and plugs. Minimum acceptable size for all drain piping and valves shall be 3/4" NPT. Drain piping shall be a minimum of Schedule 80 and welded. Valves shall be threaded and backwelded on the pressure side.

17.3 Moisture separators in wet gas service and all oil separators shall have manual drain valves only. Valves and piping shall be as specified in section 17.2. Vendor shall provide locally mounted drain valve with sufficient piping to gain access to valve. The remainder of the separator piping, together with the blowdown header, shall be provided by Purchaser.

17.4 Bypass unloading shall be provided to adequately unload the compressor during starting and stopping. Final discharge unloading plus necessary interstage unloading shall be provided to limit compressor starting and pullin torque to twenty (20) per cent of full load torque. Unloading valves shall have removable seats and plugs. The final discharge unloading valve shall be required regardless of starting torque and shall be suitable for continued throttling without damage to the valve. Where the aftercooler is mounted and piped by the Purchaser the final bypass piping will also be provided by the Purchaser. Final stage unloading shall be following the aftercooler separator.

17.5 All bypass unloading valves shall be operable from the same side of the compressor and shall be operable from the floor level. Valve stands with valve stem extensions are permitted when good piping design dictates remote valve locations. Chain operated valve wheels are not permitted.

17.6 The bypass lines shall be either manifolded for customer's connection or piped to the compressor inlet depending upon the individual job specification.

17.0 GAS PIPING (Cont'd)

17.7 Vendor shall supply all supports for the piping system with all supports being within the compressor package or compressor foundation.

17.8 All piping shall be fitted, cleaned and assembled at the factory. When necessary to ship loose piping, all sections shall be tagged for easy assembly in the field. Piping shall be thoroughly cleaned, flushed with preservative and tightly sealed.

17.9 All piping shall be designed and fabricated in accordance with American Standard Code for Pressure Piping, ASA B31.1 (1955) Sections 2 and 6.

17.10 All pipe plugs shall be forged steel, minimum 3000# rating with hexagon or round head construction. Square head plugs are not permitted.

17.11 Pipe sizes of 3/8", 1¼", 2½", 3½", 5" and 7" shall not be used.

18.0 SAFETY VALVES

18.1 Full capacity ASME approved side outlet safety valves shall be furnished following each stage of compression. All parts subject to loosening shall be secured with safety wire. Lifting levers shall be furnished when required by the ASME Code, and levers shall be spring loaded. Safety valves installed outdoors which are subject to moisture and freezing shall have packed lifting levers. Valves shall be Consolidated, Lonergan, or equal.

18.2 Safety valves shall have flat metal-to-metal seats with a lapped finish.

18.3 Safety valves shall be pop tested by the manufacturer until three (3) successive pop tests each fulfill the set pressure tolerances as set forth in the latest edition of the ASME Code, Section VIII, Unfired Pressure Vessels, Paragraph UG-133, Section (f); plus or minus 2 PSI for set pressures up to and including 70 PSI, 3% for pressures above 70 PSI.

18.0 SAFETY VALVES (Cont'd)

18.4 All safety valves shall be tested for a maximum allowable leak rate of one (1) cubic foot of air per day at 10% under set Pressure.

18.5 Safety valves shall be mounted to preclude the possibility of failure of the attachment when venting. Safety valves in excess of 1000 PSIG set pressure are to be flanged.

18.6 Outlet connection of each safety valve shall be threaded or flanged to permit Purchaser to pipe valve outlets to a common header. Valve accumulation shall be 10% maximum.

19.0 BARRING DEVICE

19.1 All compressors 1000 HP and above shall be equipped with an electric or penumatic reversible barring-over device. A safety switch shall be provided to prevent operation of the main drive motor while barring device is engaged. Vendor shall provide a protective housing over the turning gear to keep out foreign matter. Direct connected compressors below 1000 HP shall be equipped with a manual barring device. Belt driven compressors shall have adequately sized doors in the belt guard to manually rotate belt wheel.

20.0 PROTECTIVE ENCLOSURES

20.1 All oper shafts, couplings, flywheels, belts, gears or other moving machinery must be provided with suitable protective enclosures. This requirement includes the compressor as well as all auxiliary equipment covered under this specification.

20.2 Protective enclosures shall be totally enclosed on the top. Sides may be perforated where local codes permit. Perforations shall be a maximum of ½" opening. The enclosure shall be mounted from vendor's equipment where possible thus requiring no foundation mounts. The enclosure shall be structurally strong enough to support 500 pounds force in any direction without yielding. Enclosure shall be easily removed for maintenance with bolted connections. Enclosures weighing in excess of 50 pounds shall have suitable lifting lugs at the center of gravity.

21.0 GAGEBOARD

21.1 A fabricated steel floor mounted gageboard shall be supplied on all compressors 1000 HP and above. On compressors below 1000 HP, machine mounted gageboards are acceptable. The front of the panel shall be fabricated cold rolled steel plate with all raw edges ground burr-free. All edges shall be finished square to insure tight flush joints, when butted together. Substantial welded in place framing members shall be utilized to provide a rigid, self supporting unit. Top and ends shall be constructed with full depth sheet metal turnback.

21.2 Gageboard shall be finished as follows:

Sandblast - Required for all steel plate, framing and members.

Sealing Primer - Required, 3 coats for panel front, 2 coats other.

Sanding - Required after each coat of sealing primer.

Final Finish - Required 2 coats minimum DuPont #7 Eye-Ease Light Green #J-276-23707.

21.3 Panel shall be mounted on base furnished by others.

21.4 Nameplates shall be supplied on the front of the panel for instrument and service identification. All nameplates shall be laminated black plastic with white core and beveled edges. They shall be 1" high by 3" long minimum and shall be attached with machine screws and nuts. Lettering shall be minimum 3/16" high characters.

21.5 Gage panel shall contain all gas pressure gages and jacket water pressure gage when applicable. Refer to paragraph 22.8 for jacket water system requirements. All gages shall be flush mounted. Where remote compressor loading or clearance pockets requiring a control device are used, control devices shall be gageboard mounted. Legend plate shall identify proper sequence of loading.

21.0 GAGEBOARD (Cont'd)

21.6 On gage panels containing electrical apparatus, the back section of the panel containing such apparatus shall be enclosed with bolted covers or hinged sheet metal doors. The complete electrical installation including terminal blocks shall be in accordance with the requirements of the National Electrical Code for General Purpose Installation. Purchaser will supply 115 volt, 60 cycle, single phase AC source with grounded neutral to the panel. Neutral shall be color coded white. Provision shall be made for grounding the entire panel to the plant grounding system.

21.7 Wire shall be type TW, stranded 600 volt insulation, #14 AWG or larger. All wiring to be connected to terminal blocks using pressure type insulated wire terminals, Stakon or equal. In addition to terminal strip identification, each wire is to be tagged at both ends with standard electrical code markings. Wiring and terminals shall be numbered and agree with numbers shown on wiring diagram. All wiring connections between panel terminal blocks and field will be made by others.

22.0 PRESSURE GAGES

22.1 Flush mounted gages with mounting dimensions in accordance with ASA standards shall be supplied. Flush gages shall have a front flange and a back male connection. The connection shall be $\frac{1}{4}$" NPT for all pressure ranges up to 800 PSIG and $\frac{1}{2}$" NPT for all pressure ranges from 801 PSIG to 10,000 PSIG. All gages shall be $4\frac{1}{2}$" round dial type with black figures on white background. The case shall be of cast aluminum of solid front construction with rear blowout disc. The crystal shall be plastic. The bourdon tube material shall be phosphor bronze for vacuum and pressures up to 800 PSIG, and beryllium copper from 801 PSIG to 10,000 PSIG. Other metals such as alloy steel, stainless steel, and monel shall be used for special conditions of either service fluid or atmosphere. Socket shall be forged brass or bronze for use with phosphor bronze or beryllium copper tubes, and of the same material as the bourdon tube material for all others.

22.0 PRESSURE GAGES (Cont'd)

22.2 Accuracy of 0.5% of full scale (ASA Class AA) is required. Gages shall be equipped with a zero adjustment pointer. Gage shall retain calibration when subjected to overpressure as follows:

a. Up to and including 600 PSIG, 30% over range pressure.
b. 601 PSIG to 10,000 PSIG, 10% over range pressure.

22.3 When the gage is to be used for oxygen service the face of the dial shall be inscribed, "OXYGEN - USE NO OIL".

22.4 Standard Scale Ranges shall be in accordance with following Table I.

OPERATING LIMITS OF GAGE	GAGE DIAL RANGE
0 - 20 PSIG	0 - 30 PSIG
21 - 65 PSIG	0 - 100 PSIG
66 - 135 PSIG	0 - 200 PSIG
136 - 400 PSIG	0 - 600 PSIG
401 - 650 PSIG	0 - 1000 PSIG
651 - 1000 PSIG	0 - 1500 PSIG
1001 - 2000 PSIG	0 - 3000 PSIG
2001 - 3300 PSIG	0 - 5000 PSIG
3301 - 6500 PSIG	0 - 10000 PSIG
Vacuum	0 - 30" Mercury
Vacuum - 10 PSIG	30" - 0 - 15 PSIG
Vacuum - 20 PSIG	30" - 0 - 30 PSIG
Vacuum - 200 PSIG	30" - 0 - 300 PSIG

22.5 Gages shall be U.S. Gauge, Helicoid, Crosby, Ashcroft, or equal.

22.6 Pressure gages shall be provided on the gageboard to indicate the discharge pressure of each stage of compression and first stage suction where the inlet is other than atmospheric air.

22.7 An oil pressure gage shall be mounted adjacent to the oil pressure switch on the compressor frame by the vendor. This gage and switch shall be downstream of any filters, coolers, relief valves, etc., and indicate true bearing oil supply pressure. The gage and switch shall be rigidly mounted to the compressor frame, free of any damaging vibration. Oil tubing or piping shall be minimized.

22.0 PRESSURE GAGES (Cont'd)

22.8 Compressors with a closed jacket water system shall have a jacket water pressure gage located on the gageboard. This gage shall indicate the pump discharge pressure. On compressors for outdoor installation in a freezing climate, the water pressure gage shall be mounted directly on the pump discharge piping.

22.9 On multi-stage compressors 500 HP and above, locally mounted inlet and final discharge pressure gages shall be installed within easy view of the final stage unloading valve. These gages shall contain a pulsation snubber and shutoff valve plus an atmospheric bleed valve between the gage and shutoff valve if operating at 100 PSIG or above.

23.0 PRESSURE GAGE PIPING

23.1 All pneumatic signal leads, and all direct process connections for pressures less than 1500 PSIG (unless otherwise noted in the job specification), shall be ¼" O.D. x .030" wall copper tubing in accordance with ASTM Specification B68DPH. All tubing fittings for this condition are to be Crawford Fitting Co. "Swagelok".

23.2 All direct process connections for pressures 1501 PSIG to 3500 PSIG shall be 3/8" O.D. x .049" wall seamless stainless steel tubing fully annealed in accordance with ASTM Specification A269, TP316. All tubing fittings for this service shall be Parker Appliance Co., 37° flared, stainless steel, "TRIPLE-LOK", in accordance with ASTM Specification A182F316 or A276T316, with inserted Teflon conical seals.

23.3 All panel piping for field connections are to terminate at the rear of the panel on a bulkhead bar. Bulkhead connections for the field shall be ¼" FNPT. All terminal connections shall be identified by a securely fastened engraved plastic nameplate, 1/2" x 3/4". All connections shall be plugged for shipping.

23.0 PRESSURE GAGE PIPING (Cont'd)

23.4 Pressure gage piping between the compressor and gageboard will be supplied by the Purchaser. Vendor shall supply 3/4" NPT connections in his compressor piping. Connections shall be located below floor level and on the side of the compressor adjacent to the gageboard where possible. On compressors with machine mounted gageboards the vendor shall supply and install all gage piping from the compressor piping to the gageboard.

23.5 All pressure gages shall be provided with shutoff valves. Gages mounted on the gageboard shall have the valve located in the rear of the board. Gages operating in excess of 100 PSIG shall have an atmospheric bleed valve between the gage and shutoff valve. Shutoff valves shall be ½" NPT needle type forged steel, Vogt Valve Figure No. 9873, and bleed valves shall be ¼" NPT needle type forged steel, Vogt Valve Figure No. 9871. Oxygen compressors shall be equipped with equivalent stainless steel valves.

23.6 Pulsation snubbers shall be provided on all gas pressure gages.

23.7 Gage piping or tubing shall be supported and tied down within 18 inches of the gage. 12 inches or less is preferred, if possible. Additional supports every 18 inches are required on tubing runs with continuous tubing rack and tie down construction preferred.

24.0 TEMPERATURE GAGES

24.1 Temperature gages shall be supplied by the vendor as listed below. All temperature gages shall be locally mounted in the piping or vessels with separable sockets allowing gage removal while the compressor is in operation. Gages shall be mounted in accessible positions such that the gage can be easily read from the operating floor level.

24.2 Temperature gages shall be 5" round dial type with black figures on white background, with units in degrees fahrenheit. They shall be bi-metallic element adjustable "every angle" type, Manning, Maxwell and Moore Model 5-6060EH, or equal. Connections shall be ½" MNPT.

24.0 TEMPERATURE GAGES (Cont'd)

24.3 Separable sockets shall be 3/4" MNPT with ½" FNPT sockets for the temperature gages. All separable sockets furnished on a particular compressor shall have a pressure rating equal to or greater than the highest pressure encountered on that compressor. Socket well immersion shall be a minimum of two (2) inches in liquid service and a minimum of four (4) inches in gas service.

24.4 Temperature gages shall be provided to indicate the temperature at the following locations:

a. Gas inlet to each stage of compression, including first stage.

b. Gas discharge temperature of each cylinder.

c. Aftercooler discharge.

d. Cooling water inlet on manifold supplying intercoolers and aftercooler.

e. Cooling water outlet of each inter and aftercooler.

f. All compressors 1000 HP and above in the jacket cooling water outlet of each cylinder.

g. Jacket water temperature after the water-to-water heat exchanger on closed jacket systems.

h. Lubricating oil inlet and outlet of the oil cooler.

25.0 ELECTRICAL SWITCHES

25.1 Safety devices shall be supplied and installed by the vendor with the compressor for the services listed below. All electrical wiring and conduit will be supplied by the Purchaser. Vendor shall supply wiring diagrams for all furnished electrical devices.

25.2 All pressure switches shall be dual switch, S.P.D.T. with independent circuits and adjustment ranges. Switches to be precision snap acting, per NEMA IC-3, rated 15 amperes minimum, continuous, inrush, and break at 50% power factor, 115 volts, 60 cycles. Switches shall have silver contacts. Switches shall repeatedly operate at their set point within plus or minus ½% of span. Switches shall be Barksdale, Meletron, or equal.

25.0 ELECTRICAL SWITCHES (Cont'd)

25.3 Compressors operating with other than atmospheric air intake conditions shall have a suction pressure switch. This switch shall be located within the gageboard taking its pressure signal from the same line supplying the suction pressure gage.

25.4 Compressors with closed jacket water systems shall be provided with a water pump discharge pressure switch. This switch shall be located within the gageboard, taking its pressure signal from the same line supplying the jacket water pressure gage. On compressors for outdoor installation in freezing climate, the pressure switch shall be mounted directly on the pump discharge piping with the pressure gage.

25.5 Compressors with pressurized lube oil systems shall be provided with an oil pressure switch. This switch shall be mounted on the compressor frame taking its pressure signal at the most remote point in the system. A minimum of piping shall be incorporated from the lube oil system to the switch.

25.6 Compressors with force feed lubricators shall be provided with a lubricator malfunction detector. This shall consist of a special lubricator pump, located at the farthest point from the driver, which supplies a special pressure bleed-down device connected to a pressure switch. The special pump shall have a shortened suction tube so as to indicate low oil level as well as lubricator mechanical failure. Multi-compartment lubricators shall have a malfunction detector system for each compartment.

25.7 All temperature switches shall utilize remote bulbs with armored capillary tubes. The sensing bulbs shall be in separable wells allowing removal of the bulb while the compressor is in operation. The switches shall be dual switch S.P.D.T., with independent circuits and adjustment ranges. They shall be consolidated and mounted within a panel with free access for maintenance and adjustment, and per requirements of Para. 25.2.

25.8 All oxygen compressors shall have a temperature switch at the first stage suction and at every cylinder discharge nozzle.

25.0 ELECTRICAL SWITCHES (Cont'd)

25.9 All compressors shall be provided with frame mounted vibration switches. Where possible, all switches shall be located on the same side of the compressor. A minimum of one switch per two crankshaft throws is required and shall be mounted directly on the frame in line with the main bearing between or adjacent to the two throws. Vendor shall submit for Purchaser's approval the quantity and location of switches to be provided. Vibration switches for non-hazardous locations shall be Robertshaw-Fulton Model 66-A-WT without reset coil. Hazardous locations shall have the equivalent switches with explosion-proof enclosures. Switches shall be calibrated and set at the installation site by vendor's representative.

26.0 CAPACITY CONTROL

26.1 The applicable job specification will indicate the type of capacity control desired together with the amount and steps of capacity reduction. Capacity control must be designed to prevent overloading or unbalance of the compressor at any reduced capacity within the operating range. A legend plate clearly indicating the steps of capacity reduction shall be supplied. The plate shall be located adjacent to the clearance pockets when manually operated and adjacent to the control mechanism when remotely operated.

26.2 Valve lifter type unloaders shall be quick acting. Pneumatic or hydraulic systems shall have local dump valves or have adequately sized lines to permit rapid release of the valve lifter mechanism. When valve lifter unloaders are use, they must be used on all of the inlet valves on the cylinder end involved. Valve lifters on non-lubricated valves shall have suitable self lubricating features.

26.3 Clearance pocket type unloaders may be self contained or incorporated with the compressor valves. They shall have adequately designed valve plugs to prevent vibration of the plug on the stem when opened. Back seating plugs are preferred. Clearance pocket volume shall be restricted to prevent complete unloading of the cylinder end. Continuous operation of the compressor must be possible at any unloaded condition without exceeding 350°F gas temperature at any point in the system. All clearance pockets shall have a nameplate attached to them, indicating the clearance pocket volume and the percentage of capacity reduction for that pocket. Since the percentage value changes as other pockets are operated, it shall be based on the percentage capacity reduction when all other pockets are closed.

26.0 CAPACITY CONTROL (Cont'd)

26.4 Manually operated clearance pockets shall be easily accessible from the operating floor level. They shall be designed not to vibrate from their set position while the compressor is in operation.

26.5 Remote operated pneumatic-electric clearance pockets shall be furnished and installed as a system by the vendor. The system shall include the clearance pockets, pocket actuators, solenoid valves, actuator tubing, selector switch, braces and supports, plus any other equipment required to make a functional system. The Purchaser shall supply all wiring and conduit. Vendor shall supply complete wiring diagrams. The selector switch shall be mounted on the gageboard.

27.0 TOOLS

27.1 One complete set of all special tools shall be provided with each compressor. Set shall include, but not be limited to, plug valve handles, valve seat removing tools, and foundation bolt wrenches. When more than one compressor, up to a maximum of three, are supplied at one location; one set of "Special Tools and Wrenches" per location is acceptable. It shall be the responsibility of the vendor's erector to insure that one (1) complete set of "Special Tools and Wrenches" is on hand at any one location before leaving the site.

28.0 PERFORMANCE

28.1 After installation, compressors may be subjected to a performance test at the Purchaser's discretion. Test procedures will conform to the ASME Power Test Code for Displacement Compressors (P.T.C. 9-1954). Vendor may witness the test. Results of the test will be considered binding relative to compressor guarantees.

28.2 Pressure pulsation and mechanical vibration tests may be performed on the compressor to confirm vendor's compliance with Section 16.0 of this specification. Vendor shall supply sufficient plugged pressure pickup points to facilitate pulsation readings on the inlet, interstage, and final discharge piping. Pressure taps shall be a minimum of ½" NPT.

28.3 Any modifications required to meet guarantees shall be done by the vendor at no cost to Purchaser. Any subsequent tests will be performed by vendor at no cost to Purchaser.

29.0 PRESSURE VESSELS

29.1 All pressure vessels such as coolers, separators and pulsation dampeners, falling under the scope of the code, shall be designed and constructed in accordance with applicable ASME, State, and Local Codes and shall be National Board stamped.

29.2 Compressor cylinders shall be hydrostatically tested to two (2) times the normal operating gas pressure or one and one-half ($1\frac{1}{2}$) times the maximum allowable working pressure, whichever is greater. Water jackets shall be designed for a minimum operating pressure of 50 PSIG and hydrostatically tested at 75 PSIG.

30.0 UNION LABEL

30.1 All equipment covered under this specification shall bear the label of the International Brotherhood of Electrical Workers and the label of the United Association of Journeyman and Apprentices of the Plumbing and Pipe Fitters Industry of the United States and Canada or evidence thereof.

30.2 Two copies of a letter confirming that work has been performed in accordance with these requirements shall be forwarded, prior to shipment of the equipment, to: Purchasing Agent, Air Products and Chemicals, Inc.

31.0 PROPOSALS

31.1 Vendor shall submit three (3) complete sets of proposals. Proposals shall include:

a. Air Products and Chemicals, Inc. project or reference number.

b. Manufacturer's type and designation.

c. Complete description of offering.

d. Complete description of all accessories.

e. Preliminary General Arrangement Drawing.

f. Price and terms.

g. Delivery.

h. Erection supervision, number of days included in base price, daily rate, and overtime rate.

31.0 PROPOSALS (Cont'd)

31.1 (Cont'd)

i. Complete list of any and all exceptions taken to this specification and the particular job specification.

j. Priced Spare Parts List for the following items:

1. Compressor valve assembly for each stage inlet and discharge.
2. Compressor cylinder liner for each stage.
3. Piston assembly for each stage.
4. Piston rod complete with piston nut for each stage.
5. Piston rings, per set, for each stage.
6. Piston rod packing case assembly complete with packing for each stage.
7. Crosshead assembly complete.
8. Crosshead shoes or slippers.
9. Crosshead pin.
10. Crosshead pin bushings.
11. Connecting rod.
12. Connecting rod pin bushing.
13. Connecting rod journal bearing.
14. Main bearings, journal and thrust.
15. Outboard bearing or bearing insert.

32.0 DRAWINGS AND INFORMATION

32.1 Vendor shall submit two (2) reproducible certified drawings of each of the following listed areas. Drawing delivery dates and schedules shall be coordinated at time of purchase and shall be included in the Purchase Order.

32.2 Foundation Drawing including:

a. Foundation bolt locations.
b. Foundation bolting for auxiliary equipment.
c. Foundation details.

32.3 General Arrangement Drawing including:

a. Total weight.

b. Weight of heaviest part for erection.

c. Weight of heaviest part for maintenance.

d. Location of center of gravity.

e. Space required for removing pistons and cooler tube bundles.

f. Locations of all piping connections and plugged taps.

g. Size, type and rating of all connecting flanges.

h. Locations of all separately mounted equipment.

i. Primary and secondary unbalanced forces, couples, and compressor speed.

32.4 Piping Arrangement Drawing, if not included on General Arrangement Drawing, including:

a. Process gas piping and bypass unloading piping.
b. Cooling water systems with surge tanks, pumps, etc.
c. Separator drain and local drain valve locations.
d. Pressure gage taps.
e. Pulsation pickup taps.

32.0 DRAWINGS AND INFORMATION (Cont'd)

32.5 Schematic Flow Sheet including:

a. Gas, water, oil and drain piping.
b. Pressure vessels and pressure ratings.
c. Pressures, temperatures and line sizes.
d. Cooling water requirements.
e. Safety valve sizes and settings.
f. All gages, and gage connections
g. Pulsation pickup connections.
h. Bypass unloading valves, size, type and location.

32.6 Pulsation dampener drawings.

32.7 Moisture separator drawings and design calculations.

32.8 Inter and aftercooler drawings and TEMA data sheets.

32.9 Capacity control system.

32.10 Schematic wiring diagram including all safety devices and electric auxiliaries.

32.11 Instrument list complete with all set points.

32.12 Cylinder Lubrication Schematic, including exact location of each oil feed.

32.13 Equipment lubrication schedule, including all auxiliaries.

33.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS

33.1 Compressor vendor shall supply twelve (12) complete sets of bound Operating and Maintenance Instructions. Delivery date shall be as specified in the Purchase Order.

33.2 Operating Instructions shall be supplied in sufficient detail to instruct a technician in how to prepare the machine for operation (valve and control positioning, lubrication, before-operation checks), how to start the machine (loading, priming, warm-up, as applicable), how to operate the machine (normal operating adjustments; pressures, etc., tabulated normal operating conditions), how to shut down the machine (valve and control positioning, etc.).

33.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS (Cont'd)

33.3 Operating Instructions shall include all necessary precautions to be observed to prevent damage to equipment or injury to personnel as a result of failure to observe certain normal operating conditions and procedures.

33.4 Instructions shall include a trouble-shooting table presenting possible troubles that may develop, the probable causes of the troubles, and the appropriate remedies.

33.5 Instructions shall specify the lubricants to be used, the frequency and point of application, and quantity of lubricants required for initial charge.

33.6 Specific characteristic curves of the equipment furnished, marked for the designated operating point, shall be included.

33.7 Maintenance instructions shall be supplied in sufficient detail to indicate to a technician how to:

a. Replace parts subject to wear or failure.

b. Make adjustments to compensate for wear and specify the values and tolerances to be observed in making the adjustments.

c. Alter the characteristics of the machine to increase or decrease capacity, pressure, etc.

33.8 Components and special tools shall be adequately illustrated so that construction details and internal workings are described to assist in understanding operation, adjustment, and maintenance procedures.

33.9 If publications are furnished which cover more models of equipment than actually supplied, the vendor shall completely annotate such published material to strike out references, illustrations, and data pertaining to any irrelevant equipment.

33.10 All literature must be certified as accurate and complete. All literature must be revised to incorporate the last change or modification performed prior to closing of the Purchase Order and final payment.

33.0 HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS (Cont'd)

33.11 All material supplied by the vendor shall be reproduced in a manner resulting in clear and legible text and illustrations. It is preferred that material submitted be reproduced on 8½ x 11 inch paper with flowsheets and similar items requiring greater length, reproduced as 11 inch high foldouts.

33.12 All literature must be marked with Air Products and Chemicals, Inc. equipment Purchase Order number and charge number. In addition, when the Purchase Order requires that the equipment be tagged, the items of literature must also be marked with the tag number. Where one item of literature applies to several pieces of equipment purchased under the same Purchase Order, the literature must be marked with all applicable charge numbers and tag numbers. (The charge number referred to in this requirement is the number appearing in the "CHARGE" column of the Purchase Order.)

34.0 PARTS LISTS

34.1 The manufacturer shall supply complete parts lists of the equipment furnished to this specification, including subassemblies, attachments, accessories, special tools, and individual parts. The manufacturer's part number must provide positive identification of the parts listed. The complete list may be made up of individual subassembly lists or bills of material. Any such lists must be identified by a master list so that each part is identifiable as a component of the main equipment. The parts list shall specify the quantity of each item used in the assembly or component.

Common hardware items shall be completely described as to size, length, number of threads, material, finish, type of head, etc. This provision applies whether or not a hardware item has a part number.

34.2 Parts lists shall be supported by detail drawings, cross-sectional drawings, exploded-view drawings, or other illustration material identifying each part and keying it to the parts list so that each item in the list can be located on the illustration(s). Items that cannot be procured separately, such as matched sets of gears, pressed-fit items, etc., must be clearly noted.

34.0 PARTS LISTS (Cont'd)

34.3 The complete parts list shall carry notations indicating which items are recommended for spares by the manufacturer.

34.4 A separate price list shall be supplied reflecting current prices for all items appearing on the parts list.

35.0 INSPECTION

35.1 All equipment furnished to this specification, including auxiliaries, shall be subject to inspection by Purchaser's quality control representative. Purchaser's representative shall have full access to all facilities of the manufacturer and its subvendors, and have access to all drawings, inspection records, material specifications, and tests to fully determine the quality of material, workmanship, and quality control procedures.

35.2 Vendor shall notify the Chief Inspector, Air Products and Chemicals, Inc., Allentown, Pennsylvania, Telephone No. 215-395-4911, at least 72 hours prior to hydrostatic tests, piping fabrication, and start of final assembly.

35.3 Shipment shall not be made on any equipment furnished to this specification until approved by the Air Products and Chemicals, Inc. inspector or inspection has been waived by the Air Products and Chemicals, Inc. Inspection Department. Such release shall not relieve vendor of the responsibility to conform to requirements for material, specifications, and workmanship.

36.0 SHIPMENT

36.1 All internal surfaces and all external unpainted surfaces shall be coated with a suitable rust preventative. Non-lubricated gas compressors, as well as oxygen compressors which have had hot phosphate treatment (Parkerized) must have additional protection for shipping. Non-lubricated compressors, other than oxygen compressors, may be oil dipped (Lubrited) at the time of the hot phosphate treatment but must not have additional rust preservatives applied after assembly. Oxygen compressors must be absolutely oil free in the gas passages limiting any surface treatment to a flourinated wax. A sealed assembly with a dry gas atmosphere and a dessicant charge is recommended in addition to other preservation.

36.0 SHIPMENT (Cont'd)

36.2 The lube oil system shall be flushed with rust preventative.

36.3 Equipment, including all piping, shall be painted with manufacturer's standard prime coat or with paint specified in the order.

36.4 All major items shall be suitably skidded. All small items shall be wrapped in waterproof paper and boxed. Open pipe connections, frame openings and cylinder ends shall be covered with wood or metal flanges to assure tight seals during transit and field storage.

36.5 All skids and boxes shall be marked with applicable order number, project or item number and destination.

36.6 All skids and boxes shall be numbered.

36.7 A copy of the packing list shall be furnished to the Purchaser listing contents by skid or box number.

Air Products and Chemicals, Inc.

August 7, 1970

CONSTRUCTION SPECIFICATIONS

GENERAL CONSTRUCTION

AND

EQUIPMENT ERECTION

OXYGEN COMPRESSION SYSTEM

EL SEGUNDO, CALIFORNIA

200.0 to 200.20

Air Products and Chemicals
INC.

0-1187

200.0 SPECIFICATION FOR PROCESS PIPING AND EQUIPMENT ERECTION

200.1 GENERAL

The scope of work required of the Contractor includes, but is not limited to, the fabricating, cleaning, decontaminating, testing, etc., and the furnishing and installing of all pipe, tubing, pipe fittings, valves, gaskets, bolts and nuts, welding rod, solder, flux, thread dope, lead, hemp, valve packing, etc., as required for the complete installation of the process equipment and piping systems ready for "on stream" operation. Fabrication and inspection of all piping shall be per USAS B31.3 and B31.5, except as modified herein.

200.2 MATERIALS

All material shall be of first=class quality, free from defects and imperfections, of recent manufacture, unused, and of the classification and grade specified, and shall comply with these specifications and Air Products and Chemicals, Inc. Design Engineering Standards.

200.2.1 Screwed plugs shall be steel, barstock for 1-1/2" and smaller and seamless bull plugs for 2" and larger.

200.2.2 Where butt weld fittings are specified, all elbows shall be long radius, unless otherwise specified.

200.2.3 All weld neck flanges and buttweld valves shall be of the same schedule bore as the piping to which they are to be welded.

200.3 APPLICABLE PUBLICATIONS AND REFERENCES

The Air Products and Chemicals, Inc. Design Engineering Standards, codes and standards listed below are referred to herein. The requirements contained in them and in amendments or agenda thereto form a part of the requirements of this specification in the manner and to the extent indicated herein. All codes, standards, and specifications shall be of the latest editions.

200.3.1 AIR PRODUCTS AND CHEMICALS, INC. STANDARDS

Sections 500 to 596 - Contractors' Volume

200.3.2 USA STANDARDS INSTITUTE

USAS B31.3 Petroleum Refinery Piping
USAS B31.5 Refrigeration Piping

200.3.3 ASME BOILER AND PRESSURE VESSEL CODE

Section VIII Unfired Pressure Vessels
Section IX Welding Qualifications

200.3.4 ASTM SPECIFICATIONS

As listed in any of the above sections.

200.4 QUALIFICATIONS REQUIRED FOR WELDING PROCEDURES, WELDERS, AND WELDING OPERAT

200.4.1 All pipe welding shall be made according to qualified procedures as developed by the Contractor, and by qualified welders and welding operators in accordance with the requirements of USAS B31.5, Section 527.5, "Qualification," and Section 527.6 "Records" except as modified herein.

200.4.2 The Contractor shall furnish to the Air Products and Chemicals, Inc. Representative two (2) copies each of all Welding Procedure Specifications in accordance with the applicable codes. Welding Procedures shall be approved by Air Products and Chemicals, Inc. prior to initiating production of welding.

200.4.3 Each welder shall be qualified for this project and his qualification certificate shall be on file in the Contractor's jobsite office and made available to the Air Products and Chemicals, Inc. Representative.

200.4.4 Cost of all qualifications shall be borne by the Contractor.

200.5 QUALIFICATION FOR BRAZERS

200.5.1 The Contractor shall have personnel qualified for torch brazing in accordance with USAS B31.5, Section 528, "Brazing and Soldering," and as follows:

200.5.1.1 The test for qualification of each brazer shall be performed in the presence of the Air Products and Chemicals, Inc. Representative.

200.5.1.2 The material used for the test shall be pipe or tube and fittings.

200.5.1.3 The Air Products and Chemicals, Inc. Representative shall visually inspect the test specimen and accept or reject the joints prior to further processing.

200.5.1.4 Specimens approved shall be sectioned and prepared for peel testing in accordance with the Code.

200.5.1.5 The requirements which the processed test specimens must meet are listed below. Specimens which fail to meet the following requirements shall be cause for rejection.

The separated faying surfaces of the specimens shall show:

(a) The total bonded area of all faying surfaces have 100% bond.

200.5.2 Cost of all qualifications shall be borne by the Contractor.

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200.6 EQUIPMENT ERECTION

The Contractor shall erect, align, set, support and grout all Air Products and Chemicals, Inc. furnished equipment in accordance with the contract drawings and specifications.

200.6.1 The Contractor shall employ the best practices of the trade to prevent damage to equipment or injury to personnel.

200.6.2 The Contractor shall, prior to lifting any pieces of equipment, review his lifting arrangement with the Air Products and Chemicals, Inc. Representative. Such review does not relieve the Contractor of the responsibility for safe equipment handling.

200.6.3 The Contractor shall assume full responsibility for providing adequate temporary supports for the equipment during erection. Unusual weather and safety must be given primary consideration and any inadequacies which may be called to the Contractor's attention by the Air Products and Chemicals, Inc. Representative shall be immediately corrected.

200.6.4 The Contractor shall provide shims of proper material and size for steel to concrete load transfer and to obtain the elevations as shown on the contract drawings.

200.6.5 The Contractor shall cut nozzles on Air Products and Chemicals, Inc. furnished equipment to proper dimensions and nozzle ends shall be prepared for joining to piping as described in other paragraphs of this specification. The Contractor shall clean nozzles free of all chips, burrs, dirt, and any foreign material before joining to piping. Nozzles shall be temporarily resealed for full waterproof protection after preparation for fit-up unless piping is to be immediately installed. The utmost care must be exercised at all times to prevent contamination from any source.

200.7 PIPE WORK

The Contractor shall perform all piping work in accordance with the current editions of the applicable codes, specifications and standards listed in other sections of these specifications and the following:

200.7.1 In place of tees, saddles and welding bosses such as weldolets and forged steel couplings of proper material and adequate pressure rating may be used. Unless specifically shown on the drawings, the Contractor shall not do branch welding (stub-ins).

200.7.2 All branch connections shall be welded in accordance with the Code for Pressure Piping USAS B31.5, Chapter V, Fig. 527.4.6D.

200.7.3 Branch connections shall not intersect the longitudinal seam of welded pipe headers.

200.7.4 The longitudinal seams of welded pipe in adjoining pipe sections shall be staggered.

200.7.5 All flange bolt holes shall straddle the natural centerlines in all directions.

200.7.6 Large fabricated tees and mitered bends shall be backwelded on the inside of the fitting. In mitered bends in pipe sizes 14" and larger, an extra segment shall be included to allow welding inside.

200.7.7 All copper tube and fittings shall be silver brazed unless otherwise noted.

200.7.8 All copper tube to stainless steel joints shall be silver brazed.

200.7.9 Pipe bends shall not be permitted without prior approval by Air Products and Chemicals, Inc. Where permitted such bends shall have a radius of not less than five (5) times the nominal pipe diameter measured to the pipe centerline. Pipe bends shall be free of flat spots and corrugations.

200.7.10 All bends shall not exceed an out-of-roundness tolerance of ten percent (10%) of the outside diameter at any cross-section of the bend, i.e., $\frac{\text{OD max.} - \text{OD min.}}{\text{OD Nominal}} \times 100 = 10\%$

200.7.11 Open ends of all pipes, valves, etc., shall be kept capped, plugged or covered at all times until final connections are made. Wood and/or rag plugs are not acceptable and shall not be used.

200.8 WELD JOINT PREPARATION

The Contractor shall prepare all welding joints in accordance with the current edition of USAS B31.5, ASME Boiler and Pressure Vessel Code, Section IX and the following:

200.8.1 Stainless steel pipe shall be cut only by mechanical devices.

200.8.2 Robvon Type "C" or equal backup rings shall be used as follows on butt welded joints 2-1/2" and larger, except as noted in Paragraph 200.8.2.2.

200.8.2.1 Backup rings shall be used on all aluminum piping.

200.8.2.2 Backup rings shall not be used on shop fabricated interstage compressor piping or compressor discharge piping in oxygen service.

200.8.2.3 Backup rings shall be used for field closures on all piping except for interstage compressor piping or compressor discharge piping in oxygen service.

200.8.2.4 Backup rings may be used on all other shop fabricated piping.

200.8.2.5 Welds of orifice flanges shall be made without the use of backup rings. The upstream and downstream welds shall be ground internally so that the inside diameter at the weld is within 1% of the published inside diameter for the schedule of pipe specified. Any purchased meter runs will require installation in the process pipe at the upstream and downstream ends without the use of backup rings.

200.8.2.6 Stainless steel backup rings shall be used at field joints combining stainless steel pipe or fittings to carbon steel pipe of fittings.

200.9 WELDING PROCEDURE

200.9.1 CARBON AND STAINLESS STEEL WELDING

200.9.1.1 All welding of schedule 5 and schedule 10, stainless steel piping, and carbon to stainless steel piping, shall be performed by the inert gas tungsten arc method. All welding of stainless steel piping and stainless steel to carbon steel piping, heavier than schedule 10, shall be performed by the inert gas tungsten arc method for the root pass and may be completed with the coated electrode process. All welding of carbon steel piping shall be performed by the metallic arc process or inert gas shielded arc process, using direct current exclusively, except piping in oxygen service which shall be performed by the inert gas tungsten arc method for the root pass and may be completed with the coated electrode method.

200.9.1.2 Polarity for welding stainless steel shall be negative electrode for inert gas shielded arc welding.

200.9.1.3 Welding electrodes shall conform to ASTM Specification A233-48T, Classification E-6010, E-7016, and E-7018 for mild steel piping. For welding Type 304 stainless steel, Type 308 filler wire shall be used. Filler wire for welding Types 316 and 347 bear the same type numbers as the base metal. For welding carbon steel to 304 stainless steel, use Type 310 filler wire.

200.9.1.4 Materials being welded shall be carefully fitted, aligned, and retained in position during the welding operation. Adequate and proper tackwelding will be considered acceptable. Tacks shall not obstruct a full penetration weld.

200.9.1.5 The inside surfaces of piping components to be joined by butt welding shall be aligned so that the misalignment at any point on the inside circumference does not exceed 1/16 inch or 1/4 the nominal thickness of the component with the thinnest wall, whichever is smaller.

200.9.1.6 Before starting to weld, tacks must be thoroughly cleaned.

200.9.1.7 At least one pass per 1/8" of wall thickness shall be made. Downward welding will not be permitted. Slag shall be removed before depositing succeeding layers. All welds shall have full penetration and complete fusion. The finished weld shall be uniform, with the toe or edge of the weld merging smoothly into the base metal. Butt welds shall have slight reinforcement built up gradually from toe or edge toward the center of the weld. Fillet welds may be slightly concave on the finished surface. No undercutting or overlapping is permitted.

200.9.1.8 Should cracks or blow holes occur on the surface of any welding bead, they shall be chipped or grounded out to remove the defect, then wire brushed in order to present a surface from which complete fusion may be obtained with the next successive welding bead. Peening to cover defects shall not be allowed.

200.9.1.9 Welding by creating a heat pattern at a circumferential joint can draw in the weld and the base metal in the heat affected zone, so as to create a belling in, giving a reduction of the area of the pipe or tube. This belling or distortion is undesirable and the following limitations are placed on it:

> The belling or distortion tolerance cannot exceed one percent of the actual outside diameter or 1/16 inch, whichever is larger, this belling or distortion can be measured by comparing the actual outside diameter at the belled or distorted area.

200.9.1.10 For carbon steel welding each welder shall identify his production welds by stamping his regularly assigned identification number on the pipe adjacent to the weld on all carbon steel material. Stamps shall be low-stress type with a round or "U" shaped cross-section.

200.9.1.11 For stainless steel welding each welder shall identify his production welds by etching with an electric pencil, his regularly assigned identification number on the pipe adjacent to the weld on all stainless steel material.

200.9.2 ALUMINUM WELDING

200.9.2.1 Aluminum welding shall be performed by either the Inert Gas Shielded Metal Arc Welding process, with tungsten electrode, (TIG) using alternating current exclusively, or by the Inert Gas Shielded Metal Arc Process with consumable electrode, (MIG). The MIG welding process may only be employed on pipe welding on pipe diameters of 8-inch or larger. No single pass or filler bead shall be more than 3/4-inch in width. Only stringer passes shall be acceptable. "Wash" type passes will not be acceptable.

200.9.2.2 The types of filler metal to be used for welding various aluminum alloy pipe combinations are given in the following table:

Filler Metal	Aluminum Alloy Combination
1100	type 3003 to 3003
4043	type 3003 to 6061
5356	type 3003 to 5083
5356	type 5083 to 5083
5356 or 5556	type 6061 to 6061
5356 or 5556	type 6061 to 5083

200.9.2.3 All edges shall be prepared for TIG or MIG welding with the use of proper tools and preparation methods.

200.9.2.4 Clean all surfaces to be welded of oil, grease and dirt. Vapor or solvent degreasing will usually be satisfactory. If heavy oxide is present on the metal surface, they shall be cleaned by such mechanical means as stainless steel wire brushing. Each weld pass shall be thoroughly cleaned with stainless steel wire brush prior to placing the succeeding pass.

200.9.2.5 Each welder shall identify his production welds by etching with an electric pencil, his regularly assigned identification number on the pipe adjacent to the weld on all aluminum material.

200.10 SILVER BRAZING

The Contractor shall perform all silver brazing in accordance with the following:

200.10.1 Fittings shall be round, true and new. Fittings, once brazed, shall not be reused, unless approved by the Air Products and Chemicals, Inc. Representative.

200.10.2 Copper pipe and tube shall be cut to desired length with a square cut in a square end sawing vise or with a power saw, true to size, deburred and cleaned; tube cutters shall not be used.

200.10.3 Pipe or tube and socket shall be cleaned to bright metal immediately prior to brazing. The pipe or tube shall be cleaned for a distance slightly more than the depth of the fitting-socket. Cleaning shall be done carefully so that the proper clearance is maintained between the pipe or tube and fitting.

200.10.4 Flux shall be applied to both members, immediately prior to brazing.

200.10.5 Silver brazing operators shall use approved techniques which will produce joints of 100% penetration of full socket depth consistently.

200.10.6 Wherever possible, solder joints shall receive an internal visual inspection by optical inspection devices.

200.10.7 Brazing wire shall be Handy Harmon Easy Flow #35 for copper to copper and #45 for stainless steel to copper and brazing flux shall be Handy and Harmon Handy Flux.

200.10.8 Solder joints shall be kept as far as possible from threaded joints. In all cases, the distance shall be sufficient to prevent the heat of soldering from destroying the effective seal of joint compound.

200.10.9 All joints which show evidence of overheating, cracking, poor penetration, or other defects of fit-up or workmanship, shall be replaced as directed by the Air Products and Chemicals, Inc. Representative.

200.10.10 Each brazing operator shall identify his work by making his regularly assigned identification symbol on the tube adjacent to the joint, at the time the joint is made, in the manner approved by the Air Products and Chemicals, Inc. Representative.

200.10.11 All brazed joints shall be subject to the inspection of the Air Products and Chemicals, Inc. Representative. The Contractor shall, at the discretion of the Air Products and Chemicals, Inc. Representative, cut brazed joints out of lines, saw in half and tear apart, to continually monitor brazing operators techniques.

200.10.12 This monitoring shall be compensated for as follows:

Defective joints and their repair shall be to the Contractor's account. Sound joints that have been destructively tested as indicated above will be paid for by Air Products and Chemicals, Inc.

200.10.13 Should testing under other sections of these specifications reveal unsound brazed joints, the Contractor shall disassemble and replace fitting with new material or with the Air Products and Chemicals, Inc. Representative's approval, reclean to a bright finish and reassemble those joints which were unsatisfactory.

200.11 <u>THREADED JOINTS</u>

The Contractor shall make up all threaded piping with as few joints as possible. All threaded joints shall be made with clean-cut taper threads conforming to National Taper Thread Dimensions. Piping shall be reamed of burrs and kept clean of scale, dirt and chips. All connections shall be permanently gas-tight and watertight. Unions shall be provided as shown on the drawings, or as required for proper assembly and disassembly. Couplings shall not be used except where pipe is more than sixteen (16) feet in straight length between fittings. All threaded joints, including those for oxygen service, shall be made with "Permacel 412 Ribbon Dope"

200.11 THREADED JOINTS (Cont'd.)

(made by Permacel Corporation, Brunswick, N.J.), or "Thred Tape" (made by Crane Company), thread sealing compound, except in the case of piping carrying freon. The joints shall be made up using "Lead Lock" by High Side Chemical, Inc., 10 Colfax Avenue, Clifton, New Jersey, or as indicated on Air Products and Chemicals, Inc. Standard 570.5.1. For Instrument Air Headers only (Galv. Carbon Steel threaded pipe) General Electric Glyptol #1201 shall be used as a thread dope.

200.12 EQUIPMENT AND PIPE SUPPORTS, GUIDES AND ANCHORS

The Contractor shall furnish and install all equipment and pipe supports, guides and anchors required in accordance with the contract drawings, these specifications, and as may be required to provide adequate supports for a satisfactory operating installation.

Beam clamps and mechanical attachments shall be employed to support piping from structural steel members. Supports shall be welded to structural members only where specifically required by the contract drawings, otherwise, field welding, burning or drilling will not be permitted.

200.12.1 During the construction period, the Contractor shall furnish and install necessary temporary piping and equipment supports. As permanent supports are installed, the Contractor shall remove temporary supports.

200.12.2 The Contractor shall provide and install anchor bolts, expansion shields and bolts, etc., as required, to erect and attach supports.

200.12.3 Materials for pipe supports, guides and anchors shall be in accordance with the contract drawings, other sections of these specifications and/or the requirements of the Air Products and Chemicals, Inc. Representative.

200.12.4 All pipes passing through masonry construction shall be fitted with pipe sleeves. Sleeves shall be standard weight steel pipe of sufficient length to pass through the entire thickness of the floor or wall and shall be cut flush with each surface, except as otherwise specified. The Contractor shall furnish and set all sleeves and be responsible for their proper and permanent location.

200.12.5 All pipe 2-1/2" and under shall be adequately and permanently supported as part of the contract work although not specifically indicated on the contract drawings.

200.13 UNDERGROUND PIPING

The Contractor shall furnish and install all underground piping in accordance with the contract drawings and these specifications.

200.13.1 Open ends of all pipe, valves, etc., shall be kept capped, plugged, or covered until final connections are made.

200.13.2 The Contractor shall excavate whatever substance is encountered for all piping, manholes, pits, and other underground work. Trenches shall be of sufficient width for installation and inspection of pipe. Bottom of trench shall be trimmed so that the lower portion of pipe is continuously supported on undisturbed soil until the slope of pipe is uniform between established elevations.

200.13.3 If rock or shale is encountered, sand cushion shall be provided. Cushion shall continuously support the lower third of the pipe circumference. Thickness of sand under pipe shall vary from 3-inches (4- to 6-inch pipe) to 8-inches (8- to 24-inch pipe).

200.13.4 Depth of piping for various underground lines shall not be less than shown on the contract drawings.

200.13.5 Unless otherwise specified, underground steel pipe shall be protected by one of the following:

200.13.5.1 Application of two (2) coats of Val-Chem Tar-Coat 78-J-2 as manufactured by the Mobil Chemical Company, Metuchen, New Jersey, or "Tarset" as manufactured by USS Chemicals, Division of U.S. Steel Corp., 400 Manner Building, 564 Forbes Street, Pittsburgh, Pennsylvania. The Manufacturer's instructions for preparation of surfaces and application of coating shall be strictly adhered to. Each coat shall be applied at a minimum thickness of 14 mils wet to obtain a dry minimum thickness of 8 mils. All surfaces shall be covered with an even coat having a dry film thickness of 16 mils minimum.

200.13.5.2 Use pipe coated with plasticized coal tar enamel and kraft paper wrap in accordance with Pipe Line Service Corporation Specification B-2GF. All fittings and field-fabricated joints shall be covered with 2" wide Protecto Wrap #200 Cold Applied Tape and 1170 Primer as distributed by Kenneth Peisker Co., 543 Pennsylvania Avenue, Glen Ellyn, Illinois. Tape shall be spiral wrapped for 4" on both sides of each weld in accordance with the manufacturer's application procedure.

200.13.5.3 Use pipe coated with polyethylene coating (Xtru-coat). All fittings and field-fabricated joints shall be covered with polyethylene tape (Xtru-tape) or "Thermofit" heat-shrinkable sleeves as manufactured by Rayclad Tubes, Inc., Redwood City, California. Application shall be in accordance with the manufacturer's application procedure.

200.13.6 Coated pipe shall be handled carefully to prevent damage to the coating. Small imperfections caused by improper application of coating or improper handling of the coated pipe may seriously affect

200.13.6 (Continued)

its protection value. After installation, all coating shall be spark tested to detect holidays with a tester similar to that manufactured by Tinker and Rasor, P. O. Box 281, San Gabriel, California. Test voltage shall not exceed 6000 volts nor be less than 4000 volts. All defects detected in this test shall be repaired to provide continuity in the coating and then retested.

200.13.7 After the pipelines have been tested, coated, inspected and approved by the Air Products and Chemicals, Inc. Representative, the excavation shall be cleaned of trash and debris. Rocks or stones shall not be dumped directly upon pipe when backfilling. The backfilling material shall consist of excavation or borrow of sand or gravel. Backfill shall be placed in layers not to exceed 9" thickness and properly moistened to approximate optimum requirements. Each layer shall be compacted by hand or machine tampers, or by other suitable means to a density that will prevent excessive shrinkage or settlement. Backfill shall be brought to a suitable elevation above grade to provide for anticipated settlement or shrinkage. Excess excavated material shall be disposed of on the site as directed.

200.13.8 Backfill shall be placed around manholes, pits, and other work. This shall be clean subsoil material placed in 9" layers. Each layer shall be thoroughly compacted.

200.13.9 Cinders shall not be used for backfill.

200.14 CLEANING OF PIPE AND ASSOCIATED SYSTEMS

The Contractor shall clean and hydrocarbon decontaminate all process piping in accordance with contract drawings and these specifications. Ineffective cleaning of pipe or equipment is extremely hazardous and can result in loss of life, damage to property, and product impurities. Proper cleaning cannot be overemphasized. If doubt exists as to whether the line or equipment has been cleaned properly or whether the line has become contaminated, it shall be recleaned at the Contractor's expense. The Air Products and Chemicals, Inc. Representative's decision concerning the degree of cleanliness which is acceptable shall be final. The Contractor shall be responsible for cleaning any Air Products and Chemicals, Inc. furnished random pipe and fittings which require final fabrication by the Contractor.

200.14.1 The Contractor shall clean or clean and decontaminate all piping as follows:

200.14.1.1 Steam, condensate, above ground fire protection and cooling water systems shall be cleaned in accordance with Paragraph 200.14.1.6 STANDARD CLEANING.

200.14.1.2 Air compressor intake lines shall be cleaned in accordance with Paragraph 200.14.1.7 CLEANING OF CARBON STEEL PIPE AND FITTINGS, and the interior shall be painted with one coat of epoxy paint. Paint shall be Sovapon Radiance Red, Series Number 84-R-7, as manufactured by Mobil Chemical Company, Metuchen, New Jersey, or approved equal. A 6-inch clearance shall be allowed between painted surfaces and any field welds.

200.14.1.3 Lube oil systems shall be pickled in accordance with Paragraph 200.14.3 PICKLING OF CARBON STEEL PIPE AND FITTINGS.

200.14.1.4 All process air, oxygen, nitrogen and argon systems downstream of main air compressor shall be cleaned and decontaminated in accordance with Paragraphs 200.14.1.7, 200.14.1.8, or 200.14.1.9, depending on pipe material.

200.14.1.5 The Contractor shall clean or clean and decontaminate or pickle all components after all cutting and fit-up has been performed and prior to welding. The Contractor shall be responsible for any hydrocarbons, dirt, or foreign matter that may be discovered in the assemblies after welding, but not for any discoloration that might occur as a result of the fumes produced in welding.

200.14.1.6 STANDARD CLEANING

200.14.1.6.1 All pipe and fittings shall be cleaned of all foreign material, such as scale, sand, weld spatter particles, cutting chips, etc., from the inside by any suitable means, such as a mechanically-driven rotary cleaning tool and/or a wire brush, etc.

Blow out with compressed air.

200.14.1.7 CLEANING OF CARBON STEEL PIPE AND FITTINGS

200.14.1.7.1 The interior of all carbon steel pipe and fittings shall be blast cleaned with Black Beauty Blast Grit, Grade BB-4016, as manufactured by H. B. Reed and Company, Hammond, Indiana, or equal. Blasting shall be done to remove all mill scale, rust, varnish, paint, hydrocarbons and other foreign matter. The pipe shall be blown out with dry oil free air or nitrogen after it is blast cleaned.

200.14.1.7.2 Immediately after the completion of the blast-cleaning operation, the pipe and fittings shall be immersed in an unagitated rinsing solution of Oakite #77 at a concentration of 2 ounces of Oakite #77 per gallon of water. The solution shall be maintained at a temperature of 200 degrees Fahrenhei The solution shall be allowed to dry down on the work to provide an alkaline activated coating to the surface of the work to act as a temporary rust inhibitor.

200.14.1.7.3 The interior of all carbon steel pipe and pipe fittings which cannot be blast cleaned shall be cleaned in accordance with directions given in paragraphs following:

200.14.1.7.4 Immerse the work in a solution of Oakite #77 at a concentration of 8 to 10 ounces per gallon of water, maintained at a temperature of 180 to 200 degrees Fahrenheit for a period of time ranging from 30 minutes to one hour. Since the immersion time is variable due to varying degrees of contamination build-up on the work, the actual time required must be determined by periodic inspection. To assure the removal of all possible soils, especially a type of varnish used by pipe manufacturers as a rust retarder, a concentration of 1-1/2% by volume of "Oakite Stripper Additive" shall be added to the solution.

200.14.1.7.5 Remove work from cleaning solution and rinse in potable water at ambient temperature. This rinse shall be moderately agitated, by using compressed air or other mechanical means, to assure the removal of any loose soil clinging to the surface of the work.

200.14.1.7.6 Following the rinse, the work shall immediately be immersed in a solution of Oakite #31 and water at a concentration of 5% by volume. This solution shall be maintained at a temperature of 160 to 180 degrees Fahrenheit. The immersed time required shall be determined by periodic inspection. Usual time required is 30 minutes.

200.14.1.7.7 Remove work from cleaning solution and rinse in potable water at ambient temperature. This rinse shall be heavily agitated by compressed air or other mechanical means to assure the removal of all scale and rust.

200.14.1.7.8 Following the second rinse the work shall immediately be immersed in an unagitated rinsing solution of Oakite #77 at a concentration of 2 ounces of Oakite #77 per gallon of water. This rinse shall be maintained at a temperature of 200 degrees Fahrenheit. This solution shall be allowed to dry down on the work.

200.14.1.7.9 In the preceeding cleaning procedures the first stage is to remove varnish and coarse dirt and scale; the second stage is to assure complete removal of all scale and rust, and the third stage is to provide a temporary rust inhibitor.

200.14.1.8 CLEANING ALUMINUM PIPE, FITTINGS, PARTS AND FABRICATIONS

200.14.1.8.1 Prepare a solution of Oakite Aluminum Cleaner #164 at 6 to 8 ounces per gallon of water. Heat solution to a temperature of 180 degrees to 200 degrees Fahrenheit. Allow parts to

200.14.1.8.1 (Continued)

soak in solution for a period of time required for complete removal of soils and contaminants. Maintain mild agitation of solution by means of compressed air introduced into solutic

200.14.1.8.2 Upon attaining required cleanliness of parts or fabrications, remove from cleaning solution and immediately immerse in potable water rinse at ambient temperature using violent air agitation of rinse water. When rinsing tubing, piping and similarly fabricated parts, an internal pressure rinse is recommended, i.e., high velocity hose stream.

200.14.1.8.3 If necessary, the following method shall be used to remove oxides and/or residue from initial cleaning, immerse work in a solution of Oakite #34, 10 ounces per gallon at ambient temperatures (but not less than 60 degrees Fahrenheit) for a period of five minutes.

200.14.1.8.4 Following the above process, the work shall be thoroughly rinsed in a potable water rinse at ambient temperature, using violent air agitation of rinse water.

200.14.1.9 CLEANING STAINLESS STEEL AND COPPER PIPE, FITTINGS, PARTS AND FABRICATIONS

200.14.1.9.1 Prepare a solution of Oakite #77 at a concentration of 6 to 8 ounces per gallon of water maintained at a temperature of 180 degrees to 200 degrees Fahrenheit. Allow work to soak in the solution for a period of time required for complete removal of soils and contaminants.

200.14.1.9.2 Upon attaining required cleanliness of parts or fabrications, remove from cleaning solution and immediately immerse in a potable water rinse at ambient temperature using violent air agitation of rinse water.

200.14.1.9.3 If necessary, the Air Products and Chemicals, Inc. Representative may require the following method be used to remove stains, residue from initial cleaning, or similar discoloration, immerse the work in a 25 percent by volume solution of Oakite #31 maintained at a temperature of 160 degrees to 180 degrees Fahrenheit for a period of time required for complete removal of all stains and discoloration.

200.14.1.9.4 Following the removal of stains and/or discolorations, the work shall be thoroughly rinsed in a potable water rinse at ambient temperature, using violent air agitation of rinse water.

200.14.1.10 DESCRIPTION OF CLEANING MEDIUMS

200.14.1.10.1 Oakite Stripper Additive - Neutral.

Application: Additive to any regular ALKALINE Oakite solution. Applicable to metals which were initially determined suitable for the Oakite solution to which it is added.

Purpose: Considerably reduces cleaning time and improves the cleaning ability of an Oakite solution. Used to accomplish removal of acrylic and epoxy lacquers.

Mixing Proportions: 2 percent to 10 percent Oakite Stripper Additive to any alkaline Oakite solution by volume.

Operating Temperature: Do not heat in excess of 180 °F.

Precautions: NEVER ADD Stripper Additive to AN ACID OAKITE. An active reaction will occur. Do not allow contact with skin or eyes.

200.14.1.10.2 Oakite #31 - Contains Acid.

Application: All metals, except aluminum.

Purpose: Removes oxides, rust, oils and soils.

Mixing Proportions: 5 percent Oakite #31 to water by volume.

Operating Temperatures: 160 °F to 180 °F.

Precautions: Do not allow to contact skin or eyes.

200.14.1.10.3 Oakite #34 - Acid Power-Type Material.

Application: For treating aluminum, brass, bronze & copper.

Purpose: To remove oxides and brighten metal surfaces by immersion or circulation.

Mixing Proportions: 6 ounces to the gallon by spray or circulation, 10 ounces to the gallon by tank immersion.

Operating Temperature: Room Temperature.

Equipment: Stainless Steel, Alloy 347, 316 ECL or 304 ECL.

Precautions: Contains chromates. Do not allow to contact skin or eyes.

200.14.1.10.4 Oakite #77 - Strong Alkaline

Application: All metals, except aluminum.

Purpose: Remove heavy deposits of soils and oils. Remove light deposits of rust and scale.

Mixing Proportions: 8 to 16 ounces of Oakite #77 to one gallon of water.

Operating Temperature: 160 °F to 180 °F.

Precautions: Do not use at temperatures below 140 °F, or when scum forms on solution. Do not allow contact with skin and eyes.

200.14.1.10.5 Oakite #161 - Mild alkaline powder material. Inhibited against attack to aluminum. Contains depressants to prevent excessive foaming.

Application: Cleaning aluminum by pressure spray or circulation method.

Purpose: To remove all types of soils other than stains and oxides.

Mixing Proportions: 3to 4 ounces per gallon.

Operating Temperature: 180 °F to 200°F.

Equipment: Material safe on all metals. Ordinary steel solution holding tanks for spray equipment are suitable.

200.14.1.10.6 Oakite Aluminum Cleaner #164 - Mild alkaline powder material. Inhibited against attack to aluminum. Contains depressants to minimize foaming when agitat

Application: Cleaning aluminum.

Purpose: To remove all types of soils other than stains and oxides.

Mixing Proportions: 6 to 8 ounces to the gallon.

Operating Temperature: 180 °F to 200 °F.

Equipment: Safe on all metals. Ordinary steel tanks are suitable.

200.14.1.11 The Contractor shall provide holding tanks or troughs of sufficient size for the specified Oakite solutions and rinses.

200.14.1.12 During the process of cleaning the pipe and fittings, the Contractor shall perform periodic titration of the cleaning solutions to assure maintenance of the specified concentrations. Upon request, titration equipment and instructions in the use thereof will be furnished free of charge to the Contractor by the Oakite Company.

200.14.1.13 Heating of the cleaning solutions and rinses as specified may be accomplished by closed steam coils, electric or gas immersion heaters or any other method sufficient to maintain the required temperatures.

200.14.1.14 Fabricated pipe spools which have been cleaned shall be capped or plugged until time of final inspection. No rags shall be used to plug pipe at any time.

200.14.1.15 In the event that the piping becomes contaminated while in the possession of the Contractor, the Contractor shall repeat the cleaning at his own expense.

200.14.2 INSPECTION OF HYDROCARBON DECONTAMINATED COMPONENTS

All components requiring decontamination will be subjected to inspection and will be considered acceptable when they pass the following:

200.14.2.1 Visual inspection under bright, white light. Any square foot may contain no loose particles which exceed 150 micron size and only isolated particles larger than 75 microns.

200.14.2.2 Ultra-violet (black light) inspection shall indicate that the cleaned surfaces are free of any hydrocarbon fluorescence. Lint or dust that may be visible under the black light shall be removed with dry, oil-free, filtered air or nitrogen.

200.14.2.3 Wiping with a clean, white filter paper shall indicate no evidence of vegetable or animal oils which are not detectable by ultra-violet inspection.

200.14.3 PICKLING OF CARBON STEEL PIPE AND FITTINGS

Carbon steel lube oil pipe and fittings shall be pickled and passivated just prior to start-up of a particular machine or piece of equipment--as follows:

200.14.3.1 Pickling: Immerse in hot or cold solutions of Sulfuric hydrochloric (muriatic) or phosphoric acid to which sufficient inhibitor has been added to minimize attack on the base metal, followed by thorough rinsing in hot water above 140 °F.

200.14.3.1 (Continued)

Passivation: Flush with 2% caustic soda solution.

Finish: Flush with oil and leave an oil coat interior and cap or plug ends for shipment.

200.15 PIPING TOLERANCES

200.15.1 Dimensions of installed piping shall be as shown on the contract drawings within, plus or minus 1/8-inch for pipe up to and including 10-inch nominal pipe size and plus or minus 3/16-inch for 12-inch and larger nominal pipe size. Tolerances shall not be cumulative.

200.15.2 Flanges shall not be out of square more than 3/64-inch per foot of outside diameter of flange.

200.15.3 Angular tolerances shall be plus or minus 1/2 degree.

200.15.4 No cold springing unless specified on contract drawings will be allowed for piping fit-up. Improperly fitted piping shall be removed and replaced as directed by the Air Products and Chemicals, Inc. Representative at the Contractor's expense.

200.16 INSPECTION

200.16.1 In addition to any required code inspection, all fabrication and material shall be subject to inspection by a representative of Air Products and Chemicals, Inc. Approval of fabrication by inspection or waiver of inspection shall not relieve the Contractor of the responsibility to conform to the requirements for material, dimensional accuracy, workmanship, specifications or code requirements.

200.16.2 All welding operations performed shall be subject to spot radiographic examination in accordance with the ASME Boiler and Pressure Vessel Code Section VIII, Unfired Pressure Vessel, Paragraph UW-52 (latest revision The final field joints of Oxygen Compressor interstage or discharge piping shall be subject to 100% radiographic examination.

200.16.2.1 Surfaces inspected shall be free of all moisture, residue, discoloration (other than that which is due to the metal), particles having a diameter larger than 500 microns (.020 inch) and fibers exceeding 2000 microns (.080 inch) in length. The surface shall also be free of any excessive concentration of smaller particles or fibers detectable with the naked eye.

200.16.3 The cost of spot radiographic examination of welds will be paid separately by Air Products and Chemicals, Inc. The Contractor shall quote the cost in accordance with standard rates.

200.16.4 The Contractor shall be responsible for any rework and radiographic re-examination of fabrication that does not conform to the radiographic examination, Air Products and Chemicals, Inc. inspection requirements, or these specifications.

200.17 TESTING

200.17.1 All tests shall be performed in the presence of and to the satisfaction of the Air Products and Chemicals, Inc. Representative. The Contractor shall notify the Air Products and Chemicals, Inc. Representative in advance of any test performance.

200.17.2 All piping systems shall be tested with dry and oil-free air or nitrogen, by the Contractor after installation of piping. Whenever compressed air is employed for pressure testing process piping, it shall be passed through a silica gel or activated alumina drier at high pressure before entering the system being tested; and it shall have a dewpoint of minus 40°F or lower.

200.17.3 Test pressures shall be as directed by the Air Products and Chemicals, Inc. Representative.

200.17.4 Due regard for safety shall be constantly observed.

200.17.5 Water shall be used in testing utility lines.

200.17.6 Tests are to be conducted for tightness of lines and joints, valve bonnets, valve packing and other fittings.

200.18 TESTING PROCEDURE

200.18.1 Check all systems to assure compliance with the contract drawings. Check pressure and temperature ratings of all valves to assure compliance with Air Products and Chemicals, Inc. Engineering Design Standards.

200.18.2 Check all flange joints to confirm compliance with the specifications, bolting material, gasket and make-up.

200.18.3 Check all safety valves for pressure setting. Safety valves shall be removed and temporary plugs (supplied by the Contractor) installed in their place during pressure testing.

200.18.4 Test gages and test safety valves (test safety valves supplied by Air Products and Chemicals, Inc.) shall be installed, and testing medium source connections shall be made, to convenient process connections. After completion of testing, the gages and source connections shall be removed and the specified process attachments replaced as directed by the Air Products and Chemicals, Inc. Representative.

200.18.5 Start test at low pressure and gradually increase pressure in increments as leaks are found and corrected. Use soapsuds and water on all joints.

200.18.6 An accurate log and list of repairs shall be kept by the Contractor and delivered to the Air Products and Chemicals, Inc. Representative upon completion of the contract.

200.19 MISCELLANEOUS

200.19.1 The Contractor shall be responsible for the installation of all lubricants.

200.19.2 Temporary screens of a mesh determined by the Air Products and Chemicals, Inc. Representative shall be installed ahead of the intakes of all compressors, pumps, blowers, except the main air compressor, for the blow-out and start-up period.

Recommendations of the equipment manufacturers shall be followed. Screens shall be manufactured by Mack Iron Works Company, Sandusky, Ohi

200.19.3 A list of all valves that will be furnished by Air Products and Chemicals, Inc. and installed by the Contractor is included with the contract documents. All other valves required by the contract drawings and these specifications are to be furnished and installed by the Contractor.

200.19.4 Flanged or welded vessels or equipment shall be aligned and properly fitted in accordance with drawings and specifications before bolting or welding. Excessive piping strains on equipment shall be avoided.

200.19.5 Instrument taps in warm piping shall be as follows:

Pressure Tap - 1/2-inch FPT, 3000 pounds Forged Steel Coupling, Weldolet or equal.

Temperature Tap - 3/4-inch FPT, 3000 pounds Forged Steel Coupling, Weldolet or equal.

200.20 PATCHING, REPLACEMENT AND MODIFICATION OF EXISTING WORK.

After installation of the pipe lines, the Contractor shall neatly patch, repair and replace existing work where damaged, removed or altered for pipe line installation. This work shall be similar and equal in quality to the work removed or damaged, unless otherwise shown or specified. Such work shall include patching and replacement on existing lines at points of connections to new lines, patching of masonry work where new lines pass through existing masonry work, and wherever any such patching work is indicated on drawings or otherwise required.

Air Products and Chemicals INC.

STANDARD PICTORIAL SURFACE PREPARATION
STANDARDS FOR PAINTING STEEL SURFACES

by

ASTM

ASTM D2200-67, 2P, 1967

Air Products and Chemicals INC.

Date December 10, 1971

INTER-OFFICE MEMORANDUM

RECEIVED
DEC 10 1971
R. & D. DEPT.

Subject NASA Oxygen Study Project
00-1-2495.07

To A. Lapin — Allentown Labs
(Location, Organization, or Department)

From W. Schmoyer — Safety Dept.
(Location, Organization, or Department)

Procedure for determination of material compatibility in oxygen includes three important steps: (1) research of existing test data, (2) test program, and (3) hazard evaluation of the application and conditions of use.

1. References used in researching existing test data include:

   a) APCI test data
   b) Government test data
   c) Industry test data

2. Testing program includes:

   a) Open flame
   b) Oxygen index test
   c) Impact test
   d) Bomb test
   e) Material analysis test

3. Hazard evaluation includes:

   a) Application
   b) Pressure of service
   c) Temperature of service
   d) Direct contact with oxygen
   e) Accidental exposure to oxygen
   f) Identification and elimination of ignition sources
   g) Affect of surrounding activities to the application or process

Any material considered for oxygen service which has previously been tested must satisfy at least two of the steps above, while material which has never been tested must be evaluated through the all three steps.

Approval or disapproval of material for oxygen service depends on interpretation of test results in relation to the hazard evaluation and the exercise of sound professional judgement.

W. Schmoyer

mr

PRINT ROOM
SEP 27 1971

I. SCOPE

This specification covers the design, field fabrication, cleaning, testing, insulation and inspection of a flat-bottom, double wall, purged powder insulated vessel intended for the storage of a cryogenic liquid. The Vendor must be thoroughly familiar with low temperature equipment design, fabrication and construction. This specification shall be used in conjunction with a job specification furnished for each individual vessel.

II. DESIGN CONDITIONS

A. General Design Criteria

The vessel and piping shall be designed and constructed in strict accordance with the ASME, ASTM, ASA, API (Std. 620) and all other applicable codes and standards except where specifically noted in this specification. Further, the Vendor shall be responsible for conforming to any safety orders or codes which apply in the state or area in which this vessel is to be installed.

The quotation should specify any and all codes and standards which will be adhered to in the design of this vessel. Any reference to the codes or standards shall mean the latest edition including all revisions and addenda. Any deviation from the letter or intent of this specification, as well as the reference codes and standards shall be approved by Air Products and Chemicals, Inc. prior to inclusion in the design and/or fabrication of the vessel.

B. Inner Vessel

1. Design temperature shall be plus 100°F to minus 320°F.

2. The design pressure of the inner vessel shall be as follows:

   Internal pressure as specified in the attached job specification plus the pressure exerted by the liquid load when filled to capacity or the external pressure exerted after ten thermal cycles from ambient to operating conditions by the powder insulation in the annular space. Vendor shall specify the pressure due to perlite compaction in his bid proposal.

3. Materials of construction shall be aluminum (Type 5083, ASTM-GM-41A), 9% nickel steel (ASTM A353 or ASTM A553), or stainless steel (Type 304, ASTM A-240). The Vendor shall state in his proposal which of these materials he will use.

B. Inner Vessel (Cont'd.)

4. The Vendor shall include in the design calculation submittal the external purge pressure to which the inner tank can be safely subjected employing the design conditions in (B.2.) above and the maximum allowable working pressure permitted by the actual thickness of materials used in fabrication.

5. The inner vessel shall be of all welded construction and designed in accordance with the API Code, Std. 620, Appendix Q. No stamp is required.

6. The vessel shall be equipped with a manhole, 18" minimum, at the top center of the vessel.

7. The inner vessel shall be equipped with a mechanical liquid level gauge. The gauge shall be at ground level.

8. The bottom of the inner vessel shall be pitched 1/8 inch per foot from the center to the outer perimeter, the high point being in the center.

9. Materials used for internal clips, supports, etc. shall be compatible with LOX and suitable for a temperature of minus 320°F. Carbon steel is not acceptable.

10. All gaskets used on flanges of manways or piping to the inner vessel shall be Durabla or approved equal.

11. Radiographic, vacuum box, or liquid penetrant weld testing shall be done in accordance with API Standard 620 and Appendix Q. The specific tests and joint efficiencies used shall be included in Vendor's bid proposal.

C. Outer Vessel

1. Design Pressure: Internal pressure of 2" H_2O plus the pressure developed by the compaction of the powder insulation due to ten thermal cycles from ambient to operating conditions.

2. Design Temperature: See job specification.

3. Corrosion Allowance: None

4. The vessel material shall be in accordance with API Standard 620, Appendix Q.

C. Outer Vessel (Cont'd.)

5. The Vendor shall include in the design calculation submittal, the maximum internal pressure to which the outer vessel can be safely subject employing the design conditions in (C.1.).

6. The size of this vessel shall be determined by the Vendor, unless otherwise specified, but shall be such as to provide an insulation space that will limit the heat gain as specified in the job specification and in accordance with the conditions outlined in paragraph III.A.

7. The vessel shall be of all welded construction, designed in accordance with API Standard 620, Appendix Q.

8. The vessel shall be equipped with a manway, 30" minimum diameter. This manway shall be located at the top of the outer vessel and shall be concentric with the inner vessel manway.

9. The vessel shall be equipped with one or more perlite fill ports located near the top of the outer tank. One of these shall be a 20" manway provided with a 20" emergency vent.

10. The vessel shall be equipped with a breather valve located at the top of the outer vessel. Valve to be sized by Vendor.

11. The vessel is to be equipped with a minimum of four 6" or larger perlite drain nozzles and blind flanges located at the bottom of the outer vessel.

12. The vessel shall be equipped with a top platform complete with guard rails and circular stairway with handrail for maintenance purposes. A walkway with guard rails shall be provided between the stairway and platform.

13. The annular space shall contain a circular, perforated purge gas distributor located at the bottom of the annular space and running the entire periphery of the annular space. The line coming through the outer shell from the distributor shall be a minimum of 1" N.P.S.

D. Insulation

The insulation to be used in the annular space shall be expanded perlite ore. The manufacturer and grade of perlite used is to be specified by the Vendor and is subject to approval by Air Products and Chemicals, Inc.

Bottom insulation shall be formglass block, or approved equal, installed by Vendor.

D. Insulation (Cont'd.)

Vendor shall specify the "k" value used for insulation materials under steady state conditions.

E. Process Piping

1. All piping materials and fabrication techniques used in connecting the inner and outer vessels shall be in accordance with the USAS Code, Section B31.3 with the following exception:

   If aluminum is used for the inner vessel the liquid and gas piping shall be fabricated of aluminum. No aluminum to stainless steel transition will be allowed within the tank annular space.

2. The wall thickness of all piping shall be adequate to withstand the design pressure of the vessel, and any stresses due to the piping configuration and thermal contraction. The wall thickness of liquid piping shall not be less than standard weight.

3. Approximate locations of the process piping terminations shall be as shown on attached job specification. Exact orientation of the piping will be given to the Vendor by Air Products and Chemicals, Inc. at a later date at no additional cost to Air Products and Chemicals, Inc.

4. All liquid lines from the bottom of the inner vessel are to be suitably trapped within the annular space.

5. All liquid lines shall terminate external to the outer vessel as shown on sheet 17 or 18 of this specification.

6. All cold piping passing through the outer shell shall be connected to the outer shell by means of a type 304 stainless steel thermal barrier. The barrier shall be sufficiently long to prevent the carbon steel adjacent to the barrier from reaching a temperature lower than 5°F below ambient temperature.

7. All piping between inner and outer vessels shall be provided with sufficient flexibility to permit movement due to thermal contraction. Lines shall be fixed at both inner and outer vessels. The use of bellows is not acceptable with the exception of the relief valve lines and the mechanical liquid level gauge line. All lines shall be designed so that the maximum combined stress, including appropriate stress intensification factors, due to pressure, weight, settlement and thermal movements, shall not exceed the maximum allowable stress valve indicated in the ASME Code, Section VIII, Division 1 for the material used.

E. Process Piping (Cont'd.)

8. All lines 6" and smaller subject to liquid head shall have at least one oblique x-ray shot taken at each girth weld. Lines above 6" subject to liquid head require three shots per girth weld. All radiographing shall be done in accordance with the USAS piping code B31.3, Chapter 6 and shall be considered as random radiography for inspection purposes. In addition to the x-rays, certification of the fact that the piping has received a thorough visual examination and has been found free of any hidden welds is required by the Vendor.

9. All piping connections to the bottom of the inner vessel shall be located as near to the shell as possible.

10. The vessel shall be equipped with the following piping to the inner vessel. Line sizes not defined in this specification shall be sized in accordance with the job specification. (Nozzle identification letters refer to sheet 16 of 18 of this specification.)

a. Nozzle "A" - (1) Relief Valve Line
(2) Size by Vendor
(3) Located at the top of the inner and outer vessels.
(4) On the outside of tank the line is to be provided with a pressure-vacuum relief valve, S.&J. Figure No. X94156. The outlet of the valve is to be provided with a short piece of stainless steel or aluminum vent piping turned downward but away from the vessel.

b. Nozzle "B" - (1) Vent Line from Inner Vessel
(2) Size: 4" N.P.S.
(3) Located at top of inner vessel and extending into the inner vessel to an elevation equal to the top liquid filling point elevation. This line should leave the outer vessel at the lower portion of the outer shell.

c. Nozzle "C" - (1) Pressurizing Connection
(2) Size: 1 1/2" N.P.S.
(3) Attached to vent line (Nozzle "B") external to outer vessel.

d. Nozzle "D" - (1) Upper Liquid Level Line
(2) Size: 1" N.P.S.
(3) Located at top of inner vessel and the lower part of the outer shell

E. Process Piping (Cont'd)

e. Nozzle "E" - (1) Lower Liquid Level Line
(2) Size: 1" N.P.S.
(3) Located at the bottom of the inner vessel and the lower part of the outer shell. (See sheet 16 for details of inner tank connection.)

f. Nozzle "F" - (1) Pressure Gauge Connection
(2) Size: 1" N.P.S.
(3) Attached to Upper Liquid Level Line (Nozzle "D") external to outer vessel.

g. Nozzle "G" - (1) Product Outlet Line
(2) Size : 4" N.P.S.
(3) Located at the bottom of the inner vessel and the lower part of the outer shell and to be flush with the bottom of the inner vessel.

h. Nozzle "H" - (1) Trailer Unloading Line
(2) Size: 4" N.P.S.
(3) Located at the bottom of the inner vessel and projecting into the inner bottom approximately 3". This line is to leave the outer vessel near the bottom of the outer shell.

i. Nozzle "J" - (1) Fill Line
(2) Size: 4" N.P.S.
(3) Located near the bottom of the shell of inner and outer vessels.
(4) This line shall be designed in such a manner that the fill point in the inner tank will be at a minimum of 90° from the Trailer Unloading Line (Nozzle "H") in the inner tank. This may be done by entering the inner tank at a minimum of 90° from Nozzle "H" or by extending the Fill Line into the tank to provide an equivalent clearance. This requirement is to be adhered to even though Air Products and Chemicals, Inc. may choose to locate both of these nozzles adjacent to one another on the outer shell.

j. Nozzle "K" - (1) Cylinder Fill Line
(2) Size: 1 1/2" N.P.S.
(3) Located in the bottom of the inner vessel and projecting into the inner bottom approximately 3". This line is to leave the outer vessel near the bottom of the outer shell.

E. Process Piping (Cont'd)

k. Nozzle "L" - 1 1/2" Mechanical Liquid Level Gauge with following:
(1) Magnetic gauge head S & J 92020-41-XX-04-01 for LOX service with ACCOPAC gaskets.
(2) Limit switch S & J 99050 with 2 SPDT contacts for high and low liquid level alarms.
(3) Adapter S & J 9905-10300 to mount limit switch on counter housing.
(4) Accessory kit S & J 93990-X14B
(5) 90° all aluminum shiv housing if required S & J JB3560-6 with ACCOPAC gaskets.
(6) 45° all aluminum shiv housing if required S & J 9399-13110 with ACCOPAC gaskets.
(7) 180° all aluminum shiv housing if required S & J 93580-05 with ACCOPAC gaskets.
(8) Stainless Steel reinforced float JB3031-1.
(9) All aluminum cable block valve S & J 93421-24.

l. Nozzle "M" - (1) Outer vessel manway
(2) Size: 30" minimum
(3) Located at top center of roof concentric with inner vessel manway.

m. Nozzle "N" - (1) Inner vessel manway
(2) Size: 18" minimum
(3) Located at top center of roof concentric with outer vessel manway.

n. Nozzle "P" - (1) Perlite fill ports
(2) Quantity as required by vendor
(3) One shall be a 20" manway equipped with a 20" S & J Figure 94200-11 emergency vent.

p. Nozzle "Q" - (1) Breather valve line with S & J X94020-15-01 (for cryogenic service)
(2) Size: By Vendor

q. Nozzle "R" - (1) Perlite drain nozzles
(2) Size: 6" minimum
(3) Quantity: 4 minimum
(4) Nozzles shall terminate with a blind flange.

r. Nozzle "S" - (1) Annular space purge line
(2) Size: 1" minimum
(3) A circular, perforated header shall run the entire periphery of the annular space.

II. GENERAL REQUIREMENTS

A. Heat Gain

1. The total heat gain through the insulation space, piping, supports and other connections shall be such that the loss of product per day does not exceed that specified in the job specification when the vessel has been filled to rated capacity with the liquid for which it is designed and allowed to reach equilibrium. Heat gain shall be based on ambient conditions of 80°F and 14.7 psia.

2. Since loss of product is an important consideration on this vessel, the Vendor shall quote his best guaranteed heat gain if it is less than that specified, and this figure will be weighed in evaluating the bids. Vendor's calculated heat gain (including gain through insulation and piping) shall be submitted with the quotation along with the guaranteed heat gain.

B. Testing

1. The pressure testing of the vessel shall be in accordance with Section R-8 of Appendix R, A.P.I. Standard 620.

2. No welding shall be permitted on the vessel and/or piping after the satisfactory completion of testing without approval by Air Products and Chemicals, Inc.

3. After vessel has been placed in service, at a time agreed upon and with a procedure agreed upon by both the Vendor and Air Products and Chemicals, Inc., an evaporation test will be conducted by Air Products and Chemicals, Inc.

C. Cleaning and Inspection

The methods used for cleaning all surfaces are to be submitted by the Vendor in his bid and are subject to approval by Air Products and Chemicals, Inc.

1. Inner Vessel

   a. Cleaning Requirements for Internal Surfaces (Aluminum or Stainless Steel)

      (1) All surfaces of the tank, piping and fittings which will come in contact with the liquid product or its vapors shall be cleaned of all loose scale, dirt, slag and weld spatter. If wire brushing is employed, stainless steel bristles should be used.

C. Cleaning and Inspection (Cont'd)

(2) All surfaces exposed to the process shall be degreased in accordance with the Vendor's standard for liquid oxygen vessels, subject to Air Products and Chemicals, Inc. approval.

b. Cleaning Requirements for Internal Surfaces (9% Nickel)

(1) All surfaces of the tank, piping and fittings which will come in contact with the liquid product or its vapors shall be mechanically or hand cleaned to remove weld spatter and other gross particle and hydrocarbon contamination.

(2) After final hydrostatic testing and all other operations are complete, sandblast tank surfaces to remove scale, rust, dust, dirt, weld slag, weld flux, plate markings and other foreign matter. The blasting will essentially produce a near white metal surface as defined by SSPC SP10-63 and CSA3 (Danish Paint Council) pictorial surface preparation for painting steel structures. The surfaces will not be required to meet the uniform surface texture of specification CSA3, but all surfaces must be of a shade of grey and free of any rust discoloration. Care will be exercised to minimize any light rerusting of a previously blasted area. All access and piping openings shall be effectively sealed to prevent moisture infiltration when work is not in progress.

(3) After blasting all gross amounts of sand shall be removed by the most expedient methods and then the final removal of sand and dust shall be accomplished by vacuum cleaning.

(4) During assembly draw detergent or solvent soaked swabs through pipe sections to remove hydrocarbons and particles. Cover or plug inside and outside ends of lines to prevent contamination during subsequent operations. Reclean in the same manner any individual lines which subsequently become contaminated.

c. Inspection

Surfaces which have been cleaned shall then be examined in the following manner and must pass the tests indicated:

(1) Visual inspection under bright, white light.

(a) No evidence of moisture; free of scale, rust, slag, weld spatter and other foreign matter; and free of organic materials such as oil, grease, crayon, paint, ink, etc.

(b) Any square foot of cleaned surface examined for particulate contamination may contain:

1. No particle greater than 1,000 microns. (Particle: Any solid matter other than a fiber. The size is determined by the longest single dimension.)

2. Not more than ten particles between 500 and 1,000 microns.

3. No fiber in excess of 2,000 microns in length; and no accumulation of fibers. (Fiber: A nonmetallic flexible, threadlike structure with a length to diameter ratio of at least 10.)

(2) Ultraviolet (blacklight) examination.

(a) No hydrocarbon fluorescence. Particles of lint, if present, shall be removed with nitrogen, or dry, oil-free air.

(3) Wipe test.

(a) No appreciable discoloration of the wiping media, except that which is due to oxidation of the parent metal, and no evidence of oily residue.

2. Annular Space

a. Cleaning

(1) Remove loose and/or heavy scale, slag, dust, rust and dirt by mechanical means or by hand.

(2) Remove gross hydrocarbon contamination by local wiping with rags moistened with detergent.

b. Inspection

(1) Inspect accessible surfaces for freedom of loose and/or heavy scale, dust, dirt and slag.

(2) Inspect accessible surfaces for gross hydrocarbon contamination. Presence of contamination shall be cause for additional local cleaning.

D. Drying

Following testing and cleaning, the inner vessel and the annular space and its insulation shall be dried with oil-free dry nitrogen gas until the effluent purge gas reaches minus 40°F as indicated by Alnor Dew Pointer or equal apparatus. All inner vessel covers shall be sealed with clean gaskets. Both the inner vessel and outer vessel shall be sealed with positive gaseous nitrogen pressure within the safe limits of the vessel design.

E. Painting

1. All steel surfaces to be painted shall be cleaned to remove all millscale, rust and other foreign matter detrimental to paint adhesion by either of the following options:

   a. Pickling as defined by the Steel Structures Painting Council Specification SP 8-63.

   b. Commercial Blast Cleaning as defined by the Steel Structures Painting Council Specification SP 6-63.

2. All prepared surfaces shall be primer coated with APCI No. 103 before rusting occurs. If cleaned surfaces are not primed within that time, the surfaces must be re-cleaned before painting.

3. If steel surfaces are primer coated in the shop, stop primer 2" away from all edges to be welded after priming.

4. Field painting of the outer shell, ladders, stairways and other uninsulated steel supplied by the Contractor shall not be started until completion of all testing.

5. Shop primed surfaces shall have all primer abraded areas and weld zone areas commercially blast cleaned in accordance with Steel Structures Painting Council Specification SP 6-63 and they are immediately touched-up with primer, APCI No. 103.

6. The paint system shall be applied to all steel surfaces on the tank that require painting by either of the following options.

   a. Option for 4 coat system

E. Painting (Cont'd)

COAT	DESCRIPTION	APCI NO.	COLOR	DRYING TIME TO TOUCH	MINIMUM TIME BETWEEN COATS	**DFT/COAT
1	Shop Primer and Field Touch-up -or- Full Field Primer	103	Red	15 min.	3 hrs.	1.5 mils
2	Field Undercoat	100	Yellow	4 hrs.	24 hrs.	1.5 mils
3	1st Finish Coat	600	*White	6 hrs.	24 hrs.	2.0 mils
4	2nd Finish Coat	600	White	6 hrs.	------	2.0 mils

* Add sufficient black universal tint to distort the color of this coat of paint.

** Dry film thickness per coat (minimum)

b. Option for 3 coat system

COAT	DESCRIPTION	APCI NO.	COLOR	DRYING TIME TO TOUCH	MINIMUM TIME BETWEEN COATS	**DFT/COAT
1	Shop Primer and Field Touch-up -or- Full Field Primer	103	Red	15 min.	3 hrs.	1.5 mils
2	Field Undercoat	100	Yellow	4 hrs.	24 hrs.	1.5 mils
3	Finish Coat	601	White	6 hrs.	-----	4.0 mils

** Dry film thickness per coat (minimum)

7. The table below shows acceptable paint materials. Other suppliers may be used if written approval is obtained from Air Products and Chemicals, Inc.

APCI NO.	MOBIL	DUPONT	PPG
100	13-Y-5	67-773	UC-34850
103	13-R-50	67-789	UC-40054
600	12-W-3	28-5101	UC-40121
601	12-W-4	28-5101	UC-40129

F. Field Fabrication and Erection

Vessel erection, testing, and cleaning will be in an area where additional construction work will be in progress. Vendor shall conduct his work in such a manner so not to interfere with surrounding construction work by others.

G. Utilities

1. Electrical power shall be provided by the Vendor, at his expense, by portable generators.

2. A source of potable water is available.

3. The vendor shall provide and maintain his own sanitary, chemical type, temporary toilets for the use of personnel employed by the vendor and his subcontractors. These facilities shall conform to the requirements of all State, County, and local ordinances.

4. Oil free dry nitrogen gas for purging and drying will be furnished by Air Products and Chemicals, Inc. Distribution and heating of nitrogen gas (if required) will be the vendor's responsibility and at his cost.

H. Housekeeping

1. The Contractor shall be responsible for properly organizing all activities at the site to the extent that good housekeeping will be practiced at all times. This requirement applies equally to temporary buildings, indoor and outdoor storage, construction equipment and materials, grounds and roadways, as well as the equipment to be erected. The Contractor shall load and transport all refuse and debris to a suitable disposal area off of Air Products and Chemicals, Inc. property and make disposition in a lawful manner.

2. The Contractor shall, upon completion of the work, remove all temporary buildings and facilities erected by the Contractor, all construction equipment, surplus materials and supplies belonging to the Contractor or his subcontractors, and shall leave the premises and the work in proper order, clean and ready for use.

I. Guarantee

The vendor shall extend a one year warranty on all structural design, materials and workmanship from the date of acceptance by Air Products and Chemicals, Inc.

J. Drawings and Reports

1. Approval of drawings, reports, test methods, cleaning methods, etc., by Air Products and Chemicals, Inc. does not relieve the Vendor of responsibility for accuracy of dimensions, performance, code requirements, or warranty.

2. The vendor shall furnish Air Products and Chemicals, Inc. with the following information as a part of this contract at the times listed below:

		Bid	Approval	Certified
1.	Specific codes adhered to in in the design of this vessel	X		
2.	Manufacturer, grade and "k" value of perlite and bottom insulation	X		
3.	Detailed cleaning procedures	X	X	
4.	Detailed painting procedures	X	X	
5.	Welding standards and/or techniques.	X	X	
6.	Method of joining aluminum to stainless steel, if used	X	X	
7.	Vent and relief valve line sizes and relief devices used.	X	X	X
8.	Outline dimension and assembly drawings.	X		
9.	Design calculations.		X	X
10.	Foundation loadings.		X	X
11.	Calculations for heat gain through insulation, supports and piping		X	X
12.	Details of vessel construction, piping, and other pertinent components.		X	X

J. Drawings and Reports (Cont'd)

	Bid	Approval	Certified
13. Certified test results:			
a. Charpy test (where required by code).			X
b. Material mill analysis			X
c. Pressure tests			X

All items to be furnished with bid shall be in six (6) copies or one (1) reproducible copy marked preliminary.

All items for approval shall be one (1) reproducible marked preliminary-for approval.

All items to be certified shall be in one reproducible copy marked "Certified Correct for Construction" for drawings and "Certified Correct" for all reports. All certified documents must be signed by the responsible representative of the Vendor.

Two (2) weeks after completion and acceptance by Air Products and Chemicals, Inc. one reproducible copy of all drawings to be marked "Certified Correct As Built". All certified drawings must be signed and dated by the responsible representative of the Vendor and forwarded to Air Products and Chemicals, Inc.

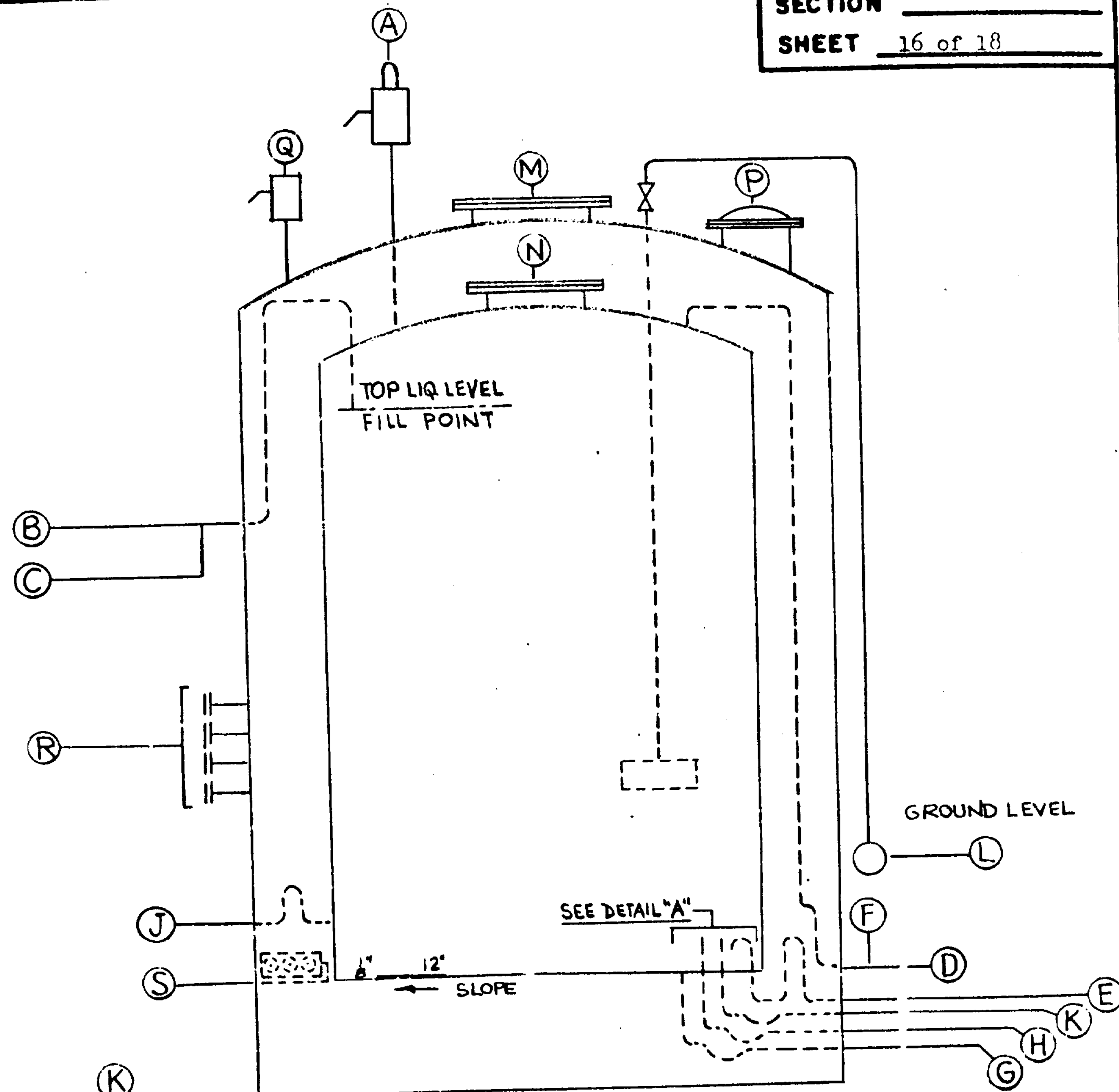
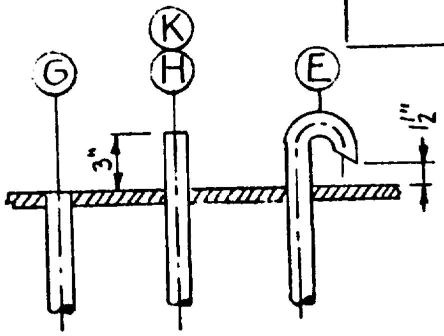


FIG. I.

SCHEMATIC OF TANK



DETAIL "A"

NOTES:
1.) REFER TO SECTION II E AND SHEETS & FOR FURTHER INFORMATION.
2.) NOZZLES C & F TO BE PROVIDED WITH MNPT ENDS.

REV.	DATE	APP'D		
			JOB NO. STANDARD	MADE BY W. R. Krill
				APP'D
			DATE 9/15/71	SCALE
			STANDARD SPECIFICATION FOR A FIELD FABRICATED CRYOGENIC LIQUID STORAGE TANK (FLAT-BOTTOM)	

Air Products and Chemicals Inc.
ALLENTOWN, PA.

NO. 99820A

8211

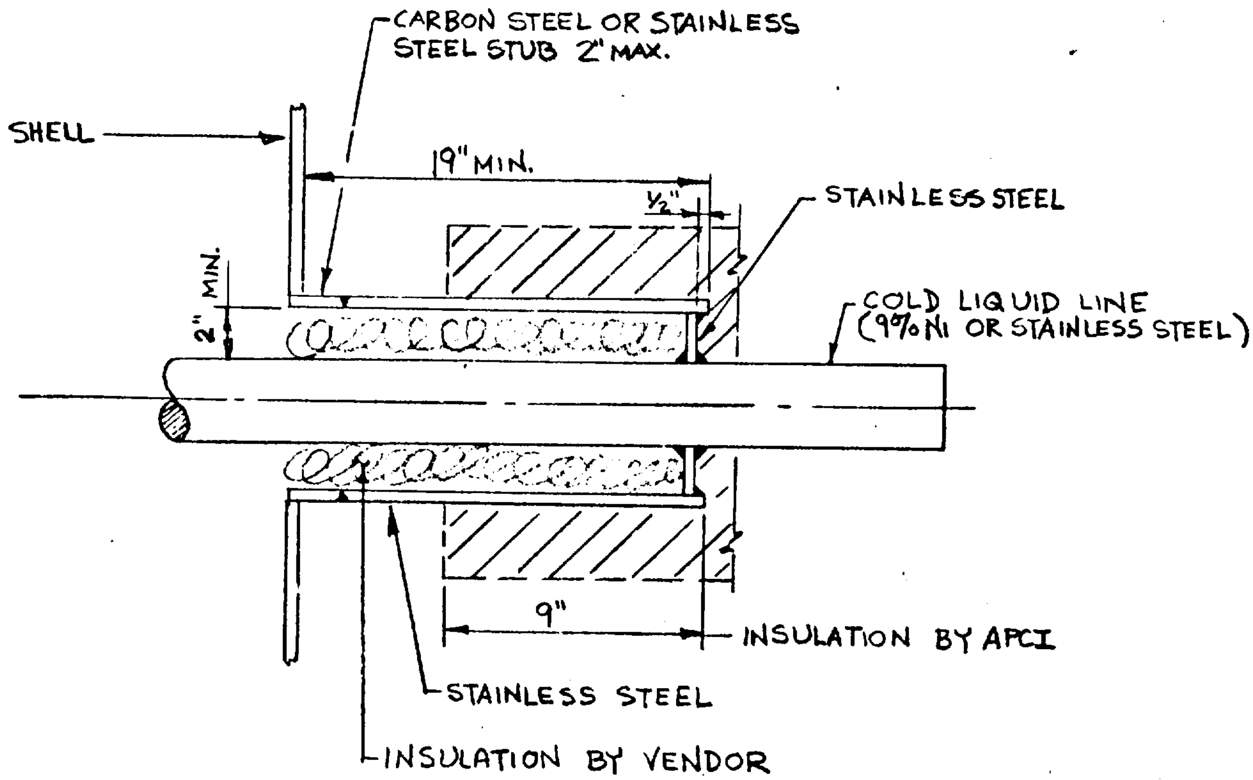


FIG. II.

THERMAL BREAK DETAIL FOR 9% NI OR STAINLESS STEEL

LIQUID LINES

(NOZZLES "G" "H" "J" & "K")

REV.	DATE	APP'D	JOB NO. STANDARD	MADE BY W. R. Krill	Air Products and Chemicals Inc. ALLENTOWN, PA.
			DATE 9/15/71	APP'D	
				SCALE	
			STANDARD SPECIFICATION FOR A FIELD FABRICATED CRYOGENIC LIQUID STORAGE TANK (FLAT-BOTTOM)		NO. 99820A

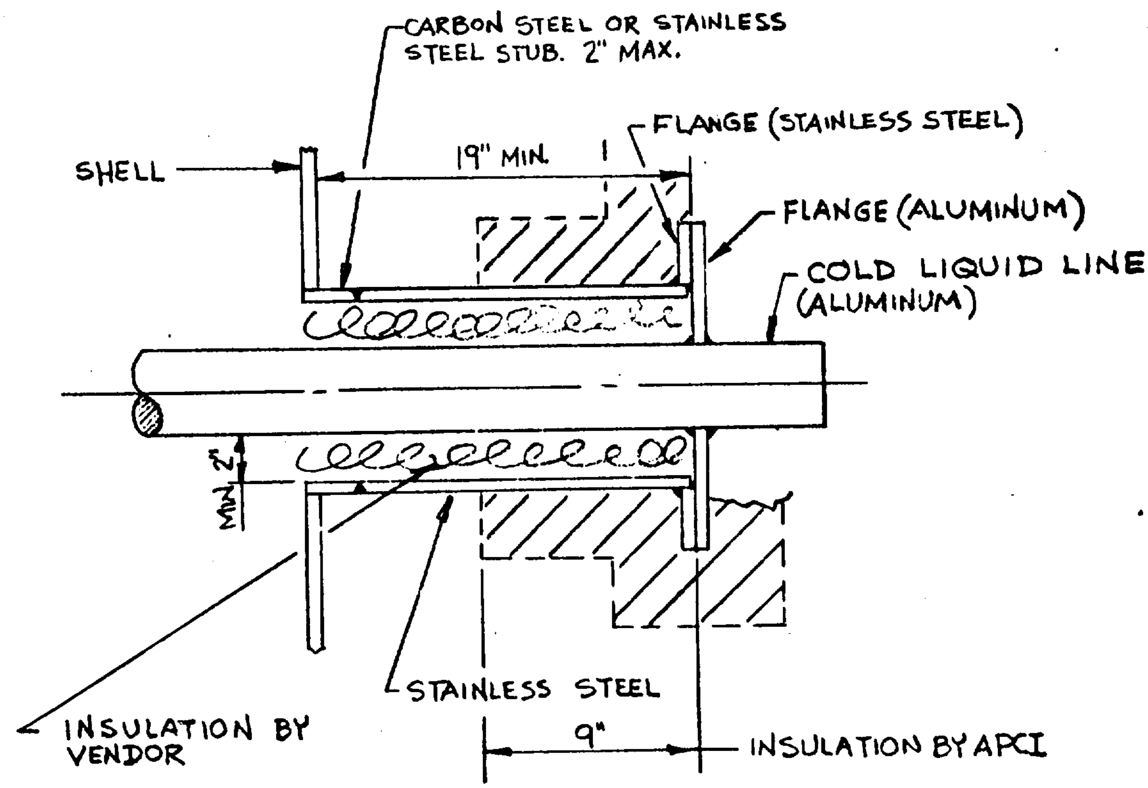


FIG. III.

THERMAL BREAK DETAIL FOR ALUMINUM LIQUID LINES

(NOZZLES "G" "H" "J" & "K")

REV.	DATE	APP'D	JOB NO. STANDARD	MADE BY W. R. Krill	Air Products and Chemicals Inc. ALLENTOWN, PA.
			DATE 9/15/71	APP'D / SCALE	
			STANDARD SPECIFICATION FOR A FIELD FABRICATED CRYOGENIC LIQUID STORAGE TANK (FLAT-BOTTOM)		NO. 99820A

8211

I. Scope - This specification defines the particular requirements for a purged powder insulated vessel intended for the storage of liquid oxygen or liquid nitrogen.

All equipment, materials and workmanship shall be in accordance with this specification and with the requirements of Air Products and Chemicals, Inc. Drawing No. 99820A, Rev. 0, entitled "Standard Specification for a Field Fabricated Cryogenic Liquid Storage Tank", which shall be considered as a part of this specification. Where any conflict exists, the job specification shall govern over 99820A.

II. Vessel configuration - Vertical

III. Vessel to be installed at Creighton, Pennsylvania and it shall be designed for prevailing natural conditions including seismic loads and wind loads as defined by the Uniform Building Code, 1970 Edition, Vol. 1. The specific loads included in his design shall be submitted with the vendor's bid proposal.

IV. The vessel will be erected on a foundation furnished by Air Products and Chemicals, Inc.

V. Rated capacity of 310,000 gallons of liquid oxygen or liquid nitrogen, plus a vapor space of approximately 5% to provide a total minimum capacity of 325,500 gallons. LOX density 71.5 lbs./ft.^{3}. LIN density 50.4 lbs./ft.^{3}.

VI. Tank design shall be based on storage of LOX.

VII. Design pressure of inner vessel 5 psig, plus static head of liquid oxygen, plus conditions listed in section II. B. of 99820A.

VIII. Design pressure of outer vessel shall be 2" H_2O plus design conditions listed in section II. C. of 99820A.

IX. The total evaporation loss due to influx of heat through conduction, convection and radiation shall be such that the loss of product does not exceed 0.22 per cent per day when the vessel has been filled to rated capacity with liquid oxygen and allowed to reach steady state conditions at 5 psig tank pressure; or 0.33 per cent per day when filled with liquid nitrogen under the same conditions.

X. Vendor shall size inner tank relief valve S & J No. X94156 for 300,000 SCFH equivalent of cryogenic liquid into a warm tank with total flashing.

XI. The Vendor shall furnish inner tank anchor straps and outer tank anchor bolts for installation in the foundation by others. Vendor shall supply bolting arrangement and foundation loadings, with calculations, within 3 weeks after order is placed.

REV	DATE	APP'D	JOB NO. 00-2-2775	MADE BY W. R. Krill	Air Products and Chemicals Inc. ALLENTOWN, PA.
			DATE 9-16-71	APP'D J. Tafuri	
				SCALE	
			JOB SPECIFICATION 310,000 Gallon Capacity LOX/LIN Storage Tank		NO. 71-2775-16.10-1A

XII. The vendor shall shim and level baseplate on the ring-wall foundation. Grouting of baseplate will be done by others at a time directed by the Vendor.

XIII. The run and pitch of the circular stairway , stairtread, all stairway handrails and platform handrails shall be designed in accordance with Dept. of Labor Standards, Part 1910, Vol. 36, No. 105, dated 3-29-71. The stairway shall be a minimum of 30" wide.

Air Products and Chemicals INC.

RECOMMENDED RULES

OF

DESIGN AND CONSTRUCTION OF LARGE, WELDED,

LOW-PRESSURE STORAGE TANKS

by

American Petroleum Institute

APCI Standard 620
February, 1970

Air Products and Chemicals INC.

UNIFORM BUILDING CODE

by

International Conference of Building Officials

Volume I, 1970

Air Products and Chemicals INC.

ASSEMBLY OF INDUSTRIAL PRACTICES USED FOR GASEOUS OXYGEN TRANSMISSION AND DISTRIBUTION

by

Compressed Gas Association, Inc.

CGA Docket 70-11
CGA Third Draft, 23P,
March 22, 1972

AIR PRODUCTS AND CHEMICALS, INC. November 3, 1966

PIPING GROUP MEMO #19

SUBJECT: SAFETY RELIEF VALVES
LOCATION AND PIPING DESIGN CONSIDERATIONS

Safety relief valves shall be installed according to this memo in regard to the valve's location and discharge pipe support or configuration.

01. LOCATION:

a. To prevent turbulence from creating a false high pressure spot and accidentally tripping the valve, it is recommended the safety valve should be located a minimum distance from the following devices:

DEVICE	MINIMUM NO. OF PIPE DIAMETERS
Regulator or Valve	25
2 Ells or Bends in Different Plane	20
2 Ells or Bends in Same Plane	15
1 Ell or Bend	10
Pulsation Dampner	10

b. The safety valve shall be located as close as is practically possible to the item it is protecting so that the pressure drop between the item being protected and the safety valve will not become excessive.

c. The location shall be such that the valve can be readily serviced and the escaping gases will not be harmful to personnel.

02. DISCHARGE PIPE SUPPORT

a. When a safety valve blows due to overpressure, a reaction force is created due to the jet effect of the escaping gas. This force acts along the centerline of the discharge pipe opening in a direction opposite to the movement of the gas. The force can be conservatively calculated by using the following formula:

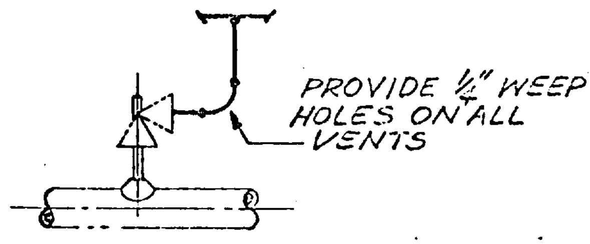
$F = PA$
F = Thrust Force (Lbs.)
P = Relief Pressure (P.S.I.G.)
A = Relief Valve Orifice (Sq. In.)

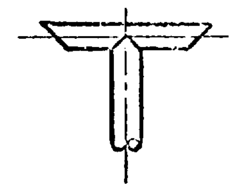
A more accurate thrust force can be obtained by using the formula and graph enclosed for Lonergan Safety Relief Valves. See PGM #19, Sheet #3

ORIFICE DESIGNATION	AREA IN^2	ORIFICE DESIGNATION	AREA IN^2
D	0.110	L	2.853
E	0.196	M	3.60
F	0.307	N	4.32
G	0.503	P	6.38
H	0.785	Q	11.05
J	1.287	R	16.0
K	1.838	T	26.0

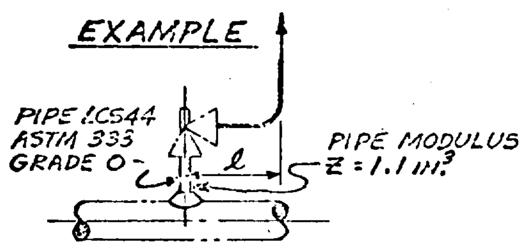
Safety valve details can be found on the Instrument Group's Specification Sheets and by discussing your problem with the Instrument Engineer on your job.

b. This reaction force can be nullified by putting a tee on the safety valve vent line. A fabricated branch is the most economical to use. It can be mounted directly on the safety valve outlet if high enough or extended as shown.





c. Sample Calculation



BOEING 00-4-3710 SV-776A, B, C, & D

Pressure = 4400 p.s.i.g.
Orifice j area = 1.287 In^2
Moment arm = 12 In.

1. Calculate Force $F = PA$
   $F = (4400)(1.287) = 5660$ Lbs. (A conservative figure)

2. Calculate Moment $M = FL$
   $M = (5660)(12) = 68{,}000$ In-Lb

3. Calculate Stress $S = \frac{M}{Z}$
   $S = \frac{68{,}000}{1.1} = 61{,}800$ p.s.i.

4. Compare Stress to Allowable Stress of Pipe
   61,800 p.s.i. is greater than 18,350 p.s.i.
   A support is needed, as was evidenced by a bent SV connection when this valve blew the first time.

d. Suggested Supports

See PGM#19 Sheets Nos. 4, 5, & 6

e. Safety valves should not be piped to a header above the valve outlet port unless certain precautions have been taken. See PGM #19 Sheet No. 7

f. If you have any questions, discuss them with our stress analyst for resolution.

L. A. Nuesslein

RAS/LAN/dlm

)

Lo..ergan Safety-Relief Va 24

PGM #18/19 SHEET #3

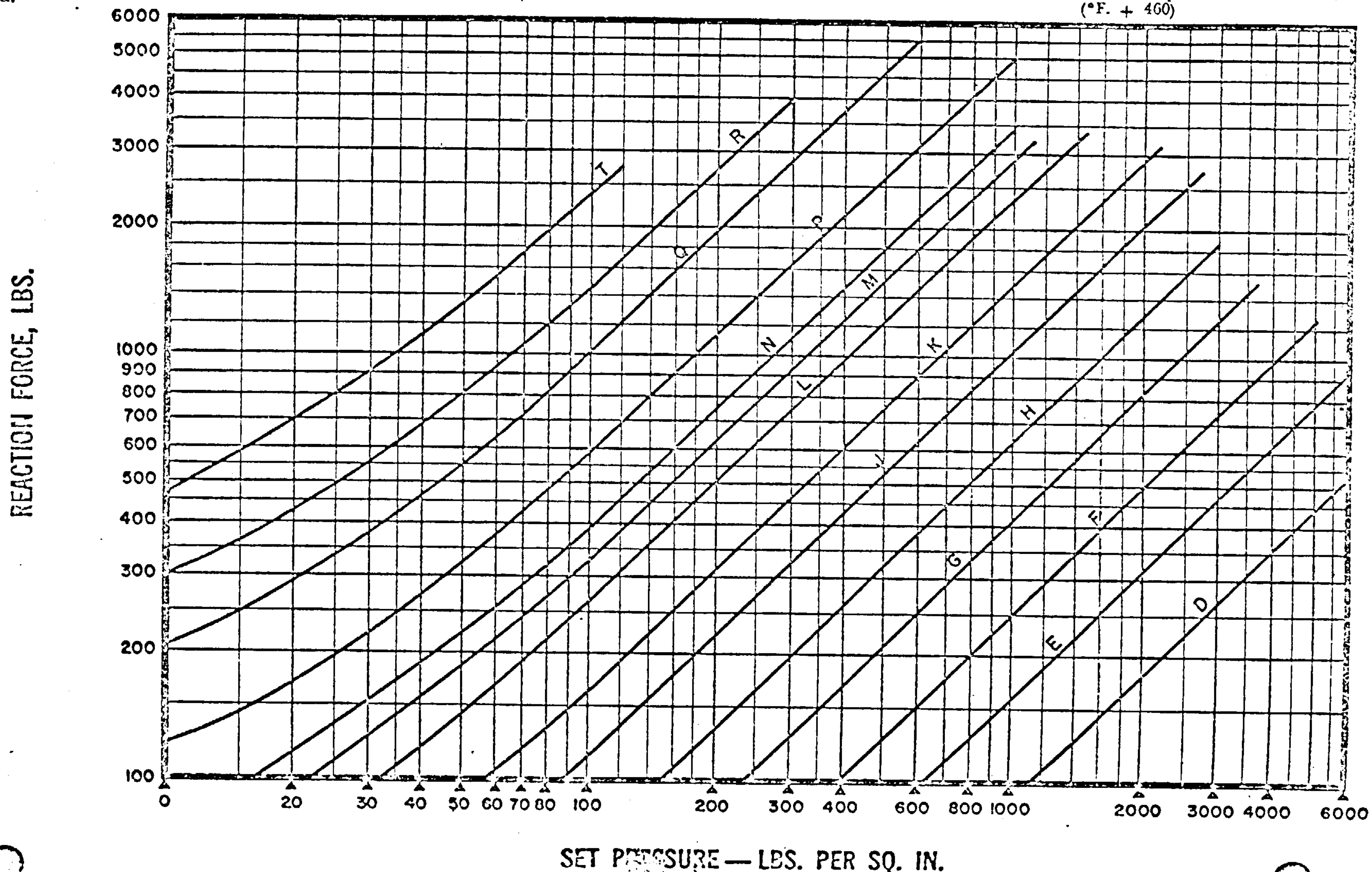
REACTION FORCES – VAPORS AND GASES

The discharge from a safety-relief valve exerts a reaction force on the valve or outlet piping. If the discharge piping is unsupported, this force is transmitted to the valve inlet and associated piping. The following formula or chart may be used to determine the reaction force. It is assumed that critical flow of the gas or vapor is obtained at the valve outlet. Under conditions of sub-critical flow, the reaction force will be less than that calculated.

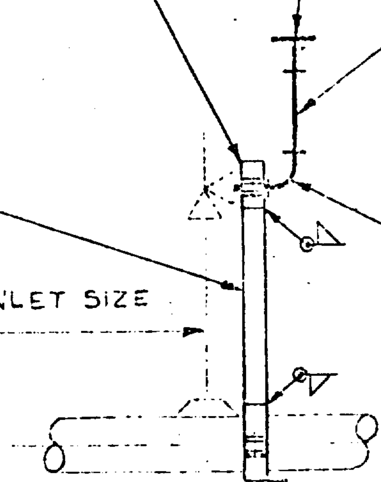
The chart is based on a valve of $k = 1.4$. This will provide a conservative value for the reaction force for most applications. However, if more accurate results are desired, the reaction forces can be determined by the following formula:

$$F_R = \frac{W_P \sqrt{\dfrac{k\ T}{(k+1)\ M}}}{366}$$

F_R = Reaction Force, Pounds
W_P = Flow Rate of gas or vapor, pounds per hour
k = Ratio of specific heats
M = Molecular weight of gas or vapor
T = Absolute temperature at Valve inlet (°F. + 460)



SECTION	
SHEET	



DISCHARGE PIPE SIZE	STD WT PIPE SUPPORT SIZE
$\frac{1}{2}$"	$\frac{1}{2}$"
$\frac{3}{4}$ TO 2"	$\frac{3}{4}$"
$2\frac{1}{2}$" TO 6"	1"
8" TO 12"	3"
ABOVE - CONSULT STRESS ANALYST	

TO BE USED ON ALL HIGH PRESSURE PIPING ABOVE 500 PSI

SAFETY VALVE DISCHARGE PIPING SUPPORT

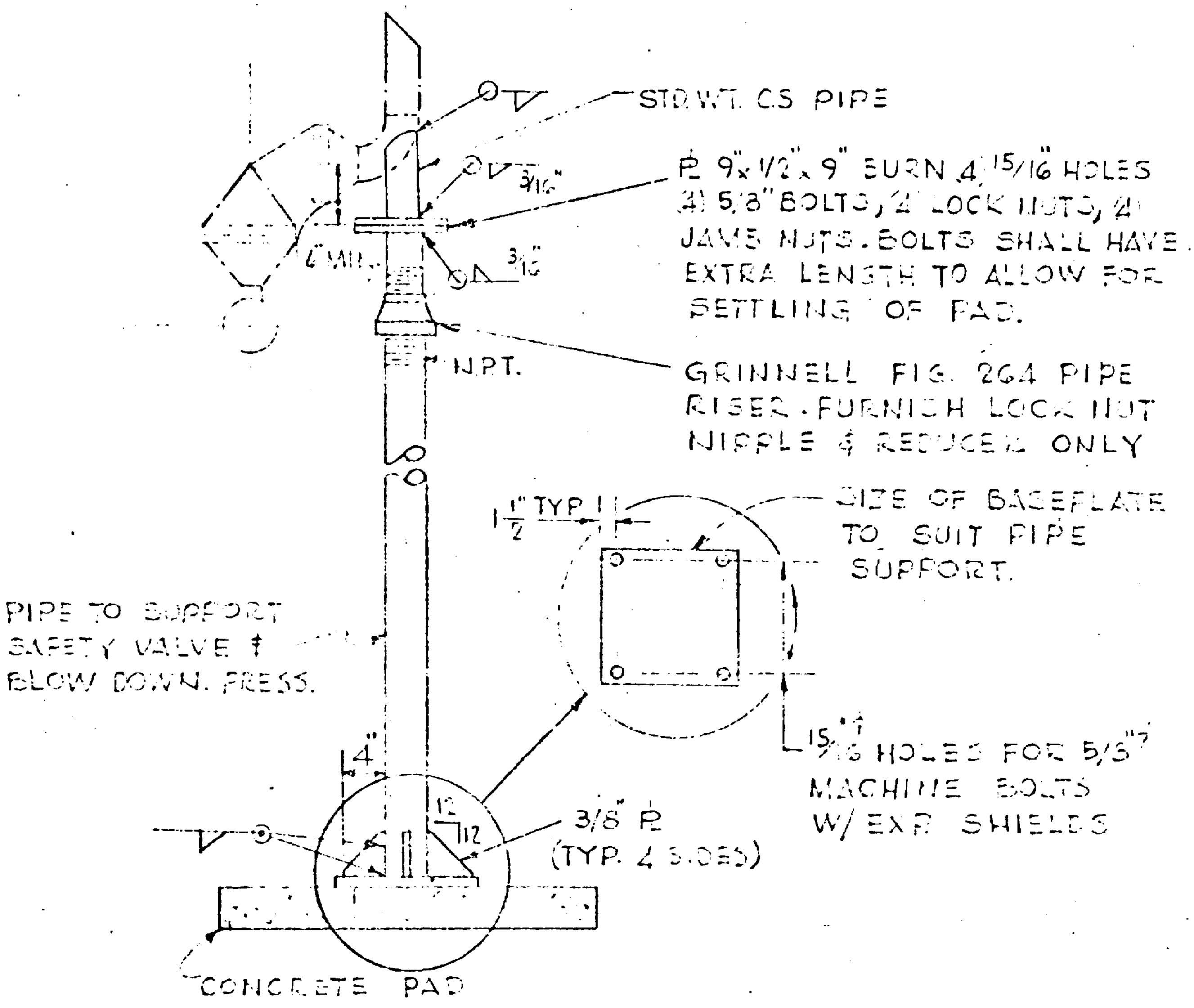
PGM # ~~18~~ 19 SHEET. # 4

REV	DATE	APP'D	JOB NO.	MADE BY J F DRUMHELLER	Air Products and Chemicals Inc.
				APP'D	
			DATE	SCALE NONE	ALLENTOWN, PA
			PIPE SUPPORT		NO. S-1800-

8211

SECTION	
SHEET	

S-1800-197



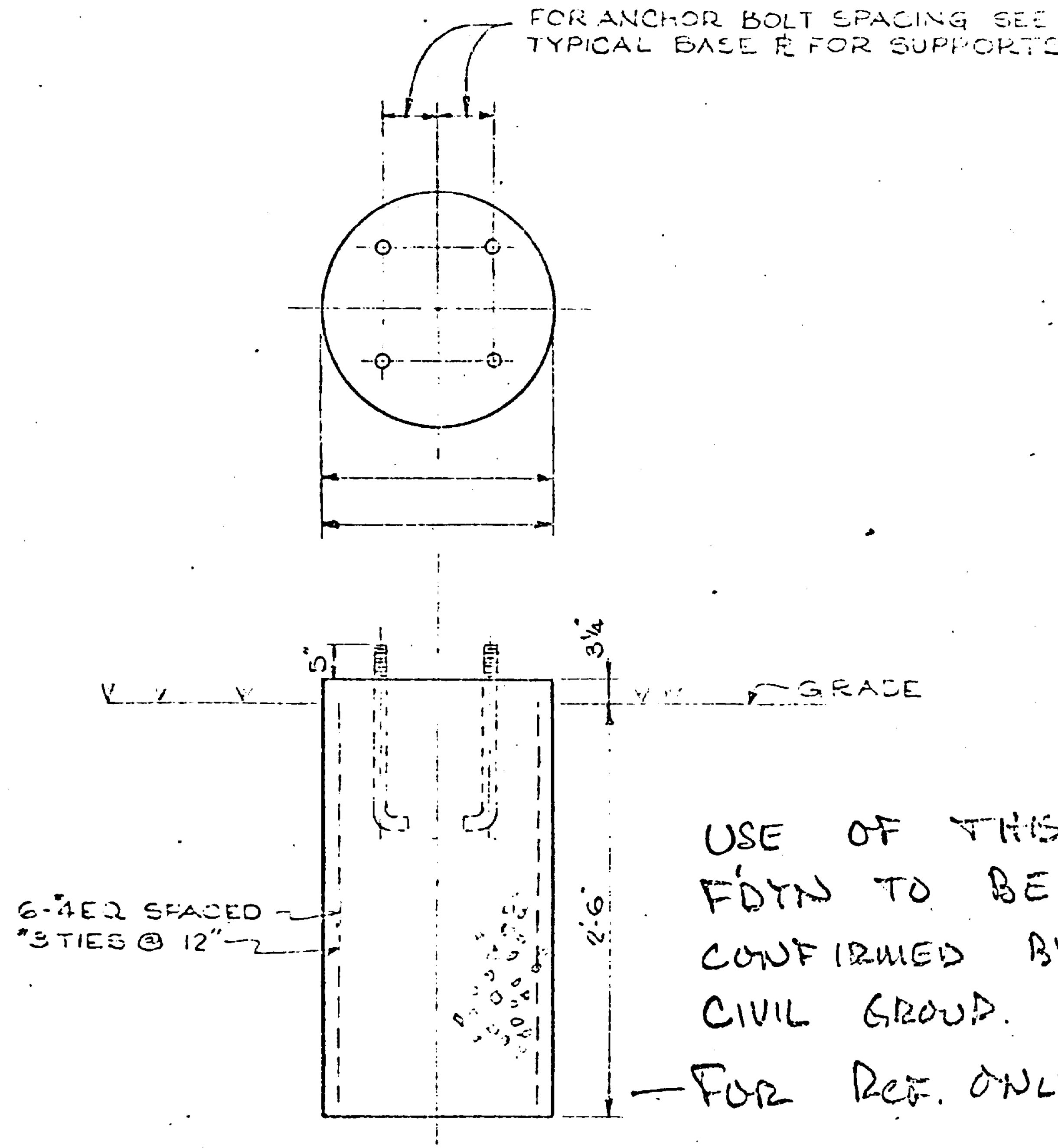
PGM. ~~18~~ 19 SHEET #5

REV.	DATE	APP'D	JOB NO.	MADE BY S. WERNERT	Air Products and Chemicals
				APP'D	ALLENTOWN, PA.
			DATE 11/5/65	SCALE NONE	NO.
			PIPE HANGERS		S-1800-197

8211

SECTION ____________

SHEET ____________



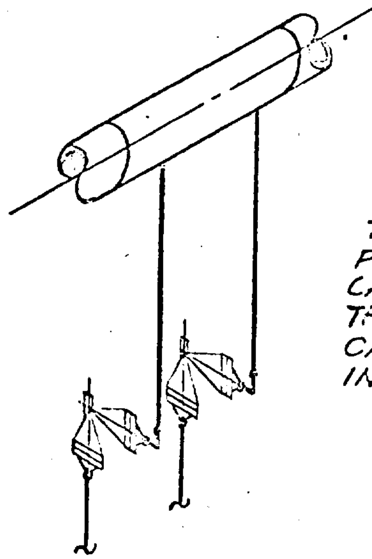
USE OF THIS FDTN TO BE CONFIRMED BY CIVIL GROUP.

— FOR REF. ONLY.

PGM #~~18~~ 19 SHEET #6

REV.	DATE	APP'D	JOB NO.	MADE BY J F DRUMHELLER	Air Products and Chemicals ALLENTOWN, PA
				APP'D	
			DATE	SCALE	
			FOUNDATION TYP		NO. S-1800-198

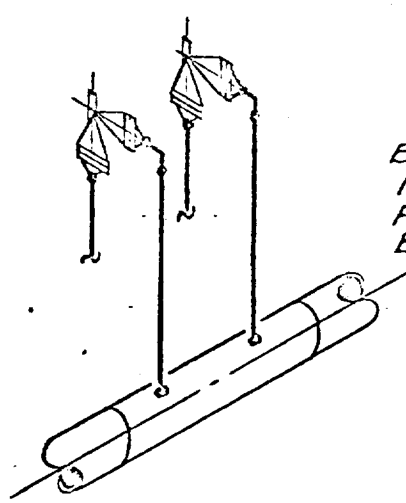
SECTION	
SHEET	



THIS SITUATION IS NOT GOOD PRACTICE. CONDENSATE CAN FORM IN THE HEADER AND THEN FLOW BACK TO THE VALVE CAUSING IT TO OPERATE INCORRECTLY.

WRONG!-

UNLESS WEEP HOLES ARE PROVIDED AT ELBOW HEEL. SOMETIMES WEEP HOLES CANNOT BE USED I.E. IN LNG, H2 & SERVICES INCLOSED IN BUILDINGS WHERE THE GASES WOULD CONTAMINATE THE ATMOSPHERE.



SAFETY VALVES SHOULD BE PIPED ABOVE HEADER IF POSSIBLE. THIS WILL PREVENT CONDENSATE FROM BACKING UP TO VALVE.

RIGHT!

SAFETY VALVE PIPING TO HEADER

REV.	DATE	APP'D	JOB NO.	MADE BY JF DRUMHELLER	Air Products and Chemicals Inc. ALLENTOWN, PA.
			DATE	APP'D	
				SCALE NONE	
			S.V. DISCHARGE PIPING		NO. P.G.M. # ~~18~~ 19 SHEET # 7

Air Products and Chemicals, Inc.

PUT IT IN WRITING

TO:	Piping Design, APCI Personnel	DATE:	April 18, 1967
FROM:	L. A. Nuesslein	SUBJECT:	P.G.M. No. 19

Please add this data sheet to piping group memo No. 19. Use of this nomograph will accurately give you an estimate of Safety Valve Reactive Forces.

LAN

L. A. Nuesslein

LAN:ta
Attach.

HPAC data sheet

Nomograph Determines Safety Valve Reactive Force

By F. CAPLAN
Kaiser Engineers, Div. Kaiser Industries Corp.

WHEN a pressure safety valve discharges, a reactive force is imposed on the piping. This force should be considered in the design of valve supports, and the nomograph on the following page will provide a quick determination.

In books on fluid mechanics (*e.g.*, *Chemical Engineers Handbook*, pp. 5-17), it is shown that the reactive force of a jet due to change in momentum of a fluid is:

$$F = W\Delta V/3600g \quad (1)$$

where

F = reactive force, lb
W = fluid flow, lb per hr
ΔV = change in fluid velocity, fps
g = 32.17 ft per sec^2

Normally, the backpressure on a pressure safety valve handling a gas or vapor is less than half the vessel or line pressure. The velocity of the gas at the safety valve nozzle outlet is therefore sonic (sometimes called acoustic or critical), and ΔV is very nearly sonic, or:

$$V = (gRkT_s/M)^{1/2} \quad (2)$$

where

V = sonic velocity, fps
R = universal gas constant, 1546 lb-ft per deg Rankine per lb mole
k = ratio of specific heat of gas at constant pressure to that at constant volume, c_p/c_v
M = gas molecular weight, lb per lb mole
T_s = absolute temperature of gas leaving safety valve orifice, deg Rankine

The temperature of the gas leaving the safety valve nozzle can be expressed in terms of the upstream (line or vessel) temperature, and for sonic flow:

$$T_s = 2T_v/(k + 1) \quad (3)$$

where

T_v = absolute upstream (line or vessel) temperature, deg Rankine

Substituting Equations 2 and 3 into 1 we obtain:

$$F = (W/367)[kT_v/(k + 1)M]^{1/2} \quad (4)$$

The reactive force can also be expressed in terms of the absolute pressure in the vessel or line when the safety valve pops. Equation 1 can be written:

$$F = Q\rho V/g \quad (5)$$

where

Q = gas flow, cu ft per sec
ρ = gas density at flow conditions, lb per cu ft

Also,

$$Q = AV$$

where

A = cross sectional area, sq ft

and therefore

$$F = A\rho V^2/g \quad (6)$$

From Equation 2 we obtain:

$$V^2 = gRkT_s/M \quad (7)$$

From the perfect gas law we obtain:

$$\rho = 144P_sM/RT_s \quad (8)$$

where

P_s = absolute pressure of gas leaving safety valve orifice, psia

Substituting Equations 7 and 8 into 6, we obtain:

$$F = P_ska \quad (9)$$

where

a = cross sectional area of safety valve orifice, sq in.

For sonic flow, the pressure of the gas leaving the orifice can be expressed in terms of the upstream (line or vessel) pressure as follows:

$$P_s = P_v[2/(k + 1)]^{k/(k-1)} \quad (10)$$

where

P_v = absolute upstream (line or vessel) pressure, psia

Substituting Equation 10 into Equation 9, we obtain:

$$F = P_vak[2/(k + 1)]^{k/(k-1)} \quad (11)$$

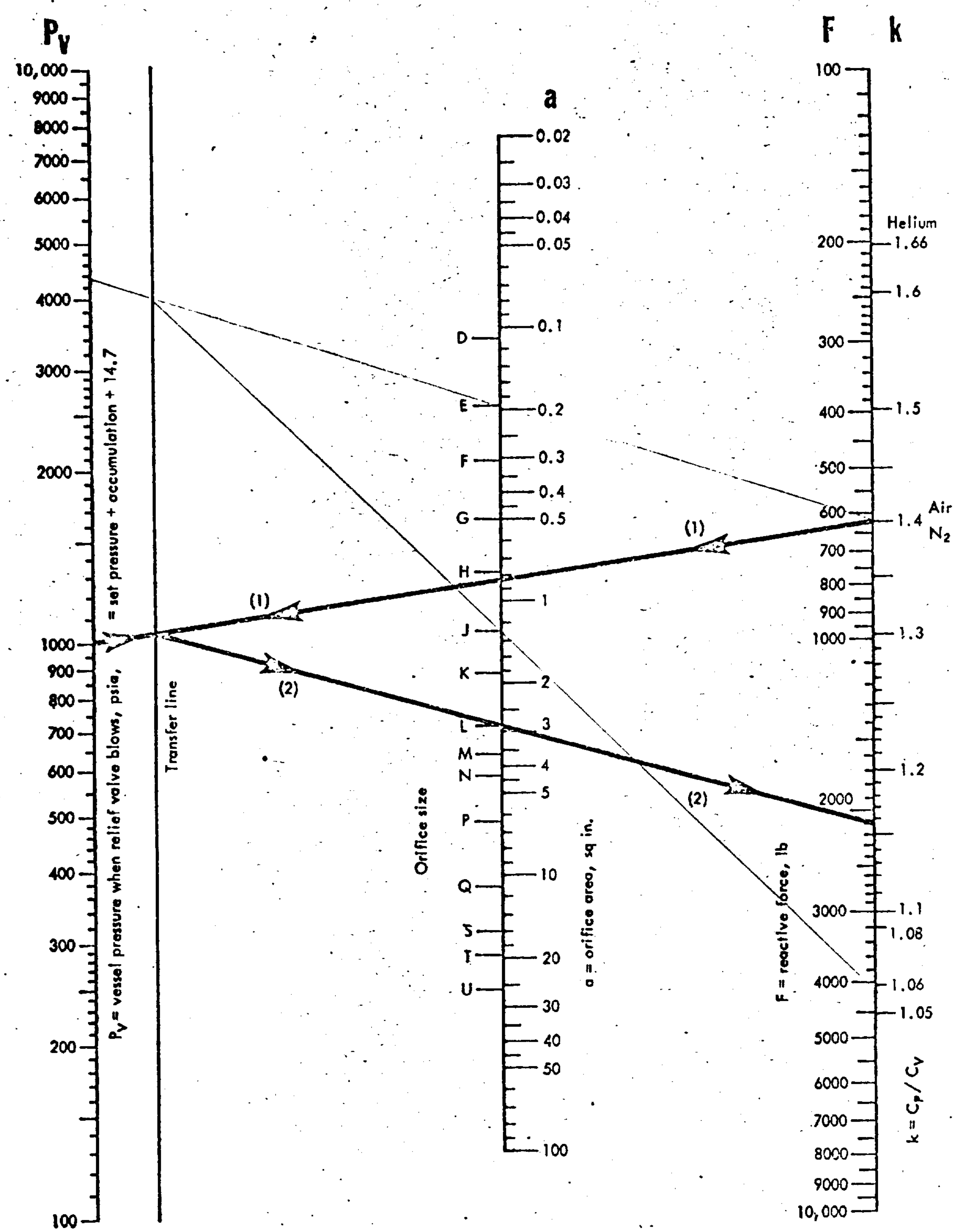
The various presure vessel codes permit various percentages of overpressure (commonly called accumulation) above the vessel design pressure at the time the safety valve is blowing (*e.g.*, the ASME Code for Unfired Pressure Vessels permits 10 percent overpressure). Safety valve capacities are determined and tabulated for the overpressure point. In using Equation 11, therefore, P_v is the set pressure of the safety valve plus the accumulation plus atmospheric pressure.

The nomograph below permits a rapid solution of Equation 11.

Example

What is the reactive force for a safety valve having an L orifice (2.85 sq. in.) if it is handling nitrogen (k = 1.4) and set at 895 psig with 10 percent accumulation permitted?

Solution: First determine P_v: 895 + 89.5 + 14.7 = 999.2 psia. Now extend a line from 1000 on the P_v scale to 1.4 on the k scale. From its intersection with the Transfer line, extend a line through L on the orifice size scale to the F scale. Read a value of 2100 lb for the reactive force.



NOMOGRAPH determines safety valve reactive force when line or vessel pressure, orifice size, and ratio of specific heats are known. Heavy lines indicate solution to example in text.

Air Products and Chemicals INC.

PETROLEUM REFINERY PIPING

BY

American Society of Mechanical Engineers

ANSI B31.3, 104P, 1966

Air Products and Chemicals INC.

REFRIGERATION PIPING

by

American Society of Mechanical Engineers

ANSI B31.5, 60P, 1966

DEFECTS AND FAILURES IN PRESSURE VESSELS AND PIPING

by

H. Thielsch

Grinnell Company

427P, 1965

GAS TRANSMISSION AND
DISTRIBUTION PIPING SYSTEMS

by

American Society of Mechanical Engineers

ANSI 831.8, 108P, 1968

Air Products and Chemicals INC.

FEDERAL REGISTER

by

Office of Pipeline Safety Transportation
of Natural and Other Gas By Pipeline

Volume 35, No. 161,

August 19, 1970

Air Products and Chemicals Inc.

MINIMUM FEDERAL SAFETY

by

Office of Pipeline Safety Transportation of Natural Gas and Other Gas by Pipeline

Federal Register

Volume 35, No. 205,
October 31, 1970

)

Air Products and Chemicals INC.

ODORIZATION OF GAS

by

Office of Pipeline Safety Transportation
of Natural or Other Gas by Pipeline

Federal Register

Volume 35, No. 220, November 11, 1970

Air Products and Chemicals INC.

MISCELLANEOUS ADMENDMENTS

by

Office of Pipeline Safety Transportation
of Natural and Other Gas By Pipeline

National Register

Volume 35, No. 223, November 17, 1970

Air Products and Chemicals INC.

CORROSION PITTING: NOTICE OF PUBLIC HEARING

by

Office of Pipeline Safety Transportation
of Natural or Other Gas by Pipeline

National Register

Volume 36, No. 126, June 30, 1971

Air Products and Chemicals INC.

REQUIREMENTS FOR CORROSION CONTROL

by

Office of Pipeline Safety Transportation
of Natural and Other Gas By Pipeline

National Register

Volume 36, No. 126, June 30, 1971

EXTENSION OF TIME FOR CONFIRMATION OR REVISION OF MAXIMUM ALLOWABLE OPERATING PRESSURE

by

Office of Pipeline Safety Transportation of Natural and Other Gas by Pipeline

National Register

Volume 36, No. 176,
September 10, 1971

AN ANALYSIS OF WATER HAMMER IN CRYOGENIC TRANSFER LINES

THE

MISSISSIPPI TEST FACILITY

OF THE

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPROVED ______________________________
C. B. McSwain, Project Manager
Air Products and Chemicals, Inc.

February 28, 1964

Prepared by

Air Products and Chemicals, Inc.

Allentown, Pennsylvania

for

Corps of Engineers

Mobile, Alabama

9. BIBLIOGRAPHY

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VII. Dodge L., Reduce Fluid Hammer, Product Engineering, December 10, 1962, Pg. 88

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X. W. B. McPherson, H. S. Straussen and J. C. Williams, Butterfly Valve Flow Characteristics, Paper 1167, Journal of the Hydraulics Division, Proceedings of the ASCE

XI. S. Logan Kerr, Effect of Valve Operation on Water Hammer, AWWA Journal, Vol. 52, No. 1, January, 1960

XII. S. Logan Kerr, Surge Problems in Pipe Lines - Oil and Water, Transactions of ASME, July, 1950

XIII. S. Logan Kerr, Practical Aspects of Water Hammer, AWWA Journal, Vol. 40, No. 6, June, 1948

XIV. S. Logan Kerr, Water Hammer Control, AWWA Journal, Vol. 43, No. 12, December, 1951

Air Products and Chemicals INC.

CRYOGENICS SAFETY MANUAL

by

Safety Panel

British Cryogenics Council

P122, 1970

TITLE Acceptance Test for Class 'B' Cleanliness May 12, 1969

1. PURPOSE

The purpose of this specification is to ensure uniformity of quality of cleanliness for materials cleaned by a vendor.

2. SCOPE

2.1 This specification applies to equipment having surfaces which can be inspected visually either in its assembled or piece small condition or and to surface which cannot be inspected visually.

2.2 It is intended that this specification should apply to vessels and components used for chemical process, storage or other application where no contact with liquid or gaseous oxygen or oxygen rich mixtures is involved.

3. CLEANING METHODS

3.1 Cleaning may be accomplished by any physical method or combination of methods which assure that all surfaces are clean as defined in clause 4.

3.2 Cleaned equipment must be drained and purged of all cleaning agents.

3.3 All flux residues resulting from brazing, soldering and welding operations must be removed.

3.4 Pressure testing, if required, after cleaning, shall be accomplished with clean tap water or filtered air. Equipment which is hydrostatically tested will require thorough drying.

4. ACCEPTANCE TEST

A surface can be considered Class 'B' Clean when it conforms with the following:

4.1 Direct Inspection

4.1.1 Visually clean under bright white light.

4.1.2 There shall be no loose particles or other foreign matter in the vessel or component which exceed $\frac{1}{8}$" (3.2 mm) maximum in two directions or 1/16" maximum (1.6 mm) in the third plane, nor any excessive amount of smaller particles.

4.1.3 There shall be no visual indication of the presence of heavy oil or grease except that all unpainted external surfaces liable to corrode or rust in normal atmospheric conditions shall be allowed to have a protective coat of light oil or rust preventive.

APCI DOCUMENT NO. 99000-360

TITLE Acceptance Test for Class 'B' Cleanliness

4.2 Indirect Inspection

4.2.1 Surfaces which are inaccessible to visual inspection should be pickled or cleaned by use of a cleaning process which must be agreed with Air Products Quality Control Department as able to achieve the acceptance standards shown in clause 4.1.

5. PACKING

5.1 Upon completion of cleaning and after establishing acceptance all openings must be sealed against entry of dirt, moisture etc. using an inert, vapour free, greaseless barrier material.

5.2 The carton or package should be labelled 'Class "B" Clean.'

ENGINEERING SPECIFICATION	No. A .02 PAGE 1 CONT. ON 2 REV 0

TITLE

Acceptance Tests for Class 'A' Cleaning

DISTRIBUTION

J.D. Scott - Technical Service Group Manager
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All construction Superintendents
All Project Managers and Engineers
All Design Department Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	AP
0	ORIGINAL ISSUE	12.5.69	J. Pegram	

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER
			B E Moody	

APCI DOCUMENT NO. 99900036

TITLE Acceptance Test for Class 'A' Cleanliness (High Purity Clean)

May 12, 1969

1. PURPOSE

The purpose of this specification is to ensure uniformity of quality of cleanliness for materials cleaned by a vendor.

2. SCOPE

2.1 This specification applies to equipment having surfaces which can be inspected visually either in its assembled or piece small condition or to inaccessible surfaces which cannot be inspected visually.

2.2 It is intended that this specification applies to bessels and components used with liquids or gases where contamination must be reduced to a minimum.

2.3 It does not apply to liquids or gases containing 25% or more of oxygen.

3. CLEANING METHODS

3.1 Cleaning may be accomplished by any physical method or combination of methods, which assure that all surfaces are thoroughly clean as defined in Clause 4.

3.2 Cleaned equipment must be drained and pruged of all solvent.

3.3 All flux residues resulting from brazing, soldering and welding operations must be removed.

3.4 Pressure testing, if required, after cleaning, shall be accomplished with clean tap water or oil free air or nitrogen. Equipment which is hydrostatically tested will require thorough drying.

4. ACCEPTANCE TESTS

A surface can be considered Class 'A' Clean when if conforms with the following:

4.1 Direct Inspection

4.1.1 Visually clean under bright white light.

4.1.2 No surface shall contain any loose particles capable of being brushed off by hand with a soft nylon brush or blown off with an air jet. There shall be no potentially loose particles which exceed 1/16" (1.6mm) Max. in two directions or 1/32" (.8mm) in the third plane.

4.1.3 In case of doubt the maximum allowable number of potentially loose particles of any size on any square foot of surface shall not exceed ten (10)

4.1.4 Wiping with a clean white lint free cloth shall detect no trace of oils or grease.

4.2 Indirect Inspection

Surfaces which are inaccessible to visual inspection either directly or with a borescope shall have a quantity of trichlorethylene or methylene chloride circulated through them and a representative sample of the effluent solvent shall be taken and inspected as follows:

4.2.1 A sample of used solvent used for the last cleaning shall be inspected under bright white light and compared with new unused solvent and the difference should not be detectable.

4.2.2 The used solvent should be inspected for residual and floating particles and these should not be greater in size than shown in clause 4.2.

4.2.3 A 25 cc. sample of the used solvent should then be evaporated on a clean watch glass and subjected to ultra violet light having a wave length of 3600 angstom and the residue should show only a faint flubresence.

5. PACKING

5.1 Pressure vessels liable to rust if left exposed to the atmosphere should be pruged of all air and filled with dry, oil free nitrogen to a pressure of 10 psig, carbon dioxide may be used providing the interior of the vessel is completely dry. The vessel should be clearly labelled that the vessel is pressurised.

5.2 Vessels liable to rust but not able to be pressurised should have packets of silica gel or activated alumina or similar moisture adsorbing agents hung inside and the outside of the vessel labelled accordingly.

5.3 Upon completion of cleaning and after establishing acceptance all openings must be sealed against entry of dirt, moisture etc. using an inert, vapour free, greasless barrier material.

5.4 The carton or package should be labelled 'Class "A" Clean'.

ENGINEERING SPECIFICATION	No. A.03 PAGE COVER SHEET CONT. ON REV 0

TITLE ACCEPTANCE TEST FOR CLASS 'AA' CLEANLINESS (OXYGEN CLEAN)

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders

	No change	1.4.71.	J.W.Pegram	
O	ORIGINAL ISSUE	12.5.69	J.W.Pegram	
REV	DESCRIPTION	DATE	ORIGINATOR	AI

Original APPROVED BY	SECTION HEAD	C.H. Bloom DESIGN MANAGER	B.E. Moody CHIEF ENGINEER	TECH. SERVICE GROUP MANAGE

APCI DOCUMENT NO. 99000362

F.911

TITLE Acceptance Test for Class 'AA' Cleanliness (Oxygen Clean)

1. PURPOSE

The purpose of this specification is to ensure uniformity of quality of cleanliness for materials cleaned by a Vendor.

2. SCOPE

2.1 This specification applies to equipment having surface which can be inspected visually either in its assembled or piece small condition or to inaccessible surfaces which cannot be inspected visually.

2.2 This specification applies to all equipment used with liquid air, liquid or gaseous oxygen or mixtures containing 25% or more of oxygen or oxygen rich atmospheres where the oxygen content is 25% or more.

3. CLEANING METHODS

3.1 Cleaning may be accomplished by any physical method or combination of methods, which assure that all surfaces are thoroughly clean as defined in Clause 4. If the vendor has any doubt as to the correctness of the method or the suitability of the cleaning agent he should consult the Quality Control Department of Air Products Limited.

3.2 Inhibited trichlorethylene and Methylene chloride are approved solvents.

3.3 Cleaned equipment must be drained and purged of all solvent.

3.4 All flux residues resulting from brazing, soldering and welding operations must be removed.

3.5 Pressure testing, if required after cleaning, shall be accomplished with drinking water filtered through a 10 micron stainless steel filter or dry, oil free filtered air, nitrogen, helium or freon. Equipment, which is hydrostatically tested will require thorough drying.

4. ACCEPTANCE TEST

A surface can be considered Class 'AA' Clean when it conforms with the following:

4.1 Direct Inspection

4.1.1 100% of all surfaces must be subjected to examination by bright white light and ultra violet light.

TITLE Acceptance Test for Class 'AA' Cleanliness (Oxygen Clean)

4.1.2 No surface when inspected under bright white light may contain any loose particles capable of being brushed off by hand with a soft nylon brush or blown off with an air jet. There shall be no potentially loose particles which exceed 0.5 mm. in two directions and 0.2 mm in the third plane.

4.1.3 The surface must be completely dry.

4.1.4 The surface shall be free of all discolouration other than that which id due to the metal.

4.1.5 <u>Black Light Inspection</u> All surfaces shall be free of any fluorescence, other than isolated spots of lint and dust, detectable by ultra-violet light having a wave length of 3600 angstroms when viewed in the dark.

4.1.6 <u>Wipe Test</u> Surfaces shall be wiped with a clean white lint free cloth and the cloth inspected to ensure the absence of any oils not detectable by black light or residue, discolouration, fibres etc. not previously detected. The cloth may be dipped in Trichlorethylene or Methylene Chloride before wiping.

4.2 <u>Indirect Inspection</u>

Surfaces which are inaccessible to visual inspection either directly or with a borescope or similar instrument shall have inhibited tri chlorethylene or methylene chloride circulated through them and a representative sample of the effluent solvent shall be taken and inspected as specified in 4.2.1, 4.2.2, and 4.2.3.

<u>Note</u> No other solvent or cleaning agent than the two mentioned is allowed for this operation.

4.2.1 A sample of used solvent shall be inspected under bright white light and compared with new unused solvents and the difference should not be detectable.

4.2.2 When the equipment is considered clean a gallon of new clean solvent should be circulated and collected. This effluent should be examined for any floating particles or residue which should not exceed the sizes stated in 4.1.1.

4.2.3 A 25 cc sample of the used solvent should then be evaporated on a clean watch glass and subjected to ultra violet light having a wave length of 3600 angstom and there should be no fluorescence.

4.3 If there is still any doubt about the cleanliness of the equipment a sample of the effluent from 4.2.2 should be analysed for the presence of hydrocarbons under the supervision of Air Products Quality Control Department.

5. PACKING

5.1 Pressure vessels liable to rust if left exposed to the atmosphere should be purged of all air and filled with dry, oil free nitrogen to a pressure of 10 psig.
Carbon dioxide may be used providing the interior of the vessel is completely dry. The vessel should be clearly labelled that the vessel is pressurised.

5.2 Vessels liable to rust but not able to be pressurised should have packets of silica gel or activated aluminium or similar moisture adsorbing agents hung inside and the outside of the vessel labelled accordingly.

5.3 Upon completion of cleaning and after establishing acceptance all openings must be sealed against entry of dirt, moisture etc. using an inert, vapour free, greaseless barrier material.

5.4 The carton or package should be labelled "AA Cleaned for Oxygen Service".

ENGINEERING SPECIFICATION

No. K.02
PAGE 1 CONT. ON 2
REV 0

TITLE

Degreasing Acceptance Tests for Oxygen Service Compressors

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders

O	ORIGINAL ISSUE	23-6-69	[signature]	
REV	DESCRIPTION	DATE	ORIGINATOR	APP'D

APPROVED BY	SECTION HEAD	~~DESIGN MANAGER~~	CHIEF ENGINEER	~~TECH. SERVICE~~ GROUP MANAGER

F.911

APCI DOCUMENT NO. 99000363

TITLE Degreasing Acceptance Tests for Oxygen Service Compressors ~~(Class AA Cleanliness)~~

1. PURPOSE

1.1. The purpose of this Specification is to establish the degree of cleanliness and preparation for shipment of all compressors, piping and associated equipment in contact with oxygen enriched atmospheres.

1.2. This Specification must be read in conjunction with Specification A.03 "Acceptance Test for AA Cleanliness".

2. SCOPE

2.1. The cleanliness of all compressors, piping and associated equipment in contact with oxygen enriched atmospheres shall conform to this Specification and A.03 unless the vendor secures written approval from the Purchaser for any exception.

2.2. Clause 4 of this Specification shall govern where there is any conflict with Clause 5 of Specification A.03.

3. RESPONSIBILITY

3.1. The vendor shall assume full responsibility for the cleanliness of all components cleaned to this Specification by themselves and sub-contractors.

4. PREPARATION FOR SHIPMENT

4.1. All ferrous materials, except pipe, after being cleaned shall be given three (3) applications of protective wax coating to all surfaces. This protective wax must not be a hydrocarbon product but a synthetic wax as for example, Halocarbon Products Corporation's wax coating type 6-25 and 6-25Z Sufficient time (approximately ½ hour) shall be allowed between coats to permit previous application to become tacky.

Wax may be applied using a clean, standard paint spray gun. Only dry, oil free air or nitrogen shall be used in spraying the protective wax.

4.2. Assemblies such as centrifugal compressors, cylinders, and vessels shall have all openings closed to prevent the entrance of dirt and moisture. Openings shall be closed by covering with clean polyethlene sheet, a gasket, and then a steel plate. Covers for openings less than 18", a minimum of ¼" thickness.

4.3. Following cleaning stainless steel, copper alloy or aluminium alloy piping the vessels shall have all openings sealed.

TITLE Degreasing Acceptance Tests for Oxygen Service Compressors (Class AA Cleanliness)

4.4. Ferrous piping and vessels, after cleaning, shall be purged using dry oil free nitrogen, and all openings covered.

4.5. Spare parts - All spare parts shall be sprayed with protective wax as described above and sealed in clean polyethlene bags. Bags shall also contain tag stating "Cleaned for Oxygen Service", part name and number.

4.6. All packages, boxes, crates and/or skids containing parts or assemblies which have been cleaned in accordance with this specification shall have a tag "Cleaned for Oxygen Service" attached in a conspicuous place.

ENGINEERING SPECIFICATION

No. [illegible].06
PAGE 1 CONT. ON 2
REV 0

TITLE

Valves - Oxygen Service: Minimum Decontamination and Test Requirements.

DISTRIBUTION

All Engineering Specification and Standard Manual Holders.
Purchasing Manager.
All Piping Engineers.

0	ORIGINAL ISSUE	7/7/69	J.W.P	
REV	DESCRIPTION	DATE	ORIGINATOR	APP'D

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

TITLE Valves - Oxygen Service: Minimum Decontamination and Test Requirements.

1. PURPOSE

This specification states Air Products minimum requirements for testing and cleaning valves for use in oxygen service (cryogenic and warm).

2. SCOPE

This specification applies to all valves to specifications L.01, L.02 and others where called for on the requisition.

3. GENERAL

3.1. Test body, seat and bonnet hydrostatically with fresh drinking water in accordance with para. 5.

3.2. Dismantle valve and degrease component parts with inhibited methylene chloride or trichlorethylene. Parts must be handled with clean lint-free gloves after this operation. (For valves having renewable seat rings not extracted at this stage, degreasing of the seat ring and body thread must be carried out before the hydrostatic test.) Valves and parts are considered degreased when the requirements of Clause 4 have been met.

3.3. Re-assemble valve with degreased tools. Body-to-seat thread sealants other than P.T.F.E. or KEL - F must be approved by Air Products Limited.

3.4. Test seat, bonnet and packing with dry, oil-free nitrogen in accordance with para. 6 (b). Seat and plug must be dry for this test; drying must be done with oil free medium.

3.5. Tag and pack in polythene bag or other suitable container to prevent contamination before use. Label "Degreased for oxygen service to Class AA Standard".

4. DEGREASING ACCEPTANCE TESTS (DIRECT INSPECTION)

The following relevant extracts from Specification A.03 constitute the acceptance tests for valves and they can be considered Class 'AA' clean when they conform to them.

4.1. No surface when inspected under bright white light may contain any moisture or loose particles capable of being brushed off by hand with a soft nylon brush or blown off with an air jet.

4.2. The surface shall be free of all discolouration other than that which is due to the metal.

4.3. Wipe Test Surfaces shall be wiped with a clean white lint free cloth and the cloth inspected to ensure the absence of any oils not detectable by black light or residue, discolouration, fibres etc., not previously detected.

4.4. Black Light Inspection All surfaces shall be free of any fluorescence, other than isolated spots of lint and dust, detectable by ultra-violet light having a wave length of 3600 angstroms when viewed in the dark.

5. PRESSURE TEST REQUIREMENTS HYDROSTATIC (SEE NOTES)

5.1. Globe, Angle and Needle Valves:-

Steel	:	Flanged	BS.1873:1960	(Body & seat)
Steel	:	Screwed and Socket weld	BS.2995:1958	(Body & seat)
Bronze	:	Flanged and Screwed	BS.2060:1964	(Body & seat)

5.2. Gate Valves:-

Steel	:	Flanged and Buttweld	BS.1414:1954	(Body & seat)
Steel	:	Screwed and Socket weld	BS.2995:1958	(Body & seat)
Steel	:	Flanged, Screwed and Socked weld (compact design)	BS.3808:1964	(Body & seat)
Bronze	:	Flanged and screwed	BS.1952:1964	(Body & seat)
Cast iron	:	Flanged and screwed	BS.1735:1966	(Body & seat)

5.3. Check Valves:-

Steel	:	Flanged	BS.1868:1960	(Body & seat)
Steel	:	Screwed and socket weld	BS.2995:1958	(Body & seat)
Bronze	:	Flanged and screwed	BS.1953:1964	(Body & seat)

5.4. For seat tests on globe gate and check valves no leakage detectable to the naked eye is permitted over a 30 second period.

6. PRESSURE TEST REQUIREMENTS PNEUMATIC (DRY NITROGEN)

6.1. Bonnets and glands of globe and gate vlaves and bonnets of check valves must be tested with dry oil-free nitrogen and soap film at the full rating of the valve. The stem must be free to turn at this pressure. No leakage visible to the naked eye is permitted in ten seconds.

TITLE Valves - Oxygen service: minimum Decontamination and Test Requirements

6.2. Globe and gate valve seats are to be tested with dry, oil-free nitrogen at 300 psi or WOG rating, whichever is the least. Test on check valve waived, excdpt for those used on cycling heat exchanger circuits.

6.3. For globe and gate valves having metal to-metal seats a leakage rate of 2 cc per minute (fifteen $\frac{1}{4}$" diameter bubbles per minute) per inch of valve size is permitted using either of the shut-off methods described in Note (b). Leakage can be measured by means of a $\frac{1}{4}$" bore rubber hose just beneath the surface in a beaker of water.

6.4. For globe and gate valves having soft seat or plug inserts no leakage is permitted by the bubble method in any period of ten seconds after at least one bubble has been released.

6.5. Note

6.5.1. Re-tests. Unlimited re-tests are permitted in all cases of failure. Valves must then pass the tests on two successive occasions.

6.5.2. Shut-off-Methods Shut-off is to be achieved manually by the Vendor's employee or agent using the standard handwheel in the normal standing or sitting position. One or two hands may be used.

Air Products

ENGINEERING SPECIFICATION

No. M.02

PAGE CONT. ON COVER SHEET

REV 2

TITLE CONSTRUCTION SPECIFICATION FOR PIPING ERECTION, TESTING AND CLEANING

DISTRIBUTION

All Engineering Specification & Standards Manual Holders

All Piping Designers

All IGD Distric Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	APP
2	4.7.1.2 added. A.3 amended	19.4.71.		
1	Para 5 amended. Para 4.1.6 + 10 added			
1	Para A6 of Appendix I added, Metric Dimensions added.	1.12.70.		
0	ORIGINAL ISSUE	1.7.70.		

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F.911

INDEX

1. PURPOSE

This specification states the requirements for the erection, testing and cleaning of piping systems, fittings and valves.

2. SCOPE

This specification applies to ferrous and non-ferrous pipework for liquids and gases at all temperatures between -450°F. and +700°F., (-267°C. and +370°C.) excluding plastic piping.

3. CODES AND STANDARDS

3.1 All workmanship, materials, testing and inspection shall be in accordance with ASA B31.3 latest edition.

3.2 All welding and brazing operatives shall be qualified in accordance with A.S.M.E. Section IX, by an approved authority for the appropriate material and technique. All valid qualifications shall be submitted to the Engineers Representative before work commences. APL form WG2-2 may be used to record Welder Qualification Tests where these are made on site.

3.3 Any items mentioned in this Specification are in addition to, or in clarification of, the relevant codes and do not replace them.

4. WELDING AND BRAZING

4.1 Backing Rings

4.1.1 Backing rings shall not be used in stainless steel and carbon steel pipes carrying oxygen (designated SSO & CSO).

4.1.2 Backing rings shall not be used for piping 2" n.b. (50 mm) or smaller.

4.1.3 Backing rings may be used for all other stainless steel and carbon steel joints. Where backing rings are not used, including oxygen lines, the root run, is to be performed by the inert-gas shielded arc method, with interior gas purge.

4.1.4 Backing rings may only be used for aluminium or aluminium alloy butt joints where they are an aid to fitting in confined spaces, or at the discretion of the Engineers Representative. On single 'V' or single 'J' preparation butt joints, the root run with full penetration bead is to be performed by the "inert gas shielded arc process (T.I.G. or M.I.G).

4.1.5 Backing strip in all materials will be supplied by the Employer.

4.1.6 When backing rings are not used the contractor must ensure that the pipe bore is not restricted by excess of weld metal, icicles and weld splatter.

4.2 Aluminium

4.2.1 Aluminium pipe shall be cut only by mechanical devices.

4.2.2. All welding of aluminium pipe shall be performed with the inert gas shielded arc process, using T.I.G. method with A.C. High Frequency Current, or M.I.G. method. A purge of similar inert gas shall be maintained on the interior of the line during the root weld process wherever possible.

4.3 Stainless Steel

4.3.1 Stainless steel unless prepared by a mechanical means shall be ground back 1/16" (1.6mm) before welding. Cutting with an oxyacetylene torch shall not be permitted.

4.4 Brazing

4.4.1 Brazing wire used shall be Easy Flo No. 1 Solder manufactured by Johnson Matthey & Co. or approved equal. Brazing flux shall be Easy Flo green label or equivalent. Solder joints shall be kept as far as possible from threaded joints to prevent destruction of the thread seal.

4.4.2 Fittings once brazed shall not be re-used.

4.5 Valves

Prior to welding any valve into a pipeline, the contractor shall open the valve fully, and take precautions to prevent thermal distortion of the valve and its components.

4.6 Joint Identification

All welded and brazed joints shall be identified by the operative with his stamp and a serial number. For example "T.22" would have been done by welder "T" and be his 22nd consecutive weld on the Contract.

4.7 Radiography and Inspection

All materials and workmanship shall be inspected by the Engineer's Representative in accordance with ASA B31.3 at any place where fabrication and erection is performed. Any defective material or workmanship shall be corrected to the satisfaction of the Engineer's Representative at the Contractor's cost.

TITLE Construction Specification for Pipework Erection, Testing and Cleaning

4.7.1 Radiography

4.7.1.1 On completion of the first ten production welds made by each welder in each material in either 2G or 5G positions (ASME IX-para Q3) two welds shall be completely radiographed. Two per cent of the remainder of the welds made by each welder with a minimum of five welds shall be radiographed. Each film shall be marked with the line and weld number and shall be to the satisfaction of the Engineer's Representative.

If any radiograph is unsatisfactory, two further radiographs shall be taken.

2 4.7.1.2 All joints between prefabricated spool pieces and all closing joints shall be subject to 100% X-Ray.

4.7.1.3 If any weld is not the standard given in ASA B31.3 it shall be cut out, repaired and radiographed. All costs involved in making such a repair shall be borne by the Contractor.

4.7.2 Socket Weld Fittings and Brazed Joints

At the discretion of the Engineer's Representative, a maximum of 5% of socket welds per welder, and brazed joints shall be cut out, sawn in half and inspected. Should any of these be unsound, then further welds or brazed joints shall be cut out and inspected until it is established that all are satisfactory. The cost of cutting out and replacing shall be borne by the Contractor.

5. THREADED JOINTS

Teflon tape shall be used for joints operating up to 240°C., but not above this temperature. No other sealant is allowed in this range. A seal weld is recommended for temperatures above 240°C.

6. VALVES AND BELLOWS

6.1 Globe valves shall normally be installed so that the disc will close against pressure. On reactivation circuits some valves will be installed counterflow and these will be marked with an arrow and the letter 'P' on the drawings.

6.2 Bellows assemblies shall be installed in accordance with the notes on the isometric drawings. The Contractor shall request the Engineer's Representative specifically to inspect installed bellows, before the plant pressure test.

7. CLEANING AND STORAGE

7.0.1 Proper cleaning of all equipment in contact with oxygen is absolutely essential. Ineffective cleaning can result in loss of life and damage to equipment. If any doubt exists as to whether oxygen equipment has been contaminated or insufficiently cleaned, it shall be recleaned at the Contractor's cost.

2

7.0.2 The Contractor shall clean all piping fittings in accordance with the contract drawings and specifications.

7.0.3 Valves required to be cleaned to Classification AA cleanliness will normally be delivered in that condition.

7.0.4 Where valves are required to be cleaned on site this will be shown in the Valve Summary. The recommended method is given in Para A.6. Any cleaned material that is not to the approval of the Engineer's Representative shall be recleaned at the Contractor's expense.

7.0.5 Cleanliness of materials is classified into 3 groups:

Service Materials	-	Classification B Cleanliness
Process Materials	-	Classification A Cleanliness
Oxygen & Cryogenic Materials	-	Classification AA Cleanliness

7.1 Classification B Materials shall be considered clean when they are visually clean under bright white light.

7.2 Classification A Materials shall be considered clean when they are:

7.2.1 Visually clean under bright white light.

7.2.2 Free from loose particles or potentially loose particles, paint and other protective coating.

7.2.3 Free from grease - wiping with a clean white lint free cloth, or pulling through shall detect no trace of oils of grease on the cloth.

7.3 Classification AA materials shall be considered clean when they conform to the following:

7.3.1 Visually clean under bright white light and ultra violet light.

7.3.2 No internal surface when inspected under bright white light shall contain any loose particles capable of being brushed off by hand with a soft nylon brush and blown off with an air jet.

There shall be no potentially loose particles which exceed 0.5mm in two directions and 0.2mm in the third plane.

7.3.3 All surfaces must be completely dry.

7.3.4 All surfaces shall be free of all discolouration other than that which is due to the metal.

7.3.5 Black light Test - Internal sources shall be free of any fluorescence, other than isolated spots of lint and dust, detectable by ultra violet light having a wave length of 3600 Angstroms when viewed in the dark. The U.V. lamp will be supplied by the Employer.

7.3.6 Wipe Test - Internal surfaces shall be wiped with a clean white lint free cloth and the cloth inspected to ensure the absence of any oils not detectable by black light, or residue discolouration, fibres etc., not previously detected. The cloth may be dipped in trichlorthylene or methylene chloride before wiping.

7.4 Cleaning Methods

Suggested cleaning methods are described in Appendix 1.

7.5 Storage

7.5.1 All valves and fittings shall be stored indoors. Protective packages labelled 'Decontaminated for Oxygen Service' or similar, shall not be removed until the equipment is to be installed. If removed, or damaged, at the discretion of the Engineers' Representative the item shall be recleaned by the Contractor at his cost.

7.5.2 During construction all cleaned materials shall be maintained clean until the installation is accepted by the Engineer's Representative. Both in storage and during installation open pipe ends and vessel nozzles shall be sealed with clean polythene sheeting.

8. PRESSURE TESTING & PLANT BLOWOUT

8.1 <u>Pressure Testing</u> (Process Piping)

All process piping will be pneumatically pressure tested under the supervision of the Engineer's Representative. Both leak tests, and a 12 hour drop test will be made with oil free air or nitrogen supplied by the Employer.

In preparation for and during the pressure testing the Contractor shall:

8.1.1 Instal test relief valves, gauges, blanks supplied by the Employer, and make other minor modifications to the plant as instructed by the Engineer's Representative.

8.1.2 Soap all joints to locate leaks, repair any leaks found, and re-soap repaired joints to the satisfaction of the Engineer's Representative and the relevant Inspecting Authority.

8.1.3 On completion of the pressure test restore the plant to its normal working condition.

8.2 <u>Pressure Testing</u> (Utility Piping)

The Contractor shall hydraulically test utility piping such as steam and water, at 1.5 times design pressure after installation and repair any leaks at his own expense.

8.3 <u>Blow-Out</u>

Either before or after the pressure test, the plant will be blown out to remove any waste.

The Contractor shall:

8.3.1 Undo and afterwards replace, certain flanged joints as instructed by the Engineer's Representative to allow blowout.

8.3.2 Afterwards thoroughly clean out any part of the system showing an accumulation of waste material.

9. <u>PROCESS PIPING ISOMETRICS</u>

Dimensions on isometric sheets are based on geometric calculations and no allowance has been made for fabrication and erection tolerances. The Contractor shall prepare and assemble the prefabricated piping allowing for such tolerances and any alterations necessary, because the prefabricated piping does not mate correctly, shall be carried out at the Contractor's cost.

10. PIPE SUPPORTS

Where pipe supports for piping below 2" n.b.(50mm) are not specifically detailed on the drawings, the supports shall be supplied, fabricated and installed by the Contractor at no additional cost to the Employer.

TITLE Cleaning of Pipes and Fittings

A.1 **All Materials**

Remove any coating of paper, lacquer, varnish, paint ect., scrub out the pipe with a dry cylindrical brush, and blow out with air. Where an internal coating is to be removed, such coating shall be removed from pipe or fittings before that item is welded.

A.2 **Grade A Cleanliness - Carbon Steel**

A.2.1 Immerse the pipe in an approved chemical descaling solution, and when descaled wash out with clean water. Hydrochloric acid may be used for extensive descaling.

A.2.2 Pacify in a 4% phosphoric acid solution, and wash in clean water and dry.

A.3 **Grade AA Cleanliness - St. Steel, C. Steel, Copper, Aluminium**

For carbon steel this procedure may be necessary following that outlined in paragraph A2 where it cannot be seen that the internal surfaces of the piping are clean.

A.3.1 Wash out or scrub out with a nylon brush, pipe and fittings with trichlorethylene or methylene chloride until clean.

A.3.2 Pull through with a clean lint free cloth. Do not re-use the cloth.

A.3.3 For small bore pipe do not pull through, but drain, and blow out with dry oil free air or nitrogen.

A.3.4 Seal the pipe ends with polythene sheets.

A.4 **General**

A.4.1 When random lengths of pipe are prefabricated, the chemical cleaning (Para A.2 and A.3) shall be carried out after prefabrication. The pipe ends and fittings and backing rings when used shall be wiped clean with a trichlorethylene soaked rag and the trichlorethylene allowed to evaporate prior to welding.

A.5 **Trichlorethylene**

The grade of Trichlorethylene shall be I.C.I. Grade 4 inhibited or equivalent.

A.6 **Valves**

Dismantle valves and match mark all parts. Decontaminate the parts with new and clean methylene chloride or trichlorethylene, handling them only with clean lint-free gloves. The parts are considered degreased when they conform to Para 7.3. Re-assemble valves with degreased tools, tag the valves, and pack in a polythene bag to maintain cleanliness. Label "Degreased for oxygen service".

[redacted]

ENGINEERING SPECIFICATION

No. M.02
PAGE
CONT. ON APPENDIX II
REV

TITLE ELECTRONICS AND WELDING WIRE.

All electrodes and welding wire shall be stored in sealed containers in a dry room. Opened packages of electrodes and welding wire shall be kept in heated storage and protected from deterioration and damage until immediately before use.

Electrodes and welding wire showing signs of damage shall not be used.

MATERIAL	WIRE OR ELECTRODES
1) **Aluminium/Manganese Alloy**	
NT5 to BS 1470/77-1955, ASTM GR 40A AA5154 (P22) (Pipe)	NG6 to BS 1475-1955, ASTM GM 41A, AA 5456 (F22)
NP8 to BS 1477 (Plate)	N6/1 to BS 1475 or ASTM SB/ER5183
2) **Stainless Steel**	
EN 58E, ASTM SA 312.TP304	BS 2901 A8, ASTM SA 371, or BS 2926-A ASTM A298(F5)
3) **Carbon Steel**	
Mild Steel BS 1501, ASTM-SA-285	BS 2901-A16 and A17, ASTM SA 233, BS 1719

TITLE PIPING LINE DESIGNATIONS

Line Designations

Each line will be designated as in the following example.

2-0-321-SS 2.7.

This is explained as follows:

2 is the nominal pipe or tubing size in inches not (OD) the piping bill of material gives the complete description.

O is the line service letter for the fluid in the line (oxygen). See listing of fluid designations.

321 is the line number. Generally, line numbers go from equipment piece to piece.

SS 2.7 - The piping material and pressure class. (SS is stainless steel 2.7 is 270 psig. nominal class).

Piping Material Designations

AL - Aluminium Alloy
CSO - Carbon Steel Oxygen
CSS - Carbon Steel Steam
CS - Carbon Steel
CT - Copper Tube
ICT - Instrument Copper Tube
SS - Stainless Steel
TA - Tungum - Alloy

Fluid Designations

A - Air
C - Caustic
F - Freon
G - Petrol
H - Hydrogen
HE - Helium
N - Nitrogen
O - Oxygen
P - Propane
R - Argon
S - Steam
CD - Carbon Dioxide
FG - Feed Gas
NG - Methane or Natural Gas
PW - Potable Water
WG - Waste Gas

Air Products	**ENGINEERING SPECIFICATION**	No. C.03 COVER SHEET REV 2

TITLE Specification for Oxygen Service Vessel Fabrication

(Designed by A.P.L Fabrication by Vendor)

DISTRIBUTION

All Engineering Specification and Standard Manual Holders

REV	DESCRIPTION	DATE	ORIGINATOR	APP'D
2	Para 4.3,5.1, 6.2, 6.4, 6.5, 6.7 & 13.1 ~~amended~~ Para 13.2.8 & 13.2.9 added	26.7.71	G.T.L Elmore	G Elmore
1	Paras 10.1 & 13.1 Amended	6.2.70	J.W. Pegram	
0	ORIGINAL ISSUE	25.6.69	J.W. Pegram	

ORIGINAL APPROVED BY	G. Elmore SECTION HEAD	C.H. Bloom DESIGN MANAGER	R.M. Thorogood CHIEF ENGINEER	M.A. Supple MANAGER OF ENGINEERING

F.911/1

APCI DOCUMENT NO. 99000366

TITLE Specification for Oxygen Service Vessel Fabrication (Designed by APL & fabricated by Vendor).

1. Purpose

1.1 This specification covers the requirements for the fabrication, inspection and testing of pressure vessels for liquid or gaseous oxygen service which are fabricated by a vendor to the design of Air Products Ltd.

1.2 The related specifications, standards and codes shall be the latest issue and shall include all addenda, revisions and supplements.

1.3 All conflicts between the requirements of this specification, the standards and codes shall be referred to Air Products Limited, hereinafter called the Purchaser, for clarification or modification before quotation, or in the event of an order before work proceeds.

2. Design

2.1 The design conditions and Code of Construction will be specified on the Purchaser's drawing.

2.2 Where drawings conflict with this specification the drawing shall govern.

3. Materials

3.1 Materials of vessel construction are specified on the drawings and/or the associated bills of material.

3.2 Unless otherwise stated in the order the Vendor will obtain and shape as necessary all materials required for completion of the work.

3.3 Substitution of material is not permissible without prior written clearance from the Purchaser.

3.4 All pressure part materials shall be identificable against certificates giving full chemical analysis and physical properties,and are subject to approval by the appointed Representative of the Approval Authority.

4. Drawings

4.1 In the event of an order the Purchaser will supply to the Vendor sufficient information to enable the Vendor to complete any additional detailed fabrication drawings.

4.2 Drawings in aid of manufacture should be submitted to the Approval Authority stated in the purchase order with two copies to the Purchaser.

4.3 Deviations from the certified drawings and/or specifications shall not be permissible except when prior clearance has been obtained from the Purchaser and Approval Authority. Such clearance does not relieve the Vendor of any responsibility for the soundness of work, completing the work in scheduled time, nor does it commit the Purchaser to accept any increase in costs.

5. Fabrication

5.1 Fabrication shall be fully in accordance with the requirements of the relevant pressure vessel code, the appointed approved authority and in accordance with the drawings.

5.2 The Vendor is to confirm that welders are qualified to the requirements of the specified Code Authority and submit certified copies of welders qualification certificates to the Purchaser prior to commencing work.

If not previously qualified to those requirements, the welders and automatic welding equipment shall qualify in accordance with the code on test plates representing each type of weld and material to be used before proceeding on production welding.

5.3 Records of test plates and production welds, including radiographs, shall be kept and made available to the Purchaser on request. Interpretation of acceptable radiographs shall be agreed with the Approval Atuhority whose decision shall be final.

5.4 Quality of welding shall be judged and radiographs interpreted in accordance with the requirements of the Purchaser's Quality Control Standards or as agreed with the Vendor and the Approval Authority. Details of such agreement must be forwarded to the Purchaser for review before manufacture commences.

6. Inspection & Testing

6.1 Inspection and testing shall be to the specified Code in accordance with the relevant drawings and Approval Authority requirements.

6.2 The Approval Authority and Air Product's Inspection Engineer shall have free access to the Vendor's works at all reasonable times after placement of order and until delivery of completed vessel. They shall be at liberty at any stage of the manufacture to inspect and reject any defective material that does not conform to the specification stated on the certified manufacturing drawings.

2 6.3 Cost of all Inspection, Tests and Certificates shall be borne by the Vendor.

6.4 On completion of fabrication the vessel shall be subject to strength test to the pressure stated on the relevant drawing and code. All welds shall be examined for leakage. No leakage is permitted. This test is to be carried out in the presence of the Approval Authority and Air Products Limited Inspector. No final inspection tests are to take place before all the material certificates, and the results of any tests or requirements of the Approval Authority, are available. 2

6.5 The fabricator must provide all the necessary materials and equipment, including closures, gaskets and test bolts for the pressure test. Under no circumstances may the test bolts and gaskets be delivered with the finished vessel, where the bolts have exceeded design yield stress or 0.1% proof stress during pressure testing. 2

6.6 After carrying out the pressure testing, all welds shall be examined for gas leakage using air at the design pressure. Detection shall be by means of detergent solution. No leakage shall be permitted. On completion of the test all traces of the detergent shall be removed.

2 6.7 The vessel shall not be despatched prior to final acceptance by the Purchaser and before manufacturing approval has been obtained from the relevant approval authority.

7. Nameplate

7.1 A suitable nameplate shall be provided by the Vendor and permanently fitted to the vessel. On satisfactory completion of tests, the nameplate shall be stamped by the Approval Authority. Information contained on the nameplate shall be as follows:

(a) Makers name and number
(b) Drawing number and design code
(c) Design pressure
(d) Maximum allowable working pressure
(e) Hydraulic test pressure and date of test
(f) Maximum and minimum allowable temperature
(g) Manufacturers test mark
(h) Approval Authority test mark
(j) Date of Surveyor's acceptance test

8. Cleaning

8.1 On completion of fabrication the inside and outside of the vessel shall be thoroughly cleaned, decon aminated and left in a physically clean condition. The degree of cleanliness will be stated on the drawing together with the Specification No. A.03 for the cleanliness acceptance tests.

8.2 Openings shall be blanked off and suitably sealed to prevent the ingress of dirt and dust.

9. Painting

9.1 All carbon and low alloy steel fabricated pressure vessels shall be descaled by shot balsting and finished painted by a four coat system, one primer, one undercoat and two top coats to Vendors own specification which should not be less than B.S. Code of Practices 231. The top coat colour scheme shall be as specified on the attached bid sketch or a purchase order.

10. Preparation for Shipment

10.1 The relevant vessel project and equipment numbers, to be painted on the outside of the vessel in 4" high letters and numerals and nozzle streams to have identification marks painted thereon. A 1" wide x 12" long line shall be painted on the North side of the vessel.

10.2 The vessel must be pressurised to 15" w.g. minimum and 15 psig maximum with dry oil free air or nitrogen gas and all nozzles suitably blanked off and the vessel suitably protected for road and/or rail transport. The vessel shall carry a notice that it is under pressure during shipment.

10.3 All costs of preparation for shipment are to be borne by the vendor.

10.4 Packing will be subject to inspection by Air Products Inspector or delegated representative.

11. Delivery Address

11.1 Vessel shall be delivered as requested on A.P.L purchase order.

12. Sub Orders

12.1 Two copies of all sub-orders (unpriced) shall be submitted to A.P.L for expediting purposes.

13. Records

13.1 The vessel fabricator shall furnish 3 copies of pressure vessel record that shall declare full particulars of the vessel and shall report the results of all tests on the materials of construction on the soundness of the workmanship and on the completed vessel, to establish its suitability to withstand the design conditions, together with all tests and rectifications. The report constituting the record shall be certified by the Chief Inspector of the Fabricator or his sub-contractor, and be signed by the Approval Authority and the Purchaser's Representative who witness the acceptance tests. The original and copies of the vessel record shall be maintained at the Fabricators Works.

2

In addition, copies shall be provided as required by the Approval Authority.

13.2 The minimum documentation for pressure vessel dossier is as follows:

13.2.1 Pressure Vessel Certificate, giving the following information:-

(a) Manufacturers name

(b) A.P.L Project and Section No.

(c) A.P.L Purchase Order No.

(d) Vessel Serial No.

(e) Construction Code

(f) Approval Authority

(g) Operating Temperature and Pressure

(h) Design Temperature and Pressure

(j) Test Pressures and Dates

(k) Corrosion Allowance

The vessel information g,h,j,k above must be given for each chamber of the vessel.

The pressure vessel certificate must be signed and stamped by the Approval Authority's Representative.

13.2.2 Material Identification Sketch, showing cast numbers for all pressure and strength components of the vessel and for all the material directly welded to such parts. The sketch must be signed and stamped by the Approval Authority's Representative and the Manufacturer's Senior Inspector.

13.2.3 Material Test Certificates, giving chemical and physical properties of all material noted on the material Identification Sketch. These test certificates must be issued by the Material Manufacturer or may be certificates indicating the results of test carried out in the presence of the Approval Authority.

13.2.4 Welders Qualifications, in accordance with the relevant code and giving all results of tests performed, and test dates. Welders qualifications must be signed and stamped by the Approval Authority Representative.

13.2.5 Radiograph Sketch, which must show the extent of radiography which must indicate the film numbers and show the positions at which films were taken.

13.2.6 Radiograph Assessment, giving the results of all the films noted on the radiograph sketch and giving a final classification in accordance with the relevant code. All repair details must be noted on the assessment.

13.2.7 Heat Treatment Certificates, which must indicate the part subjected to heat treatment, the purpose of the treatment and must be accompanied by the actual furnace time/temperature chart. The chart and the certificate must be signed by the Approval Authority's Representative.

2 13.2.8 Drawings, each dossier supplied to the purchaser must include a general arrangement drawing which contains sufficient information to enable the dossier documentation to be checked.

2 13.2.9 Cleanliness Certificate, a document, signed by the manufacturer's Senior Inspector and countersigned by the Air Products Limited Inspector must show that the cleanliness of the vessel complies with Clause 8.1.

13.3 The manufacturer shall maintain the records through all stages of manufacture and shall make the various documents available to the Purchaser's Inspector and the Approval Authority's Representative on request.

13.4 Three copies of the vessel dossier shall be sent to:-

Expediting Manager,
Air Products Limited,
Coombe House,
Malden Road,
New Malden,
Surrey.

Air Products

ENGINEERING SPECIFICATION

No. C.04

COVER SHEET

REV 2

TITLE Specification for Oxygen Service Pressure Vessel Fabrication

(Designed and fabricated by the Vendor)

DISTRIBUTION

All Engineering Specification and Standard Manual Holders

All Vessel Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	APP'D
2	Para 2,1, 2.2, 3.2, 4.3, 4.5, 4.6, 4.9 5.1, 5,3, 6.2, 7.2, 13.1 & 13.4 amended Para 5.5, 6.4 deleted old para 6.5 etc renumbered 13.2.9 and 13.2.10 added	26.7.71	G. Elmore	GElmore
1	Para 10.1 and 13.1 amended	6.2.70	J.W. Pegram	
0	ORIGINAL ISSUE	25.6.69	J.W. Pegram	

ORIGINAL APPROVED BY	G. Elmore SECTION HEAD	C.H. Bloom DESIGN MANAGER	R.M. Thorogood CHIEF ENGINEER	M.A. Supple MANAGER OF ENGINEERING

F.911/1

APCI DOCUMENT NO. 99.000367

TITLE Specification for Oxygen Service Pressure Vessel Fabrication.

1. PURPOSE

1.1 This Specification, together with the relevant process design information, covers the requirements for the design, materials, fabrication, inspection, testing, cleaning, painting and shipment of oxygen service pressure vessels designed and fabricated by the Vendor.

1.2 The related Specifications, Standards and Codes shall be the latest issues and shall include all addenda, revisions and supplements.

1.3 All conflicts between the requirements of this specification the standards and codes shall be referred to Air Products Ltd., hereinafter called the Purchaser, for clarification or modification before quotation, or in the event of an order before work proceeds.

2. DESIGN

2.1 The pressure vessel shall be designed fully in accordance with the latest requirements of Division 1, or an alternative code as agreed with Air Products Limited. at time of bid, except where specified otherwise on the Process Data sheet, and/or Purchase Requisition, then it shall meet the latest Code requirements of the National Pressure Vessel Authority of the country of destination as specified. The relevant code must be clearly indicated on the drawings and documents.

2.2. The design of the vessel shall be approved by the Independent Approval Authority. It will be the Vendor's responsibility to secure Approval Authorities approval of the design fabrication and testing at Vendor's cost.

2.3 Design conditions are as stated on the appropriate process specification bid sketch or data sheet.

3. MATERIALS

3.1 The Vendor shall specify clearly in his tender and on the production drawings the specification, grade, class and temper to which each material shall conform.

3.2 Meterials for construction shall subject to approval by the appointed representative of the Approval Authority.

3.3 Test Certificates will be required for all pressure part meterails and permanent attachments giving full chemical analysis and physical properties in accordance with the relevant code.

4. DRAWINGS

4.1 The Vendor shall submit with his quotation sufficient information to enable the Purchaser to assess the merits of the proposed design.

4.2 All documents must be identified by the customers Project number, equipment item number and purchase order numbers; and on drawings Vendor's title, drawing and revision numbers; all preferably in the lower right hand corner. Where practical a 3" x 4" blank space shall be allowed near this title block for Purchaser's use.

2 4.3 The selected Vendor shall submit within three (3) weeks of receipt of order or as required by Air Products drawing register six (6) copies or one reproducible of general arrangement and detail drawings for review by the Purchaser.

4.4 The Vendor shall submit to the Purchaser within five (5) weeks of receipt of order or as required by Air Products drawing register three (3) copies of dimensioned drawing showing shipping package, including all lifting points.

2 4.5 All detail and assembly shall be fully dimensioned in metric units.

2 4.6 The drawings shall be fully dimensioned and give the following information as a minimum:-

4.6.1 Air Products Ltd., Purchase Order Number

4.6.2 Air Products Ltd., Project and Section Number.

4.6.3 Design Code.

4.6.4 Approval Authority

4.6.5 Design Pressure

4.6.6 Minimum and Maximum Design Temperature

4.6.7 Maximum allowable operating pressure, corroded condition.

4.6.8 Normal Operating Pressure.

4.6.9 Normal Operating Temperature.

4.6.10 Test Pressure and Medium

4.6.11 Leak Test Pressure

4.6.12 Corrosion Allowance

4.6.13 Thickness of all pressure parts.

4.6.14 All dimensions necessary for calculation of thickness.

4.6.15 Cleaning processes internal and external

4.6.16 Specifications for all materials including wled and brazing alloy material.

4.6.17 Extent of Radiography, and post weld treatment.

4.6.18 Welding techniques and preparations.

4.6.19 Maximum permissible loads due to piping on each nozzle.

4.6.20 Internal Volume of each stream.

4.7 After drawings submitted have been reviewed by the Purchaser and the Approval Authority, and they are accepted as satisfactory, the Purchaser will return one copy of the drawings sent to them by the Vendor for clearance stamped 'NOTED'. It will be the Vendors responsibility to secure the Approval Authorities approval of the drawings.

4.8 One reproducible copy of certified correct general arrangement and detail drawings shall be submitted to A.P.L. by the Vendor within 7 days of receiving full design clearance.

4.9 Deviations from the certified drawings and/or specifications shall not be permissible except when prior clearance has been obtained from the Purchaser and Approval Authority. Such clearance does not relieve the Vendor of any responsibility for the soundness of work, completing the work in scheduled time, nor does it commit the Purchaser to accept any increase in costs.

5. FABRICATION AND WORKMANSHIP

5.1 Fabrication shall be fully in accordance with the requirements of the relevant pressure vessel code, the appointed approval authority and in accordance with the certified drawings. Clearance from the Approval Authority and A.P. Ltd., must be obtained before manufacture of the vessel commences.

5.2 Records of test plates and production welds, including radiographs shall be kept and made available to the Purchaser on request.

5.3 Unless previously qualified to the requirements of the relevant Pressure Vessel Code Authority, the welders and automatic welding equipment shall qualify in accordance with the Code on test plates representing each type of weld and material to be used before proceeding on production welding.

5.4 Quality of welding shall be judged and radiographs interpreted in accordance with the requirements of the Purchaser's Quality Control Standards or as agreed with the Vendor and the Approval Authority. Details of such agreement must be forwarded to the Purchaser for review before manufacture commences.

TITLE Specification for Oxygen Service Pressure Vessel Fabrication

6. INSPECTING AND TESTING

2 6.1 Inspection and testing shall be in accordance with the requirements of Air Products or their appointed approval authority and in accordance with the relevant drawings, code and Approval Authorities requirements.

2 6.2 The Approval Authority and Air Product's Inspection Engineer shall have free access to the Vendor's Works at all reasonable times after placement of order and until delivery of completed vessel. They shall be at liberty at any stage of the manufacture to inspect and reject any defective material that does not conform to the specification stated on the certified manufacturing drawings.

6.3 Cost of all Inspection Tests and Certificates shall be borne by the Vendor.

2 6.4 On completion of fabrication the vessel shall be subject to strength test to the pressure stated on the relevant drawing and code. All welds shall be examined for leakage and no leakage is permitted. This test is to be carried out in the presence of the Approval Authority and A.P. Ltd., Inspector. No final inspection tests are to take place before all the material certificates, and the results of any tests or requirements of the Approval Authority, are available.

2 6.5 The fabricator must provide all the necessary materials and equipment, including, closures, gaskets and test bolts for the pressure test. Under no circumstances may the test bolts and gaskets be delivered with the finished vessel, where the bolts have exceeded the design yield stress or 0.1% proof stress during pressure testing.

6.6 After carrying out the pressure testing, all welds shall be examined for gas leakage using air at the design pressure. Detection shall be by means of detergent solution. No leakage shall be permitted. On completion of the test all traces of the detergent shall be removed.

6.7 The vessel shall not be despatched prior to final acceptance by the Purchaser or before manufacturing approval has been obtained from the relevant approval authority.

7. NAMEPLATE

2 7.1 A suitable nameplate shall be provided by the Vendor and permanently fitted to the vessel. On satisfactory completion of tests, the nameplate shall be stamped by the Approval Authority. Information contained on the nameplate shall be as follows:-

a) Makers name and number

b) Drawing number and Design Code

c) Design Pressure

d) Maximum allowable work pressure.

e) Hydraulic test pressure and date of test.

f) Maximum and minimum allowable temperature.

g) Manufacturers test mark.

h) Approval Authority test mark.

j) Date of Surveyor's acceptance test.

8. CLEANING

8.1 All internal vessel surfaces shall be free from oil, loose particles and other foreign matter fully in accordance with Air Products Specification No. A.03. Cleanliness acceptance standards for Class AA oxygen service cleanliness.

9. EXTERNAL PAINTING

9.1 All carbon and low alloy steel fabricated pressure vessels shall be descaled by shot blasting and finished painted by a four coat system, one primer, one undercoat and two top coats to vendors own specification which should not be less than B.S. Code of Practices 231. The top coat colour scheme shall be as specified on the attached bid sketch or a purchase order.

10. PREPARATION FOR SHIPMENT

1 10.1 The relevant vessel project and section numbers, to be painted on the outside of the vessel in 4" high letters and numerals and nozzle streams to have identification marks painted thereon. A 1" wide x 12" long line shall be painted on the North side of the vessel.

10.2 The vessel must be pressurised as stated in the Cleaning Specification A.03 and the vessel suitably protected for road and/or rail transport. The vessel shall convey a notice that it is under pressure during shipment.

10.3 All costs of preparation for shipment are to be borne by the Vendor.

10.4 Packing will be subject to inspection by Air Products Inspector or Delegated Representative.

11. DELIVERY ADDRESS

11.1 Vessel shall be delivered as requested on A.P.L. Purchase Order.

12. SUB ORDERS

12.1 Two copies of all sub-orders (unpriced) shall be submitted to A.P.L. for expediting purposes.

13. RECORDS

13.1 The vessel fabricator shall furnish 3 copies of pressure vessel record that shall declare full particulars of the vessel and shall report the results of all tests on the materials of construction on the soundness of the workmanship and on the completed vessel, to establish its suitability to withstand the design conditions, together with all tests and rectifications. The report constituting the record shall be certified by the Chief Inspector of the Fabricator or his sub-contractor, and be signed by the Approval Authority and the Purchaser's Representative who witness the acceptance tests. The original and copies of the vessel record shall be maintained at the Fabricators Works.

2

In addition, copies shall be provided as required by the Approval Authority.

13.2 The minimum documentation for a pressure vessel dossier is as follows:-

13.2.1 Pressure Vessel Certificate, giving the following information:-

a) Manufacturers name

b) [illegible] Project and [illegible] number

c) A.P.[illegible] Purchase Order number

d) Vessel Serial number.

e) Construction Code

f) Approval Authority

g) Operating temperature and pressure

h) Design temperature and pressure

i) Test pressures and dates.

j) Corrosion allowance

The vessel information g, h, i, j, above must be given for each chamber of the vessel.

The pressure vessel certificate must be signed and stamped by the Approval Authority's Representative.

13.2.2 Material Identification Sketch, showing cast numbers for all pressure and strength components of the vessel and for all material directly welded to such parts. The sketch must be signed and stamped by the Approval Authority's Representative and the Manufacturer's Senior Inspector.

13.2.3 Material Test Certificates, giving chemical and physical properties of all material noted on the Material Identification Sketch. These test certificates must be issued by the Material Manufacturer or may be certificates indicating the results of tests carried out in the presence of the approval Authority.

13.2.4 Welders Qualifications, in accordance with the relevant code and giving all results of tests performed and test dates. Welders qualifications must be signed and stamped by the Approval Authority Representative.

13.2.5 Radiograph Sketch, which must show the extent of radiography which must indicate the film numbers and show positions at which films were taken.

13.2.6 Radiograph Assessment, giving the results of all the films noted on the radiograph sketch and giving a final classification in accordance with the relevant code. All repair details must be noted on the assessment.

13.2.7 Heat Treatment Certificates, which must indicate the part subjected to heat treatment, the purpose of the treatment and must be accompanied by the actual furnace time/temperature chart. The chart and the certificate must be signed by the Approval Authority's Representative.

13.2.8 Drawings, each dossier supplied to the purchaser must include a general arrangement drawing which contains sufficient information to enable the dossier documentation to be checked.

2 13.2.9 Design Calculations, each dossier supplied to the Purchaser must include a full set of calculations of the scantlings of the pressure vessel to the relevant code.

2 13.2.10 Cleanliness Certificate. A document, signed by the manufacturer's Senior Inspector and countersigned by the Air Products Limited Inspector must show that the cleanliness of the vessel complies with Clause 8.1.

13.3 The manufacturer shall maintain the records through all stages of manufacture and shall make the various documents available to the Purchaser's Inspector and the Approval Authority's Representative on request.

13.4 Three copies of the vessel dossier shall be sent to:-

Expediting Manager,
Air Products Ltd.,
Coombe House,
St. Georges Sq.,
New Malden,
Surrey.

Air Products

ENGINEERING SPECIFICATION

No. E. 02
COVER SHEET
REV 4.

TITLE
BRAZED CORE EXTENDED SURFACE HEAT EXCHANGERS.

DISTRIBUTION

All Engineering Specification & Standard Manual Holders.

All Vessel Engineer.

REV	DESCRIPTION	DATE	ORIGINATOR	APP'D
	6.5 & 6.6 deleted. 6.4 amended			
	Paragraphs 3.1, 5.4, 13.4 and 5.5 amended			
4	13.2.9 & 10, 3.4, 10.5, and 10.6 added 4.4 now 4.3, old 4.3 deleted	28.6.70.	G. Elmore	[signature]
3	Paragraph 7.8 amended	14.4.70.	J.W. Pegram	[signature]
2	Paragraph 13.1 amended	5.2.70.	J.W. Pegram	[signature]
1	Paragraph 5.04 amended	2.9.69.	J.W. Pegram	[signature]
0	ORIGINAL ISSUE	7.7.69.	J.W. Pegram	[signature]

Original APPROVED BY	G. Elmore SECTION HEAD	C.H. Bloom DESIGN MANAGER	R.M. Thorogood CHIEF ENGINEER	M.A. Supple MANAGER OF ENGINEERING

F.911/1

APCI DOCUMENT NO. 99000368

TITLE Brazed Core Extended Surface Exchangers.

1. PURPOSE

This specification states Air Products Ltd.'s requirements for the design, materials, fabrication, inspection, testing, cleaning and shipment of the pressure vessel for an extended surface heat exchanger.

2. GENERAL

2.1 This specification should be read in conjunction with the relevant requisition and data sheet.

2.2 All conflicts between the requirements of this specification, and the requisition and data sheet, the standards and codes shall be referred to Air Products Limited., hereinafter called the Purchaser, for clarification or modification before quotation or in the event of an order before work proceeds.

3. DESIGN

4 3.1 The vessel shall be designed in accordance with the latest requirements of the A.S.M.E. VIII Division I, except where specified otherwise on the Process Data Sheet and/or Purchase Requisition, then it shall meet the latest Code requirements of the National Pressure Vessel Authority of the country of destination as specified. The relevant code must be clearly indicated on the drawings and documents.

3.2 The design of the vessel shall be reviewed by Air Products Ltd. and approved by the Independent Approval Authority specified or National Pressure Vessel Authority as relevant. It will be the Vendor's responsibility to secure the Approval Authorities approval of the design fabrication and testing.

3.3 Design conditions as stated on appropriate process data sheet.

4 3.4 Where dummy passages are provided on the exchanger, these shall be positively sealed as agreed with Air Products Ltd. in order to prevent ingress of moisture or foreign matter.

4. MATERIALS

4.1 The Vendor shall specify clearly in his tender or the production drawings the specification, grade, class and temper to which each material shall conform.

4.2 Materials for construction shall be subject to approval by the appointed Representative of the Approval Authority.

4 4.3 Test Certificates will be required for all pressure part materials and permanent attachments giving full chemical analysis and physical properties in accordance with the relevant code.

5. DRAWINGS

5.1 The Vendor shall submit with his quotation sufficient information to enable the Purchaser to assess the merits of the proposed design.

5.2 All documents must show equipment item number and purchase order numbers; all preferably in the lower right hand corner. Where practical a 3" x 4" blank space shall be allowed near the title block for Purchaser's use.

5.3 The Vendor shall submit to Air Products Ltd. within 5 (five) weeks of receipt of order or as required by the drawing register 3 (three) copies of dimension drawings showing shipping package, including all lifting points.

4 5.4 The Vendor shallsubmit 2 (two) copies of sketches giving block sizes and manifold sizes and positions, and preferred support locations within 2 (two) weeks of receipt of order or as required by the drawing register followed by 6 (six) copies of general arrangement and detail drawings for review by Air Products Ltd. within 5 (five) weeks of receipt of order or as required by the drawing register. The Vendor is responsible for submission of drawings to and obtaining approval from the Approval Authority.

4 5.5 All detail assembly drawings shall be fully dimensioned in metric units.

5.6 The drawings shall be fully dimensioned and giving the following information as a minimum:-

(a) Design Code.

(b) Design Pressure.

(c) Minimum and Maximum Design Temperature.

(d) Normal Operating Pressure.

(e) Normal Operating Temperature.

(f) Test Pressure and Medium.

(g) Inspection Authority.

(h) Cleaning process internal and external.

(j) Specifications for all Materials.

(k) Extent of Radiography.

(l) Operating and Shipping Weights.

(m) Maximum permissible loads and moments due to piping on each nozzle.

5.7 After drawings submitted have been reviewed by the Purchaser and they are accepted as satisfactory, the Purchaser will return one copy of the drawings sent to them by the Vendor for clearance marked "NOTED". It will be the Vendor's responsibility to secure the authorities approval of the drawings.

5.8 One reproducible copy of certified correct general arrangement and detail drawings shall be submitted to Air Products Ltd. by the Vendor within 7 days of receiving full design clearance.

5.9 Deviations from the certified drawings and/or specifications shall not be permissible except when prior clearance has been obtained from the Purchaser and Approval Authority. Such clearance does not relieve the Vendor of any responsibility for the soundness of work, completing the work in scheduled time, nor does it commit the Purchaser to accept any increase in costs.

6. <u>FABRICATION & WORKMANSHIP</u>

6.1 Fabrication shall be fully in accordance with the relevant pressure vessel code in accordance with the certified drawings and shall be carried out to the satisfaction of the Approval Authority[redacted]

6.2 Records of test plates and production welds, including radiographs shall be kept and made available to the Purchaser on request.

6.3 Unless qualified to the requirements of the relevant pressure vessel code authority the welders and automatic welding equipment shall qualify in accordance with the code on test plates representing each type of weld and material to be used before proceeding on production welding.

4

6.4 Quality of welding shall be judged and radiographs interpreted in accordance with the Purchaser's Quality Control Standards or as agreed with the Vendor's and the Approval Authority. Details of such agreement must be forwarded to the Purchaser for review before manufacture is commenced.

TITLE Brazed Core Extended Surface Exchangers.

7. INSPECTING AND TESTING

7.1 Inspection and testing shall be to the requirements of the relevant pressure vessel code authority and in accordance with the relevant drawings.
Cost of all Inspection tests and Certificates shall be borne by the Vendor.

7.2 The Approval Authority and/or the Purchaser's Inspection Engineer shall have free access to the Vendor's works at all reasonable times after placement or order and until delivery of completed vessel.

7.3 The Approval Authority and/or the Purchaser's Inspection Engineer shall be at liberty at any stage of the manufacture to inspect and reject any defective material or material that does not conform to the specification stated on the certified manufacturing drawings.

7.4 On completion of fabrication each stream of the exchanger shall be subject to a seperate strength test with other streams unpressurised to the pressures stated on the relevant drawings and code. These tests are to be carried out in the presence of the Approval Authority and Air Products Ltd. Inspector. No final inspection tests are to take place before all the material certificates, and the results of any tests or requirements of the Approval Authority, are available.

7.5 The fabricator must provide all the necessary materials and equipment, including, closures, gaskets and test bolts for the pressure test. Under no circumstances may the test bolts and gaskets be delivered with the finished vessel.

7.6 After carrying out the pressure testing, all welds shall be examined for gas leakage using air at the design pressure. Detection shall be by means of detergent solution. No leakage shall be permitted. On completion of the test all traces of the detergent shall be removed.

4 7.7 Reversing streams of all Reversing Heat Exchangers and parallel streams of multiple cores where specified on the Process Data Sheet shall be flow tested in the presence of Air Products Ltd. Inspector or Authorised Representative and all results logged and compared with the requirements stated in the requisition or data sheets. Where flow tests are required no exchanger shall be despatched until the flow results are acceptable to Air Products Ltd.

TITLE Brazed Core Extended Surface Exchangers.

8. NAMEPLATE

8.1 A suitable nameplate shall be provided by the Vendor and permanently fitted to the vessel. On satisfactory completion of tests, the nameplate shall be stamped by the Approval Authority. Information contained on the nameplate shall be as follows:-

(a) Makers name and Number.

(b) Drawing number and design code.

(c) Working pressure.

(d) Design pressure.

(e) Maximum allowable working pressure.

(f) Hydraulic test pressure.

(g) Maximum and minimum permissible temperatures.

(h) Pneumatic test pressure.

(j) Manufacturers test mark.

(k) Approval Authority Test mark.

(l) Date of Surveyors acceptance test.

9. CLEANING

9.1 All vessel elements shall be solvent washed before assemble for brazing or before welding to the vessel.

9.2 Unless pressure tested by air from a NON Oil lubricated compressor or by clean oil free nitrogen, all passages of the vessel shall be hydrocarbon decontaminated, using vapour or solvent circulation methods. If the unit is pressure tested by air from non oil lubricated compressor or by pure oil free nitrogen then pure oxygen and crude oxygen passages only need be decontaminated using vapour or solvent circulated method.

9.3 Vendor shall quote separately price for Hydrocarbon decontamination. He shall specify procedure, cleaning media, the stages of assembly at which cleaning is carried out and the state the acceptance standard he proposes to use if it is other than as follows:-

Crude Oxygen, Pure Oxygen and Oxygen Rich (25% and over) circuits as specified to Class AA Cleanliness Acceptance Test. (See Specification No. A. 03) other circuits to Class A Cleanliness. (See Specification No. A 02).

10. PREPARATION FOR SHIPMENT

10.1 The relevant exchanger, project and equipment item numbers, to be painted on the outside of the vessel in 4" high letters and numerals and nozzles to have stream identification marks painted thereon.

10.2 All nozzles shall be blanked off for shipment.

10.3 A transport/erection jig shall be provided by Vendor, details in paragraph 5. 03 above.

10.4 For shipment the exchanger shall be pressurised to 15" w.g. minimum with dry, oil-free air or nitrogen gas and suitably protected for road and/or rail transport. The vessel shall carry a notice that it is under pressure during shipment. All costs of preparations for shipment are to be borne by the Vendor. Packing will be subject to inspection by Air Products Ltd. Inspector or delegated representative.

4 10.5 Exchangers with exposed open passages are to be fitted with temporary blank plates over exposed passages, and the complete unit sealed in polythene sheet, or similar, after cleaning and prior to shipment.

4 10.6 Assemblies of reversing exchangers shall be provided with protective plates over the outside faces of the core blocks for shipment.

11. DELIVERY ADDRESS

Vessel shall be delivered as requested on Air Products Ltd. purchase order.

12. SUB ORDERS

Six copies of all sub-orders (unpriced) shall be submitted to Air Products Ltd. for expediting purposes.

13. RECORDS

13.1 The vessel fabricator shall furnish 3 copies of pressure vessel record that shall declare full particulars of the exchanger and shall report the results of all tests on the materials of construction on the soundness of the workmanship and on the completed vessel, to establish its suitability to withstand the design conditions, together with all tests and rectifications. The report constituting the record shall be certified by the Chief Inspector of the Fabricator or his sub-contractor, and be signed by the Approval Authority and the Purchaser's Representative who witness the acceptance tests. The original and copies of the vessel record shall be maintained at the Fabricators Works.

In addition copies shall be provided as required by the Approval Authority.

13.2 The minimum documentation for a pressure vessel dossier is as follows:-

13.2.1 Pressure Vessel Certificate, giving thr following information:

(a) Manufacturer's name.

(b) A.P.L. Project and Section Number.

(c) A.P.L. Purchase Order number.

(d) Vessel Serial number.

(e) Construction Code.

(f) Approval Authority.

(g) Operating Temperature and Pressure.

(h) Design Temperature and Pressure.

(j) Test Pressures and Dates.

(k) Corrosion Allowance.

The pressure vessel certificate must be signed and stamped by the Approval Authority's representative.

13.2.2 Material Identification Sketch, showing material cast numbers for all pressure and strength components of the vessel and for all material directly welded to such parts. The sketch must be signed and stamped by the Approval Authority's representative and the Manufacturer's Senior Inspector.

13.2.3 Material Test Certificates, giving chemical and physical properties of all material noted on the Material Identification Sketch. These test certificates must be issued by the material manufacturer or may be certificates indicating the results of tests carried out in the presence of the Approval Authority's representative.

13.2.4 Welders Qualifications, in accordance with the relevant code and giving all results of tests performed, and test dates. Welders qualifications must be signed and stamped by the Approval Authority's representative.

13.2.5 Radiograph Sketch, which must show the extent of radiography which must indicate the film numbers and show positions at which films were taken.

13.2.6 Radiograph Assessment, giving the results of all the films noted on the radiograph sketch and giving a final classification in accordance with the relevant code. All repair details must be noted on the assessment.

13.2.7 Heat Treatment Certificates, which must indicate the part subjected to heat treatment, the purpose of the treatment and must be accompanied by the actual furnace time/temperature chart. The chart and the certificate must be signed by the Approval Authority's representative.

13.2.8 Drawings, each dossier supplied to the purchaser must include a general arrangement drawing which contains sufficient information to enable the dossier documentation to be checked.

4 13.2.9 Design Calculations, each dossier supplied to the Purchaser must include a full set of calculations of the scantlings of the pressure vessel to the relevant code.

4 13.2.10 Cleanliness Certificates, each stream which is specified as Class AA clean in the Process Data Sheet or Purchase Requisition shall have a cleanliness certificate, which must list the stages at which cleaning was carried out, method of inspection for cleanliness, and standard of acceptance (e.g. to Air Products Engineering Specification No. A03). Each certificate must be signed as accepted to the cleanliness standard by the Vendors Senior Inspector.

13.3 The manufacturer shall maintain the records through all stages of manufacture and shall make the various documents available to the Purchaser's inspector and the Approval Authority's representative on request.

13.4 Three copies of the Vessel dossier shall be sent to:-

Expediting Manager,
Air Products Ltd.,
Coombe House,
Malden Road,
NEW MALDEN,
Surrey.

Air Products

ENGINEERING SPECIFICATION

No. E.04
PAGE CONT. ON COVER SHEET
REV 1

TITLE SHELL & TUBE TYPE COOLER, OTHER THAN FOR O_2 SERVICE (APL PLANTS)

DISTRIBUTION

All Manual Holders

All Vessel Designers

All Machinery Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	AP
1		1.6.71.	G. Elmore	G. Elmore
0	ORIGINAL ISSUE	1.11.70.	G.Elmore	G. Elmore

ORIGINAL APPROVED BY	G. ELMORE	J. GRANT	K. WILSON	
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGE

F.911

APCI DOCUMENT NO. 99000369

TITLE Shell & Tube Type Cooler, Other than for O2 service (APL Plants)

1. GENERAL

1.1 This specification, together with the relevant process design information, covers the requirements for the design, materials fabrication, inspection, testing cleaning, painting and shipment of shell and tube coolers designed by the Vendor.

1.2 The related specifications, standards and codes shall be the latest issues and shall include all addenda, revisions and supplements.

1.3 All conflicts between the requirements of this specification, the standards and codes shall be referred to Air Products Limited, for clarification or modification before quotation, or in the event of an order before work proceeds.

1.4 The Vendor shall submit with his quotation:

1.4.1 Sufficient information to enable Air Products to assess the merits of the proposed design, including type designation, heat transfer surface area, tube size and pitch, baffle cut and spacing, tube pass arrangement, and a preliminary outline drawing giving connection positions, overall dimensions and weights. Refer to attachments listed on requisitions for design data.

1.4.2 A list of any departures from this specification.

1.4.3 A list of spares required for:-

a) Testing and initial operation.

b) Operational spares for 12 months.

c) A spare bundle and other relevant spares.
The list of spares to be accompanied by sufficient literature to enable the parts to be identified.

1.5 A copy of all sub orders (unpriced) shall be submitted to APL for expediting purposes.

2. DESIGN

2.1 Heat exchangers shall be designed to TEMA-C standards, the latest requirements of the ASME Section VIII Division I, Pressure Vessel Code, or an alternative code as agreed with Air Products Limited at time of bid, except where specified otherwise on the Process Data Sheet and/or Purchase Requisition, then it shall meet the latest code requirements of the National Pressure Vessel Authority of the county of destination as specified. The design conditions are as stated on the appropriate process specification, bid sketch, or data sheet. The relevant codes must be clearly indicated on the drawings and documents.

TITLE Shell & Tube Type Cooler, Other than for O2 service (APL plants)

2.2 The arrangement shall be preference be of the horizontal shell and tube type with removable tube bundle, removable channel and shell covers.

2.3 The design of the Vessel shall be reviewed by Air Products Limited and approved by the Independent Inspecting Authority nominated on the requisition before manufacturing proceeds. It will be the Vendors responsibility to secure the Inspection Authority's approval of the design fabrication and testing.

2.4 Where condensation is expected from the process gas stream the cooler shall be arranged to ensure that stagnation of the condensate cannot occur. Particular care must be taken in the case of an air compressor cooler to safeguard against corrosion from air compressor condensate, which can be acidic up to 4pH due to atmoshperic pollution.

2.5 Where galvanic action can take place the Vendor shall provide protection by sacrifical plates of suitable material, to be agreed with Air Products.

2.6 Maximum pressure drop on the water side of the cooler shall not exceed 10 psi measured from inlet to discharge flange unless otherwise specified.

2.7 At all high or low points not vented or drained by the nozzle connections, 1" N/B connections shall be provided, each fitted with a screwed plug.

2.8 All connections larger than 1½" shall be flanged. All connections 1½" and smaller shall be screwed.

2.9 Rupture discs shall be provided in the cooler shell if gas pressure in tubes exceeds shell side pressure by 75 psig. All rupture discs shall be manifolded by Vendor.

2.10 It shall be made possible for the tube bundle to be removed for maintenance or cleaning, including the provision of lifting points on the tube bundle, if its weight is over 50 lbs.

2.11 Vendor to include in quotation the additional cost of providing 5% extra tubes over and above design to allow plugging for maintenance purposes.

2.12 The cooler shall be supplied complete with fabricated steel saddles or supports drilled at the mounting level to meet the bolting requirements.

2.13 The cooler shall have suitable lifting attachments for erection at site.

2.14 Carbon and low alloy steel exchangers shall have a corrosion allowance of ⅛" on all pressure parts except for tubes (on each wetted surface).

TITLE Shell & Tube Type Cooler, Other than for O2 service (APL plants)

3. MATERIALS OF CONSTRUCTION

Materials given in the following paragraphs are a general guide to Air Products requirements. The Vendor is to ensure that all materials offered are suitable for the operating and design conditions specified on the relevant design data specification.

3.1 The Vendor shall specify clearly in his tender and on the production drawing the specification, grade, class and temper to which each material conforms.

3.2 Shell - Carbon Steel

Where cooling is provided by the use of sea water, all shell materials in contact with the sea water shall be protected against corrosion by the use 'sakaphen' coating or equal, as agreed by Air Products Limited. The design of the cooler shall be such that no sliding contact occurs between metal parts and the coating provided. Sacrificial soft iron anodes, if provided, are to be supplied in sizes and position as agreed with Air Products Limited.

3.3 Tubes

These shall generally be selected in accordance with the table given below. Where the process stream contains corrosive elements incompatible with the materials listed, vendor shall make specific recommendations for Air Products consideration.

Note: Carbon steel tubes shall not be used.

Service	Material
Fresh water Cooling tower circuits with solids in suspension below 2,000 ppm.	Brass
Polluted fresh water	Admiralty Brass (with 1% Sn 0.04% AS)
Brackish water or polluted sea water	Aluminium Brass Cu 76% Al 2% AS 0.04% remainder Zn
Sea Water	70/30 Copper Nickel Ni 31% Fe 0.6% MN 0.8% remainder Cu
Sea Water with sand and other solid particles	Ni 31% Fe 2% Mn 2% remainder Cu.

3.4 Tube Sheets

Carbon Steel tube sheets shall nto be used

Service	Material
Fresh water cooling tower circuits	Brass
Brackish water polluted water Sea water	Naval Brass 60/39/1 Copper Zinc Tin

3.5 The following materials are specified for coolers with water on the shell side.

3.5.1 Baffles and Support Plates - Naval Rolled Brass

3.5.2 Bonnets - Carbon steel

3.5.3 Channel and Channel Cover - Carbon steel, cast bronze, or cast iron

3.6 Materials for construction shall be subject to approval by the appointed Representative of the Approval Authority.

3.7 Test Certificates will be required for all pressure part materials permanent attachments giving full chemical analysis and physical properties in accordance with the relevant code.

4. DRAWINGS

4.1 The Vendor shall submit with his quotation sufficient information to enable Air Products Limited to assess the merits of the proposed design.

4.2 All documents must be identified by the customers Project number, equipment item number and purchase order numbers, and on drawings Vendor's title, drawing and revision number; all preferably in the lower right hand corner. Where pratical a 3" x 4" blank space shall be allowed near this title block for Air Products Ltd's use.

4.3 The selected Vendor shall submit 2 copies of sketches giving overall sizes, nozzle sizes and positions and preferred support locations within two (2) weeks of receipt of order or as required by Air Products drawing register, followed by six (6) copies or one reproducible of general arrangement and detail drawings within five (5) weeks of receipt of order or as required by the drawing register for review by Air Products Ltd. The Vendor is responsible for submission of drawings to, and approval from, the Approval Authority.

4.4 The Vendor shall submit to Air Products Ltd. within five (5) weeks of receipt of order or as required by Air Products drawing register, three (3) copies of one dimensioned drawing showing shipping package, including all lifting points.

Information on the drawings must give sufficient dimensions to enable accurate location to be made for foundation, bolting and all nozzle connections.

4.5 All detail and assembly drawings shall be fully dimensioned in metric units.

4.6 The drawings shall be fully dimensioned and give the following information as a minimum:

4.6.1 Air Products Ltd. Purchase Order Number

4.6.2 Air Products Ltd. Project and Section Number

4.6.3 Design Code

4.6.4 Approval Authority

4.6.5 Design Pressure

4.6.6 Minimum and Maximum Design Temperature

4.6.7 Maximum allowable operating pressure, corroded condition

4.6.8 Normal Operating Pressure

4.6.9 Normal Operating Temperature

4.6.10 Test Pressure and Medium

4.6.11 Leak Test Pressure

4.6.12 Corrosion Allowance

4.6.13 Thickness of all pressure parts

4.6.14 All dimensions necessary for calculation of thickness

4.6.15 Cleaning processes internal and external

4.6.16 Specifications for all materials including weld and brazing alloy material

4.6.17 Extent of Radiography, and post weld treatment

4.6.18 Welding techniques and preparations

4.6.19 Maximum permissible loads due to piping on each nozzle

4.6.20 Internal Volume of each stream

4.6.21 Vessel weights empty, operating

4.6.22 Mechanical tests on coupon plates

4.7 After drawings submitted have been reviewed by the Purchaser and the Approval Authority and they are accepted as satisfactory, the Purchaser will return one copy of the drawings sent to them by the Vendor for clearance stamped "NOTED". It will be the Vendors responsibility to secure the Approval Authorities approval of the drawings.

4.8 One reproducible copy of the certified correct general arrangement and detail drawings shall be submitted to Air Products Limited by the Vendor within 7 days of receiving full design clearance.

4.9 Deviations from the certified drawings and/or specification shall not be permissible except when prior clearance has been obtained from the purchaser and Approval Authority.

4.10 Deviations from the certified drawings and/or specifications shall not be permissible except when prior clearance has been obtained from the Purchaser and Approval Authority. Such clearance does not relieve the Vendor of any responsibility for the soundness of work, completing the work in scheduled time, nor does is commit the Purchaser to accept any increase in costs.

5. FABRICATION AND WORKMANSHIP

5.1 Fabrication shall be fully in accordance with the requirements of Air Products Limited., or their appointed approved authority and in accordance with the certified drawings and shall be carried out to their satisfaction. Clearance from the Approval Authority and Air Products Limited must be obtained before manufacture of the vessel commences.

5.2 Records of test plates and production welds, including radiographs shall be kept and made available to Air Products Limited on request.

5.3 Unless previously qualified to the requirements of the relevant pressure vessel code authority the welders and automatic welding equipment shall qualify, in accordance with the code, on test plates representing each type of weld and material to be used before proceeding on production welding.

5.4 Quality of welding shall be judged and radiographs interpreted in accordance with the requirements of Air Products Limited. Quality Control Standards or as agreed with the Vendor and the Approval Authority. Details of such agreement must be forwarded to the Purchaser for review before manufacture commences.

TITLE Shell & Tube Type Cooler, Other than for 02 service (APL plants)

6. INSPECTING AND TESTING

6.1 Inspection and testing shall be in accordance with the requirements of Air Products or their appointed approval authority and in accordance with the relevant drawings, code and Approval Authority requirements.

6.2 Cost of all Inspection tests and Certificates shall be borne by the Vendor.

6.3 The Approval Authority and Air Product's Inspection Engineer shall have free access to the Vendor's works at all reasonable times after placement of order and until delivery of completed vessel. They shall be at liberty at any stage of the manufacture to inspect and reject any defective material that does not conform to the specification stated on the certified manufacturing drawings.

6.4 On completion of fabrication the vessel shall be subject to strength test to the pressure stated on the relevant drawing and code. This test is to be carried out in the presence of the Approval Authority and Air Products Limited Inspector. No final inspection tests are to take place before all material certificates, and the results of any tests or requirements of the Approval Authority are available.

6.5 The fabricator must provide all the necessary materials and equipment, including, closures, gaskets and test bolts for the pressure test. Under no circumstances may the test bolts and gaskets be delivered with the finished vessel where the bolts have exceeded design yeild stress or 0.1% stress during pressure testing.

6.6 After carrying out the pressure testing, all welds and tube joints shall be examined for gas leakage using air at the design pressure. Detection shall be by means of detergent solution. No leakage shall be permitted. On completion of the test all traces of the detergent shall be removed.

6.7 The Vessel shall not be despatched prior to final acceptance by Air Products or their delegated representative and before manufacturing approval has been obtained from the relevant Approval Authority.

7. NAMEPLATE

A stainless steel nameplate shall be provided by the Vendor and permanently fitted to the vessel. On satisfactory completion of tests, the nameplate shall be stamped by the Approval Authority. Information contained on the nameplate shall be as follows:-

(a) Makers name

(b) Makers serial number

(c) Drawing number

(d) Design Code

(e) Design Pressure

(f) Maximum allowable operating pressure in corroded conditon.

(g) Hydraulic test pressure

(h) Date of test

(j) Maximum and minimum allowable temperature

(k) Manufacturers test mark

(l) Approval Authority test mark

(m) Date of Approval Authority's Surveyors

8. CLEANING

8.1 All internal vessel surfaces shall be free from oil, loose particles and other foreign matter fully in accordance with the attached cleaning specification or as stated on the attached bid sketch.

9. PAINTING

9.1 All carbon and low alloy steel fabricated pressure vessels shall be descaled by shot blasting and finished painted by a four coat system, one primer, one undercoat and two coats to Vendors own specification which should not be less than BS. Code of Practices 231. The top coat colour scheme shall be as specified on the attached bid sketch or the purchase order.

10. PREPARATION FOR SHIPMENT

10.1 The relevant vessel project and section numbers, shall be painted on the outside of the vessel in 4" high letter and numerals and nozzles to have identification marks painted thereon, a 1" wide x 12" long line shall be painted on the North side of the vessel.

10.2 Upon completion of cleaning and after establishing acceptance all openings must be scaled against entry of diret, moisture etc.

Flange faces shall be protected by bolted on 12 mm minimum thick timber blanks.

Threaded connections are to be plugged. All threads on connections and studs to be protected with adhesive tape and, where necessary, rust preventative.

11. DELIVERY ADDRESS

11.1 Vessel shall be delivered as requested on the hire purchase order.

13. RECORDS

The vessel fabricator shall furnish 3 copies of pressure vessel record that shall declare full particulars of the exchanger and shall report the results of all tests on the materials of construction on the soundness of the workmanship and on the completed vessel, to establish its suitability to withstand the design conditions, together with all tests and rectifications. The report constituting the record shall be certified by the Chief Inspector of the Fabricator or his sub-contractor, and be signed by the Approval Authority and the Purchaser's Representative who witness the acceptance tests. The original and copies of the vessel record shall be maintained at the Fabricators Works.

In addition copies shall be provided as required by the Approval Authority.

13.2 The manufacturer shall maintain the records through all stages of manufacture and shall make the various documents available to the purchaser's inspector and the Approval Authority's Representative on request.

13.3 The minimum documentation for a pressure vessel dossier is as follows:

13.3.1 Pressure Vessel Certificate giving the following information:

(a) Manufacturer's name
(b) A.P.L. Project and Section number
(c) A.P.L. Purchase Order Number
(d) Vessel Serial Number
(e) Construction Code
(f) Approval Authority
(g) Operating Temperature and Pressure
(h) Design Temperature and Pressure
(j) Test Pressures and Dates
(k) Corrosion Allowance

The vessel information g,h,j,k above must be given for each chamber of the vessel.

The pressure vessel certificate must be signed and stamped by the Approval Authority's Representative.

13.3.2 Material Identification Sketch showing cast numbers for all pressure and strength components of the vessel and for all material directly welded to such parts. The sketch must be signed and stamped by the Approval Authority's Representative and the Manufacturer's Senior Inspector.

13.3.3 Material Test Certificates, giving chemical and physical properties of all material noted on the Material Identification Sketch. These test certificates must be issued by the Material Manufacturer or may be certificates indicating the results of tests witnessed by the Approval Authority.

13.3.4 Welders Qualifications, in accordance with the relevant code and giving all results of tests performed, and test dates. Welders qualifications must be signed and stamped by the Approval Authority Representative.

13.3.5 Radiograph Sketch, which must show the extent of radiography, indicate the film numbers and show the positions at which films were taken.

13.3.6 Radiograph Assessment, giving the results of all the films noted on the radiograph sketch and giving a final classification in accordance with the relevant code. All repair details must be noted on the assessment.

13.3.7 Heat Treatment Certificates, which must indicate the part subjected to heat treatment, the purpose of the treatment and must be accompanied by the actual furnace time/temperature chart. The chart and the certificate must be signed by the Approval Authority's Representative.

13.3.8 Drawings, each dossier supplied to the purchaser must include a general arrangement drawing which contains sufficient information to enable the dossier documentation to be checked.

13.3.9 Design Calculations, each dossier supplied to the purchaser must include a full set of calculations, of the scantlings of the pressure vessel, to the relevant code.

13.4 Three copies of the vessel dossier shall be sent to:-

Expediting Manager,
Air Products Limited,
Coombe House,
Malden Road,
New Malden,
Surrey.

Air Products

ENGINEERING SPECIFICATION

No. E.05

PAGE CONT. ON COVER SHEET

REV 1

TITLE SHELL & TUBE TYPE COOLERS FOR O2 SERVICE

DISTRIBUTION

All Engineering Specification & Standards Manual Holders

All Vessel Designers

All Machinery Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	APP'D
1	2.1, 4.3, 13.1 amended			
1	2.14, 2.15, 4.10, 13.3.9 added	1.6.71.	G. Elmore	[signature]
0	ORIGINAL ISSUE	1.11.70.	G. Elmore	[signature]

ORIGINAL APPROVED BY	G. ELMORE	J. GRANT	K. WILSON	
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

TITLE Shell & Tube Type Coolers for O2 service

1. GENERAL

1.1 This specification, together with the relevant process design information, covers the requirements for the design, materials fabrication, inspection, testing, cleaning, painting and shipment of shell and tube type coolers for O2 service designed by the Vendor.

1.2 The related specifications, standards and codes shall be the latest issues and shall include all addenda, revisions and supplements.

1.3 All conflicts between the requirements of this specification, the standards and codes shall be referred to Air Products Ltd., for clarification or modification before quotation, or in the event of an order before work proceeds.

1.4 The vendor shall submit with his quotation:-

1.4.1 Sufficient information to enable Air Products Ltd. to assess the merits of the proposed design, including type designation, heat transfer surface area, tube size and pitch, baffle cut and spacing, tube pass arrangement, and a preliminary outline drawing giving connection positions, overall dimensions and weights. Refer to attachments listed on requisition for design data.

1.4.2 A list of any departures from this specification.

1.4.3 A list of spares required for :-

(a) Construction, testing and initial operation

(b) Operational spares for 12 months

(c) A spare bundle and other relevant spares

The list of spares to be accompanied by sufficient literature to enable the parts to be identified.

1.5 A copy of all suborders (unpriced) shall be submitted to APL for expediting purposes.

2. DESIGN

2.1 Heat exchangers shall be designed to TEMA-C standards, the latest requirements of the ASME Section VIII, Division I pressure vessel code or an alternative code as agreed with Air Products Limited, at the time of bid, except where specified otherwise on the process data sheet and/or purchase requisition, then it shall meet the latest code requirements of the National Pressure Vessel Authority of the country of destination as specified and the design conditions as stated on the appropriate process specification, bid sketch or data sheet. The code must be clearly indicated on the drawings and documents.

TITLE Shell & Tube type Coolers for O2 Service

2.2 The arrangement shall by preference be of the horizontal shell and tube type with removable tube bundle, removable channel and shell covers.

The oxygen stream is preferred on the tube side, due to difficulties of cleaning the shell side. Special care shall be taken in the design to ensure that the oxygen side of the cooler can be thoroughly clean to the acceptance level of specification A.03.

Should the oxygen stream be on the shell side by agreement with Air Products Limited, a sample tapping is to be provided at the lowest draining point of the shell.

2.3 The following table is a guide to the maximum allowable flow velocities for oxygen gas service. Vendor is to advise Air Products Limited where these values are exceeded for agreement.

Velocity	Oxygen Condition	Allowable Material
Less than 200 f.p.s.	Temp. -20°F. or above dry (dew point below -40°F.)	Carbon Steel
Less than 200 f.p.s.	Temperature -20°F. or above. Wet gas or if the pipe bore contacts atmospheric air	Copper, Copper Alloy Stainless steel
Above 200 f.p.s.	Temp. -20°F or above Wet or Dry	Copper, Copper Alloy

2.4 The design of the Vessel shall be reviewed by Air Products and approved by the Independant Inspecting Authority nominated on the requisition. It will be the Vendors responsibility to secure the Inspection Authorities approval of the design fabrication and testing at Vendors cost.

2.5 The design conditions are as stated on the appropriate process specification, bid sketch or data sheet.

2.6 Where galvanic action can take place the Vendor shall provide protection by sacrifical places of suitable material, to be agreed with Air Products Limited.

2.7 Maximum pressure drop on the water side of the cooler shall not exceed 10 psi measured from inlet to discharge flange unless otherwise stated.

2.8 At all high or low points not vented or drained by the nozzle connections, 1" N/B connections shall be provided, each fitted with a screwed plug.

2.9 All connections larger than 1½" shall be flanged.
All connections 1½" and smaller shall be screwed.

2.10 Rupture discs shall be provided in the cooler shell if gas pressure in tubes exceeds shell side pressure by 75 psig.

2.11 It shall be made possible for the tube bundle to be removed for maintenance or cleaning, including the provision of lifting points on the tube bundle if its weight is over 50 lbs.

2.12 Vendor to include in quotation the additional cost of providing 5% extra tubes over and above design to allow plugging for maintenance purposes.

2.13 The cooler shall be supplied complete with fabricated steel saddles or supports drilled at the mounting level to meet the bolting requirements.

2.14 The cooler shell shall have suitable attachments for erection at site.

2.15 Carbon and low alloy steel exchangers shall have a corrosion allowance of ⅛" on all pressure parts except for the tubes (on each wetted surface).

3. MATERIALS OF CONSTRUCTION

Materials given in the following paragraphs are a general guide to Air Products requirements. The Vendor is to ensure that all materials offered are suitable for the operating and design condition specified on the relevant design data specification.

3.1 The vendor shall specify clearly in his tender and on the production drawing the specification, grade class and temper to which each material conforms.

3.2 Shell - Carbon Steel

Where cooling is provided by the use of sea water all steel materials in contact with the sea water shall be protected against corrosion by the use of "sakaphen" or equal, as agreed by Air Products Limited.

The design of the coolers shall be such that no sliding contact occurs between metal parts and the coating provided. Sacrificial soft iron anodes, if provided, are to be supplied in sizes and positions as agreed with Air Products Limited.

3.3 Tubes

These shall generally be selected in accordance with the table given below. (Note: Steel tubes shall not be used).

Service	Material
Fresh water Cooling tower with solids in suspension below 2,000 ppm.	Brass
Polluted fresh water	Admiralty Brass (with 1% Sn 0.04% AS)
Brackish water or polluted sea water	aluminium brass Cu 76% Al 2% AS 0.04% remainder Zn
Sea Water	70/30 Copper Nickel Ni 31% fe 0.6% MN 0.8% Remainder Cu.
Sea water with sand and other solid particles	Ni 31% Fe 2% Mn 2% Remainder Cu.

3.4 Tube Sheets shall be selected in accordance with the table given below.

Carbon steel tube sheets shall not be used.

Service	Material
Fresh water Cooling tower circuits	Brass
Brackish water polluted water Sea Water	Naval Brass 60/39/1 Copper Zinc Tin

3.5 The following materials are specified for coolers with water on the shell side.

3.5.1 Baffles and Support Plates - Naval Rolled Brass

3.5.2 Bonnets - Carbon Steel

Where the oxygen is on the tubeside the gas flow shall be prevented from impinging on the carbon steel by fitting a rolled naval brass impingement plate.

3.5.3 Channel and Channel Covers - carbon steel, cast bronze or cast iron.

Where the oxygen is on the tube side and the channel or cover is of steel the note in clause 3.5.2 is applicable.

3.6 Gaskets etc.

All gasket, sealing and gland materials in contact with an oxygen stream must be agreed with Air Products Limited as compatible with oxygen in service.

3.7 Materials for construction shall be subject to approval by the appointed Representative of the Approved Authority. ? al.

3.8 Test certificates will be required for all pressure part materials and permanent attachements giving full chemical analysis and physical properties in accordance with the relevant code.

4. DRAWINGS

4.1 The Vendor shall submit with his quotation sufficient information to enable Air Products to assess the merits of the proposed design.

4.2 All documents must be identified by the customers Project number, equipment item number and purchase order numbers; and on drawings Vendor's title, drawing and revision numbers; all preferably in the lower right hand corner. Where practical a 3" x 4" blank space shall be allowed near this block for Air Products use.

4.3 The selected Vendor shall submit 2 copies of sketches giving overall sizes, nozzle sizes and positions and preferred support location within two (2) weeks of receipt of order, or as required by Air Products drawing register, six (6) copies or one reproducible of general arrangement and detail drawings, within five (5) weeks of receipt of order or as required by APL drawing register, for review by Air Products Limited. The Vendor is responsible for submission of drawings to and obtaining approval from the Approval Authority.

4.4 The Vendor shall submit to Air Products Limited within five (5) weeks of receipt of order or as required by Air Products drawing register, three (3) copies of dimensioned drawing showing package including all lifting points.

Information on the drawings must give sufficient dimensions to enable accurate location to be made for foundation, bolting and all nozzle connections.

4.5 All detail and assembly drawings shall be fully dimensioned in Metric Units.

4.6 The drawings shall give the following information as a minimum:-

4.6.1 APL Purchase Order Number
4.6.2 APL Project and Section Number
4.6.3 Design Code
4.6.4 Approval Authority
4.6.5 Design Pressure
4.6.6 Minimum and Maximum Design Temperature
4.6.7 Maximum allowable operating pressure, corroded condition
4.6.8 Normal Operating Pressure
4.6.9 Normal Operating Temperature
4.6.10 Test Pressure and Medium
4.6.11 Leak Test Pressure
4.6.12 Corrosion Allowance
4.6.13 Thickness of all pressure parts
4.6.14 All dimensions necessary for calculation of thickness
4.6.15 Cleaning processes internal and external
4.6.16 Specifications for all materials including weld and brazing alloy material
4.6.17 Extent of Radiography, and post weld treatment
4.6.18 Welding techniques and preparations
4.6.19 Maximum permissible loads due to piping on each nozzle
4.6.20 Vessel weights both empty and operating
4.6.21 Mechanical test on coupon plates

4.7 After drawings submitted have been reviewed by Air Products Ltd. and the Approval Authority, and they are accepted as satisfactory, Air Products will return one copy of the drawings sent to them by the Vendor for clearance stamped "NOTED". It will be the Vendors responsibility to secure the Authorities approval of the drawings.

4.8 One reproducible copy of certified correct general arrangement and detail drawings shall be submitted to A.P.L. by the Vendor within 7 days of receiving full design clearance.

4.9 Deviations from the certified drawings and/or specification shall not be permissible except when prior clearance has been obtained from Air Products Ltd. and Approval Authority.

4.10 Deviations from the certified drawings and/or specifications shall not be permissible except when prior clearance has been obtained from the Purchaser and Approval Authority. Such clearance does not relive the Vendor of any responsibility for the soundness of work, completing the work in scheduled time, nor does it commit the Purchaser to accept any increase in costs.

5. FABRICATION AND WORKMANSHIP

5.1 Fabrication shall be fully in accordance with the requirements of Air Products Ltd., or their appointed approval authority and in accordance with the certified drawings and shall be carried out to their satisfaction. Clearance from the Approval Authority and A.P.L. must be obtained before manufacture of the vessel commences.

5.2 All welds on the oxygen side are to be smooth and of regular form. Any slag or weld icicles must be removed. Backing rings should be avoided where possible, and only used with the agreement of APL.

5.3 Tube to tube sheet joints must be assembled without the use of oil or hydrocarbon compounds. The tube surface and the tube sheet holes must be degreased and inspected prior to assembly.

5.4 Records of test plates and production welds, including radiographs shall be kept and made available to APL on request.

5.5 Unless previously qualified to the requirements of the relevant pressure vessel code authority the welders and automatic welding equipment shall qualify, in accordance with the code, on test plates representing each type of weld and material to be used before proceeding on production welding.

5.6 Quality of welding shall be judged and radiographs interpreted in accordance with the requirements of the APL Quality Control Standards or as agreed with the Vendor and the Approval Authority. Details of such agreement must be forwarded to Air Products Ltd. for review before manufacture commences.

6. INSPECTING AND TESTING

6.1 Inspection and testing shall be in accordance with the requirements of Air Products or their appointed approval authority and in accordance with the relevant drawings, code and Approval Authorities requirements.

6.2 Cost of all Inspection, tests and Certificates shall be borne by the Vendor.

6.3 The Approval Authority and/or Air Product's Inspection Engineer shall have free access to the Vendor's works at all reasonable times after placement or order and until delivery of completed vessel. They shall be at liberty at any stage of the manufacture to inspect and reject any defective material that does not conform to the inspection stated on the certified manufacturing drawings.

6.4 On completion of fabrication the vessel shall be subject to strength test to the pressure stated on the relevant drawing and code. This test is to be carried out in the presence of the Approval Authority and A.P.L. Inspector. No final inspection tests are to take place before all the material certificates, and the results of any test or requirements of the Approval Authority, are available.

6.5 The fabricator must provide all the necessary materials and equipment, including closures, gaskets and test bolts for the pressure test. Under no circumstances may the test bolts and gaskets be delivered with the finished vessel where the bolts have exceeded design yield stress or 0.1% proof stress during pressure testing.

6.6 After carrying out the pressure testing, all welds and tube joints shall be examined for gas leakage using air at the design pressure. Detection shall be by means of detergent solution. No leakage shall be permitted. On completion of the test all traces of the detergent shall be removed.

6.7 The vessel shall not be despatched prior to final acceptance by Air Products or their delegated representative and before manufacturing approval has been obtained from the relevant Approval Authority.

7. NAMEPLATE

7.1 A stainless steel nameplate shall be provided by the Vendor and permanently fitted to the vessel. On satisfactory completion of tests, the nameplate shall be stamped by the Approval Authority. Information contained on the nameplate shall be as follows:-

(a) Makers Name

(b) Makers Serial Number

(c) Drawing number

(d) Design Code

(e) Design Pressure

(f) Maximum allowable operating pressure in corroded condition

(g) Hydraulic test pressure and date of test

(h) Date of test

(j) Maximum and minimum allowable temperature

(k) Manufacturers test mark

(l) Approval Authority test mark

(m) Date of Approval Authority's Surveyors

8. CLEANING

8.1 All internal vessel surface shall be free from oil, loose particles and other foreign matter in accordance with Air Products specification No. A.03 "Acceptance Test for Class AA Cleaning".

9. PAINTING

9.1 All carbon and low alloy steel fabricated pressure vessels shall be descaled by shot blasting and finished painted by a four coat system, one primer, one undercoat and two top coats to vendors own specification which should not be less than BS. Code of Practice 231. The top coat colour scheme shall be as specified on the attached bid sketch or the purchase order.

10. PREPARATION

10.1 The relevant vessel project and section numbers, shall be painted on the outside of the vessel in 4" high letters and numerals and nozzles to have identification marks painted thereon. A 1" wide x 12" long line shall be painted on the North side of the vessel.

10.2 The vessel must be pressurised to 15" w.g. minimum and 15 psig. maximum with dry oil free air or notrogen and all nozzles suitably blanked off. The vessel shall be suitably protected for transport. The vessel shall display a warning notice stating it is under pressure during shipment, and a further notice that the oxygen passages have been cleaned for oxygen service and are not to be opened during shipment without instructions from Air Products Representative.

10.3 All cost of preparation for shipment are to be borne by the Vendor.

10.4 Packing will be subject to inspection by Air Products Inspector or delegated representative.

11. DELIVERY ADDRESS

11.1 Vessel shall be delivered as requested on the purchase order.

TITLE Shell & Tube Type Coolers for O2 service

13. RECORDS

13.1 The vessel fabricator shall furnish 3 copies of pressure vessel record that shall declare full particulars of the exchanger and shall report the results of all tests on the materials of construction on the soundness of the workmanship and on the completed vessel, to establish its suitability to withstand the design conditions, together with all tests and rectifications. The report constituting the record shall be certified by the Chief Inspector of the Fabricator or his sub-contractor, and be signed by the Approval Authority and the Purchaser's Representative who witness the acceptance tests. The original and copies of the vessel record shall be maintained at the Fabricators Works.

In addition copies shall be provided as required by the Approval Authority.

13.2 The manufacturer shall maintain the records through all stages of manufacture and shall make the various documents available to the purchaser's inspector and the Approval Authority's Representative on request.

13.3 The minimum documentation for a pressure vessel dossier is as follows:-

13.3.1 Pressure Vessel Certificate giving the following information:-

(a) Manufacturer's name
(b) APL Project and Section Number
(c) APL Purchase Order Number
(d) Vessel Serial Number
(e) Construction Code
(f) Approval Authority
(g) Operating Temperature and Pressure
(h) Design Temperature and Pressure
(j) Test Pressures and Dates
(k) Corrosion Allowance

The vessel information g,h,j,k above must be given for each chamber of the vessel.

The pressure vessel certificate must be signed and stamped by the Approval Authority's Representative.

13.3.2 Material Identification Sketch, showing cast numbers for all pressure and strength components of the vessel and for all material directly welded to such parts. The sketch must be signed and stamped by the Approval Authority's Representative and the Manufacturer's Senior Inspector.

13.3.3 Material Test Certificates, giving chemical and physical properties of all material noted on the Material Identification Sketch. These test certificates must be issued by the Material Manufacturer or may be certificates indicating the results of tests witnessed by the Approval Authority.

13.3.4 Welders Qualifications, in accordance with the relevant code and giving all results of test performed, and test dates. Welders qualifications must be signed and stamped by the Approval Authority Representative.

13.3.5 Radiograph Sketch, which must show the extent of radiography indicate the film numbers, and show the positions at which films were taken.

13.3.6 Radiograph Assessment, giving the results of all films noted on the radiograph sketch and giving a final classification in accordance with the relevant code. All repair details must be noted on the assessment.

13.3.7 Heat Treatment Certificates, which must indicate the part subjected to heat treatment, the purpose of the treatment and must be accompanied by the actual furnace time/temperature chart. The chart and the certificate must be signed by the Approval Authority's Representative.

13.3.8 Drawings, each dossier supplied to the purchaser must include a general arrangement drawing which contains sufficient information to enable the dossier documentation to be checked.

13.3.9 Design Calculations, each dossier supplied to the purchaser must include a full set of calculations, of the scantlings of the pressure vessel, to the relevant code.

13.3.10 A Document, signed by the manufacturer's Senior Inspector and countersigned by the Air Products Limited Inspector must show that the cleanliness of the vessel complies with Caluse 8.1.

13.4 Three copies of the vessel dossier shall be sent to:-

Expediting Manager,
Air Products Limited,
Coombe House,
Malden Road,
New Malden,
Surrey.

Air Products	ENGINEERING SPECIFICATION	No. G.03 PAGE CONT. ON COVER SHEET REV 0

TITLE CENTRIFUGAL CRYOGENIC PUMPS

DISTRIBUTION

All Engineering Specification and
Standard Manual Holders

All Machinery Engineers

0	ORIGINAL ISSUE	1.4.71.	R. Oliver	
REV	DESCRIPTION	DATE	ORIGINATOR	APP

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

APCI DOCUMENT NO. 99000371

TITLE Centrifugal Cryogenic Pumps

1. PURPOSE

This specification defines Air Products requirements for centrifugal pumps handling cryogenic liquids.

2. SCOPE

2.1 This specification applies to all centrifugal pumps for use with cryogenic liquids on all permanently fixed, or mobile equipment and used continuously, intermittently or on stand-by duty.

2.2 This specification, which states the requirements for pumps handling liquid oxygen, will be used even where the pumps will be used for liquid nitrogen and liquid argon.

This is for reasons of safety, standardisation and interchangeability within Air Products Limited.

2.3 Where conflict between this and the applicable Job Specification exists, the Job Specification shall govern.

2.4 This specification supercedes G.01 and G.02.

3. DESIGN

3.1 General

3.1.1 Equipment supplied shall be capable of operating at the ambient conditions and in the geographical area as set forth in the Job Specification.

3.1.2 The pump shall deliver the required capacity at the head listed in the Job Specification. Its performance generally shall be in accordance with the curves defined in Para. 5. The curves shall be applicable to the liquid for which the pump is intended.

3.1.3 All equipment furnished is to be suitable for 24 hours per day continuous operation.

3.1.4 Dynamic balancing should, in general, agree with the Draft ISO Recommendation No. 1940 for the Balance Quality of Rotating Rigid Bodies (ISO) TC 108 (Secretariat - 36 105E). The quality of balance should be equal to or better than G 2.5 i.e. residual specific unbalance not greater than 2.5 g.mm/kg (or eccentricity 2.5 μm at 10,000 r.p.m.

This quality applies to the single plane balancing of impellers, but if the same greatest residual unbalance moment of the whole rotating assembly cannot be achieved by single part balancing then the assembled parts must be balanced as a unit. Relative position of the components should be maintained or alternatively, the design should only allow one fixed relationship. Vibration measured in any plane, or any part of the pump casing bearing assembly or shaft shall not exceed 2.5 μm.

TITLE Centrifugal Cryogenic Pumps

3.1.5 Material is not be be removed, for balancing purposes, from the impeller front or rear shroud faces or the shaft, unless the design has specifically accounted for this eventuality. It is preferable that balancing rings be designed into the shaft and impeller. If no balancing rings are provided, material must only be removed by scalloping metal from the impeller periphery between blades.

3.1.6 For the purpose of this specification, low speeds shall be construed as 3,000 rev/min. and below and high speeds as those above 3,000 rev/min.

3.2 Volute Casing and Backplate

3.2.1 Casings shall be designed for the specified design and test pressure and the cryogenic operating temperature. The hoop stress value, at any point, shall not be excess of the values given in the A.S.M.E. Unfired Pressure Vessel Code, Section VIII, latest edition for the material used.

3.2.2 Cold casings shall be made of bronze unless an alternative material is agreed between the Vendor and the Purchaser.

3.2.3 Casings shall be designed with very small tolerances on parallelism, squareness and concentricity in order to achieve the necessary clearances on assembly.

3.2.4 Materials used between joint faces either as gaskets, adjustment shims or thermal barriers, shall be compatible with oxygen service, and agreed by APL.

3.2.5 Each volute casing shall have securely attached a corrosion resistant nameplate indicating:

(a) Maker's name

(b) Maker's serial number

(c) Maker's type number

(d) Specified output on LOX/LIN/LAR

(e) Specified head on LOX/LIN/LAR

(f) Specified speed

(g) Shut off head established on test

(h) Actual impeller diameter

(i) Direction of rotation, if not otherwise indicated

3.2.6 The casing shall be provided with bronze wear rings (see paragraph 3.3)

3.2.7 The volute casing shall contain preferably a multi-vaned bronze diffuser or otherwise be of the double cut water type.

3.2.8 All castings shall be sound, free of shrink or blow-holes, scale blisters and similar casting defects. The surfaces of castings shall be cleaned by sand blasting, pickling or any other standard method capable of giving a smooth surface.

3.2.9 The repair of leaks and defects in the pressure casings by the use of cement or similar compounds is prohibited.

3.2.10 Casings shall be machined all over, internally, where they are within 15 mm of the rotating assembly in the assembled condition.

3.2.11 Lifting eye bolts and tapped jack screw holes shall be provided on all major components weighing 35 kg or more.

3.2.12 The Vendor shall state the magnitude of the forces and moments allowed to be exerted on the casings by the installation pipework.

3.3 Wear Rings

3.3.1 Casings shall be furnished with bronze wear rings.

3.3.2 No method of fitting shall permit the possibility of loosening of the wear rings or its locking devices.

3.3.3 Eccentricity of wear ring bore and casing spigot diameter must be minimal.

3.4 Rotating Assembly

3.4.1 Only cast bronze impellers shall be used and they shall be machined all over with the exception of the internal surface which shall be as smooth as possible in the cast condition. Absolute cleanliness of the passages is essential (cf para 13). The impeller shall be one piece construction.

3.4.2 Impeller vanes shall not be cut back to meet the specified duty. The duty should be met by adjusting the speed.

3.4.3 Design, to meet the duty, without inducers is preferred, but when inducers are required, they shall be in bronze.

Inducers shall be positively locked in the correct position. They shall be designed such as to guarantee concentricity with the shaft. Concentricity shall be checked when assembled to the shaft.

3.4.4 Impellers are to be securely fastened to the shaft to prevent relative axial or rotary motion. Threading of sleeves, nuts and screws shall be of opposite hand to the normal direction of rotation of the shaft. The impeller locking device shall be LOX compatible, and agreed by APL.

3.4.5 The design of the impeller shall be such that the axial thrust is reduced to the minimum.

3.4.6 Impeller disc stresses at the design point shall not exceed [illegible] % of the yield stress.

3.4.7 The first critical speed of the pump assembly shall be at least 25% above the maximum operating speed.

3.4.8 Rotating seat for seal system shall be finely ground and lapped stainless steel.

3.4.9 Shafts shall be made of stainless steel to ASTM A461 Grade 630, and shall be accurately machined all over. Shafts shall be of ample size to transmit the full driver output with a high factor of safety. Additionally, they must be capable of accepting all out of balance loads and moments.

Stress raisers shall be avoided in the design of shafts particularly with regard to methods used for fitting gears, impellers and inducers to shafts.

3.4.10 The warm end of the shaft shall include provision for a shaft position monitor (e.g. Bentley Nevada proximity probe).

3.5 Shaft Seals

3.5.1 The wear materials or seals of a mechanical seal system must be LOX compatible. Silver filled carbon is recommended.

3.5.2 The design of the pumps shall be such that the seal may readily be fitted or replaced in the event of seal failure.

3.5.3 Should there be complete wear out of the seal, the design should be such that there is no steel against steel rub. (Seal bellows should be made from Grade 631 Stainless Steel, with a bronze sleeve if necessary to meet the above safety requirements).

3.6 **Flanges and Connections**

3.6.1 Flanges shall be supplied on all connections 1" and larger.

3.6.2 Flanges shall conform to ANS B16.5 or BS.1560.

3.7 **Bearings**

3.7.1 Bearings shall be designed for maximum life. This life shall include 500 start/stop cycles and unusual loading conditions such as are obtained during cavitation.

3.7.2 Two types of bearings shall be used:-

(a) Pure radial loads to be taken on roller bearings.

(b) Radial and thrust loads combined, to be taken on, preferably, double row angular contact bearings. Both types shall have cages allowing free ingress of lubricant.

3.7.3 If thrust is taken on the high speed shaft the thrust bearing must be remote from the cold end.

3.7.4 Bearing housings shall be effectively sealed against the entrance of water, dust and leakage of lubricant.

3.8 **Heat Break**

3.8.1 This casing shall separate the cold end, from the gear box, if fitted, or from the motor if direct coupled. It shall be very robust stainless steel but designed to reduce heat conduction along its arms to a mimimum. A shaft slinger shall rotate in this space, the slinger being made from bronze.

3.8.2 A bronze enclosure with a close shaft clearance, shall allow nitrogen purge gas to be applied in the gear box end of the heat break space.

3.8.3 The casing shall be made from stainless steel. Absolute concentricity and squareness shall be obtained during machining of the spigot faces. The face abutting the gearbox shall be relieved to reduce metal to metal contact. The space thus generated may remain as an air-space.

The heat break design must be demonstrated by the Vendor, by calculation (substantiated by actual test) to maintain the bearing running temperature at an acceptable level.

3.9 Speed Increasing Mechanism

Two types may be offered:

3.9.1 Gearbox - if this method is used it is preferable that the gears are double helical and that they transfer thrust from the high speed to the low speed shaft. Gear box casings should be finned if necessary to keep the running temperature of the bearings between 16°C. and 60°C.

If ordinary spur gears are used, then the thrust may be taken on the high speed shaft. (see para 3.7.3.)

Provision should be made to supply oil to the bearings on the high speed shaft and to the tooth mesh point. There shall be a splash lubrication system to provide back-up for the pump system. The system should also provide positive lubrication to the above mentioned points prior to start-up (i.e. during pump cool down).

The gear box shall include an oil level indicator. Aluminium is explosive under extreme pressure with some halogenated fluorocarbon lubricants and should, therefore, be used with caution as a bearing housing or gear box casing.

3.9.2 Belt and Pulley Drive

A preferred method of belt and pulley drive is given in Fig. 1. It shows how a motor driving a pulley between pedestal bearings can drive a pump through a flexible drive such that no drive or side thrusts are taken by the bearings in the casing which carries the pump drive shaft.

3.10 Instrumentation

The pump design should cater for the inclusion of

(a) Shaft position monitor (c.f. 3.4.10)

(b) Temperature monitoring of bearing closest to cryogenic end.

3.11 Inclination of Pumps

The pump is intended for operating in the horizontal position but inclinations of ± 20° to the horizontal should be accepted by the pump without ill effect.

4. LUBRICATION

4.1 The high speed shaft bearings and tooth mesh points (if gear driven) shall be adequately lubricated. The bearing temperature during cooldown and running should never be below the pour point of the oil used or the wax point if grease is used. Hydro-carbon lubricants may be used to the right of the barrier in the warm area shown in Fig. 1 but LOX compatible lubricants must be used to the left of the barrier. i.e. in the cryogenic area.

4.2 The low speed shaft bearings may be hydrocarbon grease or oil lubricated.

4.3 Bearing housings, gearboxes etc., must be capable of operation using the following lubricants in the oxygen area:-

Oils

Voltalef 3S

Fomblin Y04)
)Montecatini
Fomblin YU)

Krytox 143 AA)
) Du Pont
Krytox 143 AB)

Nu-Trol Mk.II Nu Chem. Industries Inc.

Halocarbon 11-216 Halocarbon Products Corp.

Fluorolube MO.10 inhibited Hooker Chemical Corp.

Greases

Voltalef 90

Fluorolube GR-362

Halocarbon 25-5S

4.4 Gearbox running temperature should be kept between 16 and 60°C in order to reduce de-polymerisation of the LOX compatible lubricants mentioned above.

4.5 Lubrication to the required points should be guaranteed for the horizontal position ± 20°.

4.6 The design should be foolproof as regards assembly, particularly with regard to alignment of oilways etc.

5. PERFORMANCE

5.1 Head - Capacity Characteristics

5.1.1 The pump should have a stable head - capacity characteristic curve. The curve shall indicate that the pump gives a stable delivery for outputs greater than 25% of the specified duty point.

5.1.2 The curve shall have an abscissa of flow in m^3/h with an ordinate of differential head in metres. There shall be an auxiliary ordinate scale in p.s.i.

5.1.3 The curve will be plotted for the design speed, but additional curves shall be presented showing the head - capacity characteristic over the possible range of speeds of the pump i.e. 3,000 rev/min up to maximum speed in five or six speed increments.

5.2 NPSH - Capacity Characteristic

5.2.1 Curves shall show NPSH as ordinate in metres against flow as abscissa in m^3/h at the design speed.

5.2.2 The NPSH required by the pump must, in general, not exceed 2 metres.

5.2.3 The NPSH required by the pump must not be within 0.5 metre of the NPSH available of the system at the specified duty point.

5.3 Power - Capacity Characteristic

5.3.1 Curves shall show Power as ordinate in kw against capacity as abscissa in m^3/h at the design speed.

5.3.2 Maximum power requirements of the pump on any operating point shall not exceed the motor overload condition.

5.4 Efficiency - Capacity Characteristic

5.4.1 Curves shall show efficiency as ordinate against flow as abscissa in m^3/h.

5.5 General Performance Criteria

5.5.1 The curves defined in paras. 5.1., 5.2., 5.3. and 5.4 above shall be applicable to the type of cryogenic liquid being pumped.

5.5.2 Whenever possible, the operating point should be chosen to coincide with the peak efficiency.

6. TEST REQUIREMENTS

Detailed requirements will be given in the Job Specification. Brief requirements are as follows:-

6.1 The pump shall be subjected to hydrostatic and running tests in the Vendors works to the current relevant standards. Testing shall consist of overall performance testing including imposed cavitation conditions on the appropriate cryogenic liquid and establishing the shut off head.

6.2 Where the estimated N.P.S.H. required by the pump is within 2 metres of water of the N.P.S.H. available of the system at the specified duty point, the performance test at the Vendor's works shall include an N.P.S.H. test.

7. TOOLS

7.1 One complete set of all special tools shall be provided. Where more than one unit, up to a maximum of three, is provided at one location, one set of special tools and wrenches per location is acceptable.

8. PROPOSALS

8.1 Vendor shall submit three (3) complete sets of proposals. Proposals shall include the following.

8.2 Information:

(a) Air Products, project or reference no.

(b) Manufacturers type of designation.

TITLE Centrifugal Cryogenic Pumps

(c) Complete description of offering.

(d) Complete description of all accessories.

(e) Vendor information pages of the Job Specification.

(f) Complete list of any exceptions taken to the specification.

8.3 Characteristic performance curves plotting head, efficiency, kW absorbed and N.P.S.H. required versus output (see para. 5)

8.4 Drawings:

(a) Preliminary General Arrangement Drawing.

(b) Typical cross section drawing of the pump.

8.5 Spare part prices for the following items:

(a) Impeller

(b) Inducer

(c) Diffuser

(d) One set of mechanical seals

(e) One set of casing wear rings

(f) One set of impeller wear rings if fitted

(g) One set of bearings for pump

(h) One set of bearings for prime-mover.

(i) One coupling flexible member if fitted.

9. DRAWINGS AND INFORMATION

9.1 Prospective Vendor shall submit the number of drawings detailed on the Job Specification.

9.2 General Arrangement drawings shall include:

(a) Air Products project or reference no. and item no.

(b) Total weight

(c) Weight of heaviest part for maintenance.

(d) Location of centre of gravity.

(e) Space required for removing rotating assemblies.

(f) Location of all piping connections, drains and plugged taps.

TITLE Centrifugal Cryogenic Pumps

(g) Size, type and rating of all connecting flanges.

(h) Location of electric motor terminal box and size of conduit connection if the electric motor is in the Vendors supply.

(i) Details of foundation bolts.

(j) Recommendations as to foundations required.

10. INSPECTION

10.1 All equipment furnished to this specification, including auxiliaries shall be subject to inspection by Purchaser's quality control representative. Purchaser's representative shall have access to all facilities of the Vendor and his sub-Vendors, and have access to all drawings, inspection records, material specifications and tests to fully determine the quality of material, workmanship and quality control procedure.

10.2 Vendor shall notify the Chief Inspector, Air Products Limited prior to hydrostatic tests, and start of final assembly in accordance with Job Specification.

10.3 Immediately prior to final inspection, the vendor shall provide a graph showing the head/output characteristic, efficiency and absorbed kW as established on test.

10.4 Within two weeks following shop performance test, Vendor shall submit six (6) copies of test report. Report shall include test log sheets, calculated performance curves and typical sample calculations.

10.5 Shipment shall not be made on any equipment furnished to this specification until approved by the Air Products Limited Inspector, or inspection has been waived by the Air Products Limited Inspection Department. Such release shall not relieve Vendor of the responsibility to conform to requirements or material, specifications and workmanship.

11. HANDBOOK OF OPERATING AND MAINTENANCE INSTRUCTIONS

11.1 Pump Vendor shall supply twelve (12) complete sets of bound Operating and Maintenance Instructions. Delivery date shall be as specified in the Purchase Order.

11.2 Instructions shall cover pump and all other equipment in Vendors supply and shall include:-

(a) Sectional arrangement drawings of all equipment supplied.

(b) Recommendations as to type of foundations required.

(c) Alignment tolerance for coupling.

(d) Trouble-shooting table presenting possible troubles that may develop, the probable causes of the troubles, and the appropriate remedies.

(e) Specification of lubricants to be used, the frequency and point of application, and quantity of lubricants required for initial charge.

(f) Specific characteristic curve of the pump, marked with the designated operating point.

(g) Instructions in sufficient detail to enable components subject to wear and failure to be replaced.

(h) Instructions on adjustments to compensate for wear and specity values and tolerances to be observed in making adjustments or fitting replacement components.

(i) Parts list as detailed in clause 12.

11.3 If publications are furnished which cover more models of equipment than actually supplied, the Vendor shall completely annotate such published material to strike out references, illustrations, and data pertaining to any irrelevant equipment.

11.4 All literature must be certified as accurate and complete. All literature must be revised to incorporate the last change or modification performed prior to closing the Purchase Order and final payment.

11.5 All material supplied by the Vendor shall be reproduced in a manner resulting in clear and legible text and illustrations. It is preferred that material submitted be reproduced on A4 size paper (297 x 210 mm).

11.6 All literature must be marked with Air Products Limited equipment Purchase Order number and charge number.

12. PARTS LISTS

12.1 The Vendor shall supply with the above Operating and Maintenance Instructions, complete parts lists of all equipment furnished to this specification including prime-mover, coupling, accessories, special tools, and individual parts. The manufacturers part number must provide positive identification of the parts listed. The complete list may be made up of individual sub-assembly lists or Bills of Materials. Any such lists must be identified by a master list so that each part is identifiable as a component of the main equipment.

The parts list shall specify the quantity of each item used in the assembly or component.

12.2 Common hardware items shall be completely described as to size, length, number of threads, material, finish, type of head etc. This provision applies whether or not a hardware item has a part number.

12.3 Parts lists shall be supported by detail drawings, cross-sectional drawings, exploded-view drawings, or other illustration material identifying each part and keying it to the parts list so that each item in the list can be located on the illustration(s).

Items that cannot be procured separately, such as matched bearings, must be clearly noted.

12.4 The complete parts list shall carry notations indicating which items are recommended for spares by the manufacturer.

12.5 A separate price list shall be supplied reflecting current prices for all items appearing on the parts lists.

13. PUMP ASSEMBLY AND PACKING

13.1 Cleanliness

(a) Vendors shall observe at least the standards of cleanliness set forth in A.P.L. Engineering Specification A.03.

(b) All operators involved in cleaning and assembly processes, shall wear clean white lint free cloth gloves.

(c) All tools must be degreased and oxygen clean before use.

13.2 Packing & Shipment

(a) Vendors shall observe at least the standards laid down in APL Engineering Specification A.03 and K.02.

(b) Before the pump leaves the Vendor's works the gear box shall be purged with dry nitrogen, the pump, gearbox (if fitted) and motor assembly shall be seal welded in separate polythene bags in each of which a bag of drying agent such as Silica Gel has been placed. The drying agent should be of a type which undergoes a colour change when saturated with moisture. Clear instructions should indicate which colour is safe and which is to be rejected and replaced by fresh drying agent. When the latter occurs, the polythene container will also require replacing.

Air Products

ENGINEERING SPECIFICATION

No.	J.07		
PAGE	1	CONT. ON	2
REV	0		

TITLE

Pressure Gauge - Oxygen Service.

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders.
All Instrument Engineers.

0	ORIGINAL ISSUE			
REV	DESCRIPTION	18-6-69 DATE	J. PEGRAM. ORIGINATOR	APP

APPROVED BY: SECTION HEAD ~~DESIGN MANAGER~~ CHIEF ENGINEER TECH SERVICE GROUP MANAGER

F.911

APCI DOCUMENT NO. 99000372

TITLE Pressure Gauge - Oxygen Service

1. PURPOSE

This specification states Air Products minimum requirements for pressure gauges in oxygen service.

2. SCOPE

2.1. This specification applies to all sizes of gauges for all ranges of pressure and vacuum.

2.2. It applies to gauges supplied as part of a machine or equipment by a vendor as well as gauges purchased by Air Products direct from a gauge manufacturer.

3. GENERAL

3.01. BSS 1780 will apply except where it conflicts with other clauses of this specification when this specification will govern.

3.02. The overall accuracy should be ± 1.0% of full scale reading

3.03. The data sheet or requisition will define diameter, pressure range, type of mounting, size and position of inlet.

3.04. Cases will be metal and there will be a solid partition between tube and dial.

3.05. The rear of the case will be full blow out back type capable of relievancy pressure at 5 psig.

3.06. The front will be plastic or laminated safety glass.

3.07. The inlet will be restricted to a maximum of .050" diameter.

3.08. Bourdon tubes will be bronze up to and including 1500 psi. maximum dial reading.

3.09. Bourdon tubes will be K-Monel for full dial readings above 1500 psi.

3.10. Dials of gauges to be marked "Oxygen-use no oil", in red letters.

3.11. Gauges must be degreased to 'AA' standards of cleanliness to Spec. No. A.03 a label affixed to the gauge stating "Degreased for Oxygen Service".

3.12. If the gauge is calibrated or pressure tested after degreasing only oil free air or nitrogen shall be used.

4. **PACKAGING**

4.1 After degreasing the instrument must have all openings sealed to prevent ingress of contamination and preferably sealed into a plastic bag.

4.2 Gauges must be packed for despatch so that no damage can occur due to shock during transit.

5. **CERTIFICATES AND INSPECTION**

5.1 Three copies of test certificates must be handed to our inspector or sent to Air Products purchasing department before despatch.

5.2 Witnessing of pressure test, degreasing and final inspection will be made by Air Products or their authorised representative in accordance with the job specification or purchase order.

Air Products LIMITED

ENGINEERING SPECIFICATION

No. J.15
PAGE 1 CONT. ON 2
REV 0

TITLE

Pressure Regulating Valves for Oxygen Service.

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders.
All Instrument Engineers.

0	ORIGINAL ISSUE	18-6-69	J.W. PEGRAM	
REV	DESCRIPTION	DATE	ORIGINATOR	APP

APPROVED BY: SECTION HEAD ~~DESIGN MANAGER~~ CHIEF ENGINEER ~~TECH. SERVICE~~ GROUP MANAGER

F.911

APCI DOCUMENT NO. 99000373

TITLE Pressure Regulating Valves For Oxygen Service

1. PURPOSE

This specification states the materials required in pressure regulating valves and used for oxygen service.

This specification must be used in conjunction with the job specification and if there is any conflict between this specification and the job specification the latter shall govern.

Catagory A.

Duty - Warm Service -20°F to 100°F

Material -

(a) Body - Bronze, Aluminium Bronze, Brass or Type 316 Stainless Steel.

Carbon Steel or Cast Iron must not be used for parts in contact or possible contact with controlled fluid.

(b) Diaphragm - Bronze, Monel, Stainless Steel, Teflon or Teflon impregnated glass.

Neopr ene may be permitted. Spec must be submitted to APL and written approval obtained. Hydrocarbon material must not be used.

(c) Seat - Copper, Brass, Bronze, Stainless Steel or Teflon.

Nylon may be permitted. Spec must be submitted to APL and written approval obtained.
Hydrocarbon material must not be used.

(d) Gaskets and Seals. Copper, Teflon or Klingerit 661.

Hydrocarbon material must not be used.

Catagory B

Duty - Cold Service -320°F to + 100°F

Material -

(a) Body - As warm service.

(b) Diaphragm. Bronze, Monel, Stainless Steel.

Teflon, Teflon Impregnated Glass, Neoprene or Hydrocarbon material must not be used.

(c) Seat - Copper, Bronze or Stainless Steel.

Teflon, Nylon or Hydrocarbon material must not be used.

(d) Gaskets & Seals. Copper, Teflon or Klingerit 661.

Hydrocarbon material must not be used.

<u>Catagory A & B</u>

<u>Degreasing</u> - All valves to be degreased to AA cleanliness see specification No. A.03

<u>Connections</u> - Flanged, screwed or socket welded connections to be according to PRV schedule.

Air Products LIMITED

ENGINEERING SPECIFICATION

No. J.18
PAGE 1 CONT. ON 2
REV 0

TITLE

Relief Valves, Warm Gas Service, -20°F +100°F.

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders.
All Instrument Engineers.

REV	DESCRIPTION	DATE	ORIGINATOR	APP'D
0	ORIGINAL ISSUE	18-6-69	J.W. PEGRAM	

APPROVED BY: SECTION HEAD · ~~DESIGN MANAGER~~ · CHIEF ENGINEER · ~~TECH. SERVICE~~ GROUP MANAGER

F.911

TITLE Relief Valves, Warm Gas Service, - 20°F. + 100°F

1. SCOPE

All Relief Valves purchased by Air Products Ltd., for the above duty shall conform to this specification unless the vendor receives written approval from the purchaser for any exception. Where conflict between this specification and the applicable job specification exists the job specification shall govern.

2. MATERIALS

a) Body, nozzle, blow down ring, disc, bonnet test lever, cap and any other parts in contact with fluid shall be carbon steel stainless steel, bronze or aluminium.

b) Spring shall be carbon steel.

3. LIFTING GEAR

Standard open lever shall be provided.

4. NOZZLE RINGS

(adjustable) Single or double, dependent upon valve design.

5. GAGS

Provision shall be made on valve for fitting a gag. Gag fitting shall be common to all types of valve. Test gag to be fitted to each valve by means of chain.

6. DEGREASING

This applies to Oxygen Service, Relief Valves only. Valves must be degreased to Class 'AA' Standards. See Specification A.03.

7. CLEANING

This applies to all relief valves except those for oxygen service or those which could pass oxygen under upset conditions when clause 5 of this specification applies.

a) All parts of the relief valve must be free of all loose particles of rust, dust and other foreign matter.

b) There must be no burrs or other small slivers of attached metal adhering to machine or cast parts.

c) There must be no signs of grease or oil accumulation although a thin film of light oil applied as a preservative is allowed.

d) The whole valve must be visually clean when seen under bright white light.

7. (Continued)

e) Valves must pass Cleaning acceptance test class B. See Spec. No. A.01

8. TESTING

Use oil-free air or nitrogen at all pressures. The valve must be tight with no permissible leakage rate at the "Re-seat pressure" stated on valve schedule. The valve leakage at higher than 2% above the 'Re-Seat pressure' to be no greater than 3 bubbles per minute of free air through a 5/16" bore tube covered by ½" head of water.

100% of set pressure	- Tolerance to be within +2% of set pressure for 3 consecutive pops. Valves shall give a sharp pop with no simmer.
103% pr 110% of set pressure (see Relief Valve Schedule)	- Maximum pressure at which valve must be fully open and delivering at rated capacity. (Accumulation not observable by inspection).
Re-set Pressure	- The minimum pressure at which valve must have re-seated after 3 consecutive pops (no bubbles) will be the 'Re-seat Pressure' stated on valve schedule.

9. BODY TEST

Hydraulic test shall be 200% (minimum of set pressure).

10. RANGEABILITY

5% of set pressure i.e. the valve can be set to other pressure without spring change while above conditions are maintained.

11. TEST CERTIFICATES

A mechanical material and chemical analysis will be required for each valve and test certificates will be required upon completion of valves at the time of Air Products Limited inspection visit. Test Certificates shall be kept on file of Vendor.

12. SEALING

All valves shall be lead sealed (after inspection) at the set pressure.

13 INSPECTION

Each relief valve must be inspected at the vendors works before acceptance.

Inspection will include complete test of equipment performance as specified on this sheet.

ENGINEERING SPECIFICATION

No. D.1?
PAGE 1 CONT. ON 2
REV 0

TITLE

Transfer Hose for Cryogenic Liquids

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders
All Piping Engineers

0	ORIGINAL ISSUE	7/7/69	J.W.P.	
REV	DESCRIPTION	DATE	ORIGINATOR	AP

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER
			M. Thorogood	M A Sample

APCI DOCUMENT NO. 99000375

TITLE Transfer Hoses for Cryogenic Liquids

1. PURPOSE

This standard states Air Products Ltd's mandatory requirements for hoses to carry cryogenic liquids under pressure.

2. SCOPE

2.1 These hoses are for use between depot or plant storage and road tankers and other applications where a temporary, uninsulated transfer of cryogenic liquid is needed.

2.2 They are for use with liquid oxygen, nitrogen, argon, carbon dioxide and natural gas.

3. MATERIAL

3.1 Inner Hose. Flexible austenitic stainless steel corrugated close pitch hose.

3.2 Outer Cover Braided stainless steel covers with 10g stainless steel wire protection coil outside the braid.

3.3	Size	$1\frac{1}{2}$" nominal bore	3" nominal bore
3.4	Length O/all	10'-0"	10'-0"
3.5	Design Pressure	450 psig	50 psig
3.6	Working Temperature	$-320^{o}F$ to $+100^{o}F$	$-320^{o}F$ to $+100^{o}F$
3.7	Hyd. Test Pressure	675 psig	75 psig
3.8	Pneu. " "	565 psig	70 psig
3.9	End Fittings	Stainless steel fixed (non swivelling) ends Screwed $1\frac{1}{2}$ BSP Parallel, female for a depth of $\frac{7}{8}$". To mate with APL hose end fitting to drg STD-IGD-374C.	Bronze fixed (non swivelling) end screwed 3" National Pipe thread (NPT) parallel, female for a depth of 1" to mate with APL hose end to drg. STD-IGD-551C.

4. DECONTAMINATION

4.1 All hoses will be degreased to oxygen service standard AA. See Specification No. A.03.

4.2 After degreasing the ends shall be plugged to prevent contamination and the hose labelled "Degreased for Oxygen Service".

TITLE Transfer Hoses for Cryogenic Liquids

5. IDENTIFICATION

5.1 The hose ends are to be stamped with the APL order number and month and year of manufacture and a number to identify it with the test certificates.

6. TEST CERTIFICATES

6.1 3 copies of the pressure test certificate for each hose required to be sent to the Purchasing Department.

6.2 Test certificate to carry a number identifying it with the hose.

add

max operating pressure

temperature range

permitted fluids.

per RMT's memo
4/8/69

ENGINEERING SPECIFICATION	No. L.12.1 PAGE 1 CONT. ON 2 REV 0

TITLE

Flexible Hoses for Charging and Discharging Manifolds Oxygen Service

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders
All Piping Engineers.

0	ORIGINAL ISSUE	7/7/69	J.W.P.	
REV	DESCRIPTION	DATE	ORIGINATOR	APP

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

TITLE Flexible Hoses for Charging and Discharging Manifolds Oxygen Service

1. PURPOSE

This specification states Air Products requirements for a high pressure hose for use with gaseous oxygen within a temperature range of minus $20^{\circ}F$ to plus $100^{\circ}F$.

2. SCOPE

These hoses are for use with gaseous oxygen or any other gas which is incompatible with rubber but does not react with P.T.F.E.

3. MATERIAL

3.1 Flexible hose made from P.T.F.E. with stainless steel braiding on the outside.

3.2 Braiding to be bonded to the end fittings so that hose is electrically continuous.

3.3 End fittings fixed (non swivelling) stainless steel, bronze or brass with spanner flats. Screwed ¼ BSP taper female.

3.4 Size ¼" N/Bore x 2'-0" lg. overall.

3.5 Design 3000 p.s.i.g. at $100^{\circ}F$

3.6 Test Pressure hydraulic 4500 p.s.i.g.

3.7 Test Pressure pneumatic 3300 p.s.i.g.

3.8 Bursting Pressure 10,000 p.s.i.g.

4. DECONTAMINATION

4.1 All hoses are to be degreased to oxygen service standard AA. See Specification No. A.03.

4.2 After degreasing the ends shall be plugged to prevent contamination and the hose labelled "Degreased for Oxygen Service".

5. IDENTIFICATION

5.1 Each hose to carry a metal tag giving Air Products order number, month and year of manufacture and a number identifying it with the test certificate.

6. TEST CERTIFICATES

6.1 3 copies of the pressure test certificate for every 50 hoses are required or for every batch ordered if less than 50.

Air Products

ENGINEERING SPECIFICATION

No. L.14

PAGE 1 CONT. ON 2

REV 0

TITLE

Unsintered P.T.F.E. Tape

DISTRIBUTION

All Engineering Specifications and Standards
Manual Holders
All Piping Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	APP
O	ORIGINAL ISSUE	8.7.69	J W P	

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

APCI DOCUMENT NO. 99000372

F.911

TITLE **UNSINTERED P.T.F.E. TAPE**

1. **PURPOSE**

This specification states Air Products Limited's requirements for P.T.F.E. tape used for thread sealing.

2. **FORM**

White tape approximately ½" wide x .003" thick wound onto reels or spools.

3. **SPECIFICATION FOR LIQUID OR GASEOUS OXYGEN (-300°F to +480°F) SERVICE**

3.1 The tape should be generally as specified in BS4375 - 1968 excepting clause 6, Residual lubricant content.

3.2 The tape must be free from all residual oil, or grease and must pass the approval tests for Class AA (Oxygen clean) standard of cleanliness. See Specification No. A.03

3.3 After passing the acceptance test the tape should be wound onto spools or reels which clearly state "degreased for oxygen service" and then sealed into plastic bags either separately or in batches of 10.

4. **SPECIFICATION FOR ALL SERVICES (OTHER THAN OXYGEN) STATED IN STD. LS.03. WHICH ARE SUITABLE FOR USE WITH P.T.F.E. TAPE**

4.1 P.T.F.E. tape should all be in accordance with BS4375 - 1968.

4.2 The packing should be vendors standard.

Air Products

ENGINEERING STANDARD

No.	LS.08
PAGE	1
CONT. ON	2
REV	~~0~~

TITLE

CRYOGENIC LIQUID HOSE COUPLINGS FOR USE IN THE U.K.

DISTRIBUTION

ALL MANUAL HOLDERS, ALL PIPING ENGINEERS

REV	DESCRIPTION	DATE	ORIGINATOR	APP
0	ORIGINAL ISSUE	21/10/69	J.W. PEGRAM	

APPROVED BY	SECTION HEAD	~~DESIGN MANAGER~~	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER
21.10.69				

F.913

APCI DOCUMENT NO. 99000378

Cryogenic Liquid Hose Couplings for use in the U.K.

1. PURPOSE

1.1 This standard lists the sizes and types of threads used on hose couplings by Air Products to ensure that every liquified gas has a different connection.

1.2 By making all liquids have unlike couplings it will not be possible for contamination of tanks and tankers, by the introduction of the incorrect liquid, to occur by accidental means.

2. SCOPE

2.1 This standard is mandatory and no other threads or type of coupling may be used for 1½" and 3" hoses used on Air Products facilities, depots, tanks, or tankers without the knowledge of the plant or depot manager & the safety officer.

2.2 The only exception to clause 2.1 is where vehicles of other companies or Government departments which use their own standard couplings are involved and the policy to be adopted is then at the discretion of the plant or depot manager.

3. DESCRIPTION

3.1 All hose couplings take the form of unions as shown on Sheet No. 6.

3.2 The nut and tailpiece are always attached to the hose ends.

3.3 The male threaded part is always attached to the tank or tanker inlet or discharge point.

3.4 When not in use blank caps or plugs must be fitted to the open ends of couplings to prevent contamination.

3.5 The threads and drawing numbers are shown on sheet 4,5 & 6

4. RELATED SPECIFICATIONS

4.1 - BS 84 Parallel Screw threads of whitworth form.

4.2 - BS 251 Naval brass rods and sections.

4.3 - BS 1104 General purpose ACME Screw threads.

4.4 - BS 1490 Wrought aluminium.

4.5 - BS2779 Fastening threads to B.S.P. Sizes.

TITLE
Cryogenic Liquid Hose Couplings

5. DRAWING AND CODE NUMBERS

5.1

1½" Dia.Hose

Service		OXYGEN	NITROGEN	ARGON	LNG & ETHYLENE	CO_2
Hose Tailpiece	Drg.No. Code No.	← STD-IGD-374C 8514602 →				STD-IGD-1003C 8514629
Tank Coupling	Drg.No. Code No.	STD-IGD-375C 8514603	STD-IGD-375C 8514609	STD-IGD-751C 8514615	STD-IGD-797C 8514621	STD-IGD-1002C 8514630
Tanker Coupling	Drg. No. Code No.	SD.1169C 8514606	SD.1169C 8514612	STD-IGD-804C 8514618	STD-IGD-804C 8514624	STD-IGD-1014C 8514633
Union Nut	Drg. No. Code No.	STD-IGD-373C 8514601	STD-IGD-373C 8514608	STD-IGD-775C 8514614	STD-IGD-798C 8514620	STD-IGD-1004C 8514628
Gasket	Drg. No.	← STD-IGD-376C 8507001 - Lead →				N/A
Blank Cap	Drg.No. Code No.	STD-IGD-764C 8514604	STD-IGD-764C 8514610	STD-IGD-776C 8514616	STD-IGD-799C 8514622	STD-IGD-1018C 8514631
Blank Plug	Drg.No. Code No.	STD-IGD-762C 8514605	STD-IGD-762C 8514611	STD-IGD-781C 8514617	STD-IGD-800C 8514623	STD-IGD-1017C 8514632

TITLE ~~Cryogenic Liquid Hose Couplings~~

5. DRAWING AND CODE NUMBERS

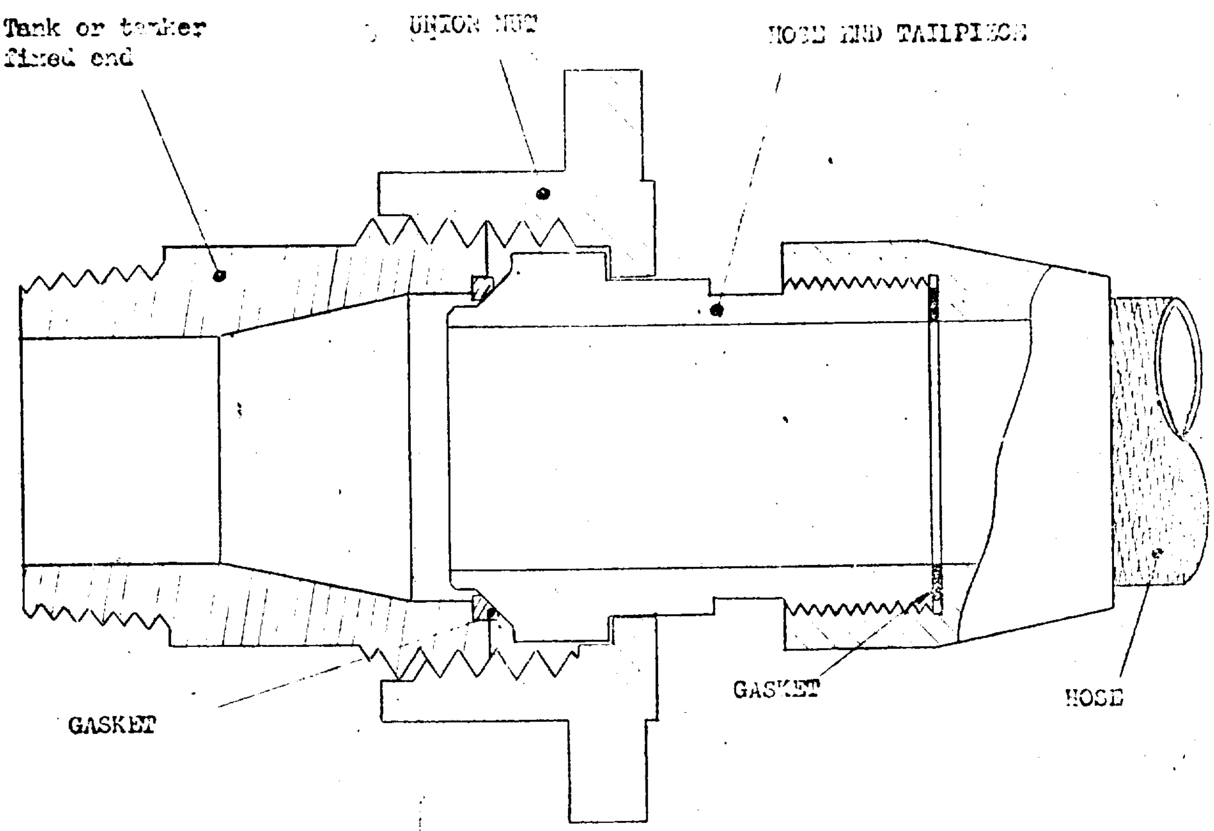
5.2

3" Dia.Hose

Service		OXYGEN	NITROGEN	ARGON	CO_2	LNG & ETHYLENE
Hose Tailpiece	Drg. No. Code No.	← STD-IGD-551C 851462 →				
Tank Coupling	Drg. No. Code No.	STD-IGD-438C 8514643	STD-IGD-777C 8514649	STD-IGD-1007C 8514655	STD-IGD-1008C 8514660	STD-IGD-1070C 8514672
Tanker Coupling	Drg. No. Code No.	SD.1170C 8514646	SD.1170C 8514652	STD-IGD-1015C 8514658	STD-IGD-1015C 8514663	STD-IGD-1068C 8514675
Union Nut	Drg. No. Code No.	STD-IGD-546C 8514641	STD-IGD-778C 8514647	STD-IGD-1009C 8514654	STD-IGD-1010C 8514659	STD-IGD-1069C 8514671
Gasket	Drg.No. Code No.	← STD-IGD-568C 8507003 →				
Blank Cap	Drg. No. Code No.	STD-IGD-765C 8514644	STD-IGD-765C 8514650	STD-IGD-1011C 8514656	STD-IGD-1011C 8514661	STD-IGD-1071C 8514673
Blank Plug	Drg. No. Code No.	STD-IGD-763C 8514645	STD-IGD-763C 8514651	STD-IGD-1012C 8514657	STD-IGD-1012C 8514662	STD-IGD-1072C 8514674

5.3 Propane couplings are purchased from L.P. Gas Ltd., of Birmingham and are selected for a specific duty and may incorporate chek-lok devices, excess flow valves and other safety equipment as required.

5.4 These tables show only standard couplings in brass. Where other material or alternative means of attaching the couplings to the pipes is needed special drawings will have to be produced.



	Oxygen	Nitrogen	Argon	LNG & Ethylene	CO_2
1½"Hose	2½"Whit. R.H.	2½"Whit L.H.	2¼" Whit R.H.	2¾"Whit L.H.	1½"BSPP R.H.
3" Hose	4¼"Acme R.H.	4¼"Acme L.H.	4¼"Whit R.H.	4¼" UNC L.H.	4¼"Whit L.H.

	Propane (Tanks up to 2 tons)	(Tanks 3 tons and over)	
	1¾" Acme	2¾" Acme	

NOTE

The 2½" Whit. R.H. male thread used for oxygen is slightly truncated to ensure that the 2¼" RH female thread used for Argon is unable to engage even minutely.

ECR	Rev	REVISIONS	date	made	ch'd	app'd
	2					
	1					
	3					

drawn IRM checked approved date

DRG. No

TITLE CRYOGENIC LIQUID HOSE COUPLINGS

Air Products

Sheet No.

ENGINEERING SPECIFICATION

No. H.01

PAGE CONT. ON

REV 0

Cover Sheet

TITLE Expanded Perlite

DISTRIBUTION

All Manual Holders
All Piping Engineers
All Buyers

REV	DESCRIPTION	DATE	ORIGINATOR	APP
0	ORIGINAL ISSUE	2.1.70	J.W.Pegram	

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

ENGINEERING SPECIFICATION

No. N.01
PAGE 1 CONT. ON 2
REV 0

TITLE Expanded Perlite

1. PURPOSE

This specification has been prepared to provide vendor with Air Products minimum requirement for perlite used in insulating vessels and pipelines in cryogenic and oxygen service.

2. SCOPE

This specification applies to all perlite used in cold boxes, inter-spaces of vessels and piping in cryogenic liquid or gaseous service below -150°F (-100°c)

3. CHEMICAL AND PHYSICAL PROPERTIES

3.1 Composition approx. 76% Silica, approx 14% alumina and lesser amounts of divalent and trivalent oxides.

3.2 Non combustible [Fusion point above 1600°F (871°c)]

3.3 Free from organic contaminants.

3.4 Odourless.

3.5 Insoluble in water and most acids.

3.6 pH. Value 6.5 - 7.5 as determined by BS 3958 Pt 3 or 4.

3.7 Bulk density approx. 3 lb. per cubic foot loose and not less than 3½ lb per cubic foot compacted. See clause 5.

3.8 Max. Thermal Conductivity 'K' at a mean temperature of 32°F to be .25 BTU/Hr/Sq.ft/°F/in.

3.9 Moisture content less than 0.5%.

3.10 Sieve Analysis:-

Sieve No. to BS. 410	Percentage Weight Retained.
Retained on 25 mesh (600 microns)	5 - 10
Retained on 52 mesh (300 microns)	25 - 35
Retained on 100 mesh (150 microns)	25 - 35
Retained on 150 mesh (105 microns)	10 - 15
Retained on 200 mesh (75 microns)	10 - 15
Passes 200 mesh	5 - 10

4. HYDROCARBON CONTAMINATION

During and after manufacture the perlite must be kept completely clear of any possible oil or other hydrocarbons and the manufacturer must guarantee a hydrocarbon content of less than 0.1%.

5. COMPACT DENSITY

To determine compact density. Place 20 lbs of perlite into a smooth walled drum and note the perlite level. Vibrate the drum for 1 minute on a vibratory floor or by hammering by hand or mechanically the lower periphery for 2 minutes. Note the perlite level and calculate the density.

6. SHIPPING

a) The preferred size of bags is 4 cu. ft. - 8 cu. ft.

b) The perlite must be packed such that the moisture content is less than 0.5% when it arrives at the delivery address and it should be transported in enclosed container bodied vehicles and not open trucks with tarpaulins.

c) Bags must be impervious to moisture and hydrocarbon contamination.

	ENGINEERING SPECIFICATION	No. M.02 PAGE CONT. ON REV 0 Cover Sheet

TITLE Mineral Wool

DISTRIBUTION

All Manual Holders
All Piping Engineers
All Buyers

0	ORIGINAL ISSUE	2.1.70	J.W. Pegram	
REV	DESCRIPTION	DATE	ORIGINATOR	

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVIC GROUP MANA

APCI DOCUMENT NO. [illegible]

F.911

TITLE Mineral Wool

1. PURPOSE

This Specification has been prepared to state Air Products requirements for Mineral Wool used as insulation for vessels and pipelines in cryogenic service.

2. SCOPE

2.1 This Specification applies to all mineral wool supplied in bulk for use in cold boxes or ducts.

2.2 The equipment being insulated will be in the range +600°F to -400°F and the outer face of the cold box or duct at ambient temperature (assumed to be 60°F)

3. CHEMICAL AND PHYSICAL PROPERTIES

3.1 The maximum percentage of alumina should be 20%

The	maximum	percentage	of	alumina	should	be	20%
"	"	"	"	silica	"	"	48%
"	"	"	"	lime	"	"	41%
"	"	"	"	ferrous & ferric oxide			4%
"	"	"	"	magnesia	should	be	8%
"	"	"	"	sulphur	"	"	1.6%

The Vendor is to supply a typical analysis of his product at time of tender.

3.2 The moisture content shall be 0.5% max. as determined by Clause 10.4.1 of BS 2972 Method of test for Thermal Insulating Materials.

3.3 The oil content as determined by Section 16 of BS 2972 Supplement No. 1 shall not exceed 0.4% This is equivalent to the mineral wool having no more than 8.96 lbs of oil per imperial ton of fibre.

3.4 The wool shall not contain any foreign material and be free from trim and off cuts of mineral wool boards, batts and other products and no fibrous materials.

3.5 The mineral wool shall be inert under conditions of moisture or heat so as not to cause or promote corrosion to steel, copper or aluminium. It shall have a pH value between 7-8.5 when tested in accordance with B.S. 3958 Part 3 or 4.

3.6 The shot content measured as pellets retained on a 60 mesh BS test seive in accordance with the test stated BS.2972, Section 14, shall not exceed 25%.

3.7 The wool must be resistant to crumbling when compressed to a density of 15 - 20 lb/cu.ft. and capable of withstanding temperatures ranging from +600°F to -400°F with no tendency to break down, change form or undergo a physical or chemical transformation.

3.8 The max. thermal conductivity shall be 0.27 BTU/Hr/sq.ft./°F/in when packed to a density of approx. 17 lb/cu.ft. K to be calculated at a mean temperature of 32°F and tested in accordance with ASTM C 177.

Vendor is to advise:-

a) Density to achieve K of 0.27

b) Compression required to achieve the vendors stated density.

4. PACKING

4.1 The mineral wool shall be supplied in containers which are impervious to moisture and hydrocarbon contamination and resistant to puncturing and tearing.

4.2 The mineral wool must have a moisture content not more than 0.5% when it arrives at the delivery address.

4.3 Containers for delivery in the UK. shall be 56 lb capacity 3 ply paper sacks or equal.

4.4 Containers for delivery overseas shall be 56 lb capacity 3 ply kraft paper with polythene liners or equal.

Air Products

ENGINEERING SPECIFICATION

No. N.05

PAGE CONT. ON COVER SHEET

REV 0

TITLE Insulation - Preformed Cellular Glass Section for Pipelines

DISTRIBUTION

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0	ORIGINAL ISSUE	1-10-70	J.W.Pegram	
REV	DESCRIPTION	DATE	ORIGINATOR	APP

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

F.911

APCI DOCUMENT NO. 9900038L

Air Products	ENGINEERING SPECIFICATION	No. N.05 PAGE 1 CONT. ON 2 REV 0

TITLE Insulation - Preformed Cellular Glass Section for Pipelines

1. Purpose

This specification states Air Products Ltd., minimum requirements for preformed Cellullar Glass external lagging material for oxygen pipelines together with the acceptable adhesives, sealers etc.

2. Scope

These materials are suitable for a temperature range of -298°F to -50°F for liquid and cold oxygen gas service. They are also suitable up to +450°F service.

3. Material

3.1 All material shall be foamed glass having cells containing non combustible and non corrosive gas.

3.1.1 Density 9lb/cu.ft.

3.1.2 Non flammable and unable to support combustion

3.1.3 Dimensions and Tolerances to ASTM C450-65T unless otherwise stated.

3.1.4 Thermal Conductivity K not greater than .38 BTU/hr/ft^2/in/°F at a mean temperature of 50°F when tested to ASTM C177.

3.1.5 Compressive strength ultimate 100lb/in^2.

3.1.6 pH value 7.5 to BSS 3958 Part 3 or 4

3.2 Acceptable material Pittsburgh Cornings 'Foamglas' or equal.

4. ACCESORY MATERIALS

4.1 Contraction Joint Insulation

Contraction joint insulation shall be a 1 lb. density fibrous glass blanket. Acceptable material is:

Johns-Manville Ltd. Microlite

Or equal.

4.2 Insulation Sealer

Insulation sealer shall be a non-shrinking, non-hardening compound. Only the following material is acceptable:

Atlas Preservative Company Foster 30-45

4.3 Insulation Adhesive

Keenes Cement. No substitutes permitted.

4.4 Vapour Barrier Jacketing

Vapour barrier jacket shall be a fire retardant aluminium - foil Kraft paper laminate with a maximum perm rating of .02 and rated "non-combustible". Acceptable material is:

British Sisalcraft Ltd - Pyrocure No. 310

Or equal.

4.5 Vapour Barrier Adhesive

Vapour barrier adhesive shall be a fast drying, fire-resistive compound. Acceptable material is:

Atlas Preservative Company Ltd	Foster Safetee Ductfas adhesive 81 - 99

Or equal.

4.6 Weather Resistant Vapour-Barrier Mastic

Weather resistant vapour barrier mastic shall consist of a tough, flexible, fire-resistive compound with a glass cloth reinforcement. Acceptable mastic is:

Atlas Preservative Company Ltd	Foster Fire Resistive Mastic 60-75 (Aluminium)

Or equal.

The reinforcement shall be openweave mesh (1.5oz./sq.yd) glass cloth. Acceptable material is:

Atlas Preservative Company Ltd	No. 10 Glass Cloth

Or equal.

4.7 Metal Jacketing

Metal Jacketing shall be .016" thick aluminium with 3/16" - ¼" corrugations (no moisture barrier required). Acceptable suppliers are:

Atlas Preservative Company Ltd - Atlas Aluminium Jacketing

Or equal.

TITLE Insulation - Preformed Cellular Glass Sections for Pipelines

4.8 Expansion Joint Covers

Expansion joint covers shall be 1/16" thick neoprene rubber sheet stock with a hardness of 40 when tested in accordance with ASTM D-2240.

4.9 Adhesive for Expansion Joint Cover

The adhesive for the expansion joint cover shall beone of the following materials:

Atlas Preservative Company	Foster Neoprene adhesive 13-29

Or equal

4.10 Insulation Banding Tape

Tape for banding the insulation shall be 3/4" wide reinforced fibreglass. Acceptable material is:

a) John-Manville - Dutch Brand - No. 400 Strapping Tape

b) 3M Company - Scotch Brand - Filament Type No. 898

c) Or equal

4.11 Metal Bands

Metal bands shall be 1/2" wide x .020" thick stainless steel with matching seals.

4.12 Insulation Tie Wire

Where specified, the wire for securing the inner layer of insulation shall be 16 SW gauge dead soft annealed type 304 or 430 stainless steel.

4.13 Bore Coating

Atlas Preservative Company Ltd. - Foster 30 - 16.

No substitution permitted.

5. Piping Insulation

5.1 All insulation shall be pre-fabricated using a minimum number of pieces and using butt-joint construction.

5.2 The maximum thickness of any layer shall be three inches.

5.3 The first layer of the insulation shall have its inner surface coated with bore-coating material which is allowed to dry completely prior to application.

TITLE Insulation - Preformed Cellular Glass Sections for Pipelines

6. Insulation Thickness

The total thickness of insulation to be used on each piping system is to be specified on the insulation schedule which is supplied by APL.

FIRE IN OXYGEN LINE

On the 28th August, 1961, shortly after preparations had been made to put the oxygen cylinder charging facility on stream, a fire originated in a stainless steel high-pressure oxygen line at the Cleveland facility. The fire was confined to approximately 14 inches of piping and fortunately there were no injuries as a result of the fire.

The cylinder charging facility was supplied by liquid product from the tonnage plant by means of a DRI pump, a booster pump and a vaporizer. The system was pressurized with oxygen up to the block valve on the charging manifold and a few seconds after the block valve was opened a loud report was heard.

Investigation of the noise revealed that a section of the stainless steel line between the vaporizer and charging manifold had ruptured due to an internal fire in the line. The pressure gauge on the charging manifold indicated 550 psi after the fire. Further investigation found that the line contained oil to such an extent that, upon cutting the line, oil was observed dripping from the cut. Also, a half-inch mild steel rod was found with the hexagonal head lodged in an elbow. The original length of the rod could not be determined as the rod had burned, contributing additional fuel to the burning oil in the line. The source of ignition may have been a spark resulting from movement of the steel rod in the pipeline.

How the rod and oil entered the piping system is not yet known. In any event, the consequences of a contaminated oxygen system are exemplified by the above incident. All personnel associated with the installation of air separation plant equipment and oxygen piping systems should be constantly alert to prevent contamination of the system. The purging of a piping system is essential to remove weld slag and other foreign material and, in addition, to detect, if possible, any blockage of the system which would be indicated by erratic movement of the pressure gauge pointer.

AIR PRODUCTS LIMITED
Safety Officer

safety

Date:

Accident at an Oxygen Charging Manifold

On a standard oxygen manifold having 50 filling points, manifold valves were Carl Esser "Gloria" type fitted with rubber diaphragm seals. Valve seat discs were made of an unspecified hard fibre.

On completion of cylinder filling the operator was closing one particular manifold valve. The valve was almost closed when there was a leak of GOX up the stem quickly followed by a blue flame and an explosion.

Subsequent investigation indicated that the hand-wheel, gland nut and spindle flew out due to distortion of the retaining threads by the heat of the reaction and gas pressure. The rubber diaphragm and seat disc had apparently been consumed in the reaction. No personal injury was sustained. The photograph illustrates the damage sustained. (1) is an undamaged valve while (2) is the damaged valve.

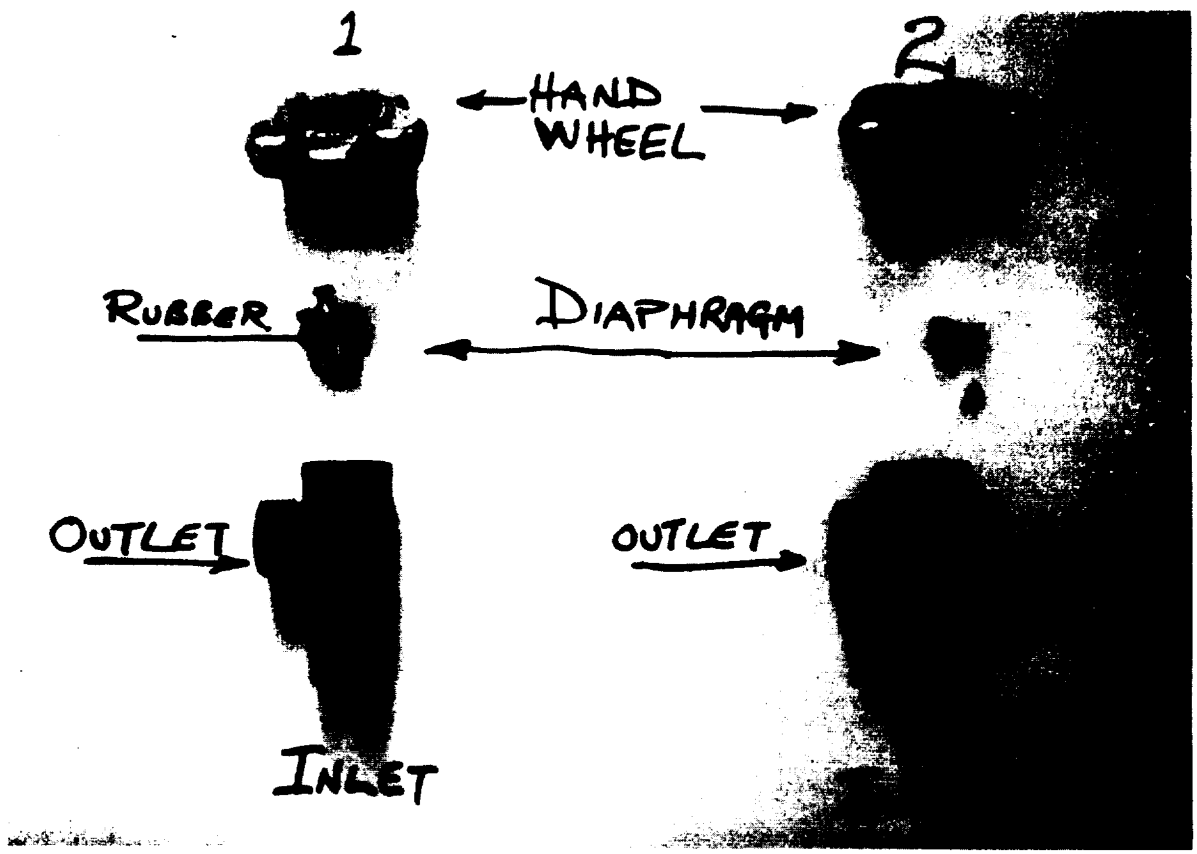
Recommendations

1. In valves for oxygen service seat discs should be ir nylon. Gland seals and diaphragm should be made of P.T.F.E.

2. If vendors propose other materials these should be cleared with Safety Department before acceptance.

3. General engineering queries on valves should be raised with either Mr. C.H. Bloom, Chief Design Engineer or Mr. J. Pegram, Head of I.G.D. Engineering.

I. Everson
Chief Safety Engineer


1
2
HAND WHEEL
RUBBER
DIAPHRAGM
OUTLET
OUTLET
INLET

SAFETY BULLETIN NO. 75

11th December, 1969

Accident Arising from Venting Oxygen Manifolds Connected to a Common Vent Pipe

At an Air Products installation, two high pressure oxygen manifolds were coupled to a common vent pipe. On one occasion the supply valve to one manifold gave trouble and it was decided to dismantle this valve to effect a repair. The pressure in this manifold was reduced to atmospheric by venting it through the common vent pipe. However, the vent valve was left open. Simultaneously, charging operations had been completed on the second manifold, which was then depressurised through the common vent pipe. Since the vent valve of the first manifold was still open it became pressurised with the result that the partially dismantled supply valve was subjected to a sudden increase in pressure, causing the valve cap to blow out, narrowly missing the operator, and smash a plate glass window.

Despite peculiarities of the layout of this particular installation, this accident would not have occurred had the operation of both manifolds been more carefully supervised.

Recommendations:

1. All high pressure Plants should be reviewed to ascertain if a number of individual vents feed into the same discharge pipe or manifold, with the possibility of accidentally pressuring parts of Plant unbeknown to local operators. If this is the case, Managers should issue written instructions explaining the hazard and procedure for its prevention.

2. Managers should verify, regularly, that small bore vent pipes are unobstructed. This can be done by observing the response of pressure and vacuum gauges when opening and closing valves.

3. To avoid a recurrence of this accident it is recommended that vent/vacuum lines from all individual high pressure cylinder filling manifolds should be provided with their own non-return valves immediately downstream of the manifold vent/vacuum valve.

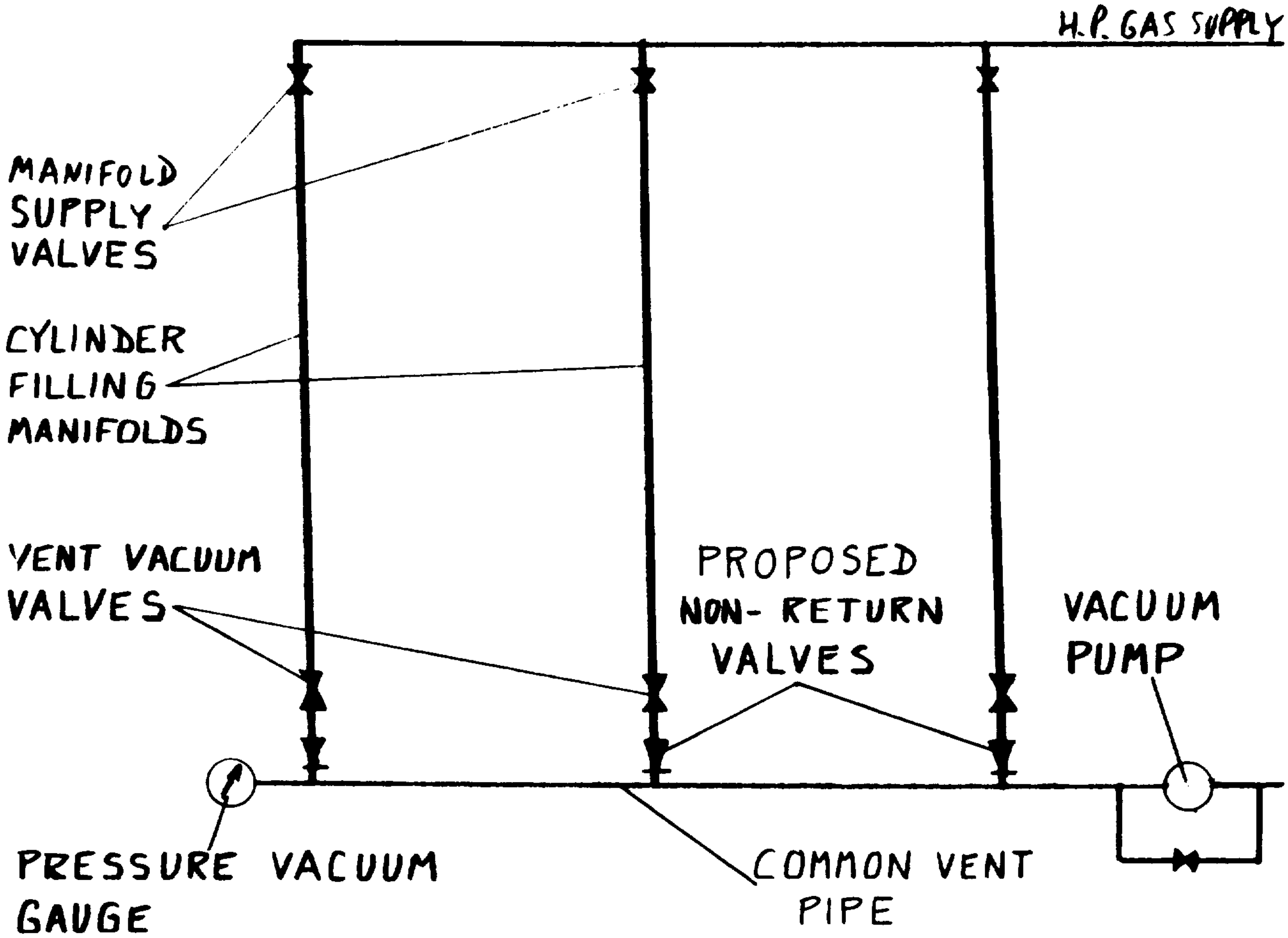
4. Vacuum gauges should be located at the remote end of the vent/ vacuum manifolds as a precaution against possible blockage of vacuum lines.

5. The attached sketch illustrates the foregoing points.

/6. ...

6. This incident illustrates yet again the need for wearing personal protective equipment, e.g. safety helmets and safety glasses, when working on high pressure equipment, even when apparently depressurised.

I. Everson
Chief Safety Engineer



SAFETY BULLETIN NO. 75

Air Products

SAFETY BULLETIN NO. 102 — 8th February 1971

MORE ACCIDENTS ON OXYGEN EQUIPMENT

Two accidents involving oxygen equipment (not A.P.L.) have been reported recently in the press.

Accident 1

At an oxygen cylinder filling depot a workman had been instructed to rectify a leak from the lid of a carbon steel drier vessel operating at about 2500 p.s.i.g. The escaping oxygen produced a cooling effect resulting in the lid and the top of the vessel being covered with frost. Without heeding the phenomenon or isolating and depressurising the vessel the workman proceeded to tighten nuts on top of the lid. Without warning the lid of the vessel blew out killing the workman.

The accident was due to:-

1. The carbon steel lid becoming brittle due to the low temperature created by the escaping oxygen.

2. Tightening a joint while still under high pressure.

Accident 2

At a steelworks an operator, contrary to instructions, suddenly opened a valve in a 600 p.s.i. oxygen line. The sudden recompression of the gas downstream of the valve caused a high temperature which ignited a filter unit causing extensive damage to the plant.

Recommendations:

1. Carbon steel components, particularly when pressurised, must not be allowed to operate at dangerously low temperatures as indicated by heavy frost build-up. Otherwise a brittle fracture may occur with serious consequences. It should be noted that stainless steels, aluminium alloys and copper alloys are not embrittled by low temperature.

2. Leaks in equipment subjected to high pressures must NOT be rectified. Equipment must be depressurised before attempting repair work.

3. Valves in high pressure oxygen equipment must be opened slowly. Otherwise sudden recompression of oxygen downstream of such valves can create dangerously high temperatures. Also rapid valve opening can cause transient, very high oxygen velocities which can create dangerously high temperatures due to friction.

I. Everson
Chief Safety Engineer

safety

F 152

Air Products

BURCKHARDT OXYGEN COMPRESSOR FIRE AT SSPC ROGNAC PLANT 3/2/71
(ABSTRACTED FROM REPORT JSL/NB - 1293 by J.S. LANBA)

1. Introduction

The oxygen compressor in question was a three stage machine built by Burckhardt's Switzerland in 1948.

The compressor cylinders were lubricated with water. This water was taken from a closed circuit used for cooling a number of machines, including air compressors, etc. This water was cooled in an air cooled heat exchanger. To reduce the sludge accumulated in this circuit a filter had been installed in 1970. This filter had been out of service following severe frost at the beginning of January. Water,taken from this circuit, passed through a demineralising vessel and arrived at the compressor through a copper pipe, 6 - 8 millimetres dia. having passed through several bends and valves. The compressor motor power was 63 Kw and was supplied by three phase 380 volts supply and operated at 1,000 r.p.m. It was suitable for continuous service and was of the totally enclosed variety. This compressor had been in service at the Marseilles plant for a number of years and was moved to the Rognac plant during 1970, and commenced operation about November 1970. After about one week of intermittent operation the compressor suffered a sudden outbreak of fire in its third stage. This was attributed to a steel skirt which was subsequently replaced by bronze in late January. On the 3rd February the compressor was started up and after two hours operation a leak was detected at the third stage. The machine was then stopped for examination. The third stage of the compressor was then stripped down and had replacement fibre piston rings fitted. The last strip down and reassembly of the piston in the third stage cylinder to change the piston rings before the incident were carried out under normal conditions. The various components were carefully degreased with trichloroethylene and then dried before reassembly. The compressor was then reassembled, taking all normal precautions and on the 3rd February the machine was started up. After about ten minutes operation the third stage delivery pressure was about 135 bars when the compressor commenced to vibrate abnormally. A flash was then seen at the upper part of the cooling jacket, flames then began to play on the third stage piston rod and the operator in descending from the platform adjoining the cooling jacket, struck a tool box and hurt himself. He was also burned about the forearms and face. The compressor motor was quickly switched off. The fire was got under control as soon as the purge bottle was emptied in about three minutes.

2. Damage Sustained

The third stage deflector and piston rod were damaged by fire. The upper part of the third stage cylinder piston rod was burnt away. Valves were destroyed, the third stage cylinder liner was burnt and severely, the cylinder head was damaged, studs securing valves had been flame cut, piston and fibre piston rings burnt, the third stage suction piping had been burnt over 20 centimetres.

3. Probable Causes of the Incident

3.1 The low pressure suction piping system including vessels were made of ordinary steel and it is possible that a piece of rust from this source entered the compressor.

3.2 It is possible that the flow of cylinder lubricating water at the moment of the incident was insufficient and perhaps this water contained organic particles.

4. RECOMMENDATIONS:

4.1 Essential recommendations include:

(a) The installation of a filter or strainer in the suction pipe to the first stage.

(b) For lubricating the cylinders, use distilled water from any other source giving water of the same quality, such as demineralised mains water.

(c) It is proposed to be able to visually inspect the water flowing through a glass section illuminated by a light.

4.2 Desirable recommendations include:

(a) To purge the compressor suction piping with a gas having the same dryness as the oxygen intended for the compressor.

(b) During start up use nitrogen in the compressor and close all valves successively.

(c) Install a non-return valve after the third stage to avoid back flow of high pressure gas.

(d) Install a decompression valve between the third stage and the proposed non-return valve.

(e) Install a conveniently located suction valve before the first stage to be immediately closed in case of a compressor accident.

(f) Install a pressure recorder.

(g) Remove the pressure gauges from the compressor and install these in the machine room.

5. Additional Comments by A.P.L. Safety Department

This compressor was being used for cylinder filling. It is of obsolete type not used by A.P.L. Nevertheless useful lessons can be learned from this incident which illustrate yet again the need for scrupulous attention to cleanliness and detail on all oxygen equipment.

I. Everson (Safety Department

J.S. Lanba (S.S.P.C.)

IE/PR

SAFETY BULLETIN NO. 114

13th July 1971

FAILURE OF BRAZED JOINTS IN HIGH PRESSURE GASEOUS OXYGEN LINE AT A CYLINDER FILLING DEPOT

Recently at one of our I.G.D. Depots oxygen cylinders were being filled at their manifold. When the pressure reached about 2000 p.s.i. a loud explosion was heard followed by a rapid escape of high pressure gas. Investigation revealed that the damage occurred in the gas line between the LOX ambient and steam vaporisers and downstream of the latter. Three brazed joints failed due to pipes pulling out of sockets into which they had been brazed. It appeared that the initial failure was at the outlet to the ambient vaporiser. The escaping high pressure gas then caused this pipe to whip violently causing the failure of the second joint. As this pipe was clipped to the outlet pipe from the steam heated vaporiser this too had been dislodged and had wound itself in a three turn coil about an adjacent pipe. A section of pipe about 5 ft. long was found about 20 yards away where it had struck the wooden office building causing some damage. Another section of pipe about 10 ft. long was found on the ground nearby. The metal jackets protecting insulation on adjoining pipes had been struck and damaged by these pipes when in violent motion and also a support bracket had been snapped off and had fallen to the ground. Fortunately no one was injured. The back flow of gas from the cylinders and manifold were quickly arrested by the valve at the manifold inlet which closed once the pressure had decreased to 1000 p.s.i.

Examination of the three failed joints indicated poor quality brazing with lack of penetration. In some instances pipes had been held together only by a combination of friction and the external fillet of braze metal.

Shortly before this incident the ambient vaporiser had been solvent washed when the outlet gas pipe had been unbrazed to enable solvent to be introduced to the vaporiser. Unfortunately, this joint having been brazed after solvent washing was never pressure tested as otherwise the poor quality brazing would have been revealed at that time. This joint probably failed first. The attached photographs illustrate the foregoing.

RECOMMENDATIONS:

1. All high pressure gas and liquid piping must be adequately pressure tested before going into service and after modifications involving remaking joints.

2. High pressure gas piping should be secured by brackets at intervals so that should a joint fail dangerous whipping of the pipe can be prevented.

3. Greater care must be taken in brazing joints as these are not subjected to non-destructive testing so that a defective joint cannot be easily detected. Special attention must be given to ensuring that the brazed components are correctly dimensioned and cleanliness to ensure that the molten braze metal will be drawn by capillary action into the annular gap between the two components to be brazed.

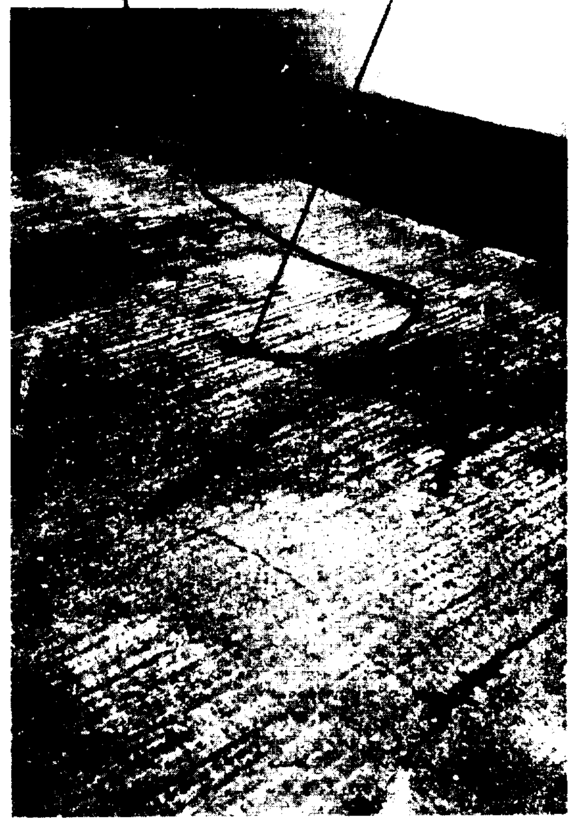
E. Gillett (I.G.D. Engineering)

I. Everson (Safety Department)

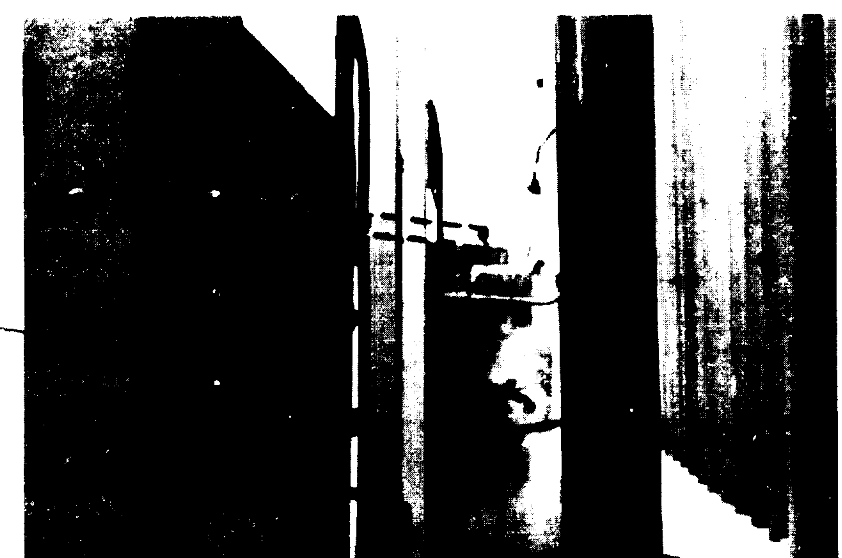
DETACHED PIPE WOUND
AROUND ADJOINING PIPE

THIS PIPE FOUND
7 YARDS AWAY

THIS PIPE FOUND
ABOUT 25 YARDS
AWAY AGAINST
OFFICE BLOCK



LOX AMBIENT
VAPORISER



PIPE PULLED OUT OF
SOCKET AS BRAZED
JOINT FAILED

SAFETY BULLETIN NO. 114

AIR PRODUCTS LIMITED

SAFETY DEPARTMENT REPORT NO. 16

PRELIMINARY REPORT ON ACCIDENT AT ZELZATE PLANT 26TH FEBRUARY 1969 WHEN AN EXPLOSION AND FIRE OCCURRED IN BURCKHARDT CENTRIFUGAL LOX PUMP, TYPE GB114, NO. 29224

I. Everson
P. Cook

28 FEBRUARY 1969

DOCUMENT NOT AVAILABLE FOR GENERAL DISTRIBUTION

AIR PRODUCTS LIMITED

SAFETY DEPARTMENT REPORT NO. 26

REPORT ON EXPLOSION OF LOX PUMP ON TANKER 400-11, 7TH JANUARY, 1970 AT JOHN SUMMERS' STEEL WORKS, SHOTTON. PUMP TYPE GB114, SERIAL NO. 79

B. J. Croxford
I. Everson
R. Naylor

15 JANUARY 1970

DOCUMENT NOT AVAILABLE FOR GENERAL DISTRIBUTION

Air Products

5th May, 1970

To: Dr. D. Spencer: D.C. Head: M. Evans: Miss D. Adjutor: J. Ross, M. West, K. Howlett, Walkden: J. Ingram, Acrefair.

SAFETY DEPARTMENT REPORT NO. 30 (Preliminary)

Accident at T. Turner Ltd., Park Lane, Royton, Oldham, Lancs., 11.40 a.m., Saturday, 2nd May 1970.

An oxygen cylinder supplied by the Walkden Depot was being prepared for attachment to a profile cutting machine at this firm. Mr. N. Woodward aged 42 of 5 Mellor Street, Royton, began to unscrew the cylinder cap when it suddenly exploded into three pieces, one of which struck his left hand removing most of it. Subsequently the remains of the hand were amputated. Mr. R. Smalley aged 26 of 294 Turn Lane, Royton, the profile machine operator, suffered face and chest injuries. However, his condition is stated to be 'not serious'. Mr. J. Ingram, Industrial Safety Officer, and M. West, Sales Engineer, Walkden, visited the premises on Tuesday, 5th May. They interviewed Mr. T. Turner, Managing Director of the Company. Mr. Ingram asked him whether there was any sound of escaping gas while the cap was being unscrewed. The reply was negative. Subsequently, when talking to a police officer, the latter stated that in Mr. Turner's statement to him he stated that escaping gas had been heard before the accident.

The remains of the cylinder cap were inspected. This cap was provided originally for the Calor Gas Company and carries the Company name. This cap is of integral construction and appears to be made of wrought iron. It was not provided with a vent hole. Mr. Turner had no knowledge of whether or not the cap was fitted to the cylinder on receipt from the Air Products driver. He stated that his firm does not use calor gas but does use propane purchased from APL Walkden. He said that caps similar to that which exploded had never been used on his premises and that he is at a complete loss to account for it.

Further investigations were conducted at Walkden. Up to the time of writing this report no one has any knowledge of this cap. However, Mr. Ingram found a similar cap, albeit containing a vent hole, in the cylinder fill building. No explanation was forthcoming to account for the presence of this cap.

The oxygen cylinder and valve were in good condition. The cylinder was last pressure tested in January, 1970, and its paintwork was in reasonably good condition so that there is no doubt about the fact that it did contain oxygen. However, as a precautionary measure Mr. Ingram is despatching the cylinder to Stoke to have its contents analysed.

It should be noted that the threads of the cap are identical with those on the cylinder. However, the cap cannot be fully screwed home because its length is such that it fouls the valve before all threads are fully engaged. Marks on the valve handwheel and on the interior of the cap strongly suggest that the two were in contact. Tests with the cap referred to which was found at Walkden and other gas cylinders indicate that it is possible for the cap to be in contact with cylinder handwheels.

Walkden staff have been requested to check all valve caps to ensure that they are all vented to prevent a repetition of this serious accident.

Further investigations are in hand during which Mr. Ingram will interview the driver who delivered the cylinder in question to Messrs. Turners' premises and all cylinder bay operators in an attempt to account for the calor gas cylinder cap which at the present time cannot be accounted for.

I. Everson,
Chief Safety Engineer.

Air Products

REVISION 1
11.2.71

SAFETY DEPARTMENT REPORT NO. 31

Investigation of Valve Fires at Texas Instruments Ltd., Bedford.

1. Introduction

Up to Friday, 22nd May Texas Instruments Ltd. used oxygen provided by BOC. This was stored in a conventional cryogenic tank. On Friday night at normal finishing time the oxygen tank was valved off and disconnected from the pipeline prior to an APL 125M tank being installed. Texas Instruments also uses other industrial gases e.g. nitrogen, hydrogen and assorted speciality gases.

2. Circumstances Surrounding the Accident

During the holiday between the 23rd and 26th May our 125M tank (max. working pressure 245 psig) was installed in position and filled from one of our road tankers. On opening up the stop valve to allow gaseous oxygen to pass into the house line it was observed that an excessive flow rate resulted causing frosting up of certain components. The causes of this excessive flow rate were then investigated during which three stop valves in oxygen, nitrogen and hydrogen lines were found to be badly damaged by fire and also a pressure reducing valve supplying oxygen to a furnace some twenty yards away was also badly damaged by fire. It is not known when the fire took place nor whether the various valves concerned were damaged by fire simultaneously or in sequence. Replacement valves were then fitted, subsequent to which all equipment has functioned correctly without further incident.

3. Results of the Investigation Carried Out on Friday, 5th June, 1970

3.1 The investigation was conducted by Brian Coleman, Assistant Plant Engineer, Texas Instruments, Jim Shea, District Technician, Edmonton, and the writer. During the course of this meeting brief discussions were also held with Pat Fitzgerald, Safety Officer, and Bill Richardson, Chief Security and Fire Officer.

3.2 A schematic flow sheet depicting points relevant to the incident is attached.

3.3 Although instructions were issued to all departmental managers and other supervisors to shut off all valves prior to finishing work on 22nd May it was apparent from discussions held with several persons that this instruction had not been observed and therefore it is possible that a number of valves were left open during the holiday weekend.

3.4 From a cursory inspection of the plant in the factory it was obvious that great use is made of screwed joints in pipelines in the interests of plant flexibility since it is necessary, for production reasons, to move items of plant from one department to another at short notice. All these screwed joints were possible leak points and it appears that little attempt was made to leak test them. A number of stop valves of the Saunders type are used in various gas lines. In these valves bonnets are screwed to bodies but it is impossible to be certain that maintenance was sufficiently rigorous to be sure that some of these screws had not worked loose, resulting in leakage.

3.5 On bonding machines oxy-hydrogen burners are provided. Apparently no shut off valves were provided in the lines feeding these burners. Reliance was placed upon non-return valves and also flash back arresters in the hydrogen lines. The non-return valves employed metal to metal seats and it is known from experience elsewhere that such valves are ineffective at low pressures. The various furnaces in the factory are never switched off for operational reasons and during the weekend in question the two relevant furnaces were known to be left running at red heat.

3.6 The oxygen, hydrogen and nitrogen stop valves were the Saunders type with rubber diaphragms held together by screws. The severity of damage decreased progressively from oxygen to hydrogen to the nitrogen valve. In the first two cases the rubber diaphragms were completely burnt away whereas in the nitrogen valve the diaphragm showed signs of overheating round its edges but was substantially intact. In the case of the pressure reducing valve V4, the rubber diaphragm was completely consumed, otherwise the damage was limited.

3.7 The factory roof is constructed in the form of domes. Hydrogen leaking from equipment can collect in these domes and there is no easy method of escape since no ventilation is provided at high level. Furthermore, the lighting in that area is of standard commercial variety.

3.8 The hydrogen piping is not given any distinctive colour so that on most parts of the plant it is indistinguishable from other process pipes.

4. <u>Explanation of the Incident</u>

The most reasonable explanation of the incident is as follows. It can be fairly assumed that the hydrogen house line stop valve was left open, so that all hydrogen lines were pressurised to the house line pressure of about 150 psi. It is quite likely that some hydrogen therefore found its way into the burners of the bonding machines. Due to the fact that the oxygen lines were depressurised from the time the BOC tank was removed and the APL tank came on stream the possibility existed that hydrogen then passed into the burner chambers and some of it found its way past the non-return valve into the oxygen line eventually building up a pocket of hydrogen.

When the oxygen house line was pressurised from our tank a combustible oxygen/hydrogen mixture then passed into the general products furnace and the ICD furnace. As the furnaces were running at red heat the emerging oxygen/hydrogen mixture ignited, a flash back occurred through the pipes despite the presence of the flash back arrester and eventually to the region of the stop valve V3, which might well have been left open. The burning mixture then ignited the diaphragm which, in the presence of the incoming supply of oxygen, would have burned vigorously. The flames from this valve then ignited the diaphragm of valve V2 in the hydrogen line, again a vigorous fire occurred due to the presence of both hydrogen and escaping oxygen. In turn the fire from the diaphragm of V2 then damaged the diaphragm of V1. Meanwhile, a similar event was occurring with valve V4.

5. Recommendations

5.1 Each bonding machine burner should be provided with effective non-return valves employing resilient seals. Valves similar to those provided in welding torches are known to be effective and are recommended.

5.2 Individual gas lines feeding bonding machine burners should be provided with stop valves.

5.3 If it is felt that staff cannot be relied upon to close manual valves then suitable automatic valves should be provided which will close once the system pressure falls below some predetermined value. The stop valve in the hydrogen line to the burners could be actuated automatically by low oxygen pressure.

5.4 Joints in hydrogen lines should be welded wherever practicable.

5.5 All screwed demountable joints in hydrogen lines should be pressure tested regularly and any joints made and broken frequently e.g. those associated with machines which are frequently moved, should be soap and water leak tested every time a joint is disturbed.

5.6 All hydrogen lines should be painted a distinctive colour e.g. red, to draw the attention of operations and maintenance staff to them, thus emphasising the need for special care with respect to hydrogen and other combustible gases.

5.7 To alleviate the risk of hydrogen explosions due to hydrogen collecting in the domed roof, each dome should be provided with an open ventilator to allow escaping hydrogen to pass harmlessly to atmosphere.

5.8 The effectiveness of the flash back arresters, with hydrogen/oxygen mixtures both up and down stream, should be verified.

Further Recommendations Resulting from Visiting the Hydrogen Storage Area

5.9 It should be established that the hydrogen storage area can be sprayed with copious quantities of firefighting water.

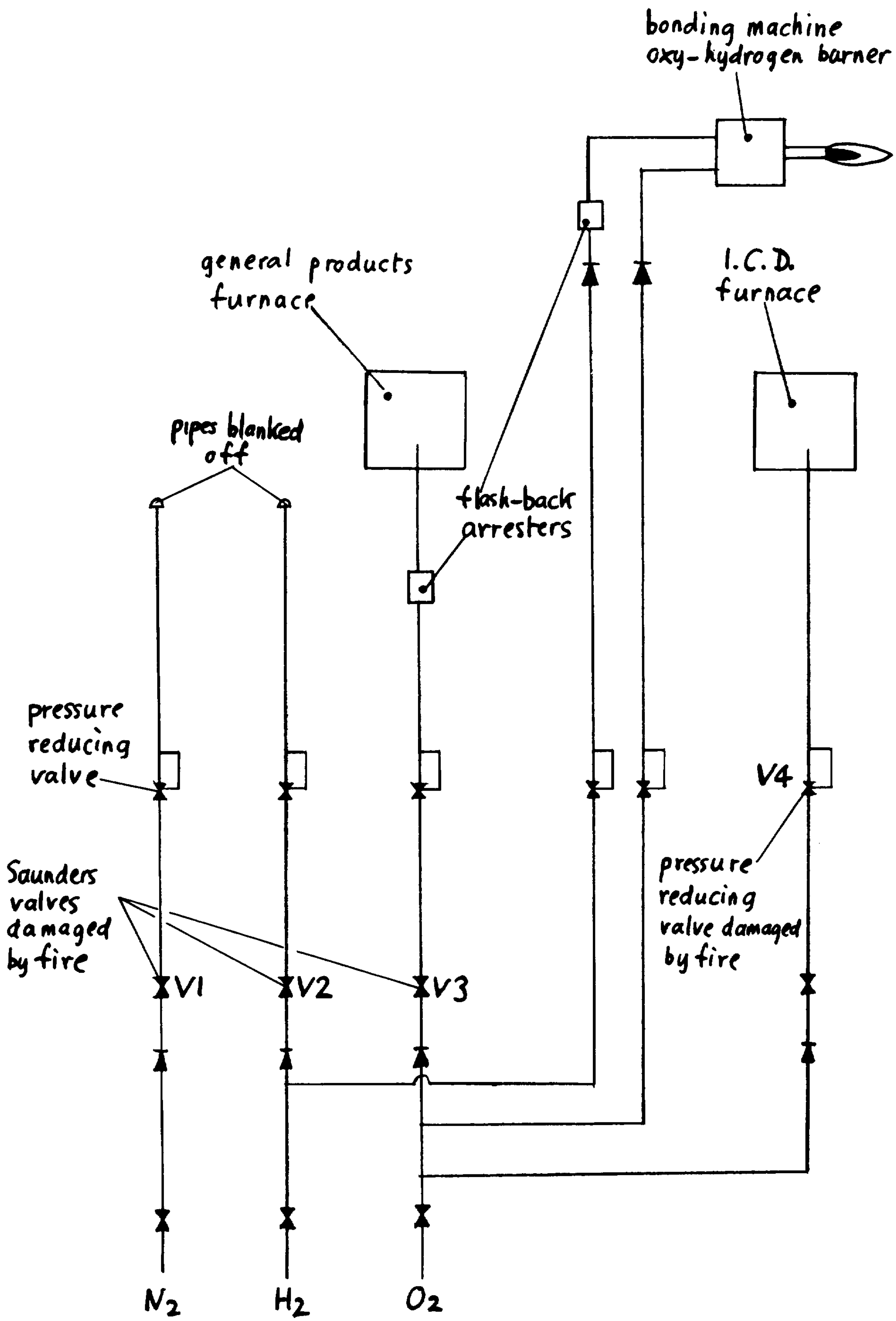
5.10 An extra stop valve is required in the line between the pressure reducing cabinet and the bank of reserve cylinders so that if one or other is rendered inaccessible by fire then the other valve can be used for quickly shutting off the flow of hydrogen.

5.11 Hydrogen trailer earthing arrangements are important and care should be taken to ensure that the earthing clip is not rusty and operates freely and is properly secured to the earthing cable which must be correctly earthed at its other end.

5.12 Arrangements should be made so that the pressure reducing cabinet doors can be secured in the open position so that in the event of a fire, water can be sprayed directly on to equipment housed in the cabinet.

5.13 To assist supervisory staff in obtaining a better awareness of the hazards of industrial gases APL Safety Department should visit Texas Instruments Ltd. and give its standard lecture and demonstration to supervisory staff to illustrate hazards and necessary safety precautions concerning oxygen, hydrogen and other fuel gases. All Texas Instruments supervisory staff concerned with these gases should be invited to attend together with the Safety and Security Officer and, if practicable, members of the local Fire Brigade.

I. Everson,
Chief Safety Engineer.



SAFETY DEPT. REPORT NO.31

AIR PRODUCTS LIMITED

SAFETY DEPARTMENT REPORT NO. 32

EXPLOSION AND FIRE DUE TO THE CRYOSTAR GB114 LOX PUMP ON AN SSPC LOX TANKER

I. Everson

10 July 1970

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AIR PRODUCTS LIMITED

SAFETY DEPARTMENT REPORT NO. 34
(Preliminary)

INVESTIGATION OF CRYOSTAR LOX PUMP EXPLOSION AT STOKE PLANT: 7TH AUGUST, 1970

I. Everson

24 AUGUST 1970

DOCUMENT NOT AVAILABLE FOR GENERAL DISTRIBUTION

AIR PRODUCTS LIMITED

SAFETY DEPARTMENT REPORT NO. 35

REPORT ON EXPLOSION OF CRYOSTAR GB.114 PUMP NO. C.75 ON TANKER 400-11 17TH FEBRUARY 1971 AT THE CARRINGTON PLANT

K. J. Coulson
B. J. Croxford
I. Everson

5 MARCH 1971

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AIR PRODUCTS LIMITED

RECOMMENDATIONS ARISING FROM EXPLOSION OF CRYOSTAR GB.114 PUMP NO. C75 AT CARRINGTON 17TH FEBRUARY 1971 AS REPORTED IN SAFETY DEPARTMENT REPORT NO. 35

W. L. Ball
B. Berrettini
I. Everson
D. K. Griffiths

10 MARCH 1971

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Air Products

2nd June 1971

SAFETY DEPARTMENT REPORT NO. 37

EXPLOSION ON OXY-FUEL BURNER EQUIPMENT AT ALCAN-BOOTH ALUMINIUM WORKS, ROGERSTONE, NEWPORT, MON. 18TH MAY 1971

by

M.C.W. Boynton (District General Manager, Cardiff)

G.I. Brown (District Engineering Manager, Cardiff)

N. Shepherd (Manager, Applied R. & D., Rotherham)

I. Everson (Chief Safety Engineer)

1. Introduction

The oxy-fuel burner and ancillary equipment was mounted on top of a re-melt furnace at the Alcan Booth Works in early 1970. Since that time commissioning has been carried out to overcome certain teething troubles. A successful run was carried out on the morning of 18th May 1971, a subsequent run commencing at about 1915 hours was terminated by an explosion and minor fire on the equipment.

2. Description of the Oxy-Fuel Burner Unit

The burner unit itself made mainly of carbon steel was about 6 ft. long and 3" in diameter consisting of a number of concentric passages. Cooling water was provided to a central passage and also to an outer passage. Fuel oil was admitted down an annular passage immediately outside the central cooling water assembly. Oxygen was admitted in an annulus immediately outside that used for oil. The oil and oxygen was mixed at the tip of the burner, the mixture spraying into the furnace relied upon the prevailing temperature to ignite the oil spray issuing from the burner. As a safety precaution the oil passage could be purged with compressed air from an air receiver fed from the Works compressed air system.

Air and oil were fed separately to a 3 way valve, the outlet passage being used for either oil and air. The attached diagram illustrates the installation schematically. Numerous safety features were provided on the equipment all of which were arranged to actuate the pneumatically operated 3 way valve so as to cut off the oil supply and to purge the burner unit with air. The 3 way valve then fed a signal via the Burrell timer to the pneumatic oxygen shut-off valve which stopped the oxygen flow after a fixed delay of 20 seconds.

The inlet cooling water flow passed through a pair of gauze filters, the intention being that one should be on stream while the other was being removed for cleaning. This was necessary, as it was known that the water supply contained a great deal of particulate matter which would quickly clog the filters.

For maximum efficiency it was necessary to locate the burner tip 12 to 18 inches away from the scrap aluminium being melted in the furnace. The burner could drop under its own weight.Provided it fell slowly, the burner moved under gravity only. However, should its rate of descent exceed a predetermined value then by means of a chain drive and clutch unit the falling burner unit would drive an electric motor which provided the necessary braking. The position on the furnace was controlled by visual inspection of the furnace itself. The motor referred to above was also used for lifting the burner unit from the furnace after operation by pressing either the manual lift or stop buttons.

3. Circumstances Surrounding the Incident

This particular furnace was being used for experimental runs involving changes in combustion conditions inside the furnace which was normally heated by three burners on one vertical face. Customer personnel on the 17th May were using compressed air from the manifold adjacent to the air receiver and reported that they could smell paraffin or fuel oil in the air. No special significance was attached to this statement.

On the 18th May the furnace was run at two conditions. At a high firing rate first with low excess air and then with high excess air.

One successful run was carried out with the oxy-fuel burner at this time. It was intended to start the second run at about 1630 hours. However, some delays took place in charging the furnace but the run commenced at about 1700 hours with one furnace door open as a large billet was protruding from it preventing the door from being closed. The furnace was at the time extremely hot with flames escaping from the open door and through apertures in the furnace roof. The oxy-fuel burner was turned on and ran successfully for about 7 minutes. However, large flames escaped from various apertures so that the run was terminated. It was then noted that the burner moving mechanism had jammed with one chain tight and the other slack. The furnace doors were finally closed and the oxy-fuel turned on again at about 1915 hours. The run lasted between 7 and 10 minutes. During this time the burner failed to function correctly, intermittent operation accompanied by spluttering was reported by customer staff.

About this time a dull plop was heard in the control box containing pneumatic equipment for controlling the oxygen shut-off valve. Smoke was seen to come from the box. The burner was then lowered a further 2 or 3 inches at this time so that it was about 12 to 18 inches from the metal. At this point the burner jammed and the furnaceman ascended to the top of the furnace and agitated the top of the burner unit with the intention of freeing it. He then heard an explosion and upon investigation found that the pipes adjoining the air receiver were red hot. He also observed small flames on top of the platform adjoining the furnace. The furnaceman then turned off the water supply.

4. Extent of Damage to the Burner Installation

4.1 The water cooling system of the burner unit had been severely damaged, 6" or so of the outer jacket had disappeared completely while the bottom of the mushroom in the centre position had also disappeared.

4.2 The flexible oil pipe had broken and was held in position by its metallic braiding only.

4.3 Pieces of the air piping had burst on top of the furnace.

4.4 The air supply pressure regulator suffered severe damage in that its bonnet had been blown off and the supporting pipe bent, presumably by recoil action.

4.5 The pressure relief valve from the air receiver showed signs of severe fire damage and had become detached from the receiver and had fallen to the ground.

4.6 The Saunders type valve adjacent to the manifold had its rubber diaphragm burnt away.

4.7 A globe valve, a little further downstream in the air line, had a hole burnt through the bottom of its body. The adjoining screw connection had been burnt through also.

4.8 A considerable quantity of fuel oil was found in the air receiver having a darker colour and a different smell than normal fuel oil.

4.9 Piping adjoining the air receiver showed signs of severe overheating consistent with the furnaceman's account of it being red hot.

4.10 Two 'O' rings had been burnt away in the water system at the top of the central jacket at the head of the burner unit.

4.11 Both water filters were completely clogged. This must have seriously impeded the flow of cooling water to the burner unit.

5. Tests of the 3 Way Valve at Cardiff Depot

The 3 way valve was tested at Cardiff Depot and up to the time of writing this report, no defect had been found. So far tests have been carried out with the valve immersed in boiling water. Without precise knowledge of temperatures prevailing on top of the furnace at the time of the incident it is of course impossible to conduct realistic tests.

6. Explanations of the Incident

6.1 The condition of the water filters makes it abundantly clear that the water flow must have been drastically reduced in the burner unit so that the intense heat of the furnace eventually caused the metal to melt and burnt away. It was reported that the setting of the low pressure switch had been previously readjusted by customer staff so as not to trip the system.

6.2 It was stated that when inspected immediately after the incident the 3 way valve was correctly set so as to admit purged air into the burner unit with the oil flow turned off. Having regard to the good condition of the 3 way valve it is inconceivable that it could have admitted oil to flow into the compressed air line.

6.3 However, an explanation was readily forthcoming to account for this phenomenon. Apparently, when the equipment was first installed both the oil and compressed air had separate shut-off valves. Unfortunately at that time it proved impossible to find effective non-return valves and it is strongly suspected that during the early commissioning stages oil had found its way into the compressed air line.

6.4 The reports by customer staff that they could smell fuel oil in the compressed air the day before the incident bears out that oil was certainly present before the incident. It is probable that the existence of fuel oil in the air receiver had not been detected earlier as the furnace had been operating normally. It was only just before the incident that the furnace was operated at elevated temperatures. This fact is regarded as highly significant.

6.5 Inspection of the equipment indicates that the various pipe lines to the burner unit ran on top of the furnace where it is reported that extremely high temperatures existed. It is known that the flash point of this fuel oil in air is about 150°F (65°C). It was stated by one of the customer's staff that fuel gas temperatures from the furnace was in the order of 1200°C. Also it was known that flue gases were escaping through apertures in the furnace lining. Had this hot gas impinged upon the oil contaminated compressed air line combustion would certainly have taken place.

6.6 Another explanation on the same lines can be found to account for the fact that ignition might have commenced in the air receiver. The shop compressed air line to the air receiver runs above the top of the furnace. Below this compressed air line a section of the furnace juts out from the main furnace wall into which a vacuum suction pipe is subsequently lowered for syphoning away molten metal. This part of the furnace was full of red hot molten aluminium so that hot air rising from it could easily have been at a temperature of several hundred degrees Centigrade. This air was observed to flow over the air line feeding the air receiver. Consequently, as compressed air was used by the customer's staff the incoming compressed air was obviously heated to a high temperature and at first caused vaporisation of the oil which would account for the smell of the compressed air, the temperature increased until eventually ignition could have occurred within the air receiver. This latter explanation appears to be more probable in view of the damage pattern.

6.7 While the cooling water failure was not of major significance, nevertheless the low pressure trip had operated so that the 3 way valve would have communicated the compressed air line with the top of the burner unit. If this coincided with the explosion then clearly the resulting pressure pulse could have damaged the flexible oil pipe as reported.

7. Recommendations

7.1 Although there is no reason to suspect the 3 way valve nevertheless to remove a possible means of oil entering the compressed air line and vice versa, this valve will be replaced by a pair of separate valves driven from a common shaft.

7.2 Effective non-return valves are required for oxygen, oil and compressed air lines. In view of the high operating temperatures these should preferably be of a simple gravity operated metal-to-metal seat type. Resilient seats should not be used. Fresh advice will be sought from the appropriate company specialist.

7.3 As part of the initial servicing of the equipment after 6 months and 12 months service, the compressed air and oxygen lines should be solvent washed to verify that they are free of oil. If no untoward effects are observed after 12 months operation, it can reasonably be inferred that the non-return valves and control system are functioning correctly and that solvent washing can be terminated.

7.4 The servicing of the water filters must be done on a regular basis to ensure that cooling water flow is unimpeded at all times.

7.5 The rubber 'O' ring in the bottom flange of the burner unit should be made of a heat resisting substance. A rubber 'O' ring in that position would have a very limited life due to the high operating temperatures consequent upon heat escaping from the furnace through the burner hole.

7.6 To reduce the possibility of oxygen entering air or oil lines consideration should be given to reducing the 20 second delay before the oxygen shut-off valve closes as much as possible.

7.7 All piping running on top of the furnace should be rerouted to be in the coolest possible position. Further protection in the shape of a metal trough should be provided to prevent hot air impinging upon the pipes.

7.8 All wiring to this burner unit should be rerouted, neatly run and protected against excess heating, bearing in mind the fact that the best available commercial insulation (Class II) has an operating temperature of 125°F. in comparison with the 1200°C. flue gas temperature. Clearly this wiring must be protected from excess heat.

8. Conclusions

(a) This incident can be rationally explained and clearly took place due to a combination of circumstances which could reasonably have been predicted.

(b) Provided the simple recommendations above are followed, there is no reason why this equipment should not give entirely satisfactory service.

(c) It is particularly important to protect the process piping and electrical equipment from excessive heat arising from the furnace.

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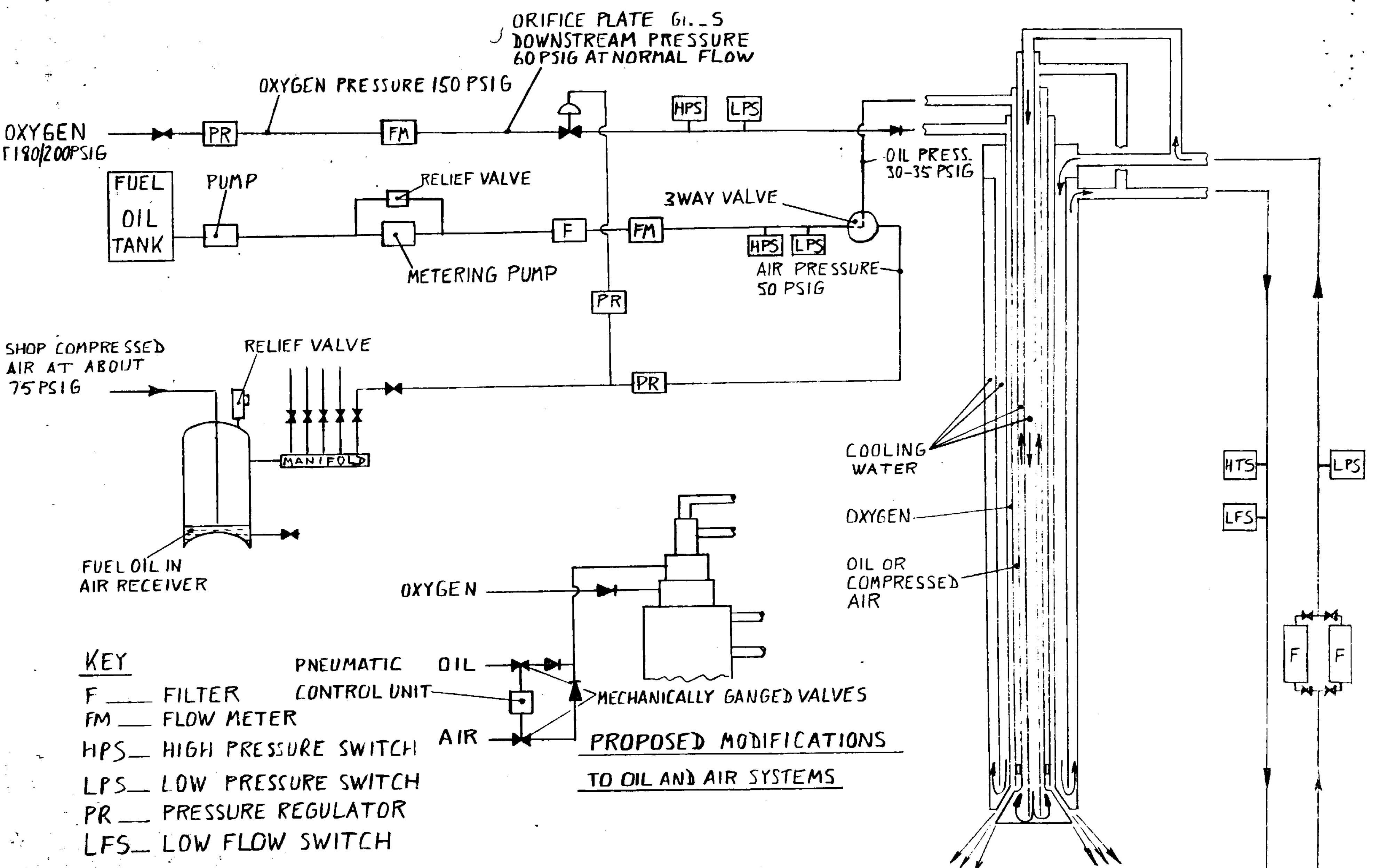

OXY-FUEL BURNER INSTALLATION

SAFETY DEPARTMENT REPORT NO.3

FURTHER POINTS ARISING FROM THE MEETING HELD AT ALCAN BOOTH, ROGERSTONE, 3 JUNE 1971

1. Fuel oil was found on the bottom of the control box containing pneumatic equipment for controlling the oxygen shut-off valve after a minor explosion was heard. This confirms that fuel oil was present in the compressed air line.

2. The air receiver was inspected internally on 3 April 1970 while the 3 way valve was installed in place of separate air and oil valves in late May 1970. Thus it is probable that some fuel oil found its way into the air receiver during April/May 1970.

3. It was estimated that 1 - 2 gallons of oil were present in the air receiver.

4. ALCAN-BOOTH stated that the air receiver was bled regularly but that no fuel oil was ever reported. APL pointed out that if the drain valve was opened for a very short time then only condensate would escape as the oil would float on top of the condensate.

5. ALCAN-BOOTH stated that the black marks inside the air receiver could have been caused only by oil flowing over a hot surface i.e. after the fire/ explosion. APL suggested that this was consistent with the explanations put forward in that after an explosion, pressure waves are often accompanied by rarefaction waves so that any oil trapped in the manifold or piping would be sucked back into the air receiver causing the black marks.

6. The water filters had not been cleaned for some months.

7. The 3 way valve had been tested by APL immersed in boiling water using correct oil and air pressures. It was impossible to interconnect the oil and compressed air lines. APL concluded that this valve could not have accounted for the presence of 1 - 2 gallons of oil in the air receiver bearing in mind that the oil hold up between the valve and burner tip is only about 1 pint. Under certain conditions some of this oil could find its way into the compressed air line.

8. The normal oil flow rate to the burner is about 50 gals/hr.

9. For stoichiometric combustion each gallon of oil requires 330 cubic feet of air. To give a slightly reducing atmosphere the air was reduced to 300 cubic feet per gallon of oil.

Additional Recommendation

As a safeguard against interruption of the compressed air supply, a stand-by source of purge gas is recommended e.g. from high pressure cylinders.

Attempted Analysis of Oil Sample Taken from the Air Receiver

This is appended and indicated that both fuel and compressor lubricating oils were present.

(Retyped 9/28/72 sba)

Air Products	**ENGINEERING SPECIFICATION**	No. M.02 PAGE CONT. ON COVER SHEET REV 2

TITLE CONSTRUCTION SPECIFICATION FOR PIPING ERECTION, TESTING AND CLEANING

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REV	DESCRIPTION	DATE	ORIGINATOR	APP
2	4.7.1.2 added. A.3 amended	19.4.71.		
1	Para 5 amended. Para 4.1.6 + 10 added			
1	Para A6 of Appendix I added, Metric Dimensions added.	1.12.70.		
0	ORIGINAL ISSUE	1.7.70.		

APPROVED BY	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER
Original	D. Hinton	C.H. Bloom	K. Wilson	M. Supple

F.911

TITLE Construction Specification for Pipework Erection, Testing & Cleaning

INDEX

TITLE Construction Specification for Pipework Erection, Testing and Cleaning

1. PURPOSE

This specification states the requirements for the erection, testing and cleaning of piping systems, fittings and valves.

2. SCOPE

This specification applies to ferrous and non-ferrous pipework for liquids and gases at all temperatures between -450°F. and +700°F., (-267°C. and +370°C.) excluding plastic piping.

3. CODES AND STANDARDS

3.1 All workmanship, materials, testing and inspection shall be in accordance with ASA B31.3 latest edition.

3.2 All welding and brazing operatives shall be qualified in accordance with A.S.M.E. Section IX, by an approved authority for the appropriate material and technique. All valid qualifications shall be submitted to the Engineers Representative before work commences. APL form WG2-2 may be used to record Welder Qualification Tests where these are made on site.

3.3 Any items mentioned in this Specification are in addition to, or in clarification of, the relevant codes and do not replace them.

4. WELDING AND BRAZING

4.1 Backing Rings

4.1.1 Backing rings shall not be used in stainless steel and carbon steel pipes carrying oxygen (designated SSO & CSO).

4.1.2 Backing rings shall not be used for piping 2" n.b. (50 mm) or smaller.

4.1.3 Backing rings may be used for all other stainless steel and carbon steel joints. Where backing rings are not used, including oxygen lines, the root run, is to be performed by the inert-gas shielded arc method, with interior gas purge.

4.1.4 Backing rings may only be used for aluminium or aluminium alloy butt joints where they are an aid to fitting in confined spaces, or at the discretion of the Engineers Representative. On single 'V' or single 'J' preparation butt joints, the root run with full penetration bead is to be performed by the "inert gas shielded arc process (T.I.G. or M.I.G).

4.1.5 Backing strip in all materials will be supplied by the Employer.

4.1.6 When backing rings are not used the contractor must ensure that the pipe bore is not restricted by excess of weld metal, icicles and weld splatter.

4.2 Aluminium

4.2.1 Aluminium pipe shall be cut only by mechanical devices.

4.2.2. All welding of aluminium pipe shall be performed with the inert gas shielded arc process, using T.I.G. method with A.C. High Frequency Current, or M.I.G. method. A purge of similar inert gas shall be maintained on the interior of the line during the root weld process wherever possible.

4.3 Stainless Steel

4.3.1 Stainless steel unless prepared by a mechanical means shall be ground back 1/16" (1.6mm) before welding. Cutting with an oxyacetylene torch shall not be permitted.

4.4 Brazing

4.4.1 Brazing wire used shall be Easy Flo No. 1 Solder manufactured by Johnson Matthey & Co. or approved equal. Brazing flux shall be Easy Flo green label or equivalent. Solder joints shall be kept as far as possible from threaded joints to prevent destruction of the thread seal.

4.4.2 Fittings once brazed shall not be re-used.

4.5 Valves

Prior to welding any valve into a pipeline, the contractor shall open the valve fully, and take precautions to prevent thermal distortion of the valve and its components.

4.6 Joint Identification

All welded and brazed joints shall be identified by the operative with his stamp and a serial number. For example "T.22" would have been done by welder "T" and be his 22nd consecutive weld on the Contract.

4.7 Radiography and Inspection

All materials and workmanship shall be inspected by the Engineer's Representative in accordance with ASA B31.3 at any place where fabrication and erection is performed. Any defective material or workmanship shall be corrected to the satisfaction of the Engineer's Representative at the Contractor's cost.

4.7.1 Radiography

4.7.1.1 On completion of the first ten production welds made by each welder in each material in either 2G or 5G positions (ASME IX-para Q3) two welds shall be completely radiographed. Two per cent of the remainder of the welds made by each welder with a minimum of five welds shall be radiographed. Each film shall be marked with the line and weld number and shall be to the satisfaction of the Engineer's Representative.

If any radiograph is unsatisfactory, two further radiographs shall be taken.

2 4.7.1.2 All joints between prefabricated spool pieces and all closing joints shall be subject to 100% X-Ray.

4.7.1.3 If any weld is not the standard given in ASA B31.3 it shall be cut out, repaired and radiographed. All costs involved in making such a repair shall be borne by the Contractor.

4.7.2 Socket Weld Fittings and Brazed Joints

At the discretion of the Engineer's Representative, a maximum of 5% of socket welds per welder, and brazed joints shall be cut out, sawn in half and inspected. Should any of these be unsound, then further welds or brazed joints shall be cut out and inspected until it is established that all are satisfactory. The cost of cutting out and replacing shall be borne by the Contractor.

5. THREADED JOINTS

Teflon tape shall be used for joints operating up to 240°C., but not above this temperature. No other sealant is allowed in this range. A seal weld is recommended for temperatures above 240°C.

6. VALVES AND BELLOWS

6.1 Globe valves shall normally be installed so that the disc will close against pressure. On reactivation circuits some valves will be installed counterflow and these will be marked with an arrow and the letter 'P' on the drawings.

6.2 Bellows assemblies shall be installed in accordance with the notes on the isometric drawings. The Contractor shall request the Engineer's Representative specifically to inspect installed bellows, before the plant pressure test.

7. <u>CLEANING AND STORAGE</u>

7.0.1 Proper cleaning of all equipment in contact with oxygen is absolutely essential. Ineffective cleaning can result in loss of life and damage to equipment. If any doubt exists as to whether oxygen equipment has been contaminated or insufficiently cleaned, it shall be recleaned at the Contractor's cost.

2 7.0.2 The Contractor shall clean all piping fittings in accordance with the contract drawings and specifications.

7.0.3 Valves required to be cleaned to Classification AA cleanliness will normally be delivered in that condition.

7.0.4 Where valves are required to be cleaned on site this will be shown in the Valve Summary. The recommended method is given in Para A.6. Any cleaned material that is not to the approval of the Engineer's Representative shall be recleaned at the Contractor's expense.

7.0.5 Cleanliness of materials is classified into 3 groups:

Service Materials	-	Classification B Cleanliness
Process Materials	-	Classification A Cleanliness
Oxygen & Cryogenic Materials	-	Classification AA Cleanliness

7.1 Classification B Materials shall be considered clean when they are visually clean under bright white light.

7.2 Classification A Materials shall be considered clean when they are:

7.2.1 Visually clean under bright white light.

7.2.2 Free from loose particles or potentially loose particles, paint and other protective coating.

7.2.3 Free from grease - wiping with a clean white lint free cloth, or pulling through shall detect no trace of oils of grease on the cloth.

7.3 Classification AA materials shall be considered clean when they conform to the following:

7.3.1 Visually clean under bright white light and ultra violet light.

7.3.2 No internal surface when inspected under bright white light shall contain any loose particles capable of being brushed off by hand with a soft nylon brush and blown off with an air jet.

There shall be no potentially loose particles which exceed 0.5mm in two directions and 0.2mm in the third plane.

7.3.3 All surfaces must be completely dry.

7.3.4 All surfaces shall be free of all discolouration other than that which is due to the metal.

7.3.5 Black light Test - Internal sources shall be free of any fluorescence, other than isolated spots of lint and dust, detectable by ultra violet light having a wave length of 3600 Angstroms when viewed in the dark. The U.V. lamp will be supplied by the Employer.

7.3.6 Wipe Test - Internal surfaces shall be wiped with a clean white lint free cloth and the cloth inspected to ensure the absence of any oils not detectable by black light, or residue discolouration, fibres etc., not previously detected. The cloth may be dipped in trichlorthylene or methylene chloride before wiping.

7.4 Cleaning Methods

Suggested cleaning methods are described in Appendix 1.

7.5 Storage

7.5.1 All valves and fittings shall be stored indoors. Protective packages labelled 'Decontaminated for Oxygen Service' or similar, shall not be removed until the equipment is to be installed. If removed, or damaged, at the discretion of the Engineers' Representative the item shall be recleaned by the Contractor at his cost.

7.5.2 During construction all cleaned materials shall be maintained clean until the installation is accepted by the Engineer's Representative. Both in storage and during installation open pipe ends and vessel nozzles shall be sealed with clean polythene sheeting.

8. PRESSURE TESTING & PLANT BLOWOUT

8.1 <u>Pressure Testing</u> (Process Piping)

All process piping will be pneumatically pressure tested under the supervision of the Engineer's Representative. Both leak tests, and a 12 hour drop test will be made with oil free air or nitrogen supplied by the Employer.

In preparation for and during the pressure testing the Contractor shall:

8.1.1 Instal test relief valves, gauges, blanks supplied by the Employer, and make other minor modifications to the plant as instructed by the Engineer's Representative.

8.1.2 Soap all joints to locate leaks, repair any leaks found, and re-soap repaired joints to the satisfaction of the Engineer's Representative and the relevant Inspecting Authority.

8.1.3 On completion of the pressure test restore the plant to its normal working condition.

8.2 <u>Pressure Testing</u> (Utility Piping)

The Contractor shall hydraulically test utility piping such as steam and water, at 1.5 times design pressure after installation and repair any leaks at his own expense.

8.3 <u>Blow-Out</u>

Either before or after the pressure test, the plant will be blown out to remove any waste.

The Contractor shall:

8.3.1 Undo and afterwards replace, certain flanged joints as instructed by the Engineer's Representative to allow blowout.

8.3.2 Afterwards thoroughly clean out any part of the system showing an accumulation of waste material.

9. <u>PROCESS PIPING ISOMETRICS</u>

Dimensions on isometric sheets are based on geometric calculations and no allowance has been made for fabrication and erection tolerances. The Contractor shall prepare and assemble the prefabricated piping allowing for such tolerances and any alterations necessary, because the prefabricated piping does not mate correctly, shall be carried out at the Contractor's cost.

10. PIPE SUPPORTS

Where pipe supports for piping below 2" n.b.(50mm) are not specifically detailed on the drawings, the supports shall be supplied, fabricated and installed by the Contractor at no additional cost to the Employer.

A.1 All Materials

Remove any coating of paper, lacquer, varnish, paint ect., scrub out the pipe with a dry cylindrical brush, and blow out with air. Where an internal coating is to be removed, such coating shall be removed from pipe or fittings before that item is welded.

A.2 Grade A Cleanliness - Carbon Steel

A.2.1 Immerse the pipe in an approved chemical descaling solution, and when descaled wash out with clean water. Hydrochloric acid may be used for extensive descaling.

A.2.2 Pacify in a 4% phosphoric acid solution, and wash in clean water and dry.

A.3 Grade AA Cleanliness - St. Steel, C. Steel, Copper, Aluminium

2 For carbon steel this procedure may be necessary following that outlined in paragraph A2 where it cannot be seen that the internal surfaces of the piping are clean.

A.3.1 Wash out or scrub out with a nylon brush, pipe and fittings with trichlorethylene or methylene chloride until clean.

A.3.2 Pull through with a clean lint free cloth. Do not re-use the cloth.

A.3.3 For small bore pipe do not pull through, but drain, and blow out with dry oil free air or nitrogen.

A.3.4 Seal the pipe ends with polythene sheets.

A.4 General

A.4.1 When random lengths of pipe are prefabricated, the chemical cleaning (Para A.2 and A.3) shall be carried out after prefabrication. The pipe ends and fittings and backing rings when used shall be wiped clean with a trichlorethylene soaked rag and the trichlorethylene allowed to evaporate prior to welding.

A.5 Trichlorethylene

The grade of Trichlorethylene shall be I.C.I. Grade 4 inhibited or equivalent.

A.6 Valves

Dismantle valves and match mark all parts. Decontaminate the parts with new and clean methylene chloride or trichlorethylene, handling them only with clean lint-free gloves. The parts are considered degreased when they conform to Para 7.3. Re-assemble valves with degreased tools, tag the valves, and pack in a polythene bag to maintain cleanliness. Label "Degreased for oxygen service".

[redacted]

ENGINEERING SPECIFICATION

No. M.02
PAGE CONT. ON
REV APPENDIX II

TITLE ELECTRONICS AND WELDING WIRE.

All electrodes and welding wire shall be stored in sealed containers in a dry room. Opened packages of electrodes and welding wire shall be kept in heated storage and protected from deterioration and damage until immediately before use.

Electrodes and welding wire showing signs of damage shall not be used.

MATERIAL	WIRE OR ELECTRODES
1) **Aluminium/Manganese Alloy**	
NT5 to BS 1470/77-1955, ASTM GR 40A AA5154 (P22) (Pipe)	NG6 to BS 1475-1955, ASTM GM 41A, AA 5456 (F22)
NP8 to BS 1477 (Plate)	N6/1 to BS 1475 or ASTM SB/ER5183
2) **Stainless Steel**	
EN 58E, ASTM SA 312.TP304	BS 2901 A8, ASTM SA 371, or BS 2926-A ASTM A298(F5)
3) **Carbon Steel**	
Mild Steel BS 1501, ASTM-SA-285	BS 2901-A16 and A17, ASTM SA 233, BS 1719

TITLE PIPING LINE DESIGNATIONS

Line Designations

Each line will be designated as in the following example.

2-O-321-SS 2.7.

This is explained as follows:

2 is the nominal pipe or tubing size in inches not (OD) the piping bill of material gives the complete description.

O is the line service letter for the fluid in the line (oxygen). See listing of fluid designations.

321 is the line number. Generally, line numbers go from equipment piece to piece.

SS 2.7 - The piping material and pressure class. (SS is stainless steel 2.7 is 270 psig. nominal class).

Piping Material Designations

AL	Aluminium Alloy	CT	Copper Tube
CSO	Carbon Steel Oxygen	ICT	Instrument Copper Tube
CSS	Carbon Steel Steam	SS	Stainless Steel
CS	Carbon Steel	TA	Tungum - Alloy

Fluid Designations

A	Air	P	Propane
C	Caustic	R	Argon
F	Freon	S	Steam
G	Petrol	CD	Carbon Dioxide
H	Hydrogen	FG	Feed Gas
HE	Helium	NG	Methane or Natural Gas
N	Nitrogen	PW	Potable Water
O	Oxygen	WG	Waste Gas

Air Products	I. G. D. ENGINEERING MANUAL	No. EM 56 - 06 Rev. 0 PAGE 1 CONT. ON 2

Solvent Washing of Piping Systems

0	ORIGINAL ISSUE	3.7.71.	E.Gillott	
REV.	DESCRIPTION	DATE	ORIGINATOR	APPRO

ORIGINATOR	DATE	APPROVED BY	SECTION HEAD		I.G.D. ENG. MANAGER

APCI DOCUMENT NO. 99000391

F.482

1. Purpose

To establish an operational procedure for solvent washing piping systems, both high and low pressure, and to ensure their cleanliness for oxygen service.

2. Associated Standards

A.P.L. Specifications A03 and M02.

3. Responsibility

It is the responsibility of the District Engineering Manager to supervise this operation and to be certain that the procedure is followed.

4. Reasons for Cleanliness

Any materials that will burn in air will burn more freely in oxygen, which vigorously accelerates combustion to the point of explosion and also reduces the temperature at which fire can start. Oils and greases at very low levels of surface contamination varying from as little as 7 milligrams per square foot to 300 milligrams per square foot may ignite, and do not become visible under white light until the contamination level reaches about 500 milligrams per square foot.

A piping system can be properly clean and put into service, but may later sustain contamination during use when other imperfectly cleaned or unsuitable equipment is connected to it. Also hydrocarbons are soluble in LOX at very low levels, these hydrocarbons may be released when the oxygen is vaporised and an unacceptable contamination level may be built up, particularly at liquid/gas interfaces.

5. Materials for use

Only materials suitable for low pressure oxygen service may be used for this solvent washing procedure, P.V.C. and Polyethylene may not be used, unplasticised nylon and P.T.F.E. tubing for making connections are permitted.

6. Solvent

I.C.I. Trichlorethylene Grade N only.

7. Method

7.1. If the piping system incorporates an item of a complicated nature, for example a reciprocating or centrifugal pump, regulator, backpressure valve etc, it must be removed from the system and a shorting connection made.

7.2. The equipment thus removed is to be degreased to A.P.L. Spec. M02 Appendix I except that Trichlorethylene I.C.I. Grade N is to be used. Pumps should be returned to Acrefair to be washed.

7.3. Study the system to select the best entry point and flow direction, it is desirable that each section of the pipework should be filled with solvent before the next section begins to be filled. Note also the location of valves that can be used to purge air from the system as it is filled. Make an estimate of the total internal surface area and record it.

7.4. Take a 500 ml. sample of the clean solvent in a previously carefully cleaned and suitable container (see section 5), close and seal it and label it.

BLANK - SOLVENT WASH AT "X" - "DATE"

7.5. Pump trico into the system via the previously selected point, ensure that all purge points are closed in sequence as trico appears. Collect the solvent at the outlet.

7.6. Take a sample of the used solvent in a container similar to that mentioned in 7.4. and compare the two against a white background under bright white light and under U.V. light of 3600 angstroms wave length in the dark. If there is discolouration,particles can be seen in the solvent or flourescence reject it for further use. Repeat the wash once after the solvent is seen to be contamination free reusing the solvent. If, on the second pass, the solvent fails the test renew it and continue washing until the second pass produces satisfactory test response. Finally wash through with completely fresh clean solvent.

7.7. Using nitrogen blow out and collect the solvent, continue blowing nitrogen through until all traces of solvent have disappeared. Draeger detector tubes may be used if difficulty is experienced in determining the absence of solvent. Check the system for cleanliness to A.P.L. Spec. M02.

7.8. Take a sample of the final wash solvent as in 6. label -

FINAL WASH SAMPLE AT "X" - "DATE"

Despatch both blank and final wash sample to Stoke Labs. for check.

7.9. Record the amount of solvent used in the final wash.

7.10. Close up the system maintaining oxygen cleanliness methods. Where high pressure joints have been remade the system must be hydraulically tested to 1.5 times max. working pressure. Use only drinking water and oxygen safe equipment. Purge out with warm nitrogen and ensure dewpoint of better than $-63^{\circ}F$ before handover for operation.

For systems operating at up to 300 psig pneumatic testing may be employed providing the proper precautions are taken.

8. Certificate

Issue a memo certifying the solvent wash, the date, surface area washed and quantity of final wash solvent together with a copy of the result of the Stoke Lab. report to,

District General Manager
District Distribution Manager
IGD Engineering Manager

TLE: GENERAL PROCEDURE FOR DECONTAMINATION OF STATIC TANK AND ROAD VEHICLE ASSEMBLIES FOR O_2 SERVICE.

1.0 Standards

1.1 All decontamination and inspection shall be carried out to achieve Engineering Standard A03 cleanliness.

1.2 The interior of vessels shall be decontamination in accordance with procedures Q.12 and Q.13 respectively.

1.3 Sealing of open pipe ends etc. after degreasing shall be effected by wrapping with clean polythene and fixing with black tape. The manufacturers plastic inserts may be used for screwed or socketed connections on valves etc. but these must be clean and in good condition.

1.4 Seals shall only be removed immediately prior to making the end joint with another decontaminated component or assembly.

In the case of piping which runs from the inner vessel and penetrates the outer, the seals may be removed to enable joints to be made between the pipe and the inner vessel and the pipe and penetration point. The bore of the pipe is to be examined for loose particles and signs of contamination immediately after the joint is made and if satisfactory, is to be sealed.

1.5 Any item discovered without sealing or not satisfactorily sealed shall be declared contaminated and shall be returned for decontamination and inspection.

1.6 All decontaminated items shall be labeled with the "Degreased for Oxygen Service" label and the label must bear an inspectors' stamp.

2.0 Valves

Properly sealed and decontaminated valves shall be maintained in the sealed containers until ready for final assembly with the decontaminated piping assembly.

2.1 On soft seal valves where it is necessary to unscrew the bonnet and remove the seat or disc in order to make a heated joint on the body, the opening of the valves shall be done under clean conditions and the parts which are not being worked on may be bagged and re-sealed.

2.2 Valves opened under conditions other than 2.1 shall be declared contaminated and must be completely stripped, decontaminated in piece-small and re-assembled under clean conditions before re-sealing.

3.0 Piping

After forming, each piping length, including pipe fittings, shall be decontaminated, inspected and sealed in accordance with Procedure Q.12.

3.1 Piping connected to the inner vessel shall be examined visually when the tape is removed from the nozzle connection during decontamination of the vessel. If the pipe is found to be contaminated at this stage, it shall be washed through with an approved cleaning agent and then blown out with clean dry air or nitrogen to remove loose particles and traces of the cleaning agent.

cont/.

3.2 All pipes connected to the inner vessel are to be blown out with clean dry air or nitrogen prior to assembly with cabinet piping and after final pressure testing.

3.2.1 Pressurize vessel and interspace pipework to highest pneumatic pressure quoted on the vessel drawing for pneumatic strength test.

3.2.2 Release pressure to leak test pressure and carry out soap and water leak testing required.

3.2.3 Release test air through all pipes into the vessel at maximum velocity obtainable in order to ensure all loose particles are removed from piping system.

3.2.4 After assembly of cabinet control piping the test air used for pressure testing the cabinet pipework system should again be blown down through all pipes at maximum velocity to remove any possible debris left during piping assembly.

4.0 Certification

The Inspectors responsible for checking the decontamination of the inner vessel and the final blowing out of the pipework shall certify on the 'Decontamination Record' that the requirements of this standard have been fulfilled.

TITLE: MANUFACTURING QUALITY PROCEDURE FOR DEGREASING OF PIPEWORK.

A. STAINLESS STEEL

1. Remove loose particles from pipe, as far as possible by blowing through with air.

2. Pump through with Hot Alkaline (APPLIED CHEMICALS 5.57).

3. Rinse by pumping through with cold water.

4. Visually inspect pipe with white light.

5. In cases of small bore piping a wash with Trichloroethylene should be taken and examined with U.V. lamp after evaporation.

6. The pipes should then be dried and examined again with white light and with U.V. lamp to achieve standards of Specification A03.

7. Blow through with clean, dry filtered air to remove any loose particles.

8. Seal pipe with tape and/or polythene sheet.

B. ALUMINUM PIPE

1. Remove loose particles from pipe as far as possible by blowing through with air.

2. Pump through with hot water to remove soluble grease from pipe bending, etc.

3. The pipe should then be given a caustic wash by pumping through with I.C.I. Sodium Hydroxide Solution. (10%).

4. Rinse pipe with cold water.

5. Wash pipe through with 10% solution of Nitric Acid to kill caustic.

6. Rinse with cold water.

7. Examine pipe with white light.

8. In cases of small bore piping a wash with trichloroethylene should be taken and examined with U.V. lamp after evaporation.

9. The pipes should be dried and examined again with white light and with a U.V. lamp to achieve standards of Engineering Standard A03.

10. Blow pipe through with clean, dry air to remove any loose particles.

11. Seal pipe with tape and/or polythene sheet.

cont/.

C. COPPER TUBE

1. Remove loose particles as far as possible.
2. Boil in Alkaline Solution (APPLIED CHEMICALS 5.57) for a minimum period of 30 minutes to remove flux.
3. Rinse with cold water.
4. Acid wash with Applied Chemicals 2.25.
5. Rinse with cold water.
6. Examine pipe with bright white light.
7. The pipe should then be dried and examined again with White light and U.V. light to standard of Specification A03.
8. In case of small bore piping a Trichloroethylene wash should be taken and examined with U.V. lamp after evaporation.
9. Seal with tape and/or polythene sheet.

NOTES:

(a) Any pipe that is examined and not up to standard should be re-degreased and the entire process repeated.

(b) Any pipe found with the seal removed or damaged after degrease should be returned and re-degreased and entire process repeated.

(c) All pipes, when degreased and passed as clean, should be labeled "Degreased for Oxygen Service" and this label must bear an Inspector's Stamp.

(d) Dry oil free Air or Nitrogen must be used in all cases when pressure testing de-contaminated piping.

TITLE MANUFACTURING QUALITY PROCEDURE FOR INTERNAL CLEANING OF ALUMINUM TANKERS & STATIC TANKS FOR OXYGEN SERVICE.

1. Vessel pipework to be degreased part small i.e. before welding to vessel, (SEE PROCEDURE NO: Q11).

2. Ensure stub ends of pipes in vessel are covered with tape.

3. Remove spatter and loose particles from vessel walls. Brush vessel out.

4. Cold wash vessel with 'Aloclene 100' (Sunbeam Chemicals).

5. Rinse with pottable water.

6. Mop up any residual water with clean 'lint-free' cloth.

7. Remove tape covering stub-ends from inside vessel.

8. Allow surfaces of vessel to dry as quickly as possible. Clean filtered warm air may be used.

9. Check internal surface of vessel and nozzles with bright white light to Engineering Standard A03.

10. Check internal surface of vessel and nozzles with U.V. lamp to Engineering Standard A03.

11. Ensure manway cover is degreased before fitting to vessel (Check with U.V. lamp).

12. When vessel has been cleared by an inspector a label 'Degrease for Oxygen Service' bearing an inspector's stamp, should be attached to the vessel.

NOTE: 1. For Hydraulic test after degrease use pottable water.

2. For Pneumatic Test after degrease use dry oil-free Air or nitrogen.

3. After Pneumatic Test allow air to discharge rapidly through every pipe to ensure all possible debris is removed.

ITLE MANUFACTURING QUALITY PROCEDURE FOR INTERNAL CLEANING OF 9% NICKEL AND HI-PROOF STAINLESS STATIC TANKS FOR OXYGEN SERVICE.

1. Vessel Shells and Heads are to be free from scale and can be cleaned by shot-blasting or pickling before assembly (in the case of 9% Nickel).

2. Vessel pipework to be degreased part small i.e. before welding to vessel. (SEE PROCEDURE NO: Q.11).

3. Ensure stub ends of pipes in vessel are covered with tape.

4. Remove spatter and loose particles from vessel walls. Brush vessel out.

5. Wash vessel with Hot Alkaline wash (6 ozs/gall Aqueous solu. of APPLIED CHEMICALS 5.57 at 160°F).

6. Rinse with pottable water.

7. Mop up any residual water with clean 'lint-free' cloth.

8. Remove tape covering stub-ends from inside vessel.

9. Allow surfaces of vessel to dry as quickly as possible. Clean filtered warm air may be used.

10. Check internal surface of vessel and nozzles with bright white light to Engineering Standard A03.

11. Check internal surface of vessel and nozzles with U.V. lamp to Engineering Standard A03.

12. Ensure backing strip for manway and manway cover are degreased before fitting to vessel (Check with U.V. lamp).

13. When vessel has been cleared by an inspector a label 'Degreased for Oxygen Service' bearing an inspector's stamp, should be attached to the vessel.

NOTE:
1. For Hydraulic test after degrease use pottable water.
2. For Pneumatic Test after degrease use dry oil-free Air or Nitrogen.
3. After Pneumatic Test allow air to discharge through each pipe in order to remove any possible debris in the pipes.

APL

ALOCLENE 100 AND APPLIED CHEMICALS 5.57

SUNBEAM CHEMICALS - ALOCLENE 100.

SULPHURIC ACID.

HYDROFLUORIC ACID.

ETHYLENE OXIDE CONDENSATE TYPE DETERGENT.

INORGANIC INHIBITOR.

APPLIED CHEMICALS 5.57.

30% CAUSTIC SODA.

SILICATES, CARBONATES AND PHOSPHATES

2 % ALKYL SULPHONATE TYPE DETERGENT.

2/5/72

(Retyped 9/29/72 sba)

Air Products	**ENGINEERING STANDARD**	No. LS.30/1	
		PAGE 1	CONT. ON 2
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TITLE Oxygen Pipelines

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders
All Piping Engineers

REV	DESCRIPTION	DATE	ORIGINATOR	API
1	Impingement Plate Defined.Para 4 added	1.7.70	J.W. Pegram	
0	ORIGINAL ISSUE			

Original APPROVED BY	D. Savory	C.H. Bloom	R.M. Thorogood	M.A. Supple
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGE

F.913.

APCI DOCUMENT NO. 99000 404

TITLE Oxygen Pipelines

1. PURPOSE

To establish the basic rules for the design of gaseous oxygen piping systems.

2. SCOPE

This standard defines the requirements of all gaseous oxygen piping systems designed or installed by A.P.L. See also LS. 30/2 for transmission lines.

3. DESIGN CRITERIA

Several observations have been made from the study of past history of fires in oxygen service.

3.1 There is no indication of ignition occurring in clean carbon steel systems sized for normal pressure drop unless precipitated by the introduction of foreign substance.

3.2 There have been a number of instances where indications are that ignition has been precipitated in both carbon steel and stainless steel systems operating at sonic or near sonic velocity without evidence of the introduction of foreign substances. Although the higher ignition temperature of stainless steel gives some added protection to these systems at high velocities.

3.3 Copper and nickel alloys both have the characteristics of melting at temperatures below the ignition temperature. This characteristic makes them extremely resistant to ignition in oxygen service.

3.4 Where it is possible to construct a clean carbon steel piping system and maintain it in a clean condition, there is no merit assigned to a stainless steel piping system. However, where systems are continuously exposed internally to atmospheric air, the system should be constructed of a non-corrosive material. Where such exposure is intermittent and of low frequence, the piping system may be constructed of carbon steel in accordance with these specifications, but extreme care must be exercised on the cleaning of all rust particles from the piping system before replacing it in service. The Maintenance and Operating Manual must note any such piping systems and specify the detailed cleaning procedures.

3.5 The following table is the guide to the correct selection of piping and valves for warm oxygen gas service.

TITLE Oxygen Pipelines

Velocity	Oxygen Condition	Allowable Material
Less than 200 fps	Temp. $-20^{o}F$ or above Dry (Dew point below $-40^{o}F$).	Carbon Steel
Less than 200 fps	Temp. $-20^{o}F$ or above Wet gas or if the pipe bore contacts atmospheric air.	Copper, Copper Alloy, stainless steel
Over 200 fps	Temp. $-20^{o}F$ or above Wet or dry.	Copper, Copper alloy.

3.5.2 VALVES (velocity less than 200 fps. at normal operating opening.)

Globe Valves) all bronze or monel
Control Valves) construction

Gate) Steel or cast iron body, all
Butterfly) spindles, wedges, discs and seating faces bronze or monel.

3.5.3 VALVES (velocity over 200 fps. at normal operating opening.)

All valves to be bronze or monel construction.

3.6 Oxygen pipe sizes shall be specified by the Process Engineer and shall normally be based on an economic pressure drop. Each line shall be checked by the Process Engineer and the Piping Engineer to verify that the velocity in the nominal pipe (as opposed to valving etc.) does not exceed approximately 200 ft. per sec. independent of pressure.

3.7 There are certain areas in oxygen piping systems which require special attention because the velocity is known to approach sonic velocity. Some of these are specified below.

In most cases, the maximum flow through the system is established by the size of valve trim operating in critical flow. Pipe velocities are to be determined at the maximum valve flow and the designated pipe operating pressure.

3.7.1 Automatic Pressure Control Vent System - see Fig.1. (Sheet

The entire system downstream of the valve is of a non-corrosive material because it is continuously exposed to the atmosphere.

The elbow shown in the sketch is not desirable, but is shown because if it is required due to physical layout, a straight run of at least six pipe diameters must be provided after the elbow before going into the tee piece.

3.7.2 Oxygen Compressor Vent System - See Fig. 1 (Sheet 5)

The considerations have been applied here that have been applied to the Automatic Pressure Control System.

3.7.3 Pressure Let Down Sytem - See Fig 2 (Sheet 6)

This system will be used for such applications as (a) let down from storage pressure to line pressure, (b) let down for lower pressure requirements in multiple user systems. Such systems will often result in near sonic velocities at the control valve discharge. The Manual block valves will be gate valves made from carbon steel or cast iron with bronze trim.

The manual by-pass valve should be a bronze or monel globe valve with stellited seat and disc sized with a Cv equal to the control valve. The position of valves and arrangement of the piping should be dictated by system economics within the guidelines of this standard.

3.7.4 Compressor Recycle System - See Fig 3. (Sheet 7)

This system is particularly critical because of the high flow rate and the conditions under which it is operated. The high pressure by-pass line is sized by process. It is preferable to take directional changes in this carbon steel line in order to minimise the need for fittings in large size lines. The control valve should be sized at 120% of the compressor full flow. D2 will normally be about 70% of D3 since D3 is usually sized for a low pressure drop. D2 should be sized such that the velocity is less than 200 ft. per sec. at the minimum downstream pressure.

1

4. Impingement Plates

4.1 The use of impingement plates in tees or the use of monel tees is confirmed to the following 2 conditions:

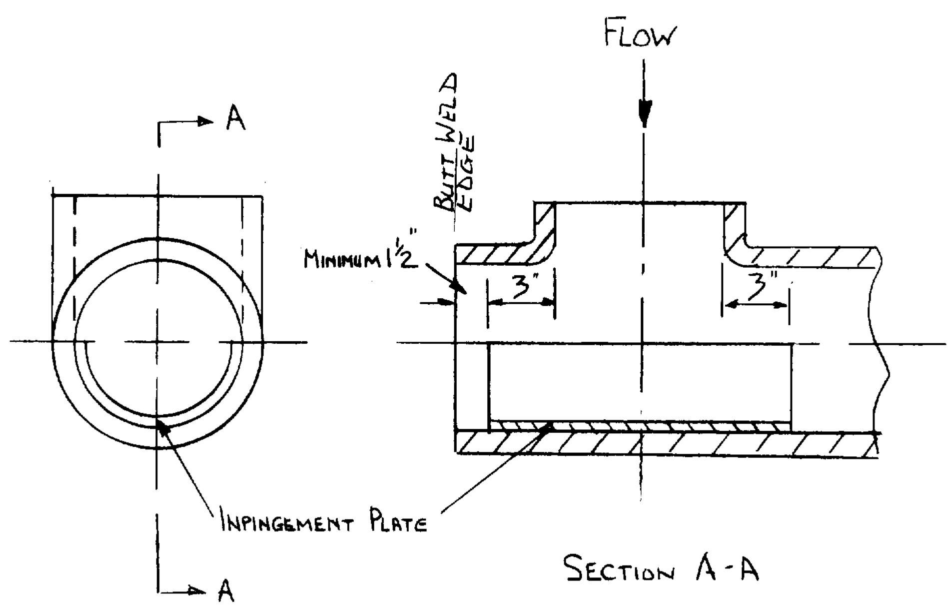
(a) When oxygen gas velocity is greater than 200 ft/sec
(b) The flow is from the branch to the run.

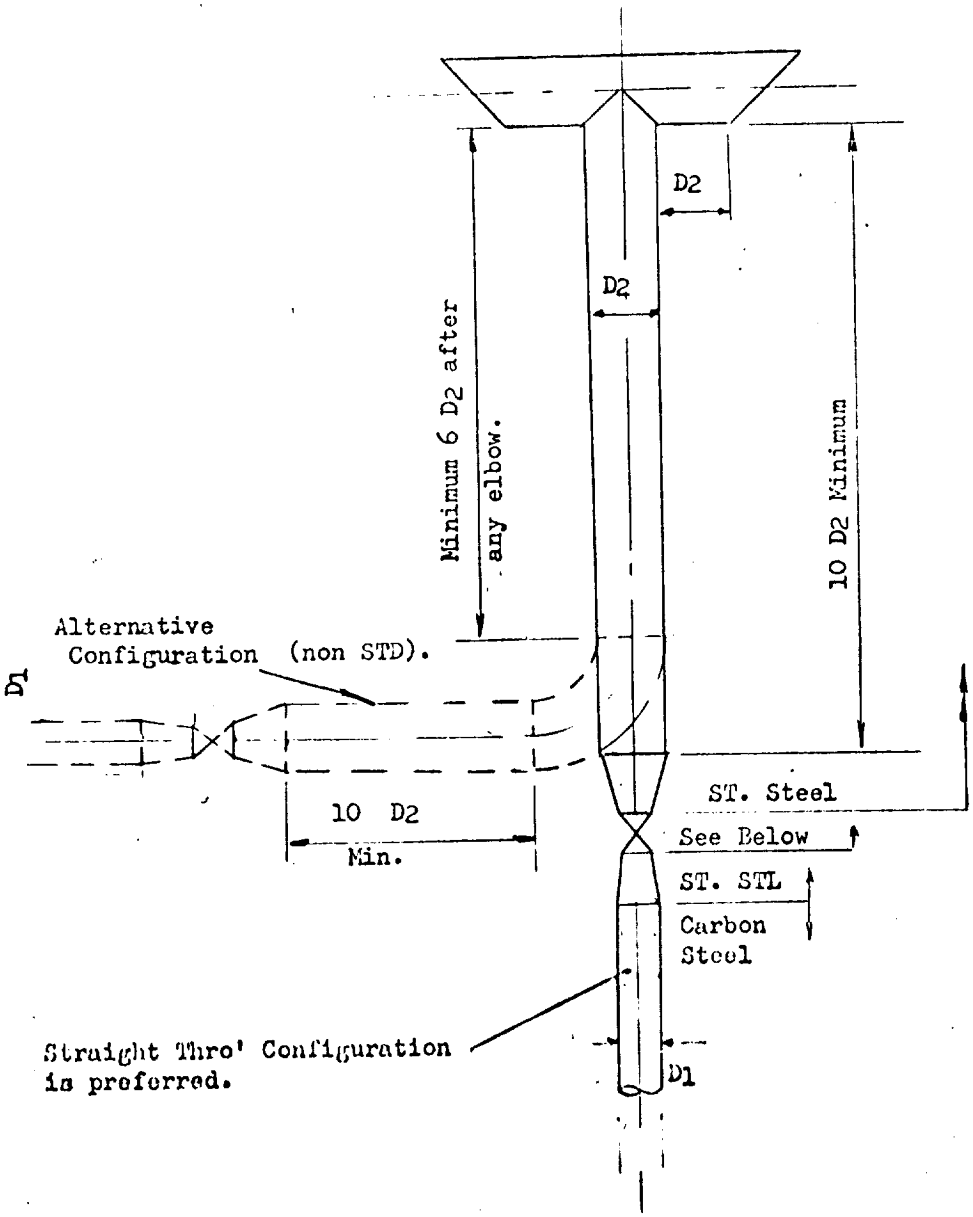
4.2 When the gas conditons as defined in 4.1. require an impingement plate the following standard will apply:

(a) For line sizes 6" and under use a monel (ASTM B164) tee

(b) For line sizes 8" over the impingement plate shall be $\frac{1}{8}$" thick half hard rolled brass sheet (ASTM B36).

The plate shall exceed the branch diameter by 3" on each side or for a total length of the branch diameter plus 6".
The end of the impingement plate must be at least 1½" from any butt weld joint.
The plate shall cover one half the pipe circumference and be tack brazed in place all as the following sketch.





D1 is Sized for V $\leq$ 200 ft/sec at maximum flow & pressure at inlet of vent valve.
D2 is Sized for V $\leq$ 200 ft/sec at Atmospheric Pressure.

1. Automatic Pressure Control Vent System Valve to be a bronze or monel control valve.

2. Oxygen Compressor Vent System Valve to be a bronze or monel valve sized at not less than the capacity of the Compressor Recycle Control Valve.

3. NOTE: No weld back up strips to be left in place.

ECN	Rev	REVISIONS	date	made	ch'd	app'd
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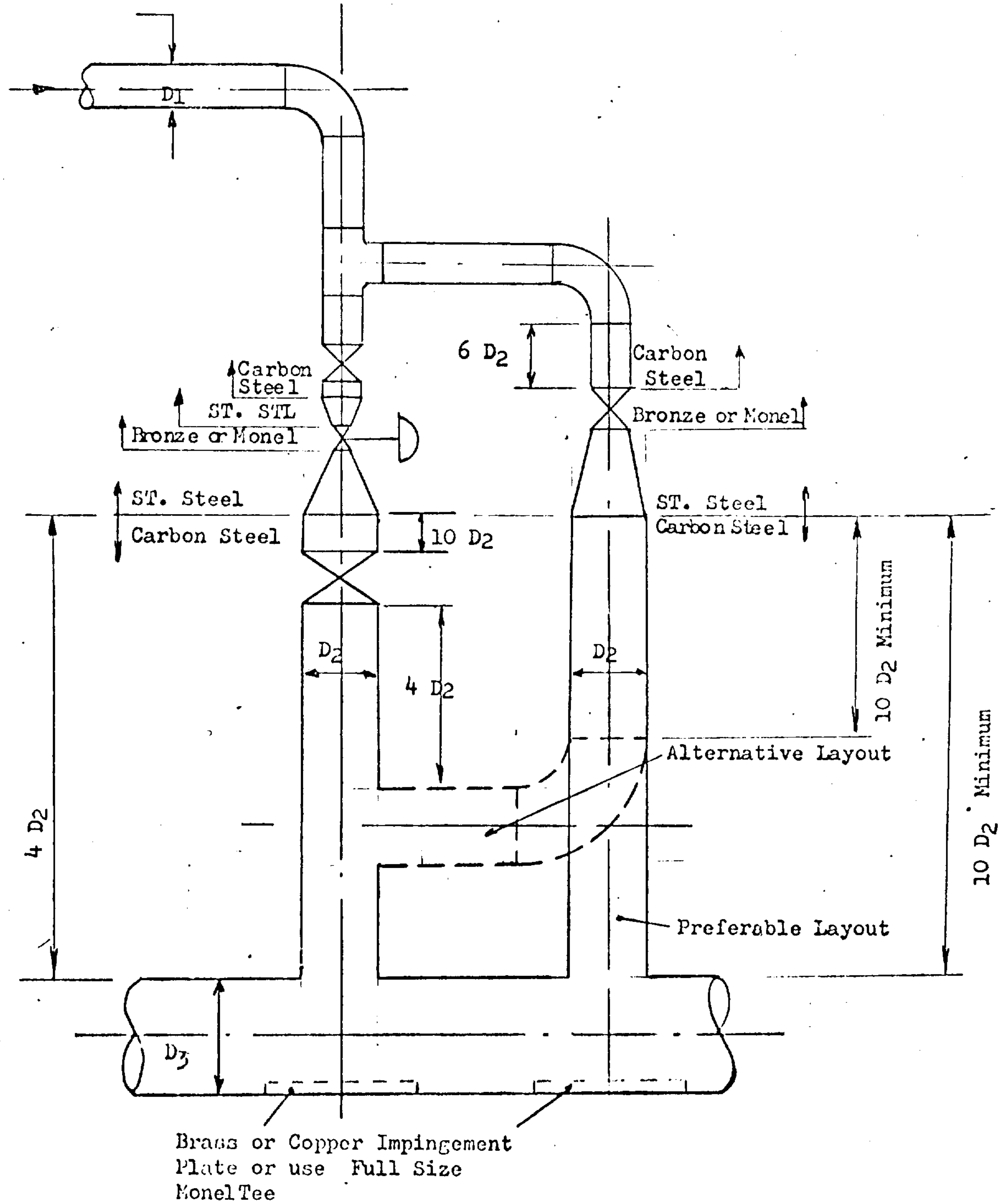
DRG. No. FIG. 1.

TITLE OXYGEN COMPRESSOR VENT SYSTEM.

D_1 - Sized by Process for V $\leq$ 200 fps.

D_2 - Sized for 200 fps. at Downstream Pressure

D_3 - Sized by Process



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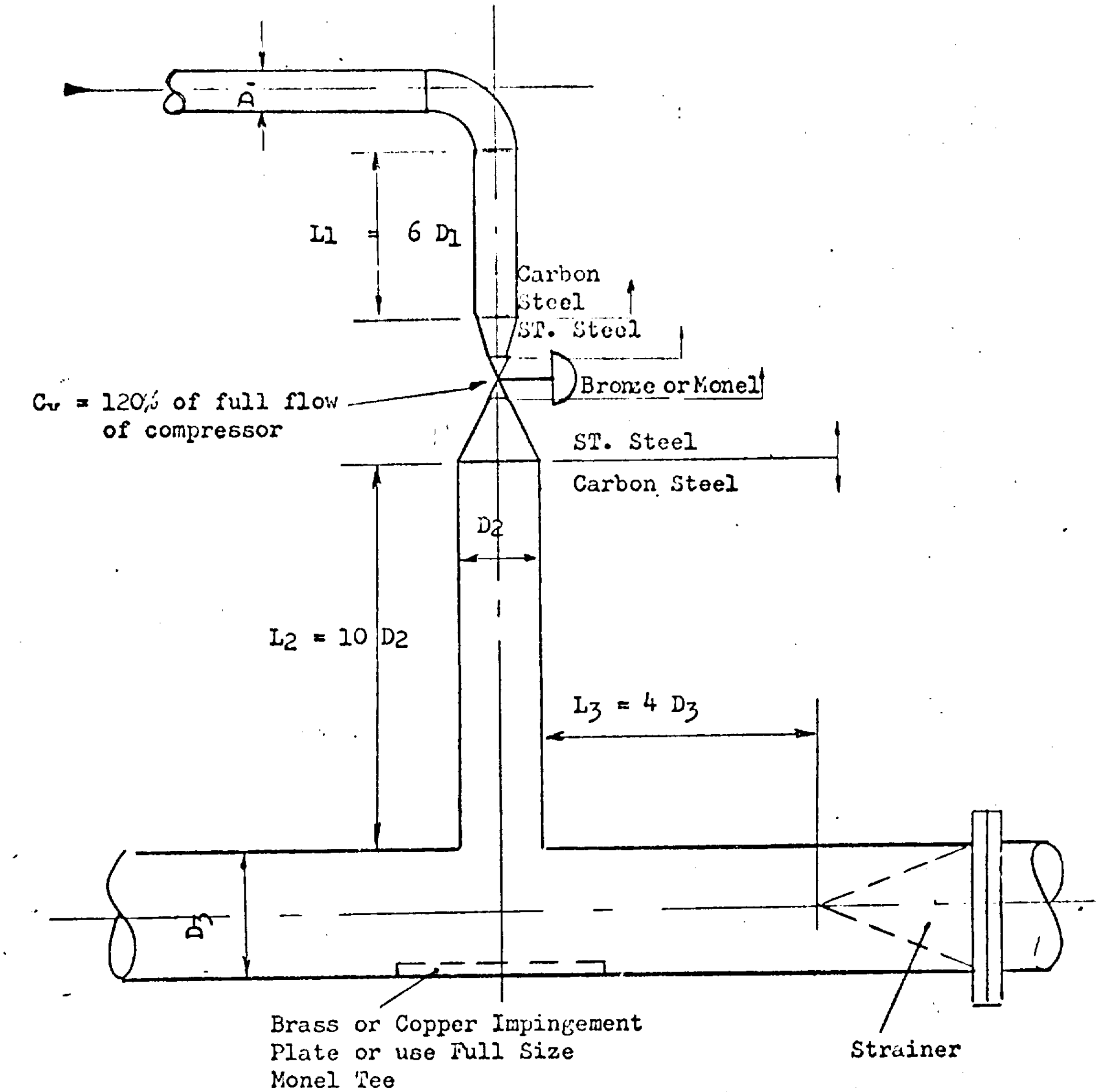
DRG. No. FIG. 2

TITLE PRESSURE LET DOWN SYSTEMS

D_1 Sized by Process for $V \leqq 200$ fps.

D_2 Sized for 200 fps. at minimum downstream pressure.

D_3 Sized by Process



<u>NOTE:</u> No Weld Back Up Strips to be left in place.

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	1					
	0	ORIGINAL ISSUE				

drawn	checked	approved	date	DRG. No.
TITLE COMPRESSOR RECYCLE SYSTEM.				FIG. 3.

Air Products

ENGINEERING STANDARD

No. LS 3012

PAGE CONT. ON COVER SHEET

REV

TITLE

Design and Safety Standards for Carbon Steel Gaseous Oxygen Transmission Lines

DISTRIBUTION

All Engineering Specifications and Standards Manual Holders
All Piping Engineers

APCI DOCUMENT NO 99000405

REV	DESCRIPTION	DATE	ORIGINATOR	AP
1	Para 2.2 Amended - Dimensions Metricated.	1-12-70		
0	ORIGINAL ISSUE	14.7.69	J.W.P.	

ORIGINAL APPROVED BY	D.W. SAVORY	C.H. BLOOM	R.M. THOROGOOD	M.A. SUPPLE
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGER

TITLE Design and Safety Standards for Carbon Steel Gaseous Oxygen Transmission Lines

1. SCOPE

This information covers gaseous oxygen transmission lines in carbon steel up to a pressure of 3000 psi (207 bars) and temperature range of -20°F to +250°F (-29°C to + 120°C).

2. GENERAL

2.1 All pipe material selection and sizing must be in accordance with relevant Design Engineering Standard, and gas velocity must not exceed 200 ft per sec. (61m/sec)

2.2 All pipe lines shall be installed in accordance with Air Products Construction, Specification M.02 and particular attention must be paid to:-

(a) Paragraph 5. Welding

(b) Paragraph 6. Cleaning of Pipe and Fittings.

2.3 Transmission lines shall be located away from a source of heat, power lines and vibration.

2.4 Protection shall be provided against physical damage where this can occur due to vehicular traffic etc.

3. UNDERGROUND

3.1 Mechanical joints are not permitted underground. All joints shall be welded to minimise leakage.

3.2 Oxygen transmission lines are permitted in pipe trenches, ducts and tunnels containing flammable gas lines only if adequate ventilation is available. Oxygen lines are not permitted in pipe trenches, ducts and tunnels containing piped flammable liquids or where oxygen leakage may contact oil.

3.3 Oxygen and flammable gas lines located in filled trenches shall be maintained a minimum distance of 18" (450mm) between the exterior surfaces of the lines. If the lines are encased in concrete a minimum distance of 12 inches (300mm), shall be maintained.

3.4 Underground lines under roadways and railways shall be encased in suitable continuous pipe sleeves. The casing pipe shall extend at least two feet each side of the roadway or railway and must be vented at each end.

3.5 As an alternative underground lines under railways or roadways may be protected by completely encasing the line in a concrete jacket. The thickness of concrete will depend on the pipe diameter and for line sizes up to 6 inches (150mm) this should be of the order of 6 - 8 inches (150 - 200mm). (See also 3.13.)

3.6 Pipe lines shut down for lengthy periods shall be purged out with clean, dry, oil free air or nitrogen. The pipe line shall be pressurised to a minimum of 5 psig (0.35 bars) on completion of purge and the line sealed off to prevent ingress of moisture.

3.7 Oxygen lines shall not be run through the same casing pipe with other lines containing flammable liquids or gases or with electrical services.

3.8 Underground piping leading to the surface shall be protected by guard posts or similar methods to prevent accidental rupture of the line.

3.9 Underground piping shall be provided with block valves such that periodic leak tests may be made by holding the appropriate pressure in the line for a minimum of one hour. Normally a block valve at each end of the line will be adequate. All valves below ground must be accessible from the surface by the provision of a brick-lined access pit.

3.10 In some locations it may be necessary to provide a sand bed or other porous beds to improve drainage.

3.11 Transmission lines shall be located below the frost line and not less than three feet (1m) below the surface.

3.12 Underground lines shall have low point drains as necessary.

3.13. The exterior surfaces of buried carbon steel piping shall be protected by applying a corrosion resistant coating as follows:-

Carbon Steel Piping

Piping should be coated with bitumen and covered with suitable felt or glass fibre bandage. Contractor shall submit details of proposed materials for approval prior to carrying out any work.

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ENGINEERING STANDARD

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REV 0
Cover Sheet

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 150 PSIG CSO 1.5

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0	ORIGINAL ISSUE			
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APPROVED BY	12.6.70. SECTION HEAD	DESIGN MANAGER	Keith Wilson CHIEF ENGINEER	TECH. SERVICE GROUP MANAGE

APCI DOCUMENT NO. 99000406

F.913.

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service-(CSO 1.5)

1. PURPOSE

1.1 The purpose of this selection sheet is to state the most suitable and economic standard piping, fittings and valves for the given pressure and temperature.

1.2 For pressure just above the given rating it may be more economic to recalculate or review the rating of individual items shown on this sheet rather than use materials from the next higher rating.

1.3 These selection sheets are also a guide to engineers preparing job specifications for special ratings or services.

2. SCOPE

The sheets list all approved carbon steel pipe and fittings and suitable valves for use with them for a duty of 150 psig max. and at all temperatures between +100°F and -20°F for Dry Oxygen Gas. (Dry oxygen gas has a dew point of -40°F and better).

3. GENERAL

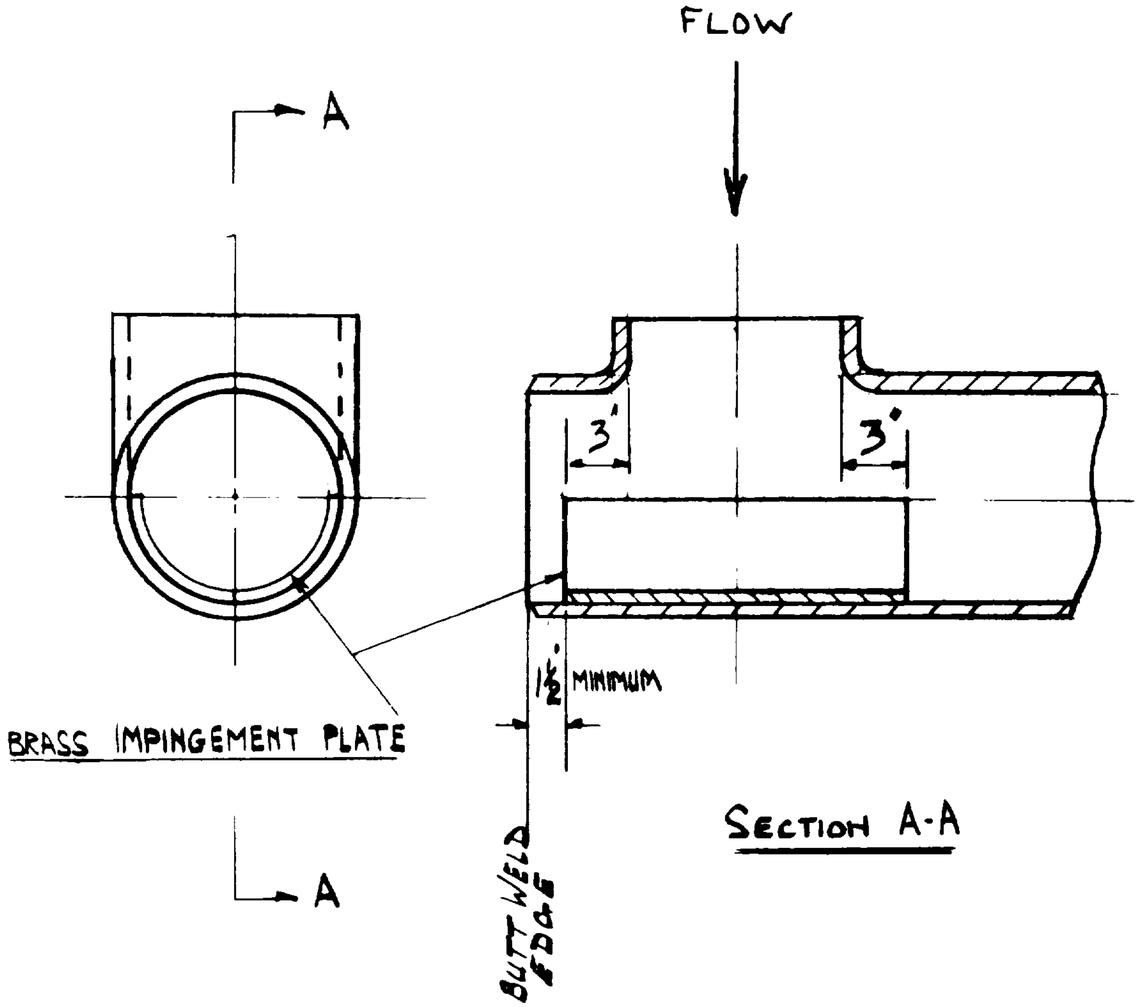
3.1 This standard is to be read in conjunction with LS.30/2 "Design and Safety Standards for Carbon Steel Gaseous Oxygen transmission lines".

3.2 THIS CLAUSE IS ONLY APPLICABLE FOR TEES IN PRESSURE LET DOWN SYSTEMS WHERE THE VELOCITY EXCEEDS 200 F.P.S. AS, FOR EXAMPLE, IMMEDIATELY DOWN STREAM OF PRESSURE CONTROL VALVES ETC.

When flow is from the branch into the run a monel (ASTM B164) tee shall be used in sizes 6" and below.

In sizes 8" and larger a brass impingement plate shall be installed in the straight run. The impingement plate shall be $\frac{3}{8}$" thick half hard rolled brass sheet, BS2874 CZ112. Its length shall be, such that when placed centrally under the branch, each end of the impingement plate extends 3" beyond the branch inside wall providing that a minimum of $1\frac{1}{2}$" is kept clear of the butt weld end of the run, it shall cover one half of the pipe circumference of the main run.

See attached Fig 1.



SEE PARAGRAPH 3

FIGURE I

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drawn [signature] checked [signature] approved date 1-7-70 DRG. No.

TITLE 8" N/B & OVER TEE FOR PRESSURE LET DOWN

3.3 Note. Due to the difficulties of welding high carbon content steels, the carbon and manganese limitations of grade 'A' must be specified when ordering grade 'B' pipe.

3.4 Fabricated bends made from pressed halves welded together may be used if for any reason forged or pulled bends are unobtainable. There is no minimum bend radius other than that due to manufacturing limitations.

3.5 Check valves listed are for centrifugal compressor systems only. For reciprocating compressor check valves consult the Design Engineering Manager.

4. PIPE

An external corrosion allowance of.05" has been included in arriving at the list of standard piping and the designer must recalculate if greater corrosion is to be expected.

Piping Size Nominal Bore	Description	Material Specification	A.P.L. Material Code Group.
4.1 Pipe Transmission			
$\frac{1}{8}$" - 2"	SCH. 40 Seamless Threaded Ends	API-5L- B	1.41.380
$\frac{1}{8}$" - 8"	SCH. 40 E.R.W. Plain Ends	API-5L- B	1.41.380
10" - 12"	SCH. 20 ($\frac{1}{4}$"Wall) ERW Plain Ends	API-5L- B	1.41.380
14" - 24"	SCH. 10 ($\frac{1}{4}$" Wall) ERW Plain Ends	API-5L- B (ASTM A53-[illegible])	

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service-(CSO 1.5)

5. FITTINGS

5.1 Pulled Bends - Allows for 15% thinning

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
1/8" - 2" (Site)	SCH.40 ERW or Seamless Plain Ends	API-5L-B	1-41-380
1/8" - 4" (Acrefair)	SCH.40 ERW or Seamless	API-5L-B	1-41-380

5.2 Tees (See Note 3.2)

Branch Size Nominal Bore	Description	Material Specification	APL Material Code Group
1/8" - 1"	SCH.40 Forged Sockolets	ASTM A105.GR.2	4-26-223
1/8" - 1"	3000 psi. Forged Threadolets	ASTM A105.GR.2	4-26-123
1-1/2" - 8"	SCH.40 Branch Welding only	API-5L-B	1-41-380
10" - 12"	SCH.20 Branch Welding Only	API-5L-B	
14" - 24"	SCH.10 Branch Welding only.	API-5L-B	
1-1/2" & 2" (See Note 3.3)	SCH.40 Forged Tees Socket Weld Ends.	ASTM A234 WPB	4-28-351
3" - 8" (See Note 3.3)	SCH.40 Forged Tees Buttweld Ends	ASTM A234 WPB	4-28-752

5.3 Reducers

Large End Pipe Size N/B			
1-1/2" - 8"	SCH.40 Fabricated from pipe. Buttweld Ends.	API-5L-B	
10" - 12"	SCH.20 Fabricated from pipe. Buttweld Ends.	API-5L-B	
1-1/2" - 6"	SCH.40 Forged Buttweld Ends. USAS B.16.9 (or BS.1640)	A234 WP.B	4-28-712

TITLE Piping Selection Sheet-Carbon Steel-~~Warm~~ Oxygen Service-(CSO 1.5)

Branch Size Nominal Bore	Description	Material Specification	APL Material Code Group
5.5 Unions. Carbon Steel			
3/8" - 2"	3000 lb. Forged Steel Threaded Ends	ASTM A105.GR.2 (BS3799 & BS 1503-161.GR.B)	4.27.680
3/8" - 2"	3000 lb. Forged Steel Socket Weld Ends	ASTM A105.GR.2 (or BS3799 & BS 1503-161.GR.B)	4.28.680

6. BACKING STRIP

Not allowed on carbon steel oxygen transmission lines.

7. FLANGES

4" - 24"	Class 150 Forged Steel R.F. Slip on Weld. USAS B.16.5 (or BS.1560)	ASTM A181 GR.1 (or BS1503-161 GR. A & B)	4.25.132
1" - 3"	Class 150 Forged Steel R.F. Weld Neck USAS B.16.5 (or BS.1560)	ASTM A181.GR.1 (or BS1503-161 GR. A & B)	4.25.152

8. BOLTING (See LS.04)

All sizes	Studs.Alloy Steel. Full Thread Nuts. Hex. Carbon Steel.	ASTM A193-B7 ASTM A194.2H	

9. GASKETS (See LS.04)

All sizes	Compressed asbestos Fibre 1/16" thick	KLINGERIT 661	4.24.111

10. VALVES (See LS.05)

Type No.	Description	Valve Type	Code No.
BZ/05/05	2" & smaller Class 150 Bronze Body & Trim	Gate	
CI/05/01 CI/05/02	Over 2" Class 125 Cast Iron Body. Bronze Trim	Gate	
BZ/03/12	2" & smaller Class 150 Bronze Body & Trim	Globe	

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service-(CSO 1.5)

10. (Cont'd)...

Type No.	Description	Valve Type	Code No.
BZ/03/12	3" & 4" Class 150 Bronze Body & Trim	Globe	
SS/03/01 modified	Class 150 St/Stl type 304 or 316 with Bronze Seat & Disc.	Globe	
BZ/07/01	½" & above Class 150 Bronze.	Check	
BZ/01/01	¼" 1" 3000 psi. Rating. Bronze.	Needle	

Air Products	**ENGINEERING STANDARD**	No. LS.31/2 PAGE CONT. ON REV 0 Cover Sheet

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 275 PSIG (CSO 2.7)

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CHIEF ENGINEER

TECH. SERVICE GROUP MANAGER

APCI DOCUMENT NO. 99000407

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 275 PSIG

1. PURPOSE

1.1 The purpose of this selection sheet is to select the most suitable and economic standard piping, fittings and valves for the given pressure and temperature.

1.2 For pressure just above the given rating it may be more economical to recalculate or review the rating of individual items shown on this sheet rather than use materials from the next higher rating.

1.3 These selection sheets are also a guide to engineers preparing job specification for special ratings or services.

2. SCOPE

This sheet lists all approved carbon steel pipe and fittings and suitable valves for use with them for a duty of 275 psig. max and at all temperatures between +100°F and -20°F for Dry Oxygen Gas. (Dry oxygen gas has a dew point of -40°F or better).

3. GENERAL

3.1 This standard is to be read in conjunction with E.S.30/2 "Design and Safety Standards for Carbon Steel Gaseous Oxygen Transmission Lines".

3.2 THIS CLAUSE IS ONLY APPLICABLE FOR TEES IN PRESSURE LET DOWN SYSTEMS WHERE THE VELOCITY EXCEEDS 200 F.P.S. AS, FOR EXAMPLE IMMEDIATELY DOWN STREAM OF PRESSURE CONTROL VALVES ETC.

When flow is from the branch into the run a monel (ASTM B164) tee shall be used in sizes 6" and below.

In sizes 8" and larger a brass impingement plate shall be installed in the straight run. The impingement plate shall be ⅜" thick half hard rolled brass sheet, [illegible]. Its length shall be, such that when placed centrally under the branch each end of the impingement plate extends 5" beyond the branch inside wall providing a minimum of 1½" is kept clear of the butt weld end of the run. It shall cover one half of the pipe circumference of the main run.

See attached Fig. 1.

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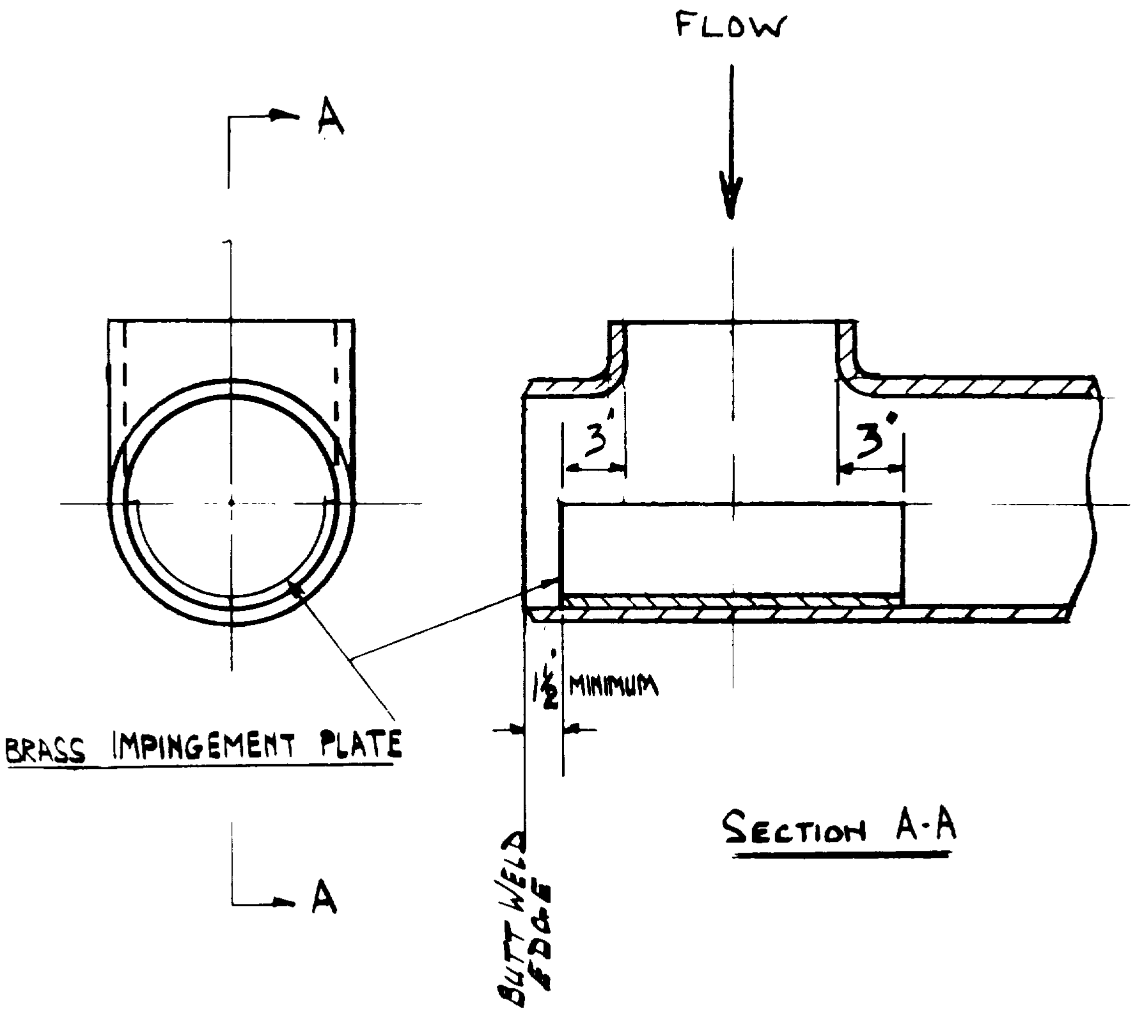
LS 31



SEE PARAGRAPH 3

FIGURE I

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TITLE 8" N/B & OVER TEE FOR PRESSURE LET DOWN

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 275 PSIG (CSO 2.7)

3.3 Note. Due to the difficulties of welding high carbon content steels the carbon and manganege limitations of grade 'A' must be specified when ordering grade 'B' pipe.

3.4 Check valves listed are for centrifugal compressor systems only, for reciprocating compressor check valves consult the Design Engineering Manager.

4. PIPE

.05" external corrosion allowance has been included in arriving at the list of standard piping and the designer must recalculate when greater corrosion is to be expected.

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
⅛" - 2"	SCH.40 Seamless Threaded Ends	API-5L-B	1.41.380
⅛" - 8"	SCH.40 E.R.W. Plain Ends	API-5L-B	1.41.380
10" - 12"	SCH.20 (¼" Wall) ERW Plain Ends.	API-5L-B	1.41.380
14" - 20"	SCH.10 (¼" Wall) ERW. Plain Ends	API-5L-B (ASTM A53-B)	

5. FITTINGS

5.1 Pulled Bends 15% Thinning allowed for.

⅛" - 2" (Site)	SCH.40 E.R.W. Plain Ends	API-5L-B
⅛" - 4" (Acrefair)	SCH.40 E.R.W. Plain Ends	API-5L-B

TITLE Piping Selection Sheet-Carbon Steel Warm Oxygen Service 275 PSIG (CSO 2.7

5.2 Tees (See Note 3.2)

Branch Size Nominal Bore	Description	Material Specification	APL Material Code Group
⅛" - 1"	SCH.40 Forged Sockolets	ASTM A105.GR.2	4.26.223
⅛" - 1"	3000 psi. Forged Threadolets	ASTM A105.GR.2	4.26.123
1½" - 8"	SCH.40 Branch Welding only	API-5L-B	
10" - 12"	SCH.20 Branch Welding	API-5L-B	
14" - 20"	SCH.10 Branch Welding only	API-5L-B	
1½" & 2"	SCH.40 Wrought Tees Socket Weld Ends	ASTM A234-WP.B	4.28.351
3" - 8"	SCH.40 Wrought Tees Buttweld Ends	ASTM A234.WP.B	4.28.752

5.3 Reducers

Large End Dia N/B			
1½" - 8"	SCH.40 Wrought USAS B16.9 (BS 1640)	ASTM A234.WP.B.	4.28.712
10" - 12"	SCH.20 Wrought USAS B16.9	ASTM A234.WP.B	

5.4 Unions, Carbon Steel

⅜" - 2"	3000 lb. Forged Steel Threaded Ends	ASTM A105.GR.2 (BS 3799 & BS 1503-161 GR.B)	4.27.680
⅜" - 2"	3000 lb. Forged Steel Socket Weld Ends	ASTM A105 GR.2 (or BS3799 & BS 1503-161 GR.B)	4.28.680

6. BACKING STRIP

Backing strips shall not be used on carbon steel oxygen lines.

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 275 PSIG (CSO 2.7)

Piping Size	Description	Material Specification	APL Material Code Group
7. FLANGES			
1" - 3"	Class 150 Forged Steel R.F. Weld Neck USAS B16.5 (or BS1560)	ASTM A181 GR.1 (or BS1503-161 GR B)	4.25.152
4" - 24"	Class 150 Forged Steel R.F. Slip on Weld USAS B16.5 (or BS1560)	ASTM A181 GR.1 (or BS1503-161 GR B)	4.25.132
8. BOLTING (See LS.04)			
All sizes	Studs Alloy Steel. Full Thread Nuts. Hex. Carbon Steel.	ASTM A193.B7 ASTM A194.2H	
9. GASKETS (See LS.04)			
All sizes	Compressed Asbestos Fibre 1/16" thick USAS B16.5 (or BS1560)	KLINGERIT 661	4.24.111

10. VALVES (See LS.05)

Type No.	Description	Valve Type	Code No.
BZ/05/05	2" & smaller Class 150 Bronze Body & Trim	Gate	
CI/05/03	Over 2" Class 250 Cast Iron Body. Bronze Trim	Gate	
BZ/03/12	½" & Over Class 150 Bronze Body & Trim	Globe	
SS/03/01	Over 4" Class 150 ST/STL type 304 or 316 - Bronze Seat & Disc	Globe	
BZ/07/01	½" & above Class 150 Bronze	Check	
BZ/01/01	¼" - 1" - 3000 psi. Rating. Bronze	Needle	

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ENGINEERING STANDARD

No. LS.31.3
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REV 0
Cover Sheet

TITLE Piping Selection Sheet- Carbon Steel- Warm Oxygen Service 500 PSIG (CSO 5.0)

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APPROVED BY	12.6.70		Keith Wilson	
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGEI

F.913.

APCI DOCUMENT NO. 99000408

Air Products	**ENGINEERING STANDARD**	No. LS.31/3 PAGE 1 CONT. ON 2 REV 0

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 500 PSIG

1. PURPOSE

1.1 The purpose of the selection sheet is to select the most suitable and economic standard piping, fittings and valves for the given pressure and temperature.

1.2 For pressure just above the given rating it may be more economic to recalculate or review the rating of individual items shown on this sheet rather than use materials from the next higher rating.

1.3 These selection sheets are also a guide to engineers preparing job specification for special ratings or service.

2. SCOPE

This sheet lists all approved carbon steel pipe and fittings suitable valves for use with them for a duty of 500 psig max and at all temperatures between +100°F and -20°F for Dry Oxygen Gas. (Dry oxygen has a dew point of -40°F or better).

3. GENERAL

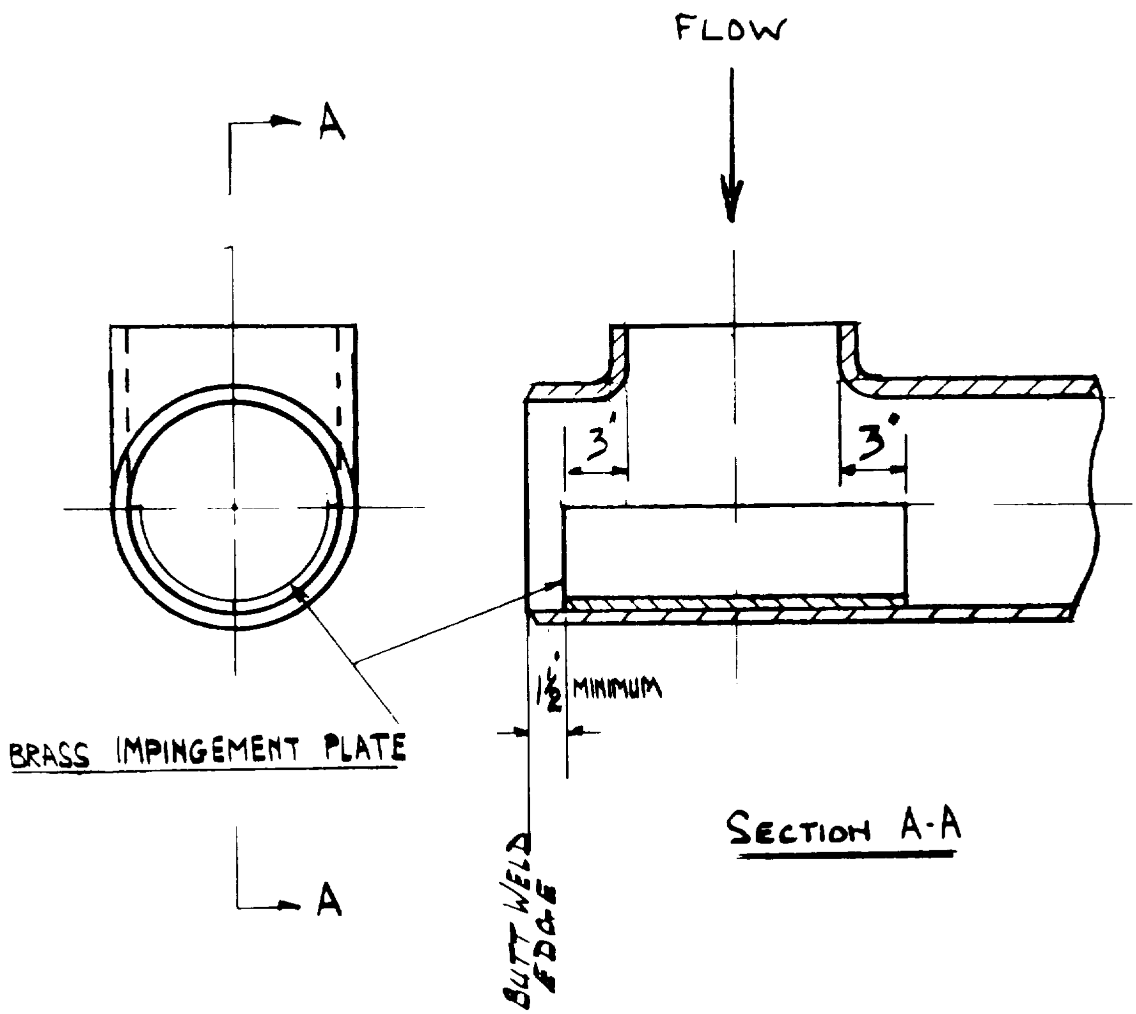
3.1 This standard is to be read in conjunction with LS.30/2 "Design and Safety Standards for Carbon Steel Gaseous Oxygen Transmission Lines".

3.2 THIS CLAUSE IS ONLY APPLICABLE FOR TEES IN PRESSURE LET DOWN SYSTEMS WHERE THE VELOCITY EXCEEDS 200 F.P.S. AS, FOR EXAMPLE, IMMEDIATELY DOWN STREAM OF PRESSURE CONTROL VALVES ETC.

When flow is from the branch into the run a monel (ASTM B164) tee shall be used in sizes 6" and below.

In sizes 8" and larger a brass impingement plate shall be installed in the straight run. Impingement plate extends 3" beyond the branch inside wall, providing that a minimum of 1½" is kept clear of the butt weld end of the run, it shall cover one half of the pipe circumference of the main run.

See attached Fig. 1.



SEE PARAGRAPH 3

FIGURE I

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DRG. No.

TITLE 8" N/B & OVER TEE FOR PRESSURE LET DOWN

3.3 Note due to the difficulties of welding high carbon content steels. The carbon and manganese limitations of grade 'A' must be specified when ordering grade 'B' pipe.

3.4 Check valves listed are for centrifugal compressor systems only for reciprocating compressor check valves consult the Design Engineering Manager.

4. PIPE

.05" external corrosion allowance has been included in arriving at the list of standard piping and the designer must recalculate when greater corrosion is to be expected.

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
4.1 Pipe Transmission			
1/8" - 2"	SCH. 40 Seamless Threaded Ends	API-5L-B (ASTM A53-B)	1.41.380
1/8" - 10"	SCH. 40 E.R.W. Plain Ends	API-5L-B (ASTM A53-B)	1.41.380
12" - 14"	STD.WT. (0.375 W.T.) E.R.W. Plain Ends		

5. FITTINGS

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
5.1 Pulled Bends 15% Thinning allowed for			
1/8" - 2"	SCH. 40 Seamless Plain Ends	API-5L-B	
1/8" - 4"	SCH. 40 E.R.W. Plain Ends	API-5L-B	
5.2 Elbows			
1/8" - 2"	3000 lbs forged Socket Weld Ends	ASTM A234-WPB USAS B16.11	
3" - 10"	SCH. 40 Wrought Butt weld Ends	ASTM A234-WPB USAS B.16.9	
12" - 14"	STD. WT (0.375" W.T.) Butt Weld Ends	ASTM A234-WPB USAS B16.9	

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 500 psig CSO 5.0

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
5.3 Tees (See Note 3.2)			
Branch Size			
⅛" - 1"	SCH. 40 Forged Sockolets	ASTM A 105.GR.2	4.26.223
⅛" - 1"	3000 psi. Forged Threadolets	ASTM A105.GR.2	4.26.123
⅛" - 2"	SCH. 40 Forged Tees Socket Weld Ends	ASTM A234.WPB	4.28.351
3" - 10"	SCH. 40 Wrought Buttweld ends USAS B16.9 (BS 1640).	ASTM A234.WPB	4.28.351
12" - 14"	STD WT Branch Welding Only	API-5L-B	
5.4 Reducers			
1½" - 10"	SCH. 40 Wrought Buttweld Ends USAS B16.9 (BS 1640)	A234.WPB	4.28.712
12" - 14"	STD WT Wrought Buttweld Ends USAS B.16.9 (BS 1640)	ASTM A234.WPB	
5.5 Unions			
⅜" - 2"	3000 lb Forged Steel Threaded Ends	ASTM A105.GR.2 (BS 3799 & BS 1503-161 GR.B)	4.28.680
⅜" - 2"	3000 lb Forged Steel Socket Weld Ends	ASTM A105.FR.2 (or BS 3799 & BS 1503-161 GR.B)	4.28.680

6. BACKING STRIP

Backing strip shall not be used on carbon steel oxygen transmission lines

7. FLANGES

1" - 3"	Class 300 Forged Steel R.F. Weld Neck USAS B16.5	ASTM A181.GR.1 (or BS 1503-161 GR. B)	4.25.132
4" - 24"	Class 300 Forged Steel R.F. Slip on Weld USAS B16.5	ASTM A181.GR.1 (or BS1503-161 GR. B).	4.25.152

TITLE Piping Selection Sheet-Carbon Steel-Warm ~~Oxygen Service~~ 500 ~~PSIG~~ CSO 5.0

	Piping Size	Description	Material Specification	APL Material Code Group
8.	BOLTING	(See LS.04)		
	All sizes	Studs Alloy Steel. Full Thread Nuts, Hex. Carbon Steel.	ASTM A193.B7 ASTM A194.2H	
9.	GASKETS	(See LS.04)		
	All sizes	Compressed Asbestos Fibre 1/16" thick USAS B16.5(or BS1560)	KLINGERIT 661	4.24.111
10.	VALVES	(See Std. LS.05)		

Type No.	Description	Valve Type	Code No.
BZ/05/06	2" & smaller Class 300 Bronze Body & Trim	Gate	
CS/05/11	Over 2" Class 300 Cast Steel Bronze Trim	Gate	
BZ/03/13	½" & Above Class 300 Bronze Body & Trim	Globe	
SS/03/06 Modified	Over 4" Class 300 St/Stl type 304 or 316. Bronze Seat & Trim.	Globe	
BZ/07/02	½" & above Class 300 Bronze	Check	
BZ/01/01	¼" - 1" - 3000 psi rating. Bronze.	Needle	

ENGINEERING STANDARD

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No. LS.31.4

PAGE CONT. ON COVER SHEET

REV 0

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 720 PSIG (CSO 7.2)

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APPROVED BY	12. 6. 70.			
	SECTION HEAD	DESIGN MANAGER	CHIEF ENGINEER	TECH. SERVICE GROUP MANAGE

F.913.

APCI DOCUMENT NO. 9900409

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 720 PSIG

1. PURPOSE

1.1 The purpose of this selection sheet is to select the most suitable and economic standard piping, fittings and valves for the given pressure and temperature.

1.2 For pressure just above the given rating it may be more economic to recalculate or review the rating of individual items shown on this sheet rather than use materials from the next higher rating.

1.3 These selection sheets are also a guide to engineers preparing job specification for special ratings or service.

2. SCOPE

This sheet lists all approved carbon steel pipe and fittings and suitable valves for use with them for a duty of 720 PSIG max. and at all temperatures between +100°F and -20°F for Dry Oxygen Gas. (Dry oxygen gas has a dew point of -40°F or better).

3. GENERAL

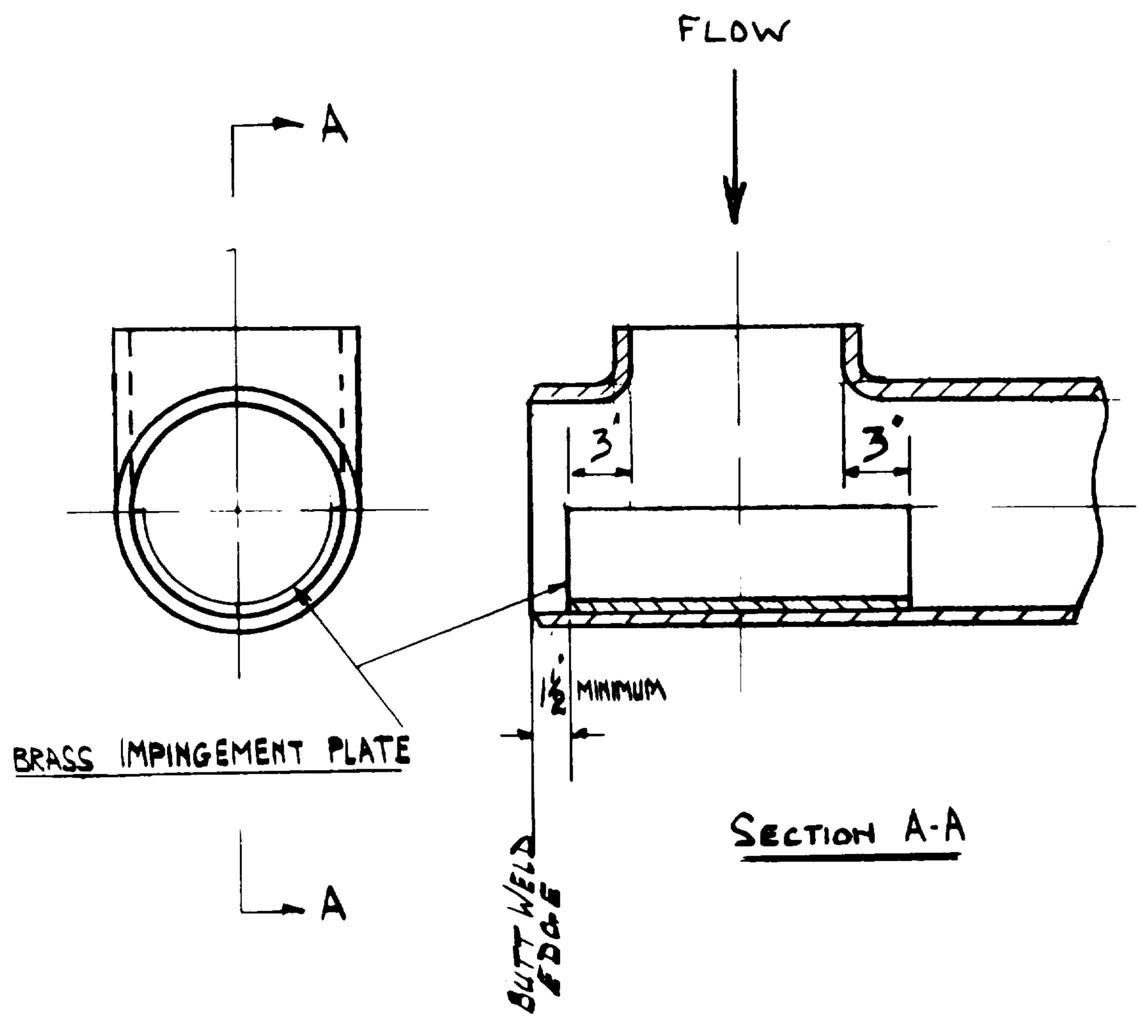
3.1 This standard is to be read in conjunction with LS.30/2 "Design and Safety Standards for Carbon Steel Gaseous Oxygen Transmission Lines".

3.2 THIS CLAUSE IS ONLY APPLICABLE FOR TEES IN PRESSURE LET DOWN SYSTEMS WHERE THE VELOCITY EXCEEDS 200 F.P.S. AS, FOR EXAMPLE, IMMEDIATELY DOWN STREAM OF PRESSURE CONTROL VALVES ETC.

When flow is from the branch into the run a monel (ASTM B164) tee shall be used in sizes 6" and below.

In sizes 8" and larger a brass impingement plate shall be installed in the straight run. The impingement plate shall be ⅜" thick half hard rolled brass sheet, BS2874 CZ112. Its length shall be, such that when placed centrally under the branch, each end of the impingement plate extends 3" beyond the branch inside wall providing that a minimum of 1½" is kept clear of the butt weld end of the run, it shall cover one half of the pipe circumference of the main run.

See attached Fig. 1.



SEE PARAGRAPH 3

FIGURE I

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TITLE 8" N/B & OVER TEE FOR PRESSURE LET DOWN

3.3 Note that due to the difficulties of welding high carbon content steels the carbon and manganese limitations of Grade 'A' must be specified when ordering Grade 'B' Pipe.

3.4 Check valves listed are for centrifugal compressor systems only for reciprocating compressor check valves consult the Design Engineering Manager.

4. PIPE

.05" external corrosion allowance has been included in arriving at the list of standard piping and the desinger must recalculate when greater corrosion is to be expected.

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
4.1 Pipe Transmission			
1/8" - 2"	SCH. 40 Seamless Threaded Ends	API-5L-B (ASTM A53-B)	1.41.380
1/8" - 8"	SCH. 40 E.R.W. Plain Ends	API-5L-B (ASTM A53-B)	1.41.380
10" - 14"	SCH. 40 E.R.W. Plain Ends	API-5L-B (ASTM A53-B)	1.41.380

5. FITTINGS

5.1 Pulled Bends 15% Thinning allowed for

1/8" - 2"	SCH. 40 Seamless Plain Ends	API -5L-B	
1/8" - 4"	SCH. 40 E.R.W. Plain Ends	API-5L-B	

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 720 PSIG CSO 7.2

Piping Size Nominal Bore	Description	Material Specification	APL Material Code Group
5.2 Tees (See Note 3.2)			
Branch Size			
1/8" - 1"	SCH. 40 Forged Sockolets	ASTM A105.GR.2	4.26.223
1/8" - 1"	3000 psi. Forged Threadolets	ASTM A105.GR.2	4.26.123
1/8" & 2"	SCH. 40 Forged Tees Socket Weld Ends	ASTM A234.WPB	4.28.351
3" - 10"	SCH. 40 Wrought Butt weld ends USAS B16.9 (BS 1640)	ASTM A234 WPB	
12" - 14"	SCH. 40 Branch Welding Only	API-5L-B	
5.3 Reducers			
1½" - 14"	SCH. 40 Wrought Buttweld Ends USAS B16.9(BS 1640)	A234.WPB	4.28.712
5.4 Unions			
3/8" - 2"	3000 lb Forged Steel Threaded Ends	ASTM A 105.GR.2 (BS 3799 & BS 1503-161 GR.B)	4.27.680
3/8" - 2"	3000 lb Forged Steel Socket Weld Ends	ASTM A105.GR.2 (or BS 3799 & BS 1503-161 GR.B)	4.28.680

6. BACKING STRIP

Backing strip shall not be used on carbon steel oxygen transmission lines

7. FLANGES

1" - 3"	Class 300 Forged Steel R.F. Weld Neck USAS B16.5	ASTM A181.GR.1 (or BS1503-161 GR. B)	4.25.132
4" - 24"	Class 300 Forged Steel R.F. Slip on Weld USAS B16.5	ASTM A181.GR.1 (or BS1503-161 GR. B)	4.25.132

TITLE Piping Selection Sheet-Carbon Steel-Warm Oxygen Service 720 psig CSO 7.2

	Piping Size	Description	Material Specification	APL Material Code Group
8.	BOLTING	(See LS.04)		
	All sizes	Studs Alloy Steel. Full Thread Nuts Hex. Carbon Steel	ASTM A193.B7 ASTM A194.2H	
9.	GASKETS	(See LS.04)		
	All sizes	Compressed Asbestos Fibre 1/16" thick USAS B16.5(or BS1560)	KLINGERIT 661	4.24.111
10.	VALVES	(See Std. LS.05)		

Type No.	Description	Valve Type	Code No.
BZ/05/06	2" & smaller Class 300 Bronze Body & Trim	Gate	
CS/05/11	Over 2" Class 300 Cast Steel Bronze Trim	Gate	
BZ/03/13	$\frac{1}{2}$" & above class 300 Bronze Body & Trim	Globe	
SS/03/06 Modified	Over 4" Class 300 St/Stl type 304 or 316. Bronze Seat & Trim	Globe	
BZ/07/02	$\frac{1}{2}$" & above Class 300 Bronze	Check	
BZ/01/01	$\frac{1}{4}$" - 1" - 3000 psi rating. Bronze.	Needle	

APL

CENTRIFUGAL OXYGEN COMPRESSOR MANUAL

HATTINGEN PLANT

Contents:

1. Purpose

This manual establishes a standard procedure for the safe operation of the Hattingen centrifugal oxygen compressor and must be read in conjunction with the manufacturers Hand Book.

2. Scope

2.1 The manual outlines the procedures to be followed during maintenance work, and startup and shutdown of the machine.

2.2 These procedures are mandatory and will be strictly enforced by plant management.

3. Responsibility

3.1 All plant management operators, maintenance personnel, and other persons associated with oxygen compressor operation must be familiar with the information contained in this procedure and are responsible for compliance.

3.2 The above persons shall also be familar with the vendors literature.

4. Forbidden and Restricted Areas

4.1 The area immediately adjacent to the compressor is enclosed by protective barriers, when the machine is on oxygen service all personnel are bo forbidden entry to the areawithin the barriers.

4.2 The area surrounding the compressor but outside the barrier shall be clearly defined by appropriate signs, and entry will be restricted as follows:

4.2.1 When the machine is in oxygen service and operating normally one operator or one supervisor for the purpose of routine monitoring.

4.2.2 When the machine is being transferred from Nitrogen to Oxygen service, or vice versa a maximum of two operators and one supervisor for the purpose of valve operation.

4.2.3 Other personnel will only be admitted when the machine is operating on Nitrogen or is shutdown.

5. Instrumentation on Oxygen Compressors

5.1 All pressure and temperature indication shall be remote.

5.2 Gauges located on the Compressor i.e. shaft movement indicators or on the pipework, including instrumentation for auxiliaries shall be outside the protective barrier.

5.3 The compressor shall be fitted with proximity probes at each bearing which shall alarm at 0.5 mils and trip at 1.5 mils above normal.

5.4 The compressor shall be fitted with a axial position indicator which shall alarm in the event of the shaft moving 0.4 mms relative to the thrust and trip should the movement reach 0.8 mms.

5.5 Pressure gauges shall be green lined at their normal operating pressures. They shall also be red lined at their operating limits. Red lines for individual stage pressure gauge markings shall be at their relief valve set pressures. Rotor shift indicator shall be red lined at shut down setting. Seal system pressures shall be red lined at alarm and trip conditions.

5.6 Temperature indicators shall be green lined at their normal operating temperatures. Indicator switches shall be red lined at both the alarm and trip positions. (These are normally 25°F.and 50°F.above normal operating temperature.) Temperature indicators at points other than those with switches shall be red lined at a maximum of 25°F.above normal.

5.7 Oxygen tubing and lubricant tubing to gauges on the oxygen compressor panels shall be segregated. Individual tubing supports and troughs shall be used, and spacing shall be adequate. Lubricant tubing shall be positioned such that leakage cannot drip onto oxygen tubing.

6. <u>Starting-up - Normal</u>

6.1 Under no circumstances will an oxygen compressor be started by operators without the prior consent of the Plant Manager or his delegate.

6.2 All barriers are to be in place and secured prior to a compressor start-up.

6.3 The Plant Manager or his delegate will make a general inspection of the oxygen compressor area and having satisfied himself that the machine can be started shall designate the supervising and operating personnel to start the compressor. The startup personnel shall be limited to one supervisor and two operators, and due regard shall be paid to the restrictions under Section 4.

6.4 The machine shall be started up on Nitrogen as in Appendix I. The machine will be operated on Nitrogen at the maximum pressure obtainable and run for fifteen minutes with all readings steady before being put on oxygen service as detailed in Appendix I.

6.5 Conditions to be observed during the nitrogen run in period are:
(a) Observe all gas and oil temperatures and pressures for abnormal readings.
(b) Analyse and record vibration readings with portable vibration analysers, also observe the behavior of the continuous monitoring systems.
(c) Observe all seal pressures to ensure proper operating conditions.
(d) Thoroughly check for any oil leak and the possibility of oil entering the oxygen side of the compressor.

7. <u>Starting up after Overhaul or Inspection</u>

7.1 In addition to all the conditions in Section 6 it will be necessary to operate the compressor at maximum possible pressure <u>on nitrogen</u> for at least two hours.

7.2 Readings must be taken every 15 minutes and the last 3 readings on temperature, pressure and vibration must be stabilized and within tolerance before reverting to oxygen gas.

8. Shutting down - Normal

8.1 The plant manager or his delegate will make a general inspection of the oxygen compressor area and designate the supervisor and personnel to shutdown the machine. The number of personnel will be restricted to a total of three, and due regard will be paid to the restrictions under section 4.

8.2 The shutdown shall be made after reverting to Nitrogen as detailed in Appendix II.

9. Shutdown - Abnormal or Emergency

9.1 There will usually be time to advise plant management before a compressor shutdown. The 2 hour checks and logs are for this purpose. Unusual noise or an obvious failure of one of the compressor safety devices would justify an emergency shutdown. Should an increase in oil discharge to the atmosphere be noted there will still be ample time to analyze the situation and consult with plant management since the seal system offers triple protection before the oxygen circuit would be contaminated.

9.2 If conditions warrant, an emergency shutdown can be performed by pushing the emergency stop buttons and following up the procedure laid down in Appendix III.

9.3 In the event of a compressor trip the procedure laid down in Appendix III paragraph 4 and 5 is to be followed and plant management informed.

10. Routine Checks and Logs

10.1 Reliable operation of the machine can only be achieved by well trained personnel. Cleanliness and care of equipment ensure that defects can be detected at an early stage.

10.2 Checks for oil must be made through barrier inspection ports once each shift. Any leakage detected must be reported immediately since excessive leakage may require immediate shutdown for repairs and cleaning.

10.3 All gauges located remotely or on the compressor panel board shall be checked every 2 hours, the reading being recorded on the log sheet or in the plant log book.

10.4 A separate log sheet shall be kept for oxygen compressor readings to be taken during the first hour of each shift. With these once a shift readings, the operators shall study the past several readings to note the trends and advise management of any significant changes or gradual trends in any of the readings.

10.5 No hand vibration checks are to be made while compressing oxygen.

10.6 Auxiliary oil pumps. The auxiliary oil pump takes over the oil supply when starting or shutting down the compressor. The water driven pump which is an emergency oil pump is only for use in emergency cases. Both pumps are started when oil pressure drops and are controlled by pressure switches. When oil pressure drops, first the motor driven pump starts and at a lower pressure the water driven pump is started. When the pressure switch for the water driven emergency oil pump is operated the compressor trips. The automatic functioning of both these pumps should be checked at regualr intervals.

10.7 The main oil filter hand wheel for cleaning the filter should be turned a few times during each shift. At a pressure drop of 0.3 to 0.4 Kg/cms^2 across the filter, they must be switched and the dirty filter cleaned. At a pressure drop of 0.6 Kg/cms^2 an alarm will be given.

10.8 The thrust bearing filter must be changed at a pressure drop of over 0.4 Kg/cms^2 and the dirty filter cleaned. Pressure after the filter must never be less than 0.5 atu.

10.9 The bearing oil supply temperature should be maintained at 35 - 40°C. The flow off temperature at each bearing should not be more than 15°C above this value; if it is the bearing should be inspected.

10.10 The oil piping should be inspected through the ports in the protective barriers to check for leaks.

Continued/...

10.11 The lube oil should be analyzed at regular intervals as laid down in the P.M. Manual.

10.12 Check intercoolers and aftercooler for leaks by blowing down gas side or venting the water side and checking for water or oxygen gas respectively.

10.13 At regular intervals check that the discharge check valve moves freely by gently pulling down the dead weight arm to cause only a few degrees rotation, so as not to affect the flow rate or discharge pressure significantly.

10.14 Check that air supply for the gland and bearing seal air is always dry and that the supply pressure is 4 atu.

10.15 Check the oxygen content of the exhaust seal gas.

11. Setting of Vibration Levels

11.1 The alarm will be set to sound at a vibration level of 0.5 mils above the normal vibration level. Plant personnel will immediately switch the compressor to nitrogen service when vibrations reach alarm level, and inform plant management of the situation.

11.2 Controlled shutdown of the compressor (Appendix II) will be carried out at a vibration level of 1.0 mils above normal operating level, whether on oxygen or nitrogen service.

11.3 Automatic shutdown of the compressor will be set at a vibration level of 1.5 mils above normal operating level.

11.4 A gradual increase in the vibration level from the normal level approaching the alarm set point shall be reported to Plant Management as soon as the increase is discovered. Operations Engineering will evaluate the increase and advise the necessary action.

12. Maintenance

12.1 Process Preparation

12.1.1 Before any maintenance is performed on an O_2 compressor, the compressor must be isolated on the suction and discharge side.

12.1.2 After isolation the compressor will be purged with nitrogen gas. A "sniff" type analyzer shall be used to determine the effectiveness of isolation. If there are indications of leakage it will be necessary to install blanks. Double blocks and bleeds where provided shall always be used.

12.1.3 All valves in the system shall be tagged out and a work permit issued.

12.2 Welding and Burning

12.2.1 If welding equipment or an oxyacetyline torch must be used to perform certain maintenance functions they must be used only after a double block and bleed or blank (between flanges) is employed.

12.2.2 A hot work permit must be issued by the Shift Supervisor on duty after he has personally checked the area with an oxygen analyzer.

12.2.3 The use of welding or cutting equipment must be kept to an absolute minimum in an oxygen compressor intercooler area, even though the area has been declared safe.

12.3 Materials approved for Oxygen Service

The following instructions for jointing compounds take precedence over those in vendor manuals.

12.3.1 Only Permatex #1516 shall be used as a split line sealing compound on oxygen compressors except in the bearing housing areas, where Silicone Sealing Compound RTV-60 (General Electric Company) shall be used. (Permatex #1516 is not recommended for oily areas, and RTV-60 will not be in contact with oxygen in the bearing housing area.)

12.3.2 Gasket jointing material will be Klingerit 661.

12.3.3 Only oxygen safe material (KEL-F Halocarbon or Fluorolube) should be used on '0' rings or on surfaces requiring lubrication. The above mentioned lubricants shall only be used from a tube or container that is sealed or known to be absolutely free of foreign contamination. These lubricants must be applied to the components in such a manner so as not to contaminate with finger prints, lint, dirt, etc.

Continued/...

12.4 <u>Overhaul Procedure</u>

12.4.1 Whenever an oxygen compressor is opened for overhaul or inspection, such work must be carried out under the direct supervision of a service engineer from the machine vendor; with a representative from Operations Engineering also in attendance.

12.4.2 It is absolutely essential that parts are cleaned as under 12.5.5 before reassembly on the machine.

12.4.3 Accurate records will be kept of all work performed on the machine and will include tolerances before strip down and after assembly.

12.5 <u>Cleanliness During Maintenance</u>

12.5.1 The restricted area designated under paragraph 4.2 shall be designated a clean area during overhaul or inspection of the machine, and the floor will be maintained scrupulously clean by frequent mopping. Entry to this area shall be across a clean doormat and will be restricted to persons wearing clean white overalls.

12.5.2 Throughout the overhaul there will be ample provision of:
(a) Polythene bags and sheets.
(b) Lint free cotton cleaning cloths (which shall be counted at the beginning and end of each shift).
(c) Containers of clean methylene chloride or trichlorethylene.
(d) Storage trays.

12.5.3 During the course of strip down and inspection each individual part shall be stored in the trays provided and where appropriate wrapped in polythene to avoid contamination.

12.5.4 Whilst overhaul proceeds all machine internals and pipe ends will be protected by polythene to prevent accidental ingress of foreign materials.

12.5.5 Before reassembly all parts that contact (or may possibly contact) the pure oxygen stream or are in contact with ejected seal air that may have high oxygen concentrations must be degreased with an approved solvent (Methylene Chloride or trichlorethylene) and after evaporation to dryness the part must be examined with a black light in accordance with Engineering Specification A.03 (Refer also to E.J. Bassler's report "Cleaning for Oxygen Service", January, 1960. #99000096).

12.5.6 White lint free cotton gloves must always be worn when handling parts cleaned for oxygen service.

Continued/...

12.5.7 In wiping operations clean, lint free, cotton clothes shall be used as provided under paragraph 12.5.2 (b).

12.5.8 Suction strainers on oxygen compressors are designed for continuous service and shall not be removed except for periodic cleaning. Strainers shall be cleaned with an approved solvent as under Paragraph 12.5.5. If it is necessary to brush the filter the solvent cleansing shall be done <u>after</u> the brushing and the filter shall be allowed to dry by evaporation in a clean dry area. Filters shall not be blown dry unless dry oil-free nitrogen or air is used.

13. Miscellaneous Operations

13.1 Do not flush lubricating oil lines inside the compressor bearing chamber or pass oil through the bearings unless the compressor sealing system is operating correctly. Stop oil pumps before shutting down the seal system.

13.2 If seal air fails on the compressor and the compressor shuts down stop oil circulation as quickly as possible (Note contrary to Appendix II paragraph 11). Before restarting after a seal air failure the shaft area shall be inspected for oil. There will usually be a slight indication of oil, but if abnormal quantities of fresh oil are visible the shaft seal labyrinth assembly must be removed and inspected. If inspection indicated oil has progressed beyond the air section of the labyrinth, the compressor top case shall be removed for complete inspection and cleaning.

13.3 If seal inlet pressures remain the same but the labyrinth seal pressure decrease, then bearing wear is indicated.

APPENDIX I

DETAILED STARTING INSTRUCTION

1. Preparation for Starting

1.01 Open main cooling water isolating valves.

1.02 Open all return valves of intercoolers, aftercoolers and motor air coolers. Vent coolers on water side.

1.03 Water outlet valve of oil cooler remains closed until oil temperature has reached 35°C. Vent cooler on water side. The vent on the oil side of cooler remains open all the time

1.04 Open air supply to gland seal air, pressure must be about +200 mmWG.

1.05 Switch in O_2 - air extractor fan, pressure must be about -400 mmWG.

1.06 Open air supply to bearing seal air, pressure must be about +80 - + 90 mmWG.

1.07 Start oil vapor extractor.

1.08 Start auxiliary oil pump.

1.09 Open main hand valves of supply to air ejector and water driven oil pump.

1.10 Check that bypass valves to ejector and water driven oil pump are closed.

1.11 Check that air ejector and water driven oil pump are not in operation after having pressed the "stop" button of each one of them respectively.

1.12 Open supply for control air in back of panel (only one filter is in operation at a time).

1.13 Set controller of intake butterfly valve in control room to "hand position and give it minimum setting of 4 psig control air pressure.

1.14 To interlock and close intake butterfly valve press "close" button on panel.

1.15 Set controller for recycle valve on panel to "hand" position and open recycle valve.

1.16 Before starting the compressor the oil temperature must be at least 20°C. If it is below keep auxiliary oil pump in operation until this temperature is obtained.

1.17 Check oil level in oil tank.

1.18 Switch off motor standstill heating.

2. Starting Conditions

The following conditions are required before compressor motor can be started (besides conditions on electric side, mainbreaker, synchronization etc.).

2.01 Auxiliary oil pump must be in operation.

2.02 Bearing oil pressure must be sufficiently high.

2.03 Oxygen intake pressure must be high enough (normal 0.20 atu).

2.04 Oxygen-air extractor fan must be in operation.

2.05 Intake butterfly valve must be closed.

2.06 Trip healthy and check warning button must have been pressed.

2.07 No warning indicated.

2.08 Emergency stop button must be out of interlock.

2.09 Motor starter must be wound to start position.

2.10 If all conditions are fulfilled the white light will show that the machine is ready for starting.

3. Start-up Procedures

Reference Flowsheet 2521-1-F.

3.1 Open valves357, 359 and 369. Close Bleed valve 371. Start Nitrogen purge blower (item 15.71). Alternatively, shut off all reactivation and defrost nitrogen valves and use reactivation blower (items 08.22). If the latter method is adopted care should be taken to box up all absorbers and vessels undergoing reactivation or defrost.

3.2 Close discharge valve 601 and (CV123). Close suction valve 617. Open suction valve CV.110.

3.3 Open nitrogen purge valve half a turn.

3.4 Crack open compressor discharge vent valve 372.

3.5 Purge compressor with nitrogen until oxygen content is less than 4% as measured at the shell side drain of the aftercooler.

3.6 Close discharge vent valve 372 and nitrogen valve 370.

3.7 Fully open recycle valve on manual control. Close suction butterfly valve.

3.8 Start Compressor, watch ammeter, synchronising speed is reached within approximately 7 seconds.

3.9 About 10 seconds after compressor has reached normal speed switch off the auxiliary oil pump and set it to position Automatic. The oil is now supplied by the main pump coupled to the gear.

3.10 Immediately open suction valve 370 and control to maintain nitrogen blower discharge pressure at 0.4 to 0.5 Kg/cm^2. The compressor discharge pressure will then build up to 10 Kg/cm2 with the recycle valve fully open.

3.11 When the discharge pressure reaches 10 Kg/cm2 crack open the discharge vent valve CV124. Do not open the valve too wide otherwise the nitrogen blower pressure will fall below 0.4 Kg/cm^2.

3.12 Check performance of compressor to determine that vibration levels, bearing temperatures etc., are normal.

3.13 When the machine has run for fifteen minutes with conditions normal open oxygen suction valve 617 and oxygen suction butterfly valve.

3.14 Close nitrogen valves 370 and 369. Open bleed valve 371.

3.15 Allow machine to run for about 3 minutes to purge out the nitrogen. Check oxygen purity at aftercooler shell side drain with portable analyser.

Continued/....

3.16 Build up machine discharge pressure by slowly closing recycle valve manually.

3.17 When the discharge pressure is normal put machine on line by opening discharge valve 601 and closing vent valve 372, (CV124). Put recycle and suction valves on automatic control.

3.18 Open water outlet valve of oil cooler when oil temperature reaches 35°C., keep oil temperature to bearings at 35 - 40°C. by adjusting the water flow with this valve.

4. Automatic Trips and Alarms

The following warnings, trips respectively, are given automatically.

4.1 Bearing oil pressure below 0.9 atu: Warning and starting of auxiliary oil pump.

4.2 Bearing oil pressure below 0.5 atu: Trip and starting of emergency water driven oil pump.

4.3 Bearing seal air pressure below to mmWG: Warning

4.4 Oxygen intake pressure below 0.054 atu: Trip

4.5 Gland seal air below 150 mmWG: Warning

4.6 Gland seal air below 100 mmWG: Trip

4.7 Oil vapour extractor not in operation: Warning

4.8 Oxygen air extraction pressure rising to -300 mmWG: Warning and starting of air ejector. If pressure does not return to normal pressure (-400 to -500) trip within 5 seconds.

4.9 Cooling water pressure below 2.0 atu: Trip

4.10 Water pressure for water driven oil pump below 1.65 atu: Warning

4.11 Cooling water valves on inter and aftercooler not completely open: Warning

4.12 Shaft displacement higher than $\pm$ 0.5 mm: Trip

4.13 Oil level in oil container too low: Warning

4.14 Motor protection energized: Trip

4.15 24 Volt supply failure: Warning

4.16 Differential pressure at main oil filter above 0.6 kg/cm^2: Warning

4.17 Oxygen temperature before coolers will give alarms as follows:

1 st Stage intercooler	155°C	Alarm
2 nd Stage intercooler	160°C	Alarm
3 rd Stage intercooler	155°C	Alarm
Aftercooler	145°C	Alarm

Continued/...

4.18 Oxygen temperature before coolers will trip the machine at the following temperature:

1 st Stage intercooler	170°C	Trip
2 nd Stage intercooler	180°C	Trip
3 rd Stage intercooler	170°C	Trip
Aftercooler	160°C	Trip

In the event of one of the above trips the auxiliary oil pump will not start when machine runs down (fire!). Only the emergency water driven pump will start and run for a period of 4 minutes.

4.19 Bearing white metal temperature above 95°C: Warning

4.20 Bearing white metal temperature above 110°C: Trip

4.21 5 Kv supply failure: Trip

4.22 Motor bearing temperature above 60°C: Trip

4.23 Motor cooling air too high, cold air 40°C, arm air 60°C: Warning

APPENDIX II

Controlled Shutdown

1.1 Open valves 357, 359, and 369. Close bleed valve 371. Start Nitrogen purge blower (Item 15.71). Alternatively shut off all reactivation and defrost nitrogen valves and use reactivation blow(Item 08.22). If the latter method is adopted care should be taken to box up all vessels undergoing reactivation and to switch off reactivation heaters.

1.2 Op n recycle valve fully on manual control.

1.3 Close discharge valve 601.

1.4 Close manual suction valve 617.

1.5 Crack open vent valve 372 (Cv124 after modifications) such that the discharge pressure falls to 10 Kg/cm^2.

1.6 Open nitrogen valve 370 and control to maintain a minimum pressure of 0.4 Kg/cm^2 at the blower discharge.

1.7 Check the oxygen content of the gas at the shell side drain of the after-cooler. When it is less than 4% slowly open discharge vent CV124 (V372).

1.8 Stop the compressor.

1.9 When the machine has come to rest purge with nitrogen for about three minutes and then close valve and the vant valve CV124.

1.10 When compressor runs down oil pressure will reduce and at about 0.9 atu the auxiliary oil pump starts, automatically. Watch oil pressure if because of malfunction pump does not start switch on by hand.

1.11 After run down leave auxiliary oil pump in operation for about 40 minutes.

1.12 Maintain seal gas supply during the period the machine is shut down whenever possible.

1.13 Switch on motor heater.

APPENDIX III

Emergency or Abnormal Shutdown

1.1 Open vent valve CV124.

1.2 Close suction valve CV110.

1.3 Stop machine using the switch on the compressor panel, or the emergency stop button in the control room. Note: Stopping the machine will automatically open CV124 and close CV110.

1.4 Close valves 617 and 601.

1.5 Commence N_2 purge as detailed in Appendix II, Paragraphs 1.1, 1.2, 1.6 and 1.7.

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I. G. D. ENGINEERING MANUAL

No. EM 40 - 01 Rev. 0
PAGE 1 CONT. ON 2

LOX installation at Customer Sites

For installation layout details refer to EM 06 - 01

For LOX/Propane installations refer also to EM 40 - 07.

0	ORIGINAL ISSUE	19.7.71.	J.Chambers	
REV.	DESCRIPTION	DATE	ORIGINATOR	APPROVE

ORIGINATOR	DATE	APPROVED BY	SECTION HEAD		I.G.D. ENG. MANAGE

F.482

APCI DOCUMENT NO 99000411

1. Purpose

1.1 This code is to define the requirements for siting of bulk liquid oxygen installations at customer premises.

2. Introduction

2.1 Gaseous oxygen is colourless, odourless and tasteless; it is non-toxic; it is slightly denser than air.

2.2 Liquid oxygen boils at -183°C at atmospheric pressure. 1 volume gives 850 volumes of gas at ambient conditions.

2.3 Oxygen supports combustion. Combustible material catches fire more easily and burns more vigorously in oxygen, or in an atmosphere enriched by a small percentage of oxygen, than in atmospheric air.

2.4 Cold gaseous oxygen and liquid oxygen are considerably heavier than air and will accumulate in pits and trenches.

2.5 Liquid oxygen and cold gaseous oxygen may cause severe burns when in contact with the skin or respiratory tract.

2.6 Most steels are brittle at liquid oxygen temperature.

3. Precautions

3.1 For the above reasons, bulk LOX storage installations must not be installed unless they conform to this Code.

3.2 Oil and grease constitute a particular hazard with oxygen, and on no account may they be used in an oxygen installation.

3.3 All equipment must be specifically designed, protected and prepared for oxygen service.

3.4 Good housekeeping to prevent contamination by combustibles or loose debris is an overall requirement.

4. Definition

4.1 A bulk liquid oxygen storage installation is defined, for the purpose of this Code, as the total assembly of liquid storage tanks together with their associated gaseous storage, evaporating equipment and controls connected in service, in a static position to supply a customer with liquid or gaseous oxygen.

4.2 The boundary of the installation is defined as that line, real or imaginary, which encompasses the equipment defined in section 3.1 above.

4.3 The Code covers an installation, on customer's premises where the capacity of liquid is more than 200 or less than 125,000 litres (6,000 cu. ft. to 3.5 MM cu. ft.).

5. General

5.1 Siting

To prevent fire at the installation, and oxygen enriched fires in the vicinity, the surrounding area shall be so controlled that combustible material, smoking and naked lights are prohibited within a distance of 6M (20 ft) from the installation, except where this area is cut by substantial and impervious walls or partitions of wholly non-combustible materials and built to a minimum height of 2.4M (8ft).

5.2 Installations must not be positioned closer than 6M (20 ft) to places such as cinemas, churches, residential premises stadia, cloakrooms, offices, canteens, time clocks, etc.

Private roads or footpaths can pass within not less than 3M (10 ft) of the installation.

5.3 Windows, cellar openings, trenches, manholes, cable ducts, gullies or traps constitute a hazard to a major or minor degree according to location. Within the prescribed 6M (20 ft) these shall be avoided, if possible, or at least kept to an absolute minimum. If pits and trenches are unavoidable, they must be adequately ventilated to dispel oxygen which might be contained therein.

5.4 Doors or access passages from which the installation can not be seen be at least 3M (10ft) from the outline area of the installation.

N.B. Indoor installations are allowable, see section 13.

5.5 Location to be chosen so that damage to the installation by electric arcing under fault conditions cannot occur.

5.6 Location to avoid, as far as possible, pipelines carrying flammable liquids or gases. Where unavoidable, ensure that the pipeline is continuous (i.e. no joints) and so positioned to avoid accidental liquid oxygen spillage, but not in a trench.

5.7 Installations shall not be sited on top of existing buildings. Where they are required to be at high level, they shall be sited on top of purpose-designed and built supporting structures, having due regard to the effects of possible liquid spillage on adjacent structures and plant.

5.8 Safety relief devices for the main liquid storage vessel shall vent to a safe place in the open away from occupied buildings and combustible materials.

6. Exception

When unavoidable work is performed involving use of a naked flame in the vicinity of an installation, a 'permit to work' must be obtained from a responsible official.

7. Access

7.1 It is considered essential that when any tanker is in position for filling the installation, it shall be in the open and shall not be in a walled enclosure from which the escape of liquid or heavy vapour is restricted. Tankers should have easy access to the installation at all times.

7.2 Authorised persons should have easy access to the installation at all times.

8. Construction of Access Apron

The required 'hardstanding' shall be of concrete or similar inorganic and non-porous substance. Asphalt, chippings and tar base substances constitute a hazard, and if saturated with liquid oxygen an explosion could be caused by a falling weight or tyre friction.

N.B. 'Hardstanding' is defined as:
The area upon which the tanker stands whilst it is decanting liquid oxygen into the installation. It should be shown on the drawings of the installation.

9. Non-access by Public

In view of the possible danger of contact with oxygen liquid or vapour, which may be spilled during the process of filling; a standing space, from which the public can be excluded, shall be provided for the tanker whilst filling a bulk oxygen storage installation. A tanker shall not stand on the public highway or public ground whilst in the process of transferring liquid to or from a static vessel.

10. Warning Notices

10.1 Notices carrying the words 'LIQUID OXYGEN' should be prominently placed. It is also vital to warn that smoking or presence of naked flames near the plant is strictly prohibited.

10.2 Suitable warning notices, forbidding access to the installation to all unauthorised persons shall be displayed.

10.3 Before putting the installation into full operation, controls for emergency operation shall be clearly labelled. Emergency operating instructions shall be displayed immediately adjacent to the emergency controls. These must be kept up-to-date and legible.

11. Modifications

11.1 Supplier owned equipment must not be modified by the customer.

11.2 Customer owned equipment must not be modified without reference to the oxygen supplier.

12. Peculiar Hazards

12.1 In certain locations, there may exist hazards peculiar to the case which affect safety, but which are not specifically covered by this Code. These cases must be given expert consideration. A list of examples of such hazards appears in Table 1.

12.2 Storage of compressed, liquefied or dissolved gases which are inflammable shall not be allowed within 6M (20 ft) of the installation.

12.3 Storage of combustible material such as paper, timber, coal or inflammable liquids shall not be allowed within 6M (20 ft) of the installation.

PERMANENT OUTDOOR INSTALLATIONS

13. Separate Compound

13.1 A site shall be chosen which is for the exclusive use of the bulk installation, and shall be suitably prepared. The base of the site shall be raised sufficiently above ground level to avoid ponding, and shall be made of concrete or similar inorganic and non-porous substance. The installation shall be clearly defined and surrounded by an open design and non-combustible barrier, provided with adequate emergency exists clearly marked.

13.2 The equipment must be installed, tested and commissioned to the satisfaction of the oxygen supplier.

INDOOR INSTALLATIONS

14. Separate Compartments

14.1 Where it is not possible to have a separate building for the exclusive use of the installation and plant space forms part of existing buildings, the actual space shall be entirely separated by means of a continuous partition of non-combustible material from floor to ceiling or roof and one shall be an outside wall, wire mesh, if necessary, to provide good ventilation.

Where wire mesh is provided, the equipment must be weather-proofed and extra care taken to keep clean from airborne dirt. The safety distances specified in 4.3 shall apply to the area outside the wire mesh wall. The installation will be erected at ground level and no trenches, manholes, cable ducts, gullies or traps shall be allowed in the enclosure. An adequate emergency exit, additional to the door used for filling the installation, shall be provided. Should this exit communicate with existing buildings it shall be fitted with a 6" deep cill to prevent the escape of liquid.

15. Ventilation

15.1 The compartment containing storage and vaporising equipment must be properly ventilated. Openings used for access and/or for ventilation shall lead to a safe place i.e. where there will be no accumulation of combustible material liable to form a hazard.

15.2 In certain installations forced draught will be necessary. Taking account of the possible hazards, expert consideration must be given to the design of ventilation facilities in such installations.

16. Access

16.1 The driver shall have unobstructed freedom of movement between his tanker and the controls in the plant house. Filling through a 'hatchway' constitutes a hazard and is not acceptable.

16.2 The building and equipment must be installed, tested, and commissioned to the satisfaction of the oxygen supplier.

17. Couplings

17.1 The design of liquid couplings used in the installation shall be exclusively for liquid oxygen use.

TABLE I

BULK LIQUID OXYGEN STORAGE INSTALLATIONS
CUSTOMER SITES

Examples of peculiar hazards requiring expert consideration are:

Overhead electric cables
Overhead gas or otherpipework
Underground pipework
Craneage in the vicinity
Storage of large quantities of petrol, oil, LPG, LNG
Storage of large quantities of timber, coal
Storage of large quantities of paint, etc.
Ground sloping to an adjacent hazard

Procedure for filling Cryogenic tanker by pump at Carrington.

This procedure covers the filling of all semi-trailers and rigid tankers in Cryogenic service.

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G. Gray	13.7.71.				

APCI DOCUMENT NO 99000 4/12

1. Procedure for Filling Cryogenic Tankers by Pump at Carrington.

1.1. Before starting to fill tanker:

1.1.1. Check that tanker has been properly weighed in, and note weigh ticket number.

1.1.2. Check with Plant Control Room that tanker can be filled, and give them the number of the weigh ticket, tanker number and product.

1.1.3. Proceed to appropriate fill point and correctly position tanker.

1.1.4. Put on safety glasses, face shield or goggles, hard hat and gloves.

1.1.5. Check piping and controls and clean where necessary.

1.2. The valve positions on the fill point, prior to filling.

1.2.1. Transfer pump outlet valve - shut.

1.2.2. Vapour Return valve - shut.

1.2.3. Filling hose and transfer pump suction drain - open

1.3. Procedure:

1.3.1. Place in position "Hoses Connected" sign.

1.3.2. Connect vapour return hose using sealing washers.

1.3.3. Connect up liquid fill hose using sealing washers.

1.3.4. Note tanker pressure.

1.3.5. Open vapour return valve on filling point.

1.3.6. Crack open vapour recovery valve on tanker and reduce tanker pressure to 5 psig below suction pressure of transfer pump gauge

1.3.7. Shut filling hose drain valve on fill point (and open hose drain valve on tanker).

1.3.8. Open transfer pump suction valve. (Liquid should now be passing through the transfer pump and hose, cooling them down). Allow 2 minutes cool down. Close drain valve.

1.3.9. Open pressure delivery valve on tanker (liquid filling valve).

1.3.10. Start transfer pump (green button). (If the pump fails to start ask for help from the Control Room.)

1.3.11. When the pump is pumping properly, close in on the vapour recovery valve on the tanker.

1.3.12. Maintain the tanker pressure until the tanker liquid level shows that the tanker is full.

	pump discharge pressure
2000 rigid tanker without pump fitted	
2000 Rigid tanker with pump fitted -	50 psig (max)
3500 Semi-trailer with pump fitted -	15 psig (max)
4000 Semi-trailer with pump fitted -	15 psig (max)
6000 Semi-trailer with pump fitted -	33 psig (max)
7000 Semi-trailer with pump fitted -	33 psig (max)

1.3.13. Stop transfer pump (red button).

1.3.14. Shut off transfer pump outlet valve.

1.3.15. Defrost filling hose pushing liquid into the tanker.

1.3.16. Shut off pressure delivery valve (liquid filling valve) on tanker.

1.3.17. Immediately open filling hose drain on fill point, and hose drain on tanker.

1.3.18. Shut vapour recovery valve on tanker, vapour return valve on fill point and open vapour recovery hose drain on tanker.

1.3.19. Finish off defrosting both hoses and disconnect from tanker. Place hose ends in hose holder.

1.3.20. Connect and purge out the sample line and give a small flow down the line to the analyser.

1.3.21. Inform Control Room that the tanker is ready to test. When the test is complete, disconnect sample line.

1.3.22. Remove "Hoses Connected" sign.

1.3.23. Weigh the tanker out, taking the top copy of the weighbridge ticket back to the Control Room and obtain a Quality Control release note for your load.

NOTE: PRESSURE FILLING IS EXTREMELY WASTEFUL, AND SHOULD ONLY BE USED ON INSTRUCTIONS FROM YOUR SUPERVISOR.

Procedure for filling Cryogenic Tankers by pump at Bracknell.

This procedure covers the filling of all semi-trailers and rigid tankers in Cryogenic service.

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Procedure for filling Cryogenic tankers by pump at Bracknell.

1. Before starting to fill tanker:

   1.1. Check that tanker has been properly weighed in, and note weigh ticket number.

   1.2. Check with Plant Control that tanker can be filled, and give them the number of the weigh ticket, tanker number and product.

   1.3. Proceed to appropriate fill point and correctly position tanker.

   1.4. Put on safety glasses, face shield, or goggles, hard hat and gloves.

   1.5. Check piping and controls and clean where necessary.

2. The valve positions on the fill point, prior to filling:

   2.1. Transfer Pump by-pass valve - shut.

   2.2. Transfer pump suction valve - open.

   2.3. Transfer pump outlet valve - shut

   2.4. Vapour return valve - shut.

   2.5. Transfer pump discharge (top) drain - shut

   2.6. Filling hose (middle) drain - shut.

   2.7. Transfer pump suction (bottom) drain - shut.

3. Procedure

   3.1. Place in position "Hose Connected" sign.

   3.2. Connect vapour return hose using sealing washers.

   3.3. Connect up liquid fill hose using sealing washers.

   3.4. Note tanker pressure.

   3.5. Open vapour recovery valve on filling point.

   3.6. Crack open vapour recovery valve on tanker and reduce tanker pressure to 5 psig below suction pressure of transfer pump gauges

   3.7. Open fill hose drain valve on tanker.

   3.8. Open transfer pump outlet valve (liquid should now be passing through the transfer pump and hose cooling them down). Allow 2 mins. cool down. Close drain valve.

3.9. Open pressure delivery valve on tanker (liquid filling valve).

3.10. Start transfer pump (green button). (If the pump fails to start, ask for help from the Control Room.)

3.11. When the pump is pumping, close in on the vapour recovery valve on the tanker.

3.12. Maintain tanker pressure until the tanker liquid level shows that the tanker is full.

2000 rigid tanker without pump fitted	- discharge pressure
2000 rigid tanker with pump fitted	- 50 psig max.
3500 semi-trailer with pump fitted	- 15 psig max.
4000 semi-trailer with pump fitted	- 15 psig max.
6000 semi-trailer with pump fitted	- 33 psig max.
7000 semi-trailer with pump fitted	- 33 psig max.

3.13. Stop transfer pump (red button).

3.14. Shut off transfer pump outlet valves.

3.15. Defrost filling hose pushing liquid into the tanker.

3.16. Shut off pressure delivery valve (liquid filling valve) on tanker.

3.17. Immediately open filling hose (middle) drain on fill point, and hose drain on tanker.

3.18. Shut vapour recovery valve on tanker, vapour return valve on fill point and open recovery hose drain on tanker.

3.19. Finish off defrosting both hoses and disconnect from tanker. Place hose ends in hose holders.

3.20. Connect and purge out the sample line, and give a small flow down the line to the analyser.

3.21. Inform Control Room that the tanker is ready to test. When the test is complete, disconnect sample line.

3.22. Remove "Hose Connected" signs.

3.23. Weigh the tanker out, taking the top copy of your weighbridge ticket back to the Control Room and obtain a Quality Control release note for your load.

NOTE: PRESSURE FILLING IS EXTREMELY WASTEFUL AND SHOULD ONLY BE USED ON INSTRUCTIONS FROM YOUR SUPERVISOR.

Procedure for filling Cryogenic Tankers by pump at Stoke-On-Trent.

This procedrue covers the filling of all semi-trailers and rigid tankers in Cryogenic service.

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Procedure for Filling Tankers by Pump at Stoke:

1. Before starting to fill tankers:

   1.1. Ring Control Room, ask them to open the barrier.

   1.2. Check that tanker has been properly weighed in and note the weight ticket number.

   1.3. Check with Control Room that tanker can be filled and give them the number of Weight ticket, Tanker number and product.

   1.4. Proceed to appropriate fill point (and correctly position tanker).

   1.5. Put on safety glasses, face shields, or goggles, hard hat and gloves.

   1.6. Check piping and controls and clean where necessary.

2. The valve positions on the fill point, prior to filling:

   2.1. Transfer pump outlet valve - shut

   2.2. Vapour recovery valve - shut

   2.3. Filling Hose Drain - open

   2.4. On LIN storage, pump suction valve open.

   On LOX storage, pump suction valve closed.

3. Procedure:

   3.1. Place in position "Hoses Connected" sign.

   3.2. Connect up vapour recovery hose using sealing washers.

   3.3. Connect up liquid fill hose using sealing washers.

   3.4. Note tanker pressure.

   3.5. Open vapour recovery valve on fill point.

   3.6. Crack open vapour recovery valve on tanker and reduce tanker pressure to 5 psig below the pressure shown on the transfer pump pressure gauge.

   3.7. Shut filling hose drain valve on fill point and open hose drains on tanker.

   3.8. Open transfer pump outlet valve (Liquid should now be passing through the transfer pump and cooling hose). Allow 2 minutes to cool down.

   3.9. Open pressure delivery valve on tanker (Liquid filling valve) and close hose drain valve.

3.10. Start transfer pump. (Starters are positioned behind left-hand LOX point)

3.11. If pump fails to start, ask for help from the Control Room.

3.12. When pump is pumping properly close in on the vapour recovery valve on tanker.

3.13. Maintain the tanker pressure until tanker liquid level gauge shows that the tanker is full.

2000 Rigid tanker without pump fitted - discharge pressure

2000 Rigid tanker with pump fitted - 50 psig max.

3500 Semi-trailer with pump fitted - 15 psig max.

4000 Semi-trailer with pump fitted - 15 psig max.

6000 Semi-trailer with pump fitted - 33 psig max.

7000 Semi-trailer with pump fitted - 33 psig max.

3.14. Stop transfer pump. (Red button)

3.15. Shut off transfer pump outlet valve.

3.16. Defrost filling hose pushing liquid into the tanker.

3.17. Shut off pressure delivery valve (liquid filling) on tanker.

3.18. Immediately open filling hose drain on Fill Point and Hose Drain on tanker.

3.19. Shut vapour recovery valve on tanker, vapour return valve on fill point and open vapour recovery drains.

3.20. Finish off Defrosting both hoses and disconnect from tanker. Place hose ends in hose holders.

3.21. Connect and purge out sample line and give small flow down the line to the analyser.

3.22. Inform Control Room that the tanker is ready to test. When the test is completed, disconnect sample line.

3.23. Remove "Hoses Connected" sign.

3.24. Weigh tanker taking the top copy of the weighbridge ticket back to the Control Room. Obtain a quality control release note for the load.

NOTE: PRESSURE FILLING IS EXTREMELY WASTEFUL, AND SHOULD ONLY BE USED ON INSTRUCTION FROM YOUR SUPERVISOR.

Purge Procedure for Cryogenic Liquid Container

This procedure outlines the methods and practices employed in purging cryogenic containers which are employed as customer stations, district storage tanks, or for transporting cryogenic products.

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J Chambers	3-6-71				

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1. Scope

1.1. This procedure will apply to all cryogenic containers which contain a pressure build-up coil; and are to be placed in liquid oxygen, liquid nitrogen, or liquid argon service. Each container, whether new and being placed in service for the first time, or used, and being changed from one service to another, will be purged for the 'new' product service in accordance with this procedure.

2. Limitations

2.1. This procedure applies only to the products - liquid oxygen, liquid nitrogen, and liquid argon. It does not include purge procedures for placing a product container in liquid hydrogen service.

2.2. Where tanks are to be changed from L.N.G., CO2, Ethylene or any other cryogenic liquid other than LOX, LIN and LAR, the Quality Control Department of I.G.D. must be advised and no action taken by the Districts until a procedure is issued from them.

2.3. For new LOX, LIN or LAR, installations, where quality is critical and for all changes of tanks from LOX, LIN or LAR, to LOX, LIN or LAR, the purge and analysis procedures given in pages must be followed with the co-operation of the Quality Control Department.

2.4. Any tank about which there is any doubt what so ever as to the presence of hydrocarbon or other impurities which may have got into the tank from the customer's process then it is essential that Quality Control Department at Stoke is consulted before this tank is put into any other duty.

2.5. If it is necessary to send such a tank to Acrefair for degreasing or decontamination then I.G.D. Quality Control will co-operate with Acrefair and issue a certificate of cleanliness when the tank has been cleaned.

2.6. For new installation where quality is not critical, if agreed by the District Manager, the purge procedures only may be carried out without any analysis. If there are any doubts about such a case, the Quality Control Department should be consulted.

3. General Procedure

3.1. Generally, the purging procedure will involve introducing a small amount of liquid into the container through the liquid fill and drain line with the pressure build-up valve open and all other valves closed. Liquid will be introduced slowly, so that when the maximum purge pressure is attained, a minimum excess of liquid will be present in the tank. When the pressure has reached the maximum purge pressure, the liquid introduction will be discontinued, LIN and LAR ONLY can be drained from the container, and the gas will be bled to the minimum purge pressure. This procedure will be repeated until analysis or other means indicate the container to be adequately purged.

3.2. Maximum Purge Pressure

The maximum purge pressure is that pressure which will be attained after each liquid addition. This pressure will be attained by vaporising the liquid in the pressure build-up coil and will be equal to 50% of the relief valve setting. Determine the maximum purge pressure prior to commencing to purge the container.

3.3. Minimum Purge Pressure

In order to prevent back diffusion of atmospheric contaminants into the container, a minimum gas pressure must be maintained within the container at all times during the purging procedure. The minimum purge pressure should be equal to 2 psig or the smallest graduated division on the container gauge; which ever is the greater value.

4. Tanker Trailer Purging Procedure

Specific instructions for purging tanker trailers for liquid oxygen, liquid nitrogen, or liquid argon service are:

4.1. Determine the product which the tanker trailer has most recently contained; or, if it is a new piece of equipment. This information is necessary in selecting the analyser to be used to monitor the purge gas and determine when the purge is completed.

4.2. Attach the liquid source of the new product to the liquid fill and drain line on the tanker trailer. Close all valves except the valve to the pressure build-up coil. Slowly introduce liquid into the tanker allowing the liquid to vaporise in the lines and in the pressure build-up coil. When the pressure in the tanker equals the maximum purge pressure, discontinue adding liquid.

4.3. Open all valves which should normally drain liquid from the tanker and allow all liquid (if any) to drain from the tanker. Be sure to drain liquid through the pump and the pump cool down line, if possible. (The appearance of gas in indicates that all liquid has drained). When all the liqid has drained from the liquid valves, open all valves which would normally vent vapour from the tanker. Close all valves ("Liquid" and "vapour") when the pressure in the tanker is equal to the minimum purge pressure.

4.4. Extreme care must be taken as to where liquid is drained.

4.5. Repeat the procedure outlined in Paragraph 3.4. until analysis of the vapour indicates the tanker to be purged. (see Analysis, Paragraph 6 below).

<u>NOTE</u>:

Certain districts have large vaporisers which can be used to supply vapour as a purge medium. If vapour is used as a purge medium, there should be no change in the sequence of valve manipulation for presurization and venting as outlined in Paragraph : 4

5. <u>Storage Tank Purging Procedure</u>

5.1. Specific instructions for purging permanently mounted tanks (customer stations and district storage tanks) for liquid oxygen, liquid nitrogen, or liquid argon service are:

5.2. Determine the product which the storage tank has most recently contained; or, if it is a new piece of equipment. This information is necessary in selecting the analyser to be used to monitor the purge gas and determine when the purge is completed.

5.3. Attach the liquid source of the new product of the liquid fill line. Close all valves except the valve to the pressure build-up coil. Slowly introduce liquid through the lower fill line into the tank allowing the liquid to vaporise in the lines and in the pressure build-up coil. When the pressure in the tank equals the maximum purge pressure, discontinue adding liquid.

5.4. Open all valves which should normally drain liquid from the tank and all all liquid (if any) to drain from the tank. (The appearance of gas indicates that all liquid has drained). When all liquid has drained from the "liquid" valves, open all valves which would normally vent vapour from the tank. Be sure to allow vapour to vent from the liquid top fill line. Close all valves ("liquid" and "vapour") when the pressure in the tank is equal to the minimum purge pressure.

5.5. Repeat the procedures outlined above until analysis of the vapour indicates the tank to be purged. (See Analysis, Paragraph 6 below).

6. <u>Analysis</u>

(This section is taken from APCI District Operations Manual Section 1.5 and Equipment Specified may not be available in the U.K. Equivalent test would be acceptable).

6.1. Analysis will be performed to determine when the container has been completely purged. These analyses will be performed on vapour from the container usually as the vapour is being vented during the depressurisation step of the purge procedure. A 1/4" copper tubing line should be attached to one of the vapour discharge lines (full tricock or vapour leg of liquid level gauge are acceptable) on the container to be used to supply the sample of the analyser.

6.2. Selection of the analyser to use for monitoring the purge gas will be in accordance with Table I. (See Sheet No .7)

6.3. Column 1, Previous Service, indicates the product which the container has most recently contained. If it is a new container, it is assumed that the container is filled with air.

6.4. Column II, New Service, indicates the product service into which the container is being placed.

6.5. Column III, Analyser, lists the analysers to be used in monitoring the purge gas.

6.6. The oxygen orsat is the standard Air Products Oxygen purity test set (Burette and Copper-Ammonium Solution).

6.7. The trace oxygen analyser can be either the ASC Model 300 with appropriate range or the APCI Hot Filament Trace Oxygen Analyser (Puff Tester) or equal.

6.8. The thermal conductivity analyser should have a sensitivity capable of indicating a 0 - 500 ppm full-scale range of nitrogen contamination in argon, or 0 - 500 ppm full-scale range of argon in nitrogen.

6.9. The ion mobility analyser shall be as manufactured by Air Products and Chemicals, Inc., Speciality Gses Dept., with a full-scale range of 0-50 ppm nitrogen in argon.

6.10. Column IV, Analysis Requirements, lists the level of measurement of the compound listed which must be attained before the container is considered to be completely purged. $<$ = less than; $>$ = greater than.

7. Safety

7.1. Proper safety precautions should be considered in these procedures to safeguard against the following hazards:

7.2. Exposure of personnel to high concentrations of nitrogen or argon in the atmosphere. (No personnel should be permitted to work at an atmospheric containing less than 18% oxygen).

7.3. Combustibility problems may arise from venting liquid oxygen where it may combine with combustible materials or where personnel may be exposed to high concentrations of oxygen in the atmosphere containing more than 25% oxygen).

7.4. Personnel should take due to prevent exposure to liquid or structural materials which may be at cryogenic temperatures.

TABLE I

PURGE GAS ANALYSER SELECTOR TABLE

Column I Previous Service	Column II New Service	Column III Analyser	Column IV Analysis Requirement
New Container	Oxygen	Oxygen Orsat	> 99.5% Oxygen
Argon	Oxygen	Oxygen Orsat	> 99.5% Oxygen
Nitrogen	Oxygen	Oxygen Orsat	> 99.5% Oxygen
New Container	Nitrogen	Trace Oxygen	< 25 ppm Oxygen
Oxygen	Nitrogen	Trace Oxygen	< 25 ppm Oxygen
Argon	Nitrogen	Thermal Conductivity	> 99.99% Nitrogen
New Container	Argon	Trace Oxygen & Ion Mobility or Thermal Conductivity	< 10 ppm Oxygen < 40 ppm Nitrogen or > 99.99% Argon
Oxygen	Argon	Trace Oxygen	< 10 ppm Oxygen
Nitrogen	Argon	Ion Mobility or Thermal Conductivity	< 40 ppm Nitrogen or > 99.995% Argon

Air Products

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Procedure for Cylinder Filling and Quality Control (Standard Purity Gases)

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1. Purpose

The purpose of this procedure is to establish a standard method within the company for filling high pressure, standard purity, permanent gas cylinders and to ensure compliance of the gases with the company's specifications.

2. Responsibility

It is the responsibility of the District General Manager and the Transport Depot Manager to ensure that this procedure is implemented and adhered to.

3. Procedure

3.1. Collect cylinders that are currently in service with the gas to be filled.

3.2. The cylinder should be free from dents or severe corrosion and the valve in good working order.

3.3. Reject cylinders that do not comply with company standard colour code and labelling requirements.

3.4. Tap the cylinder with a solid object and listen for a ring to indicate that the cylinder is free from water. Reject non ringers.

3.5. Reject cylinders that have not been tested within the last 5 years.

3.6. Roll acceptable cylinders to filling manifold and open all pigtail valves.

3.7. Sniff cylinders, reject any with detectable odour, and connect pigtails; cylinders with residual pressure should have their valves closed.

3.8. Any pigtails that are not used should be isolated with their respective valves.

3.9. Open vac valve and start vac pump.

3.10. When a vacuum of 5 mm Hg has been drawn close vac valve and switch off pump.

3.11. Open residual pressure cylinders valves and allow pressure to equalise throughout the manifold.

3.12. Analyse the manifold gas, enter results in charging log.

3.13. Evacuate manifold if impurity levels exceed three times specification.

3.14. Fit surface thermometer to one cylinder on the manifold.

3.15. Open gas filling valve.

3.16. Analyse gas being filled when manifold pressure exceeds 1000 psig, enter results in charging log.

3.17. Observe cylinder temperature near the end of filling and adjust the final pressure log results.

3.18. Analyse cylinders according to schedule EM 56-01 of this Manual.

Send one cylinder taken at random to Stoke for analysis each month.

Procedure for the Installation of a Cryogenic Tank.

This procedure covers the installation requirements for all cryogenic tanks where gas or liquid off-take is desired.

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APCI DOCUMENT NO. 99000417

1. Before starting any erection check that:-

   1.1. The foundation for the tanks is ready and has been cast long enough for it to stand the weight of the tank.

   1.2. The tank has not suffered any damage in transit and check vacuum.

   1.3. The crane is suitable for the load at the radius you want the jib to work at and that there are enough chains or slings for the job in hand.

2. Remove tank from lorry and place in position on foundation. If tank was transported standing on its feet it can be placed straight onto its foundation, but if it has been sent lying down then the tank must be placed on the ground and then carefully raised to a standing position before being put onto the foundation.

   Note: Never allow anyone to walk or stand under the tank whilst it is hanging on the crane hook and do not allow the lorry to drive away if the cab of the lorry has to pass below the tank hanging on the crane hook.

   The basic safety precaution of never to walk or stand below a hanging load can be seen to be broken in every factory every day but should not be allowed to be ignored on our sites, neither should any person stand or sit on the tank as it is being lifted.

3. Place any remote ambient air, steam or electrically heated vaporisers in position.

4. Pipe up tank to vaporiser and to customer line using copper tube. Fit appropriate hose coupling for service required if not already fitted. (Refer to Spec. EM22-01)

5. Test all piping with gaseous nitrogen at 360 psig. The remote vaporiser circuit will have to be fed with the testing gas at the most convenient point. It might be necessary to fit a tee in a line specially for this purpose, the branch of the tee being blanked off with a screwed plug after the successful test.

6. Fill tank with liquid (Standard Method).

   The first filling of a tank should be done with care and the District Engineer or Senior Technician should be present.

   Check first, all valves are operative and that all screwed unions are tight.

   Check that the following valves are shut (all valve reference numbers refer to A.P.L. manufactured tanks)

   V1, V2, V3, V4, V5, V6, V7, V10, V12, V14, V16, V18 (if fitted).

   and that the following valves are open:-

   V8, V9, V11, V13, V17

Connect hose from tanker to tank. Open V17, allow liquid to flow from tanker and when hose has cooled down (liquid present at V7) open V1 and V3 and close V7.

For filling a new warm tank the above will be found to be the most effective method. Liquid allowed to enter the tank via the top fill valve V2 will only tend to get carried out through the vent.

Check the vacuum at regular intervals during the fill and watch for any frosting on what should be warm or static lines indicating that there is a leak somewhere.

Loosen unions on liquid level gauge and tank pressure gauges and allow gas to flow for a few seconds, this will blow any residual trichlorethylene from these small bore pipes which could freeze and cause instruments to read incorrectly.

As more and more liquid is present in the tank the vent V13 can be gradually shut.

Unless the tank is going on stream immediately after filling it is suggested that the tank only be filled to 60% of its capacity at the first fill. This will allow a larger vapour space to be available to take the vaporisation that will take place from this semi-warm tank.

7. Filling tank with liquid (High purity method).

Butterfield tanks are given a cold shock test at their works using liquid nitrogen. A.P.L. tanks are not shock tested.

The boiling point of nitrogen at 15 psi is -320°F, Argon -302°F oxygen -297°F.

Nitrogen or Argon put into a tank containing Oxygen could condense the gas causing impurities in the Argon. If the tank has been thoroughly purged of the test gas using air, the Oxygen in the air could also contaminate the Argon or Nitrogen. Therefore it is essential that the product to the customer is to be as pure as possible and the following procedure must be adopted. If possible the tank should arrive on site a few days before filling and the vent valve V13 cracked open and valves V3 and V12 opened fully. Any cold gas or liquid still in the tank will then be warmed up in the pressure build up vaporiser and go out via the vent. Couple up tanker to tank in usual way, check that the following valves are shut:-

V1, V2, V3, V4, V5, V6, V7, V10, V13, V14, V15, V16 and V18 (if fitted).

and that the following valves are open:-

V8, V9, V11, V17.

Open valve V7 and pass liquid through hose, when liquid appears at V7 shut V7 and open V1 and V3. Allow tank pressure to build up to about 100 psi. Shut valve V1 and open V13.

When tank has vented down to zero pressure, shut V13 and open V1 again allow pressure to rise to about 100 psi. Shut V1 and open V13. When vented close V13 and proceed once more to open V1, build up pressure to 100 psi and again vent by opening V13.

This operation should have cleared out all but a few parts per million of the contaminating gas and filling can proceed as in the Standard Method.

When filling with Argon use of the vent should be kept to a minimum as Argon gas is expensive and wastage must be minimised.

8. The tank now containing liquid should be left with the following valves shut:-

V1, V2, V3, V4, V5, V6, V7, V10, V12, V13, V14, V16, V18 (if fitted).

and the following valves open:-

V8, V9, V11, V17.

Unless the tank is to go on stream immediately, when the procedure for setting a tank to work is to be followed. This is shown in paragraph 9.

9. First ascertain the maximum line pressure the customer requires. The tank pressure will then be 20 psi higher than this and the economiser regulator setting about 40 psi higher than the line pressure.

The first regulator to adjust will be the economiser regulator PCV3.

Starting with the valves shut and open as given in paragraph 8 the procedure is as follows:

Open V3 and V12 and screw the adjustment of the pressure build up regulator PCV1 in until the tank pressure is about 10 psi above the required setting of the economiser regulator.

Crack open a valve on the customer pipe line or loosen the union on the pipeline pressure gauge P.1.2. and V16, this will allow a small quantity of gas to flow. No regulator can be set against a dead ended line.

If gas is flowing the setting of the economiser regulator as sent from the manufacturer is too low and the adjustment screw must be screwed down (clockwise) about half a turn at a time until the flow ceases at the required pressure. If gas is not flowing the adjustment screw is to be unscrewed (anticlockwise) until gas begins to flow.

The economiser regulator is not an easy valve to set and the setting is only accurate to + or - 10 or 15 psi. It can be assumed to be shut off when the non return valve down stream of it only 'ticks' at a slow rate. It is not important that this valve be set accurately so long as there is an appreciable margin of pressure between the set pressure and the 245 psi set pressure of the tank relief valve. Judicious tapping of the body of the regulator after each half turn on the adjustment screw will be found to be useful.

Having set the economiser regulator the valve V13 should be opened to allow the tank pressure to drop below the required setting of the pressure build up regulator PCV1 and the adjustment screw on the PCV1 unscrewed. When the tank pressure is about 20 psi below the required setting on PCV1 shut off V13.

Screw the adjusting screw on PCV1 in (clockwise) half a turn at a time until the tank pressure is at the required pressure.

To set the line pressure regulator PCV3 open V14. Liquid gas will now flow through the external and internal vaporisers and the adjustment screw on PCV1 should be screwed in (clockwise) to increase the line pressure or unscrewed (anticlockwise) to decrease the line pressure.

The tank is now ready for service.

10. With the tank still feeding gas to the customer's pipeline go round to every down drop point and open the valve for a short time, this is to ensure that the pipeline is purged of all test gas or air. When you are satisfied that the line is purged check that all down drop valves are shut and then turn off valve V16 on tank.

Instruct the customer engineers as to the function of the tank and point out quite clearly that the only valves he has to bother with are V14 and V16. You should tell him to turn off either or both of these valves at the end of each working day so that if any drop point valves are left open accidently overnight he will not lose any gas.

11. The following special procedure is to be followed where the tank has only a very low gas take-off rate:

It sometimes happens that a small tank, say a 35M is installed for a continuous flow which is very small, as could happen for any argon supply to the benches of argon arc welders who might only be taking about 350 scf per day.

The natural heat leak into the smaller sizes of tank could well be 1% per day of the total capacity of the tank, i.e. approximately 350 scf for a 35M tank. Therefore, if the tank is only used five days a week there will be a build up of pressure at the week ends which will not be lowered by the gas consumption during the working week, eventually pressure will build up high enough for the relief valve to lift.

12. To install a tank for the above type of application proceed up to paragraph 9 in the previous instructions and then do as follows:

First ascertain the maximum line pressure the customer requires. The setting for both the pressure build up and the economiser regulator will be 20 psi higher than this figure.

This will mean that during relatively high flow periods gas will be passing through the pressure build up coil and through pressure build up regulator PCV.1., maintaining a pressure on the tank and also flowing through the economiser regulator PCV 3. to the customer's vaporiser and to the houseline.

After the tank has been standing for some time without gas being drawn from it, the tank pressure will have risen to about the setting of pressure build up regulator PCV.1. and then when gas is withdrawn this excess pressure will be taken off first through the economiser.

Starting with the valves shut and open as given in paragraph 8 the procedure is as follows:

Open V3 and V12 and screw the adjustment of the pressure build up regulator PCV.1. in until the tank pressure is 20 psi higher than the required customer line pressure.

Crack open a valve on the customer pipeline or loosen the union on the pipeline pressure gauge P.1.2. Open V.16 this will allow a small quantity of gas to flow. No regulator can be set against a dead ended line.

If gas is flowing the setting of the economiser regulator as sent from the manufacturer is lower than the tank pressure and can be left as it is. If gas is not flowing the adjustment screw is to be unscrewed (anti-clockwise) until the gas begins to flow.

NOTE AT NO TIME SHOULD VALVE V18 BE OPENED OR V12 BE CLOSED. In fact the handwheels should be removed to make sure they are not operated by mistake by the customer's engineer or other persons having access to the tank.

Finally, set line pressure regulator PCV.2 and the tank is now ready for service.

13. With the tank still feeding gas to the customers pipeline, go round to every down drop point and open the valve for a short time, this is to ensure that the pipeline is purged of all test gas or air. When you are satisfied that the line is thoroughly purged, checked that all down drop valves are shut and then turn off valves V3 and V16 on the tank.

Instruct the customer's engineer as to the function of the tank and point out quite clearly the only valves he has to bother with are V3, and V16. You should tell him to turn off both of these valves at the end of each working day so that if any drop point valves are left open accidentally overnight he will not lose any gas.

14. All valve handwheels are to be colour coded as follows:

14.1. The handwheels of valves that must be shut in an emergency are to be painted RED. These valves are -

V3, V12, V14, V16 and V18.

14.2. All other handwheels are painted yellow.

OPERATIONS DEPARTMENT

NEW MALDEN

OVERHAUL PROCEDURE

C 155/9.5

1971

Written By: G. Davies
Operations Mechanical
Engineer

Checked By: A. D. F. Ferguson
Operations Chief
Mechanical Engineer

CONTROL PROCEDURE

U. K. Plants

Plant: Despatch pump and motor assembly to Acrefair covered by W.M.C. copy to J. Pritchard, Central Operations giving:

1. Maker Serial No. and Type
2. Hours of Service
3. Details of failure
4. Notify J. Pritchard the date that the overhauled pump is returned to plant.

Acrefair: Return pump and motor assembly to plant with the following completed documentation (Copies to J. Pritchard at Central Operations).

1. Final Inspection report - specifying pump type, Makers Serial No. and Destination.
2. Sheet showing measured clearance and dimensions found on reassembly of pump and motor assembly.
3. Sheet showing condition of pump and motor assembly on stripping - list of parts replaced and summary of work done.

CONTINENTAL PLANTS

1. Inform central operation of:

    1.1 Make, type, and serial No.

    1.2 Hours of Service.

    1.3 Details of failure.

2. Obtain permission of central operations to undertake the repair. It will probably be necessary for a specialist engineer to attend.

3. On completion of repair send to central operations:

    3.1 Sheet showing measured clearance and dimensions found on reassembly of pump/motor assembly.

    3.2 Sheet showing condition of pump and motor assembly on stripping a list of parts replaced and summary of work done.

Cryostar Pump and Motor Assembly C155/9.5

General Instructions

1. The shaft of the pump is at the same time the shaft of the drive motor and it is therefore essential that the pump and motor are treated as one assembly.

2. Whenever the pump and motor assembly come for overhaul, a new mechanical seal will be fitted and new motor bearings.

3. Motor should have insulation check and be visually inspected.

4. On reassembly those parts of pump which show signs of wear or are dimensionally unacceptable should be replaced and the information recorded.

5. On the assembly of the cold end, all parts to be thoroughly degreased and then inspected with a black lamp for contamination.

6. The use of a grease which is compatible with oxygen must only be used sparingly on all threaded parts.

   NOTE: Grease used must conform with APL specifications.

Removal of Pump Assembly

And Preparation for the Clean Room

1. Obtain work permit.
2. Disconnect the electric feed cables to the motor.
3. Disconnect suction and discharge line flanges, cover all the flange openings with a clean polythene bag.
4. Remove the four holding down bolts from the motor base and remove the pump assembly.
5. Thoroughly clean the outside of the assembly, the assembly can then be taken into the clean work area.

TOOL REQUIREMENTS

1. Hard insulated micrometer.
2. Bearing extractor kit.
3. Clock gauge with a clamp stand.
4. Black light.
5. Shaft clocking clamp.
6. Inspection torch.
7. Warming plate.
8. Soft paint brush.
9. Test megger.
10. Lint free gloves and cloths.
11. Plastigauge in four sizes 1.0 2.0 3.0 and 4.0 millimeters
12. Mechanical Seal Tool No. 320623
13. Inspection Centers

PUMP

DISMANTLING COLD END

C 155/9.5

Dismantling the Pump

(See Drawing No. 436389) Page No. 26

Stripping the pump is, thanks to its simple construction, not very difficult as long as it is done carefully and in the right order:

1. Unscrew the eight bolts Item 9.

2. Remove the volute, Item 1 and the flexitallic gasket Item 10.

3. Remove the nut, Item 20.

4. Separate carefully the impeller from the shaft.

5. Remove the rotating seal ring, Item 17 as well as seal, Item 18.

6. Lift the back plate Item 4 off the shaft.

7. Unscrew the bellows seal assembly Item 16 in a clockwise direction (the seal assembly has a left hand thread). The special tool according to drawing No. 320 623 must alone be used to loosen the seal assembly. The use of other tools is discouraged as the carbon ring can easily be damaged.

8. After loosening the screws Item 23, the support can be removed.

9. Remove the gas slinger Item 13.

10. Remove the shaft retaining pin Item 21.

11. Slightly warm the pump shaft Item 5 - it can now be slid off the motor shaft.

MOTOR

C 155/9.5

MOTOR OVERHAUL

FITTING NEW BEARINGS TO THE DRIVE MOTOR

1. Dismantle the bearing housings from each end of the motor.

2. Remove the old bearings using the correct extracting tool.

3. Clean all the internal parts with a recommended cleaning agent.

4. Measure shaft sized to check the fitting tolerances for the bearings. See Appendix. Page 13.

5. Measure the motor bearing housings to check the fitting tolerance. See Appendix. Page 13.

6. An insulation check and a visual inspection will be made of the motor windings.

1. Fit bearing retainer to the motor shaft and press on the bearings using the correct tool.

2. Fit the rotor to the motor assembly.

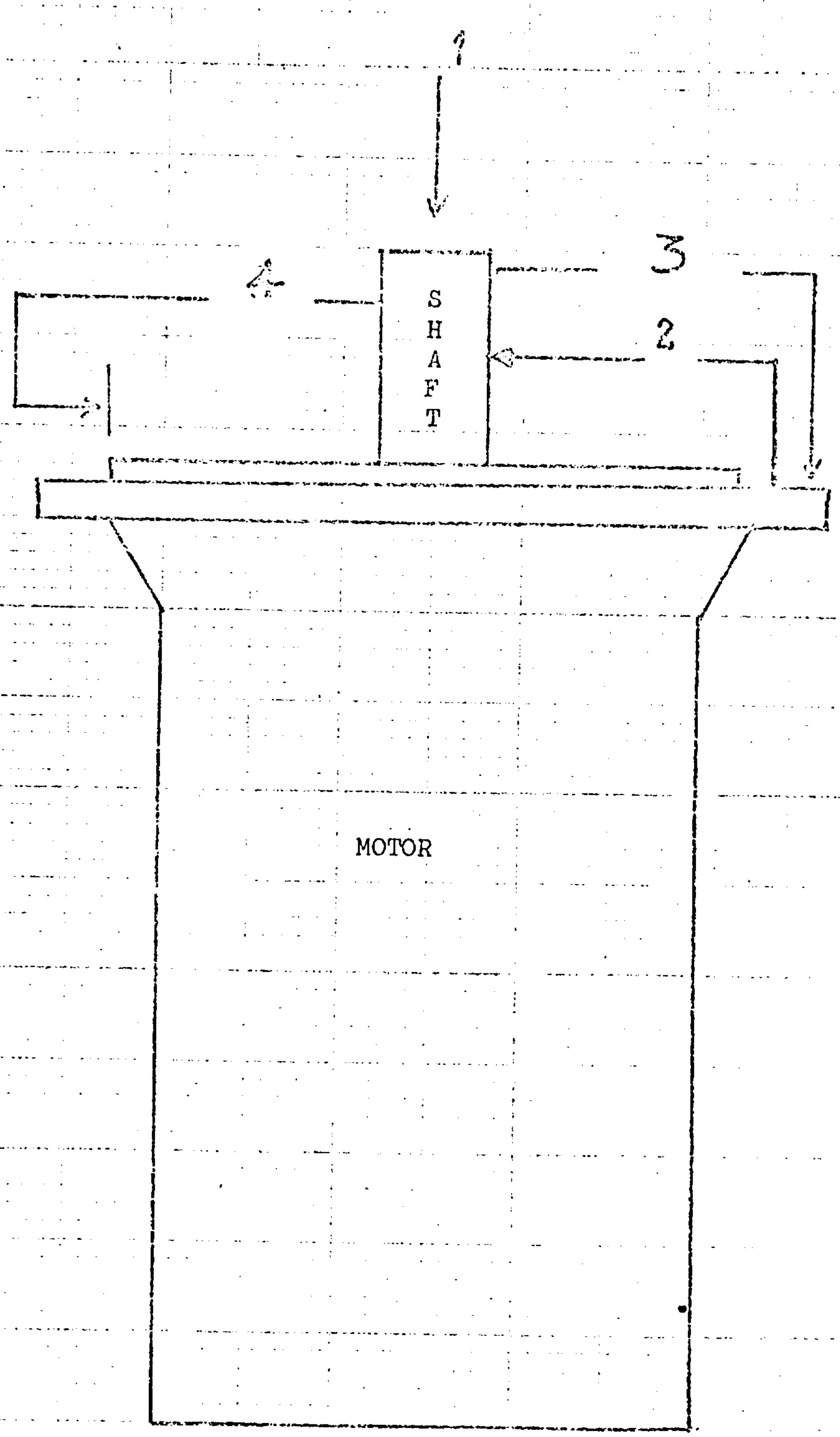
3. Fit new shaft seals to the motor housings.

4. Inspect the bearing spring ring and refit.

5. Grease the bearings with the recommended grease, and fit the motor end housings with the bearing retainer and tighten.

9

DRAWING 1



AXIAL MOVEMENT

1. With a clock mounted on the motor flange face, measure the axial float of the motor shaft, at position 1.

2. With a clock gauge mounted on the motor flange face,scan the motor shaft at position 2.

3. Mount the clock gauge on the motor shaft, scan the motor flange face for alignment to the shaft, position 3.

4. Mount the clock gauge on the motor shaft, scan the motor flange rim position 4.

TEST RUN

5. On completion of the above checks, the motor will be given a test run for a period of one hour, monitoring the bearing temperature and checking the noise level of the bearings.

Drawing 1

All measurements in millimeters

Position	Design	Permissible
1	.04	.3
2	zero	.08
3	zero	.06
4	zero	.08

DRIVE MOTOR APPENDIX

All measurements in millimeters

Position	Design	Permissible	
		MIN	MAX
1	.04	.04	.3
2	zero	zero	.08
3	zero	zero	.06
4	zero	zero	.03

FITTING TOLERANCES

Motor Bearings

Bearing Housing 72 m/m at J6 = + .013 - -.006

Shaft 30 m/m at K5 = + .011 - +.002

PUMP

ASSEMBLY OF THE COLD END

C 155/9.5

COLD END ASSEMBLY

(See Drawing No. 436389 & Parts List No. 434047) Pages 26 & 27

When it is found necessary to fit a new pump shaft Item 5, the following procedure will be followed.

Measure the location of the drilled hole in the old pump shaft, and mark off the same position on the new shaft.

Drill one hole in the new pump shaft, then warm the shaft on a hot plate to allow it to slide over the meter shaft to take up the pin position.

A drill can then be guided through the located holes to drill the other side of the pump shaft.

A new retaining bolt, Item 21, is then fitted to the shafts.

Fit the gas slinger, Item 13, to the shaft and tighten locking bolt, Item 12.

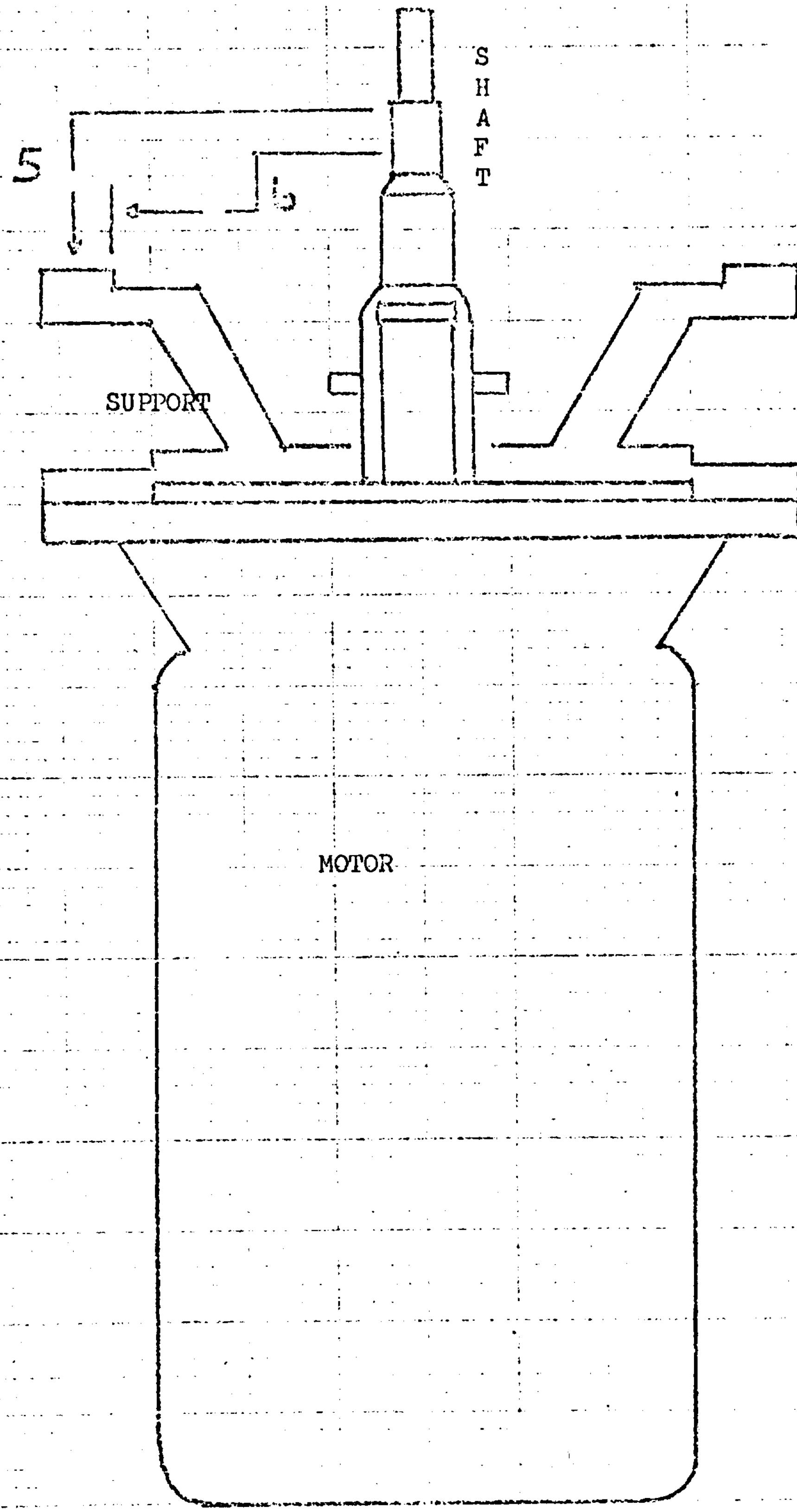
If the old shaft Item 5 is to be refitted it will require warming on a hot plate - it can now be slid over the motor shaft to locate the retaining pin hole.

A new retaining bolt Item 21 can now be fitted to the shafts.

Fit the gas slinger Item 13 to the shaft and tighten the locking bolt Item 12.

13

DRAWING NO.2



PUMP SUPPORT Item 6

1. Inspect pump support faces for any burrs.

2. Using bolts Item 23 and washers Item 7, tighten support to motor.

3. Clamp a clock gauge to the pump shaft, check the support flange face for alignment to the pump shaft at position 5.

4. With the clock still clamped to the pump shaft, check the support rim for concentricity position 6.

Position	Design	Permissible	
		MIN	MAX
5	zero	zero	.08
6	zero	zero	.08

BACK PLATE Item 4

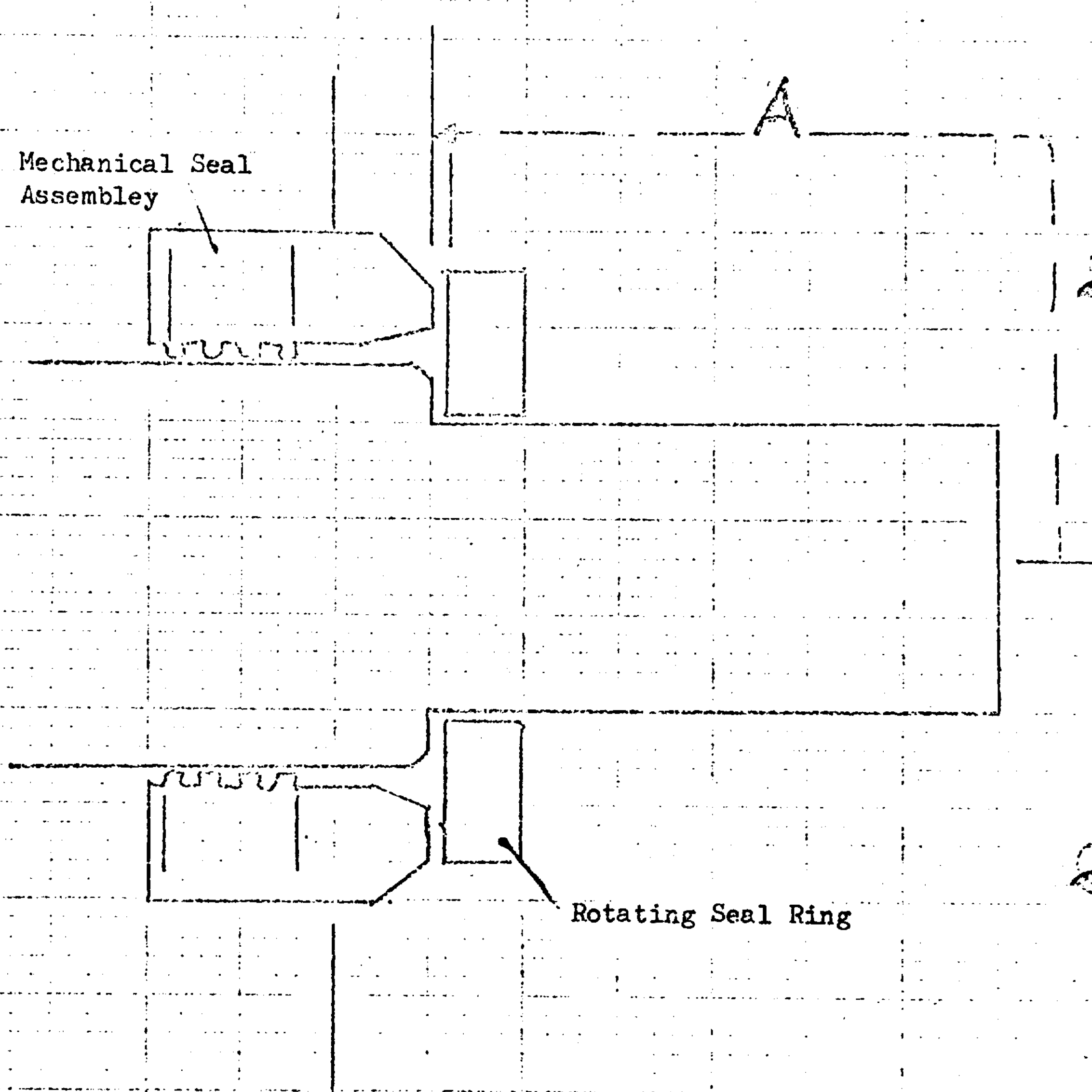
1. Fit two new Teflon seals Item 14 to the back plate.

2. Fit a new O ring Item 15 and seal assembly to the back plate, tighten down using tool No. 320623.

3. Fit a new insulator ring Item 11 to pump support, then fit back plate to pump support.

16

DRAWING No.3

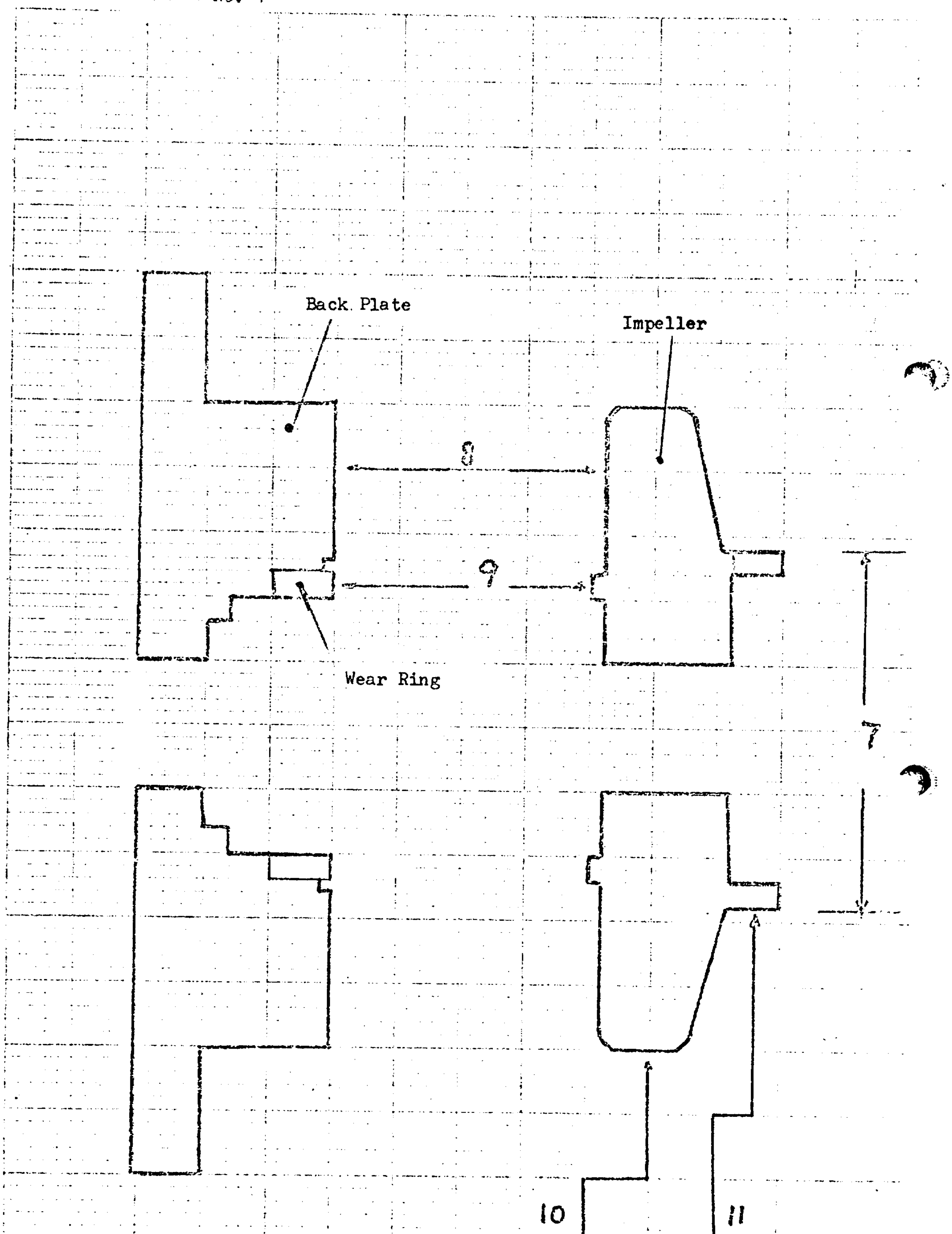


MECHANICAL SEAL ASSEMBLY

1. Renew Teflon seals Item 14 in the back plate.
2. Install a new O ring Item 15 in the back plate then fit the new or reconditioned seal assembly, use the special tool 320623.
3. Install insulator ring Item 11 then fit back plate to the pump support.
4. Fit one seal distance ring gasket Item 18 to pump shaft then fit on Item 17 the rotating seal ring.
5. With the rotating ring against the seal assembly, use a precision depth gauge to measure the distance from the surface of the rotating ring to the end of the shaft position A. Measure to the nearest hundredth of an millimeter.
6. Make sure the back plate assembly is pressed firmly against insulator ring when the measurements are made.
7. Compress the bellows by pressing on the rotating seal ring until it bottoms, in the compressed position measure the distance from the surface of the rotating ring to the end of the shaft to the nearest hundredth of a millimeter.
8. The difference between the two measurements is the seal compression.
9. Install required number of gaskets Item 18 between the shaft shoulder and seal ring to establish the correct seal compression of 1.2 to 1.5 millimeters.
10. Caution. Never have more compression of the bellows than the amount of carbon extending beyond the metal holder of the bellows assembly.
11. Check the seal compression after installing the gaskets.

NOTE: Compression can be measured using a clock gauge clamped to the pump support.

DRAWING No. 4



PUMP IMPELLER

1. Using a micrometer measure the impeller labyrinth diameter position 7.

   Fit the impeller key to the pump shaft and slide the impeller in position, fit cap nut Item 20 and tighten.

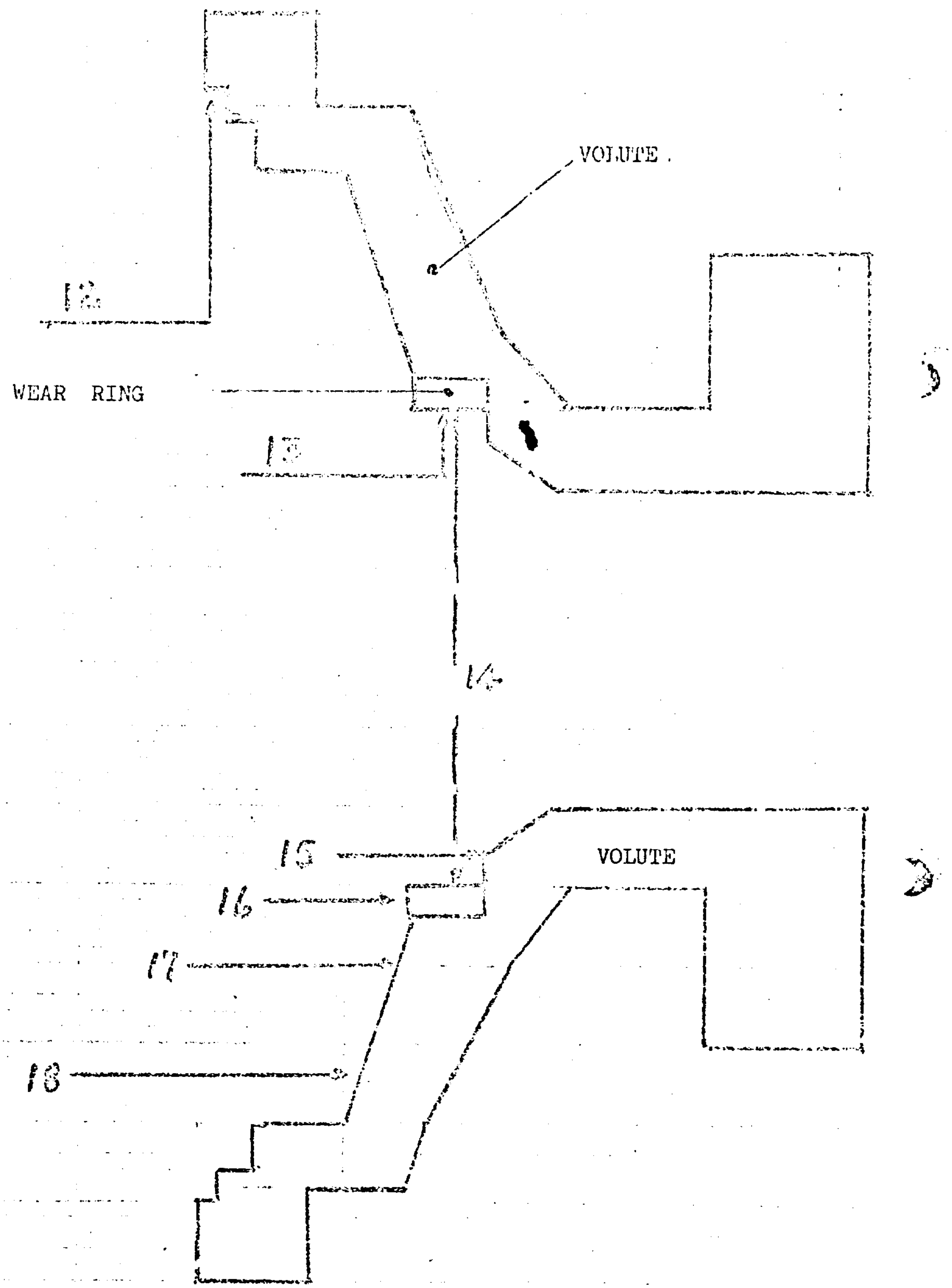
2. Using a set of feeler gauges, measure the axial clearance between impeller and back plate at position 8 and the clearance between impeller and wear ring position 9.

3. With a dial gauge clamped on the pump support, check the concentricity of the outside circumference of the impeller position 10 and the concentricity of the impeller labyrinth at position 11.

4. Remove impeller cap nut fit new thread lock retainer Item 21, cap nut lock washer Item 24 and tighten cap nut, the tab washer can now be locked over.

Position	Design	Permissible	
		MIN	MAX
7	97	96.95	97
8	3	2.8	3.2
9	1.4	1.4	1.6
10	zero	zero	0.08
11	zero	zero	0.08

DRAWING No. 5



VOLUTE

1. Set volute in lathe check the concentricity at position 12 outer rim position 13 volute wear ring.

2. Check the volute labyrinth diameter position 14.

3. Using a micrometer measure the inside diameter of the wear ring, with the measurement of the impeller labyrinth record the impeller clearance.

4. Without fitting the Flexitallic gasket Item 10, place plastigauge at 180° apart on positions 15, 16, 17 and 18.

   Making allowance for the gasket measurement, the compressed plastigauge will give the axial clearances at these positions.

5. Thoroughly degrease the volute and impeller, inspect with a black light for contamination.

6. Fit a new Flexitallic gasket Item 10 to back plate and tighten up the volute, use feeler gauges to measure that the volute is tightened up equally.

Position	Design	Permissible	
		MIN	MAX
12	zero	zero	.08
13	zero	zero	.08
14	97.50	97.50	97.55
15	4.0	4.0	4.5
16	1.4	1.2	1.6
17	3.5	3.0	3.5
18	3.5	3.0	3.5

COLD END APPENDIX

All measurement in millimeters

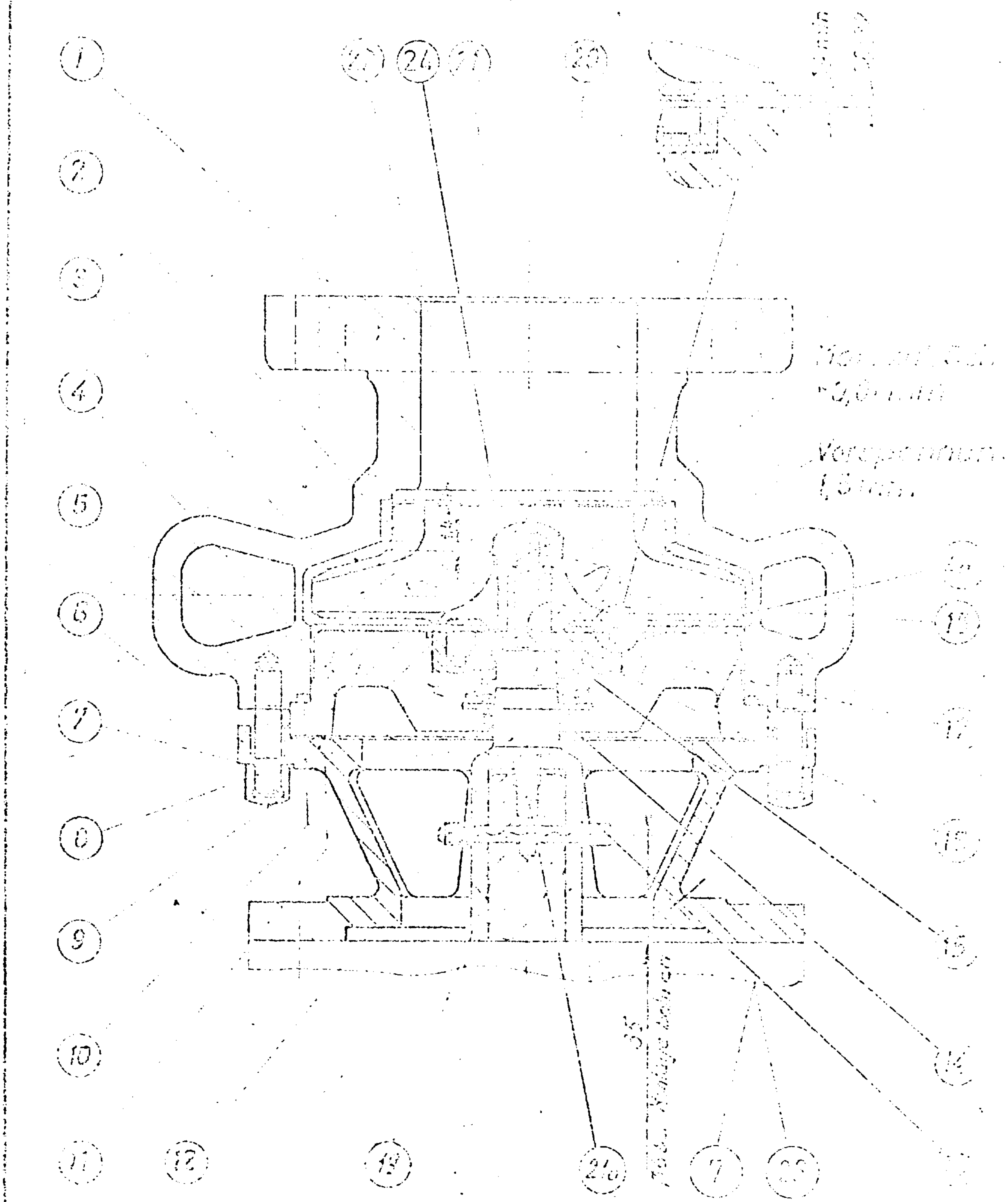
Position	Design	Permissible MIN	Permissible MAX
5	zero	zero	.08
6	zero	zero	.08
A	1.4	1.2	1.5
7	97	96.95	97
8	3	2.8	3.2
9	1.4	1.4	1.6
10	zero	zero	.08
11	zero	zero	.08
12	zero	zero	.08
13	zero	zero	.08
14	97.50	97.50	97.55
15	4.0	4.0	4.5
16	1.4	1.2	1.6
17	3.5	3.0	3.5
18	3.5	3.0	3.5

Spare Parts for "Cold End" of 43 40 47

Centrifugal pump C 155/9.5

Item	Number of parts per unit	Recommended number of parts	Drawg. or Stock Number	Designation	Unit Price
1	1	1	632753	Volute	1430.--
2	1		632764	WEAR ring	150.--
3	1	1	632754	Impeller	680.--
4	1	1	632766	Backplate	117.--
5	1	1	632759	Shaft	320.--
6	1		632765	Support	
7	12		630005	Washer	1.--
8	8		630006	Bolt M 10 X 30	2.50
9	8	8	630002	Cap nut M 10	3.50
10	1	1	632720	Gasket - Flexitallic	55.--
11	1	1	632733	Insulator Ring	57.50
12	1		630010	Bolt M 5 X 10	1.--
13	1		632760	Slinger	15.--
14	1	2	630969	Teflon seal	3.60
15	1	1	631013	O-Ring 42 X 2	3.26
16	1	1	630966	Mechanical seal assembly	790.--
17	1	1	631836	Rotating seal ring	113.--
18	1	2	631967	Seal ring Gasket	1.90
19	1		880080	Pin 6 X 40	1.--
20	1	1	632832	Cap nut M 8	2.50
21	1		632761	Bolt retaining	11.50
22	1	1	632762	Key	12.--
23	4		880055	Screw	4.50
	1	2	630041	Ballbearing - Motor	35.--
	1	1		Seal Bearing - Motor	47.50

The above prices are subject to change without notice. They do not include state and local taxes. FOR Basel, Terms: 30 days net. Minimum S. Fr. 100.--.



Montagewerkzeug f. Welle Pos.5 nach Zch. [illegible]

RECORD SHEET

C 155/9.5

CRYOSTAR C 155/95

MEASUREMENT CLEARANCE AND DIMENSION
ALL IN MILLIMETERS

PUMP SERIAL NO:...................................... DATE:..........................

MATERIAL OF IMPELLER: SHOP ORDER NO:..................

MATERIAL OF WEAR RINGS: PROJECT NO:....................

POSITION.	LOCATION.	DESIGN RANGE.		ACTUAL.
1.	Axial Float of Motor Shaft........	.1	.3	....
2.	Motor Shaft Concentricity........	Zero	.08	....
3.	Motor Flange Face to Shaft........	Zero	.06	....
4.	Motor Flange Rim to Shaft........	Zero	.08	....
	Motor Bearing fitting Tolerances........			....
	Pump End Housing 72 at J6........	+ .013	-.006	....
	Fan End Housing 72 at J6........	+ .013	-.006	....
	Shaft Pump End 30 at K5........	+ .011	+.002	....
	Shaft Fan End. 30 at K5........	+ .011	+.002	....
5.	Support Flange Face to Shaft........	Zero	.08	....
6.	Support Flange Rim to Shaft........	Zero	.08	....
A.	Mechanical Seal Compression........	1.2	1.5	....
7.	Impeller Laryrinth Diameter........	96.95	97.00	....
8.	Axial Clearance Between Impeller and Back Plate........	2.8	3.2	....
9.	Axial Clearance between back plate Wear Ring and Impeller........	1.4	1.6	....
10.	Concentricity of Outside circ.of the Impeller........	Zero	.08	....
11.	Concentricity of Impeller Wear Ring........	Zero	.08	....
12.	Concentricity of Volute Rim........	Zero	.08	....
13.	Concentricity of Volute Labyrinth........	Zero	.08	....
14.	Inside Diameter of Wear Ring........	95.50	97.55	....
15.	Impeller Labyrinth face to volute........	4.0	4.5	....
16.	Impeller Labyrinth to Wear Ring........	1.2	1.6	....
17.	Impeller to Volute........	3.0	3.5	....
18.	Impeller to Volute........	3.0	3.5	....

SIGNED:.......................(INSPECTOR).

MOTOR MODIFICATION

C 155/9.5

Modification to Motor Bearing Housing

1. Early pumps of this type did not have a captured "pump end" motor bearing.

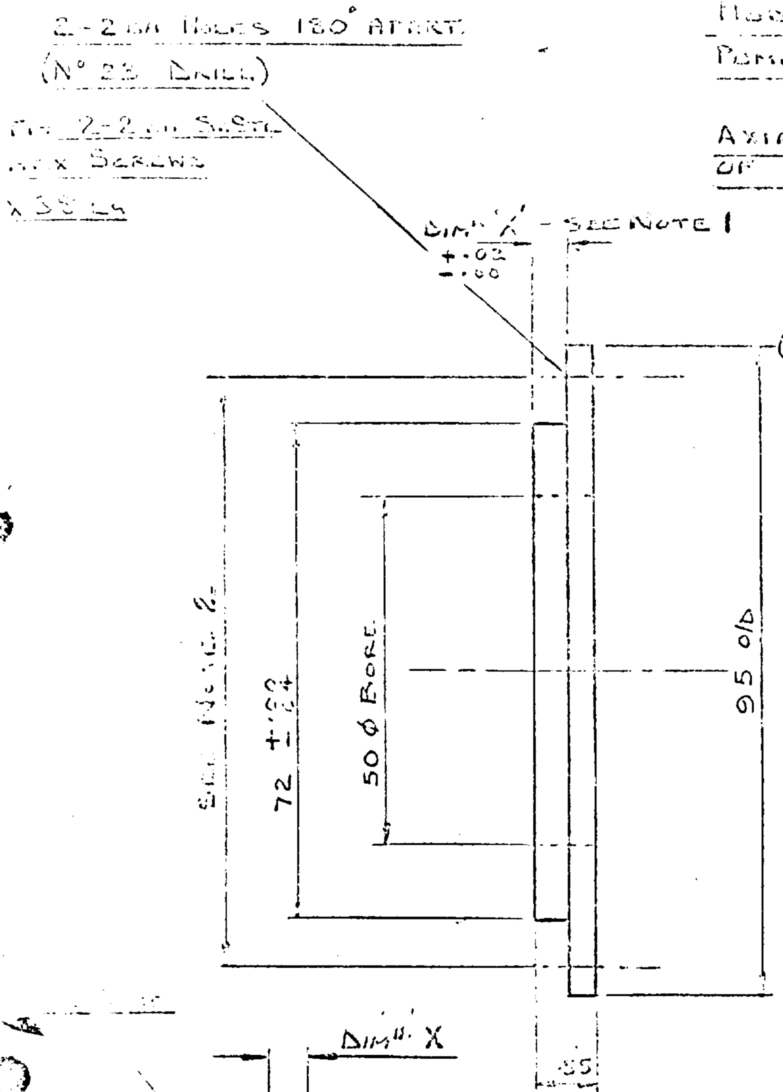
2. Page 32 details the modification to capture the "Pump End" motor bearing.

(Retyped 9/29/72 sba)

BEARING RETAINING PLATE

MODIFICATIONS TO CRYO-STAR PUMP MOTOR TYPE C 155/35

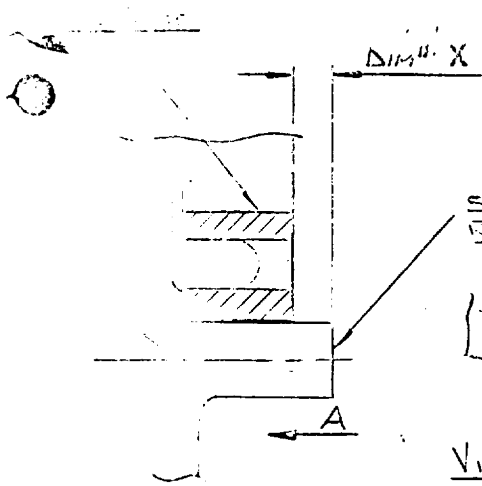
AXIAL MOVEMENT ON COMPLETION OF MODS. = 0.1 MM

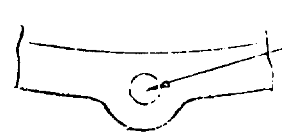


NOTES

1. TO OBTAIN DIM^N X
SKIM SURFACE OF BRG. HSG.
REFIT BALL RACE AFTER CLEANING HSG.
TAKE DIM^N WITH MICROMETER DEPTH GAUGE.

2. MARK OUT HOLE CTRS IN CENTRE OF BOSSES ON SKIMMED SURFACE OF BRG. HSG.
DRILL THRO' WITH 1/8" DRILL.
FIT RETAINING PLATE & REDRILL FROM OPPOSITE SIDE WITH NO 23 DRILL THRO' HSG. & RETAINING PLATE.
TAP RETAINING PLATE 2 BA.
OPEN OUT HOLE IN HSG TO 2BA CLEARANCE WITH NO 12 DRILL.





VIEW ON ARROW A

PART VIEW OF BRG. HOUSING IN MOTOR COVER.

NOTE MAT^L C/S BS 15
M/C ALL OVER.
REMOVE BURRS & SHARP CORNERS

REV 0 WAS FOR MOTOR SERIAL N° 43359 ONLY 12/5/71 SC

AIR PRODUCTS LIMITED DRG NO. WDS 02

EXPERIMENTS WITH LIQUID OXYGEN

A member of the Company was recently fortunate to avoid serious injury while experimenting with liquid oxygen. The experiment consisted of immersing wooden blocks in liquid oxygen and then subjecting them to impact tests.

Recent experiments carried out by Linde in Germany, show that explosions will nearly always be initiated when an impact is applied to wood saturated with oxygen.

This Bulletin will remind all Company personnel that experiments of any sort involving the use of liquid oxygen may only be conducted with the express approval of the Safety Department. Experiments involving the immersion of inflammable objects in liquid oxygen must never be carried out.

It should be noted that in the case in question, a satisfactory result could have been obtained using liquid nitrogen rather than liquid oxygen.

AIR PRODUCTS LIMITED
Safety Officer

safety

Lack of Oxygen Kills Two Workmen

A recent incident resulted in the death of two workmen who were working on the conversion of a Lox storage building. They entered the Lox storage building through a vent/manhole in the roof, and were asphyxiated by a nitrogen enriched atmosphere.

In the operation of air separation plants and the distribution of gases and cryogenic liquids, personnel should be aware of the hazard of asphyxiation due to the venting of asphyxiants such as nitrogen, and the failure of adhering to Safety regulations.

The following Safety precautions should be followed when working in areas susceptible to the venting of nitrogen.

1. Personnel should not enter an area suspected of having a nitrogen enriched atmosphere until the atmosphere has been checked and found to have a minimum of 18% oxygen or until personnel are equipped with self contained breathing apparatus.

2. Anyone entering a tank, cold box, or similar enclosure which has been in operation must obtain a Safety Work Permit. Before entering the enclosure, personnel should wear a safety belt and have a manned safety line attached to the belt. A self contained breathing apparatus should be on hand for someone to assist personnel in the confined area, in the event of an emergency.

3. All valves which can result in flow to a section of piping which is being worked on should be closed and tagged out.

4. When nitrogen in limited quantities, is vented inside a building, adequate ventilation should be provided.

   Venting large quantities of nitrogen should be external to the building.

5. In areas where heavy venting of nitrogen can occur, a sign should be posted warning - "Oxygen Deficient Area May Exist".

REMEMBER. LACK OF OXYGEN KILLS.

AIR PRODUCTS LIMITED
Safety Officer

safety

APCI DOCUMENT NO 99000420

AIR PRODUCTS LIMITED

SAFETY DEPARTMENT MEMORANDUM

REPORT OF THE INVESTIGATION INTO BURCKHARDT CENTRIFUGAL PUMP EXPLOSION AND TANKER FIRE, AT SHEEPBRIDGE ALLOY CASTINGS LIMITED

5TH FEBRUARY 1964

J. Zurawski

DOCUMENT NOT AVAILABLE FOR GENERAL DISTRIBUTION

Air Products

SAFETY DEPARTMENT INFORMATION SHEET NO. 19

Notes for Guidance of Customers Having Air Products Ltd. Oxygen Equipment.

by

I. Everson
Chief Safety Engineer

These notes are intended to give general guidance on safety matters to customers having oxygen equipment supplied by Air Products Limited. The main hazards are briefly described together with necessary firefighting precautions.

Liquid oxygen storage tanks together with their associated gaseous oxygen piping are referred to. Safety precautions required for storing and handling oxygen cylinders and when using oxy-acetylene equipment are discussed.

Hazards associated with electrical insulation, chemical cleaning, pressure gauges, valves and the use of mercury are briefly mentioned.

In any case of doubt, customers are strongly advised to consult their local Air Products Limited District Engineer.

1. Introduction

These notes are intended to give customers guidance on safety matters associated with their oxygen equipment supplied by Air Products Ltd. Due to the wide variety of oxygen installations these notes must of necessity be brief, covering general principles only. Customers are strongly advised to discuss safety aspects with their local Air Products Ltd. District Engineer, who will, if necessary, enlist the aid of the Safety Department which can give lectures, demonstrations etc. to customers' staff at all levels to illustrate safety features in greater detail.

Oxygen equipment as supplied is carefully designed and manufactured in accordance with detailed Air Products standards. However, experience has shown that problems can arise after prolonged service, when due to staff changes and modifications to installations for example, good practise may not always be observed, resulting in fires and explosions. It is strongly recommended that any modifications or changes in use or procedures be discussed with your District Engineer.

It is suggested that at regular intervals, perhaps annually, safety procedures are reviewed in conjunction with Air Products Ltd.

2. Main Hazards

2.1 Liquid oxygen in presence of a fuel (e.g. oil, wood, asphalt, paint, cork etc.) and an igniter (e.g. naked light, lighted cigarette or pipe, heat from an electrical fault, high temperature due to sudden compression of gas) can explode violently.

2.2 Due to its low temperature (-297°F) liquid oxygen can damage body tissue by causing "cold burns". Immersion in <u>COLD</u> water is the only recommended first aid measure. This should be followed immediately by an examination by a Medical Practitioner.

2.3 Should liquid oxygen come into contact with carbon steel, the latter will eventually become very cold and brittle. If it is then subjected to impact loading it will suffer "brittle fracture" and shatter into small fragments. If it is suspected that carbon steel has been contacted by liquid oxygen the APL District Engineer should be informed so that he can inspect.

2.4 Liquid oxygen can also embrittle and crack electrical insulation with the danger of exposing live wires.

2.5 If liquid oxygen is allowed to drip on to concrete for an appreciable time the latter can crumble to a depth of several inches. While this is essentially an inconvenience, the presence of liquid oxygen is a serious hazard.

2.6 Gaseous oxygen is non-flammable but supports combustion vigorously once the correct temperature has been reached. For guidance materials can be separated into four groups as follows:-

Highly Dangerous <u>Materials</u>	Easily Ignitable <u>Materials</u>	Materials not easily <u>Ignited</u>	Materials which will not <u>normally Ignite</u>
(a)Combustible gases (e.g. Carbon monoxide, hydrogen ethylene.	(a)Wood	(a)Stainless steel	(a)Copper
(b)Combustible liquids which vaporise freely at room temperature (e.g. petrol, paraffin, alchohol)	(b)Asphalt	(b)Carbon steel	(b)Brass
(c)Oils and greases	(c)Paint	(c)Cast iron and steel	(c)Bronze
(d)Porous combustible materials which can absorb LOX.	(d)Cotton waste	(d)Aluminium	(d)Nickel
	(e)Cotton clothing	(e)Zinc	(e)Monel and other non-ferrous alloys
	(f)Powdered metal	(f)PTFE or Teflon	(f)Pure asbestos
	(g)Metallic swarf		(g)Oil free silicate based insulants (e.g. foamglass)
	(h)Powdered carbon		
	(i)Cork		
	(j)Trichlorethylene*		

It is important to recall that oxygen enriched air containing more than 21% oxygen (normal atmospheric air) causes more rapid burning. Also increased pressure reduces ignition temperatures of all materials.

2.7 LOX leakage will tend to settle at low levels and GOX formed will initially be cold and dense so that dispersal will be slower than for GOX at room temperature.

2.8 LOX leakage will seep into and through porous materials, fissures in soil, cracks in concrete and through drainage ducts. The resulting GOX can thus appear considerable distances away from the initial source of leakage.

*However, it is quite safe to degrease oxygen equipment with trichlorethylene since after degreasing operations trichlorethylene will evaporate.

2.9 GOX cannot be seen or smelled. Potentially hazardous areas must be surveyed using special oxygen detectors and never by test igniters, e.g. lighted cigarettes.

2.10 In an oxygen enriched atmosphere apparently extinguished pipes or cigarettes can burst into flame if the ash contains only very small hot particles.

2.11 Another serious hazard with oxygen is its penetration into clothing. In this state a small particle of hot ash from a pipe or cigarette can ignite clothing.

2.12 GOX must never be used for the following or similar applications:

2.12.1 starting internal combustion engines
2.12.2 pressurising oil resevoirs
2.12.3 operating pneumatic tools
2.12.4 paint spraying
2.12.5 tyre filling
2.12.6 purging pipelines (other than oxygen service lines).
2.12.7 instead of air in self-contained breathing sets.
2.12.8 for clearing fumes in a confined space.

3. Action in the event of Fire or Explosion

3.1 All actions must be carefully considered and carried out methodically. Hasty, ill considered action can create serious hazards.

3.2 In an incident involving escape of oxygen there is a possibility that clothing worn by personnel nearby will become contaminated with gaseous oxygen thus exposing these personnel to fire risk. Consequently such persons must not approach within range of flames, heat or any sort of smouldering material. Such personnel must not of course be permitted to smoke.

3.3 Provided no undue risk is involved the oxygen source should be isolated by closing appropriate valves.

3.4 Carry out previously established FIRE ALARM procedure pertaining to the affected premises, as quickly as possible.

3.5 Utilise available firefighting equipment to extinguish fire. Water is the best firefighting medium for oxygen fires. Certain chemical extinguishers e.g. methyl bromide must not be used.

3.6 Ensure that only persons engaged in firefighting are allowed into the danger area.

4. Guidance of Air Products Limited

It is impossible to give comprehensive guidance concerning all hazards and safety precautions in this note. It is essential to discuss such matters with your local District Engineer who will give specific guidance on each installation.

5. Precautions in connection with Liquid Oxygen Storage Tanks

5.1 When a new liquid oxygen storage tank is being considered its location with respect to adjoining installations and features should agree with the local District Engineer.

5.2 All operating procedures should be discussed, agreed with the District Engineer and be available as written instructions. All valves should be numbered and copies of flowsheets affixed to control cabinets.

5.3 In general all liquid oxygen storage tanks should be fenced and surrounded by a low wall, continuous except for a small break positioned to allow liquid oxygen leakage to flow to a selected area harmlessly. Continuous bund walls are not recommended.

5.4 It is important to ensure that all liquid oxygen tanks are inspected regularly by a representative of the Industrial Gas Division so that necessary remedial work can be noted in good time.

5.5 The immediate vicinity should be kept oil free and as clean as possible.

5.6 Small storage tanks are insulated by perlite filled vacuum jackets. It is important to check the pressure in the insulating jacket. Vacua between 50 and 200 microns are adequate. Should the pressure build up beyond 200 microns the vacuum should be restored by means of a vacuum pump. Should the insulating vacuum deteriorate, increased heat gains will occur resulting in pressure build up and perhaps appreciable loss of gaseous oxygen through pressure relief valves. A bursting disc is provided as a pressure relief device.

5.7 Large liquid oxygen storage tanks are often insulated with an annular gap filled with perlite, the space being purged with nitrogen at about atmospheric pressure. Nitrogen is piped to a ring main around the tank and then admitted to the annular gap through several connections to ensure good distribution.

5.8 Special care should be exercised in deciding the runs of vent pipes which might discharge liquid oxygen. It is best that such vents should terminate at low level to discharge into metal trays so as not to injure staff or damage the concrete.

5.9 Generally liquid oxygen storage tanks are doubly skinned. The inner being made of stainless steel, aluminium or 9% nickel steel, all of which are safe at liquid oxygen temperatures (-297°F). The outer vessel is normally made of carbon steel which is prone to brittle fracture. It is therefore important to ensure that cryogenic liquids are not allowed to spray on to the outer vessel to prevent possibility of brittle fracture.

5.10 Piping associated directly with the tank and installed in the insulating space is normally made of stainless steel. Piping in the control cabinet is normally made of copper or a copper alloy (Tungum) as is oxygen piping up to $1\frac{1}{2}$" diameter. Normally liquid oxygen is evaporated into gaseous oxygen. Large bore gaseous oxygen piping is usually made of carbon steels and therefore prone to brittle fracture. Consequently devices are provided to monitor gaseous oxygen temperatures and should those decrease to dangerously low levels, the liquid oxygen supply to the gaseous oxygen vaporiser is instantly cut off.

5.11 If it is required to fill dewars from the main liquid oxygen tank a special dewar filling device is necessary which should be discussed in detail with your local District Engineer. Due to the possible hazards associated with liquid oxygen, only experienced, qualified persons should be allowed to fill liquid oxygen dewars.

5.12 Liquid oxygen is transformed to gaseous oxygen in atmospheric vaporisers backed up by steam or electrically heated vaporisers. These can be welded or bolted into the piping system.

5.13 Bolted joints must withstand the full system pressure and permit the process lines to be broken into as required. Klingerite gaskets are recommended for flanged joints. The type of Klingerite used should be approved by your APL District Engineer. Screwed joints are acceptable. Thin PTFE tape should be used as sealant and lubricant when assembling screwed joints. An aqueous PTFE preparation called "T-Film" can be used as a sealing agent.

5.14 Ancillary liquid oxygen/gaseous oxygen equipment should be cleaned as and when necessary using methylene chloride or trichlorethylene.

5.15 Piping insulation must be liquid oxygen compatible e.g. Foamglass. Care must be taken to use oxygen compatible adhesives to secure insulation to pipework. To prevent ingress of rain adversely affecting out of doors insulation, completed insulation should be covered as quickly as possible with over-lapping sheets of thin aluminium.

6. Oxygen Piping

6.1 Liquid oxygen will be transformed into gaseous oxygen in special air, water or steam heated vaporisers made of copper or aluminium. In interest of economy gaseous oxygen piping is normally made of carbon steel which is perfectly satisfactory provided essential precautions are taken. (See 5.10). However, for pipe diameters less than say 1½", copper, a copper alloy (Tungum) or stainless steel are often used.

6.2 However, as a safety measure in case gaseous oxygen piping ignites it is customary to install stainless steel sections at intervals which will prevent fire proceeding further, as stainless steel is non-flammable. These sections are referred to as "firebreaks". Bends, elbows and reducers are made of stainless steel as a fire precaution.

6.3 The bores of gaseous oxygen pipes must be kept free of rust and clean. This condition can be readily achieved during manufacture but to maintain it requires freedom from leaks. Gaseous oxygen pipes must be suitably protected from mechanical damage, corrosion etc. and must not run too close to pipes carrying potentially dangerous substances e.g. oil, paraffin, or near high voltage electrical cables. Periodically leak tests should be carried out to verify the continued integrity of gaseous oxygen pipes.

6.4 When a new gaseous oxygen pipeline is being commissioned it is vital to install removable filters for remaining weld slag, rust etc. before admitting gaseous oxygen. Failure to do this can result in severe fires.

6.5 Operating staff must open/close gaseous oxygen valves slowly to avoid sudden large temperature rises which could lead to dangerous conditions.

6.6 Gaseous oxygen velocities must be kept within safe limits as specified by your District Engineer.

6.7 Welders must not strike arcs on gaseous oxygen pipes.

6.8 It is strongly recommended that above ground gaseous oxygen piping be suitably coloured and captioned to ensure that its identity is widely known. British Standard Specification 1710 recommends that oxygen pipes be painted dark grey with black bands at regular intervals.

6.9 To ensure proper attention it is most desirable that a responsible person be appointed to be fully responsible for every gaseous oxygen pipeline and system to vet any proposed extensions. No unauthorised alterations must be permitted to any gaseous oxygen pipe. Oxygen pipelines should not be too near pipelines containing combustible substances and buried pipelines can suffer accelerated corrosion if too near electrical cables unless special care is taken.

6.10 All instrumentation must be oil free and of recommended construction.

6.11 All take off points are protected by non-return valves built into oxy-acetylene torches to prevent reverse flow of oxygen should a fire or explosion occur in or near an oxy-acetylene torch. Pressure reducing valves also give some protection against this hazard.

6.12 If a valve is difficult to operate due to apparent stiffness it must not be forced since friction can generate sufficiently high temperatures to start a fire. Defective valves must be repaired before further use is attempted.

7. <u>Oxy-Acetylene Equipment</u>

7.1 Oxy-acetylene equipment is used mainly for welding and flame cutting.

7.2 While acetylene is normally dissolved in acetone at pressures up to 350 psig when mixed with oxygen its pressure must be reduced in a pressure reducing valve to not more than 9 psig to avoid the possibility of spontaneous (explosive) decomposition. This is a statutory Home Office requirement. Acetylene cylinders must be kept as vertical as possible for the above reason and also to prevent escape of acetone which might cause a fire.

7.3 Gaseous oxygen pressure is reduced from its normal storage pressure (2,500 psig for gaseous oxygen cylinders and about 250 psig maximum in liquid oxygen storage tanks) down to about 15 psig before being mixed with acetylene at the welding/cutting torch.

7.4 Cleanliness is important, especially freedom from oil.

7.5 It must be verified that pressure reducing and non-return valves are fully effective and clean to avoid possibilities of explosion.

7.6 Ensure that only best quality gas hoses are used and that they are never interchanged. Normally this is no problem since oxygen union nuts use a right hand thread while acetylene unions use left hand threads.

7.7 If an oxy-acetylene torch does not function correctly, completely shut off both gas supplies, oxygen first. If it is suggested that combustion is taking place inside the torch , immediately close the gas cylinder valves and allow several minutes to elapse to ensure that combustion has ceased.

Then check the torch gas pressures, adjust pressure regulator settings if necessary and finally relight. It sometimes happens that unnecessarily large nozzles are used resulting in the torch tip being overheated. This gives rise to a possibility that combustion can occur inside the torch perhaps resulting in a very undesirable blow back. It is recommended that under such conditions the torch tip be periodically cooled in water.

7.8 See 6(12) regarding stiff valves. This is particularly relevant since acetylene is readily decomposed, perhaps explosively above 125°F.

8. Oxygen Cylinders

8.1 Storage of Oxygen Cylinders

8.1.1 Preferably store under cover in a detached building of non-combustible construction.

8.1.2 Protect against frost and corrosion. No flames or smoking should be permitted in oxygen cylinder store.

8.1.3 If cylinders are stored in a building used for some other purpose the store should fulfill three conditions, viz.

(a) be built of non-combustible materials:
(b) be on the ground floor of the building, against an outside wall with doors leading directly outside.
(c) be separated from the building by walls and floor, fire resistant for at least two hours.

8.1.4 Nothing else should be housed in the store.

8.1.5 Good natural ventilation is most desirable.

8.1.6 Cylinders must be readily accessible and easily removed.

8.1.7 Artificial heat should not be provided.

8.1.8 If possible cylinders should be stored standing vertically. If they are stacked horizontally, stacks should not be more than four layers deep using positive stops to prevent rolling.

8.1.9 Cylinders should not be exposed to any external heat source e.g. hot sunlight, to avoid needless overpressurisation.

8.1.10 Full and empty cylinders should be separated to avoid confusion.

8.1.11 When cylinder caps or guards are available they should be used primarily to protect cylinder valves in case cylinders topple over or are struck by other objects.

8.2 Care of Oxygen Cylinders

8.2.1 Rough handling should not be permitted. For example, when unloading from a truck do not allow cylinders to drop onto concrete. Use a ramp.

8.2.2 Cylinders should be kept cool and away from flame or sparks.

8.2.3 Valves and fittings should not be lubricated or be contaminated by oil or grease.

8.2.4 Keep away from acids and other corrosive substances.

8.2.5 Keep away from electrical equipment.

8.2.6 Cylinders with damaged valves or threads should be suitably labelled and returned to the supplier.

8.2.7 The identifying colour (black) should not be obscured.

8.2.8 After use, cylinders should contain some positive pressure. Protection caps or guards should be replaced and cylinders labelled EMPTY. Keep apart from full cylinders.

8.2.9 If high pressure cylinders are to be connected to lower pressure circuits suitable pressure regulators must be used.

8.2.10 All persons handling oxygen cylinders should be free of all traces of grease or oil. Otherwise they run a risk of being severely burned.

8.2.11 Grit and dust must be rigorously excluded from valves and fittings as these could result in fittings not mating properly causing oxygen leakage and danger of fire if they get into oxygen pipelines.

8.2.12 All cylinders being transported should be secured to the vehicle to minimise movement.

9. Miscellaneous

9.1 Electrical Insulation

It is not desirable that PVC or other plastic insulated electrical wiring should not be located in regions where they can be sprayed by liquid oxygen as the insulation may freeze and crack permitting short circuits to occur, with the attendant fire risk.

9.2 Cleaning

Components for oxygen service must be clean. Several firms specialise in this field and their advice should be sought. So far as degreasing is concerned, trichlorethylene and methylene chloride are acceptable. A simple check on cleanliness is to wipe the area of interest with a piece of clean white lint-free absorbent fabric moistened with solvent when the cloth should not be darkened. A very rigorous check involves the use of ultra-violet light (blacklight) when hydrocarbon deposits will fluoresce. Cleaning of components should be done in a clean, dry, well ventilated area.

9.3 Pressure Gauges

These should be of one piece, solid front construction, have plastic or laminated safety glass fronts, blow out backs built-in restrictions to minimise escape of oxygen in case the gauge fails and be mounted well above head height to protect personnel in case of failure.

9.4 Valves

These must be made of oxygen compatible materials. Rubber neoprene PVC etc. and any lubricant except molybdenum disulphide must be rigorously excluded from shut off valves.

In pressure reducing valves, nylon and PTFE components may be employed in the first (high pressure) pressure reduction stage while in the second (low pressure) stage, neoprene coated components are acceptable.

9.5 Mercury Contamination

Mercury must be rigorously excluded from all oxygen containing equipment made of aluminium since severe and rapid corrosion can occur. In such situations mercury thermometers and mercury containing manometers must not be used.

Air Products

SAFETY DEPARTMENT INFORMATION SHEET NO. 33

Fire Hazards in Compressed Air and Oxygen Rich Environments

by I. Everson (Chief Safety Engineer)

CONTENTS:

1. Introduction

Relevant research has been carried out at the R.A.F. Institute of Aviation Medicine, Farnborough, by Cresswell, Dennison and Ernsting.

The following reports have been issued describing the work:

1. The Fire Risks to Man in Compressed Air Environments - FPRC 1249.
2. The Fire Risks to Man of Oxygen Rich Gas Environments - FPRC/memo 223.
3. An Assessment of the Fire Risks of the Oxygen Environment Experiments - FPRC/memo 217.

These experimental studies in oxygen-enriched atmospheres are specially relevant to hyperbaric oxygen therapy carried out in special small containers in which patients are completely contained, aircraft and space craft breathing equipment.

Its relevance to A.P.L. stems mainly from the information given concerning combustion of constructional materials in oxygen rich atmospheres and fire damage to clothing, human hair and skin. This emphasises the need for persons working in oxygen rich environments to exercise care and to follow established safe procedures.

2. Summary of Experiments Carried out

2.1 Simulation of Effects of Fire in Oxygen Rich Environments upon Clothing Materials and Human Tissue

In these experiments, specimens of various materials were electrically ignited and also pieces of pig corpse were dressed in various materials into which were sewn electrical ignition coils. These experiments were carried out under closely controlled conditions.

2.2 Flammability of Constructional Materials in Oxygen Rich Environments

Samples of a wide range of constructional materials were subjected to atmospheres containing various oxygen concentrations and ignited electrically and their subsequent behaviour carefully observed.

3. Summary of Experimental Results

3.1 Characteristics of Combustion in Oxygen Rich Environments

Compared with ignition in air, in an oxygen environment ignitability increases 1000fold, and burning rate 5fold. Most conventional fire-proofing agents are ineffective. Smothering as a means of extinction is also ineffective. From the experiments on dressed pig corpse in an oxygen environment, when ignition occurred the following characteristics were observed -

3. 3.1 (contd)

(a) Immediately upon ignition a 5 cm deep flame front flashed over the entire surface of the overall leaving it virtually unscathed but flaming at all edges and at many points on its surface.

(b) For the next two seconds the separate fires remained small, then over the next two seconds they rapidly enlarged and coalesced into a 6 foot column of fire.

(c) This fire persisted for about 30 seconds after operation of the sprinkler system.

(d) The clothing and skin were almost completely destroyed. Most of the human body is covered by hair comparable to nap on denim and one would expect "flashover" to occur on man as well, probably igniting the body, facial and scalp hair as it passed, but not setting fire to flesh.

3.2 Clothing

Untreated glass fibre and asbestos are the only non-flammable materials in 100% oxygen. Neither is a practicable material for clothing. All commercially available glass fibre and asbestos (which is known to contain some cotton) is suspect until tested in oxygen. Fluorocarbon polymers such as Teflon or PTFE are almost non-flammable and have been used as binders. No combination suitable for clothing is available at present. Conventional non-inflammable materials are common natural or man-made fibres coated with a fire-retardant. However, they burn vigorously in atmospheres containing more than 30 to 40% oxygen but extinguish themselves rapidly in air. Nylon melts when heated, forming adherent hot masses producing severe local burns. "Proban" treated poplin or wool are believed to be the best available materials for clothing at the present time. Although they will flame in oxygen enriched atmospheres, they will extinguish themselves in a few seconds when subjected to air. It is proposed that pocketless one piece overalls with short sleeves and three-quarter length trousers reduce the risk of accidental ignition. Canvas shoes with conducting rubber soles are also recommended.

3.3 Rubber Seals

Natural rubbers, nitryl rubber and foam neoprene burn modestly in air and vigorously in oxygen. Compact neoprene and silicone rubbers burn with difficulty in air and with ease in oxygen. A fluorocarbon synthetic rubber, Viton, will not burn in air and will only incandesce or burn feebly in oxygen. Viton costs about 3 times neoprene, is reasonably compressible but difficult to extrude. It may be a practicable material for seals. It has been suggested that the use of a heat reflective plastic spray, e.g. Teflon, on rubber may be valuable.

3.4 Paints and Metal Surface Protection

Conventional and epoxy resin (fire-resistant) paints are both inflammable in 100% oxygen. Available fireproof paints when

3. 3.4 (contd)

allowed to dry on asbestos or glass fibre wicks will burn in air and oxygen. If allowed to dry on ⅜" thick steel sheet they will not burn in either air and oxygen presumably due to the cooling effect of the steel plate. It is good practice to protect exposed steel with a non-inflammable coat, e.g. zinc spray, phosphate coating or fire retardant paint.

3.5 Electrical Wiring

Mica-insulated copper will not burn in oxygen. P.V.C. insulated wiring is readily combustible in oxygen. Commercially available asbestos, glass fibre and silicone rubber insulation will burn in oxygen. If the P.V.C. covering is removed from a common screened cable, the metal screen will act as a flame barrier. However, the P.V.C. insulation of the internal cores eventually melts and exudes to the outer surface and then flames feebly. This can be overcome by sheathing the metal screen with ceramic fish spine beads. This combination is flexible and relatively fireproof.

3.6 Lubricants

Most common lubricants burn in air and oxygen. PTFE and Teflon are almost non-inflammable in oxygen. Dry molybdenum disulphide powder will not burn in air but will incandesce, but does not flame in oxygen. Tricresylphosphate is rapidly self-extinguishing in air but is known to burn moderately in oxygen.

Tricresylphosphate is accepted as a lubricant for work in oxygen and is used in vacuum pumps.

3.7 Flammability Tests

A wide range of materials were checked for flammability in oxygen. All the materials tested, with the exception of Zeolite (used in molecular sieves) untreated asbestos and glass fibre are all combustible. Teflon, PTFE, Viton and molybdenum disulphide are acceptable for most applications. Commercial asbestos and glass fibre, silicone rubbers, lubricants, fireproof wiring, insulating materials, fire retarding paints, rainproof clothing and normal clothing materials are all inflammable in oxygen. Fish spine (ceramic) beading is an effective flame barrier for P.V.C. insulated wiring, P.V.C. and rubber tubing. Charcoal will not burn in air but incandesces visibly in oxygen.

4. Conclusions

4.1 In air at 1 atmosphere, material slowly smouldered but did not burn and the pig skin showed no detectable singeing. At 2 to 5 atmospheres the material ignited with increasing ease and burnt more vigorously. The areas of burnt clothing and skin increased with the total pressure. Fire risks to man in compressed air environments are greater than in air at 1 atmosphere but less than in oxygen at 1 atmosphere.

4. (contd)

4.2 Compared with air there is a greatly increased fire hazard to man in oxygen enriched gas environments. This arises from the greatly increased ignitability and burning rates of materials in these circumstances. These tendencies are particularly aggravated by the presence of "nap" or body hair which explosively propagates the fire across the surfaces of clothing. In experiments carried out at total pressures not exceeding 1 atmosphere, there was a dramatic increase in fire hazard due to flash burning when the partial pressure of oxygen exceeded 0.4 to 0.5 atmospheres.

4.3 In oxygen at 1 atmosphere the material ignited almost instantaneously and the flash fire propagated quickly over the surfaces of the clothing and the pig skin leading to a very vigorous fire.

4.4 Skin is inflammable in 100% oxygen.

4.5 Fires in oxygen rich environments are of a fundamentally different character to those in air.

Igniting a clothed man in these environments may lead to fatal damage within 5 to 20 seconds from onset of fire.

A dense local water spray may control this fire, but a manually operated system could not hope to arrest it in the few seconds available.

Damage to the man is critically dependent upon the type, fit and proofing of his clothing and upon the timing, density and distribution of the extinguishing water sprays.

4.6 Sudden pressure surges in oxygen are dangerous in that large temperature rises can be created, perhaps leading to ignition.

4.7 The spark energies required to ignite common clothing materials in an oxygen environment correspond to those of electrostatic sparks from the human frame.

Spark energy of a few milliwatts is sufficient to ignite some materials in 100% oxygen.

4.8 Mechanical sparking can be prevented by coating adjoining surfaces which come into contact with each other with Teflon, PTFE or phosphor-bronze and lubricating hinges with Teflon, PTFE, tricresylphosphate or molybdenum disulphide. Aluminium and its alloys and steels should be separated or failing that there should only be rigid contact between these substances.

4.9 Of available fire detectors a thermistor device appears to be the most suitable. This depends upon a large change of resistance should the temperature increase due to a nearby fire.

4. (contd)

4.10 Apart from Zeolite, untreated asbestos and glass fibre all materials tested will burn to varying degrees in oxygen rich environments.

5. Recommendations for minimising fire risk and consequent damage to persons liable to prolonged exposure to Oxygen rich environments

5.1 Wear tight fitting, single layered garments, of light weight open meshed material, fireproofed with 10% pick up of borax/boric acid.

5.2 The extinguisher system should provide water sprays of at least 5 cc/min./cm^2 over the entire body within 2 seconds of operation.

5.3 An open ended hose should be provided to douse areas shaded from the general water spray e.g. crutch, arm pits.

FPRC/Memo 217

FLYING PERSONNEL RESEARCH COMMITTEE

AN ASSESSMENT OF THE FIRE RISKS OF THE OXYGEN ENVIRONMENT EXPERIMENTS

by

Flight Lieutenant D. M. Denison

RAF Institute of Aviation Medicine,
Farnborough, Hants.

MINISTRY OF DEFENCE
(AIR FORCE DEPARTMENT)

January 1965
(Received August 1964)

FLYING PERSONNEL RESEARCH COMMITTEE

THE FIRE RISKS TO MAN OF OXYGEN RICH GAS ENVIRONMENTS

by

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July 1965
(received April 1965)

FLYING PERSONNEL RESEARCH COMMITTEE

FURTHER STUDIES UPON THE HUMAN ASPECTS OF FIRE IN ARTIFICIAL GAS ENVIRONMENTS

by

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MINISTRY OF DEFENCE
(AIR FORCE DEPARTMENT)

September 1967
(Received March 1967)

Air Products

IE/PR

8th April 1971

SAFETY DEPARTMENT INFORMATION SHEET NO. 41

Important Data Extracted from a Paper Presented by W.L. Ball (A.P.C.I.) At The A.I.Ch.E. Annual Meeting, Air and Ammonia Plant Symposia, September 25th-27th 1961

HAZARD LEVEL OF HYDROCARBON FILMS IN OXYGEN SYSTEMS

1. The most rigorous cleaning can reduce hydrocarbon contamination down to 4 mg/ft.^{2} (milligrams per square foot). This is both time consuming and expensive. Tests were conducted to ascertain if such rigorous cleaning was necessary.

2. A.P.C.I. carried out these experiments using n-hexadecane deposited uniformly in the test equipment by dissolving the hydrocarbon in carbon tetrachloride which was then evaporated while rotating the test section made of stainless steel pipe.

3. Tests were conducted at hydrocarbon concentrations carrying between 28 and 6500 mg/ft.^{2} at varying oxygen pressures using electrical ignition.

4. At 100 mg/ft.^{2} no oil is visible and no smear can be detected when the surface is rubbed with a finger and the area inspected under a bright white light. At 250 mg/ft.^{2} the surface has a slight oily appearance but no smearing is discernible after testing as above. At 500 mg/ft.^{2} the oil has a definite flow characteristic and a slight smear can be detected. At 1000 mg/ft.^{2} smearing is considerable and at 2500 mg/ft.^{2} the oil can be pushed with a finger.

5. No reaction occurred at 1000 mg/ft.^{2} and 200 p.s.i.g. oxygen pressure apart from a burn spot at the point of ignition.

6. At 1050 mg/ft.^{2} and 1500 p.s.i.g. reaction occurred.

7. At 6500 mg/ft.^{2} and 50 p.s.i.g. detonation occurred.

8. The ignition tests indicated that concentrations up to 1000 mg/ft.^{2} would be acceptable.

9. However, as noted previously, surface films of 500 mg/ft.^{2} and greater began to show definite flow characteristics. These film concentrations would tend to flow to and concentrate in low portions of a system and increase the hazard of ignition locally. This would be intolerable in any process equipment. Also, in a cold system, the film tended to freeze and flake off at concentrations above 500 mg/ft.^{2}. With a hydrocarbon such as n-hexadecane, which is lighter than liquid oxygen, these flakes float and

concentrate on the surface. These two phenomena, the flow characteristics and the freezing and flaking in a cold system, require the reduction of a maximum safe concentration to something less than 500 mg/ft.^{2}.

10. For hydrocarbons with the same characteristics as n-hexadecane, W.L. Ball suggests that if contamination is assumed to be uniform then the maximum permissible value of the average concentration should be limited to 100 mg/ft.^{2} i.e. maximum concentration = 5 x average concentration. This factor of 5 is of necessity arbitrary but should be accepted in the absence of other evidence.

11. At present the effectiveness of A.P.L. cleaning procedures in terms of mg/ft.^{2} hydrocarbon contamination is not known. Q.C.D. (Acrefair) is investigating this matter further.

12. This document should be read in conjunction with Safety Department Information Sheet No. 42.

I. Everson
Chief Safety Engineer

IE/PF

8th April 1971

SAFETY DEPARTMENT INFORMATION SHEET NO. 42

LIMITING VALUES OF OIL CONTAMINATION OF STAINLESS STEEL SURFACES EXPOSED TO GASEOUS OXYGEN

If the values of oil contamination in mg/ft.^{2} (milligrams per square foot) of surface area quoted below are exceeded then should a source of ignition be present the oil will react perhaps explosively.

Item Type of Oil	Maximum Permissible Oil Concentrations mg/ft.^{2}
Ester base cutting oil	300
Hydrocarbon base cutting oil	7
[illegible] base cutting oil	150
[illegible] and salt base cutting oil	300
[illegible]	150
Ester type compressor oil	200
Hydrocarbon type compressor oil	15

Whenever oxygen equipment is solvent washed careful records should be kept so that oil contamination values can be estimated. To allow for non-uniform distribution, the above figures must be regarded as optimistic. In plants if average concentrations are close to the above it should be concluded that a dangerous situation exists.

While experiments were done only in stainless steel equipment it should be assumed that the above figures apply to any surface exposed to oxygen.

This document should be read in conjunction with Safety Department Information Sheet No. 41.

The supporting experimental work was conducted by R.A. Walde (A.P.C.I.)

I. Everson
Chief Safety Engineer

APCI DOCUMENT NO. 99000428

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. LUBRICANTS

Form No. IA1a-1 to IA1a-18

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. SEALANTS AND THREADING COMPOUNDS

Form No. IA2a-1 to IA2a-12

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. THERMAL AND ELECTRICAL INSULATIONS

Form No. IA3a-1 to IA3a-7

May 12, 1972

AIR PRODUCTS AND CHEMCIALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. PLASTICS, ELASTOMERS, AND ADHESIVES

Form No. IA4a-1 to IA4a-7

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. GASKETS AND PACKINGS

Form No. IA5a-1 to IA5a-14

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. METALS, ALLOYS, SOLDERS, AND SURFACE TREATMENTS

Form No. IA6a-1 to IA6a-38

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

A. CHEMICALS, SOLVENTS, AND MISC.

Form No. IA7a-1 to IA7a-6

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

B. COMPATIBILITY CHECK --
FIRE COMPATIBILITY

Form No. IB1c-1 to IB1d(2)-2

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

I. MATERIAL COMPATIBILITY

B. COMPATIBILITY CHECK --
STRUCTURAL MATERIALS COMPATIBILITY

Form No. IB2-1 to IB2e(2)-1

May 12, 1972

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LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS

A. OVERPRESSURE

Form No. IIA-1 to IIA4-2

May 12, 1972

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LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS.

B. DISPOSAL OF VENTED GASES

Form No. IIB-1 to IIB4-1

NOTE: 99000546 - V O I D

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AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS

C. COUPLING TO OTHER SYSTEMS

Form No. IIC1-1 & IIC2-1

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS

D. SPILLS AND LEAKAGE

Form No. IID-1 to IID4-1

May 12, 1972

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LIQUID AND GASEOUS OXYGEN SAFETY REVEIW FORM

II. OPERATIONAL HAZARDS

B. CONTAMINANTS ACCUMULATION

Form No. IIE-1

May 12, 1972

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LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS

F. OXYGEN TRANSFER

Form No. IIF1-1 to IIF3c-1

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

II. OPERATIONAL HAZARDS

G. FIRE AND EXPLOSIONS

Form No. IIG-1

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

III. MAINTENANCE PROGRAM

A. CHECK AND INSPECTION

Form No. IIIA1-1 to IIIA5-2

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

III. MAINTENANCE PROGRAM

B. SAFE CLEANING PROCEDURES

Form No. IIIB-1

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORMS

III. MAINTENANCE PROGRAM

C. PRESSURE TESTING

Form No. IIIC-1

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

IV. SYSTEM EMERGENCIES

Form No. IV-1 to IVE-2

May 12, 1972

AIR PRODUCTS AND CHEMICALS, INC.

LIQUID AND GASEOUS OXYGEN SAFETY REVIEW FORM

V. ACCIDENT/INCIDENT INVESTIGATION AND REPORT

Form No. V-1 to V-4

Air Products and Chemicals INC.

COMPANY CONFIDENTIAL

THE BURNING OF METALS IN OXYGEN ATMOSPHERES

(80 TO 100%)

Technical Memorandum No. 186

EA-2156

March 1972

John Daly

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A. Lapin 3/26/72 Date

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SUMMARY

An exploratory experimental program has been carried out in the Allentown laboratories between February and May 1970 in order to observe and measure the burning rates of several metals. The test runs did not involve any equipment for measuring temperature, heat input, or heat evolved. The observations made for the most part were qualitative but there were some combustion rates measured in two of the experimental apparatuses.

There were five basic set-ups used in this experimental program (Figures 1 to 5), four involving gaseous oxygen at atmospheric pressures and one using LOX at atmospheric pressure. Experimental results for two of the set-ups, Figures 2 and 5, are recorded on 16mm movies. Typical runs for mild steel, stainless steel, and aluminum were filmed.

There were two ignition methods used. Initially an oxyacetylene torch was used to heat the sample to ignition or melting whichever the case might be. Later an ignition "pill" made of compressed steel wool, stainless steel wool, or aluminum wool was used. This pill was ignited by means of a 6 volt battery and two electrodes. The second method was the better of the two since the oxygen atmosphere around the sample was not disturbed as much as in the case of the torch, which emits a high velocity flame.

Table I lists the metals with their compositions, which were tested. All metals were tested in every set-up except Apparatus No. 3. Mild steel and stainless steel were run in this set-up.

In addition to the experimentation, a literature survey was conducted on the combustion of metals. The Appendix contains a list of pertinent reports along with abstracts. Some of the more important articles are the eight papers by Dr. L. Kirschfeld, who has done extensive work in the field of combustion of metals.

CONCLUSIONS

For the most part, metals will react with oxygen if exposed to the right conditions. The degree with which a specific metal reacts depends on a number of variables. Pressure, temperature, phase of oxygen and oxygen concentration are among the most important ones. It appeared that the metals tested reacted faster and to a greater degree in liquid than in gaseous oxygen. The reason for this is not clear but two possible answers are: higher oxygen concentrations or better contacting of oxygen in the reaction zone. Combustion rates increase as the flow rate of oxygen increases, at least in the case of mild steel as shown in figure 6.

The data taken during these series of tests agree in a qualitative way with those of other researchers in the field of combustion of metals (4,5,6,7). In general most agree that mild steel is the easiest to ignite and burns readily in oxygen. Nickel and its alloys appear at the other end of the scale, being the most resistive to burning in oxygen regardless of conditions. Aluminum lies somewhere in the middle, being a very reactive metal in oxygen after ignition, but its low melting point and high ignition temperature make it one of the hardest metal to ignite and keep burning. The list of metals which were tested, is arranged, in Table II, in order of decreasing resistance to ignition and burning in oxygen atmospheres.

TABLE I

Compositions of Metals Tested

Stainless Steel	C (Max) %	Mg (Max) %	Composition Si (Max) %	Cr %	Ni %	Others %
309	0.2	2.00	1.00	22-24	12-15	--
316	0.1	2.00	1.00	16-18	10-14	Mo 2-3
316 L	0.03	2.00	1.00	16-18	10-14	Mo 1.75-2.5
410	0.15	1.00	1.00	11.5-13.5	---	--
17-4 Ph	0.04	--	--	16.5	3.5-4.0	Cu 3.4-4.0

Commercial Leaded Bronze: 89% Cu, 1.75% Pb, 9.25% Zn

Monel 400: 66.5% Ni, 0.12% C, 1.0% Mn, 1.35% Fe, 0.15% Si, 31.5% Cu

Inconel 600: 76.0% Ni, 0.04% C, 0.2% Mn, 7.2% Fe, 0.20% Si, 0.10% Cu, 15.8% Cr

Nickel 200: 99.5% Ni, 0.06% C, 0.25% Mn, 0.15% Fe, 0.05% Si, 0.05% Cu

Hastelloy B: 65% Ni, 0.1% C, 0.5% Mn, 6% Fe, 0.5% Si, 28% Mo

Aluminum 5357: 1.0% Mg, 0.25% Mn, 98.75% Al

Carbon Steel 1010: 0.08-0.13% C, 0.30-0.60% Mn, 0.040% P, 0.050% S, Balance Fe

Molybdenum Steel 4140: 0.33-0.43% C, 0.75-1.0% Mn, 0.040% P, 0.040% S, 0.2-0.33% Si, 0.8-1.10% Cr, 0.15-0.25% Mo, Balance Fe

TABLE II

Metals Tested Arranged in Order of Decreasing Resistance to Ignition and Burning

Nickel 200	- only melted
Commercial bronze	- only melted
Inconel 600	- very little reaction
Monel 400	- very little reaction
Hastelloy B	- very slow reaction rate
Aluminum	- hard to ignite but very reactive after ignition
Stainless steel	- self-sustaining reaction in some runs
Mild steel	- very easy to ignite--complete combustion of sample

RESULTS

Variations in burning characteristics of metals were determined in each of the tests in the five experimental set-ups. These characteristics are classified into five catagories.

1. Metals for which self-sustaining burning was sufficient to allow a combustion rate to be measured. In addition these metals burned until oxygen was removed (√).

2. Metals which burned in a long enough self-sustaining manner, that a rate of combustion was measured, but differed from number 1 in that they were eventually self-extinguishing in nature (√+).

3. Metals which burned or reacted in a manner which did not allow the determination of a rate of combustion. For example, stainless would melt off the sample rod and react with the oxygen in the molten form at the base of the experimental equipment (√*).

4. Metals which reacted only when outside heat was supplied (S.R.).

5. Metals which did not react; the test sample only melted (N.R.).

Table III has a listing of all the metals tested and the testing apparatuses. In addition, the metals are classified into the above mentioned categories, and some typical burning rates are mentioned.

With regard to the resistance of metals in reacting with oxygen, nickel and its alloys are probably the most resistive, while steel, stainless steel, and aluminum are the least resistive of the metals tested. Aluminum, although reacting most violently with oxygen, was very hard to ignite. This is a factor in its favor for its use in some oxygen atmosphere applications.

EXPERIMENTATION AND DISCUSSION OF RESULTS

Apparatus No. 1 (Figure 1)

In this equipment although very simple, three types of reactions could be distinguished (see Table III). Mild steel is the easiest of the metals to ignite. Once heated to glowing red and lowered into the beaker containing oxygen it would continue to burn as long as there was oxygen available. The reason being, mild steel ignites and burns in oxygen at, or just below its melting point, causing the reaction to remain on the rod. Stainless steel on the other hand, reacts with oxygen at, or just above its melting point, therefore, it was very difficult to sustain a reaction on the rod for a long period of time. Stainless steel because it reacts with oxygen at a higher temperature and in a different phase than mild steel, was very sensitive to positioning. Combustion rates for stainless steel were obtained when the stainless steel rod was burning horizontally and vertically from bottom to top. Aluminum, like stainless steel ignites above its melting point (5). It is estimated in the literature that its ignition temperature in oxygen is around 3700°F (5,6). Since aluminum's melting point is about 1220°F there was very little chance of getting the test piece hot enough to cause ignition in this type of equipment. Nickel and its alloys are other metals which ignite above their melting point, so ignition of these metals was again not achieved. Low oxygen concentration,

Air Products and Chemicals INC.

TABLE III

Metals Tested Classified into Degrees with which they Reacted with Oxygen in Each Apparatus

Metal		Apparatus 1	2	3	4	5
Mild Steel 1/16", 1/8" & 1/4" rod	Data on 1/16" rod	√*	√ .3 in/sec (up) .5 in/sec (down)	√* No Data	√*	√ .435 in/sec
Aluminum 1/16" rod		N.R.	√+ 10 in/sec (up) approximate	-----	√*	√*
309 Stainless Steel 1/16" rod		√*	√ .171 in/sec (down)	-----	√*	√ .38 in/sec
316 Stainless Steel 1/16" rod		√*	√+ .08 in/sec (up)	-----	√*	√ .3 in/sec
316 L Stainless Steel 3/32" rod		√*	√+ .07 in/sec (up)	-----	√*	S.R.
410 Stainless Steel 1/16" rod		√*	√+ .052 in/sec (up)	-----	√*	√+ .24 in/sec
17-4 Ph Stainless Steel 1/16" rod		√*	√+ .12 in/sec (up)	-----	√*	√ .3 in/sec
4140 Steel 3/16" rod		√*	√ .013 in/sec (up)	-----	√*	√ .06 in/sec
Nickel 200 1/16" & 1/8" Rod		N.R.	N.R.	N.R.	N.R.	N.R.
Monel 400 1/16" rod		S.R.	S.R.-9 sec of glowing	-----	N.R.	S.R. - 4 sec of glowing
Inconel 600 1/16" & 1/8" Rod		S.R.	N.R.	-----	N.R.	S.R.-4 sec of glowing
Commercial Bronze 1/16" rod		N.R.	N.R.	-----	N.R.	N.R.
Hastelloy B 5/64" rod		S.R.	√ .06 in/sec (up)	-----	S.R.	√ .08 in/sec

Note: See Results on page 4 for explanation of symbols

APPARATUS # 1

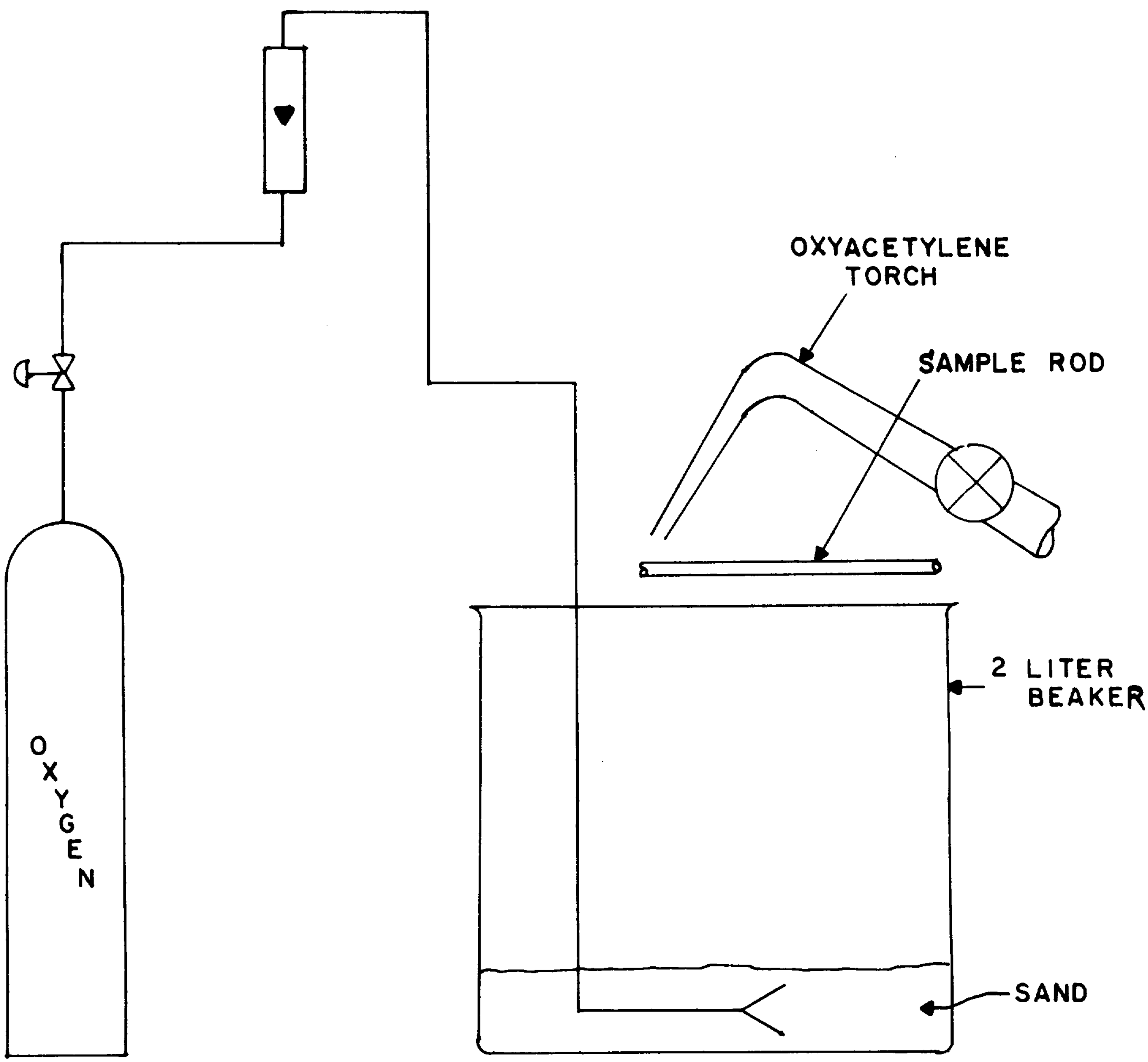


FIG. # 1

(around 80%) and poor oxygen distribution, are two conditions inherent in this open system and were eliminated in later equipment.

Apparatus No. 2 (Figure 2)

In this experiment the effect of oxygen velocity on burning was studied (Figure 2). Initially oxygen was passed through the glass tube for one to three minutes, depending on the flow being used, to insure an oxygen concentration of 95%. The concentration of oxygen was measured using a Beckman analyzer. Oxygen velocities from 0 to 6 ft/sec were used. Mild steel rod (1/16" dia) was tested over this range of velocities. Its combustion rate increased from .15 in/sec at the low end to .425 in/sec at the high end (average values). Figure 6 is a plot of the combustion rate vs oxygen velocities for mild steel. Combustion data were taken on the other metals but only at one or two velocities (see Table III for some average values), [for more data refer to laboratory notebook #1589 pages 4-20].[1] To see the effect of the direction of burning on the combustion rate, some runs were made with the apparatus inverted thus allowing the molten product to run down the sample rod. In most cases the combustion rate was increased. The combustion rate of mild steel doubled by burning in this fashion (see Figure 6 at oxygen velocity of 1.5 ft/sec).

In comparing the burning characteristics of mild steel for Apparatuses 1 and 2, there was very little difference in the combustion process, except that the rate was faster in apparatus 2 than in 1, even at the low flow rates. This is probably due to the higher oxygen concentration (90-95%) in Apparatus 2 in comparison to 80% in Apparatus 1 (both measured with a Beckman oxygen analyzer).

The combustion rate of aluminum was very difficult to measure because the reaction is so fast and usually stops suddenly. From the literature and observations it probably is in the range of 10 in/sec. In spite of the fact that aluminum is a very reactive metal it was very hard to ignite, and ignition occurred occasionally. Its fast reaction rate can probably be attributed to aluminum's high heat of combustion, 13,400 Btu/lb compared to 2000 Btu/lb for steel. See Table IV for a listing of some physical and thermodynamic properties of metals.

Five types of stainless steels were tested in Apparatus 2. Again referring back to Table III, reading down the appropriate column it is possible to distinguish between the burning characteristics of the different stainless steels. Except for type 309 it was very difficult to sustain a reaction on the stainless steels. For the most part, the amount of material consumed was very small and the reaction self-extinguishing. One possible reason for the reaction not continuing is the low oxygen concentration present. As was stated before, the oxygen concentration was about 90 to 95% in Apparatus 2, relatively low in comparison to the 100% oxygen which was desired. This could be a very important factor in determining the rate of combustion. It is known through the literature that cutting speeds in oxy-fuel cutting techniques is greatly reduced if the purity of the oxygen is less than 98% (8).

Nickel and its alloys did not react with the oxygen to any great extent, except for Hastelloy B which did react long enough to give a rate of .06 in/sec. Monel 400 was the only other one to show any signs of reaction. After the torch was removed, the sample continued to glow until a large molten drop was formed on the end of the rod. At this point, the drop

APPARATUS # 2

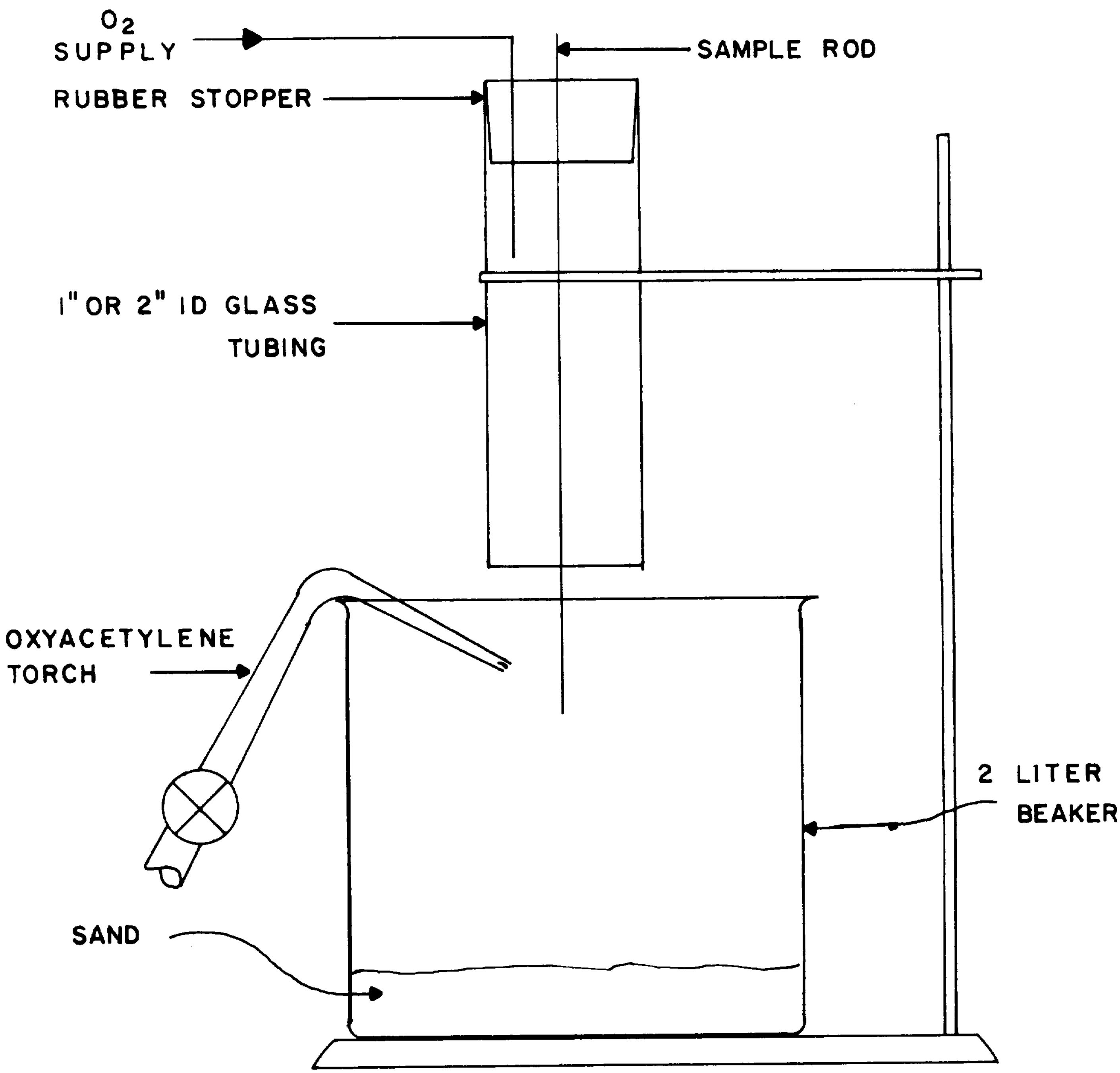


FIG. # 2

TABLE IV

Physical Properties of Metals Tested

Metal	Atomic Weight	Density #/in^3	M.P.	B.P.	Heat of Fusion Btu/lb.	Heat of Comb. Btu/lb Fuel	Therm. Cond. Btu/ft^2 /hr °F in	Spec. Heat Btu/lb °F	Oxide Formed	Oxide M.P.	Oxide B.P.	Standard Heat of Formation Btu/lb
Ingot Iron	55.847	.284	2800°F	4960°F	117	2,000	490	0.108	Fe_3O_4 FeO	2906°F 2480°F	3254°F	-5700
Carbon Steel		.284	2760°F				360	0.107				
Aluminum	26.97	.097	1200°F	3740°F	170	13,400	960	0.23	Al_2O_3	3713°F	5396°F	-7120
Magnesium	24.32	.065	1200°F	2030°F	160	11,600	650	0.243	MgO	5072°F	6512°F	-6450
Nickel 200	58.69	.321	2635°F	4950°F	133	1,780	420	0.11	NiO	3614°F		-1390
Monel 400		.316	2415°F		122		174	0.108				
Inconel 600		.305	2560°F		138		104	0.106				
Hastelloy B		.334	2430°F		135		72	0.091				
309 Stainless Steel		.29	2600°F		130		96	0.12				
316 Stainless Steel		.29	2525°F		129		113	0.12				
316 L Stainless Steel		.29	2525°F		129		113	0.12				
410 Stainless Steel		.28	2750°F		124		173	0.11				

cooled and the reaction stopped. As this molten drop was formed (as is the case for most metals) the forces holding it together and holding it to the rod were too great to allow it to fall off and expose fresh metal to continue the reaction. In other words, the rate of transportation of the molten product was the rate controlling step in the total reaction (3). Dr. Kirschfeld, noted for his work in burning metals, describes two processes which might control the reaction rate in the combustion process:

1. The rate of transportation: The removal of the products of combustion is slower than the rate at which they are being produced, therefore, it controls the rate at which the combustion takes place.

2. The rate of reaction: Just the opposite is meant by this statement, that is, the rate of production of products is the slower step and controls.

Commercial bronze would not react in this experimental set-up, again probably due to the sample melting before it reached its ignition temperature.

Apparatus 2 has the following main advantages over Apparatus 1:

1. A higher concentration and better distribution of oxygen.

2. The ability to study combustion rate vs. oxygen velocity.

Apparatus No. 3 (Figure 3)

This apparatus was constructed in an attempt to determine the effect of rotation on the burning rate of materials in high oxygen atmospheres. The test procedure went as follows: the box was initially purged with oxygen for 3 minutes at a flow rate of .9 scfm. After this, the flow rate was cut back to .3 scfm during testing. As can be seen from Figure 3 an ignition pill was used to ignite the sample. In a stopped position the two electrodes were brought into contact with the pill causing its ignition. After approximately 3 seconds the sample would ignite and at this time the 4" disk was put in motion. Only mild steel and 304 stainless steel were tested because of the availability of the 2 metals in thin sheets (.005" and .010" thickness). It was very difficult to determine a rate of burning at different rotation speeds. From observation, it was felt that the burning rate increased with speed of rotation. However, it was not possible to measure the burning rate, even by weighing the disc before and after the combustion, because of the metal thrown from the combustion zone by centrifugal force.

Apparatus No. 4 (Figure 4)

This experimental set-up involved the use of LOX instead of gaseous oxygen. The reasons for this change were: 1. to ensure 100% oxygen around the specimen, and 2. to see if the low temperature had any different effects on the ignition or burning process.

APPARATUS #3

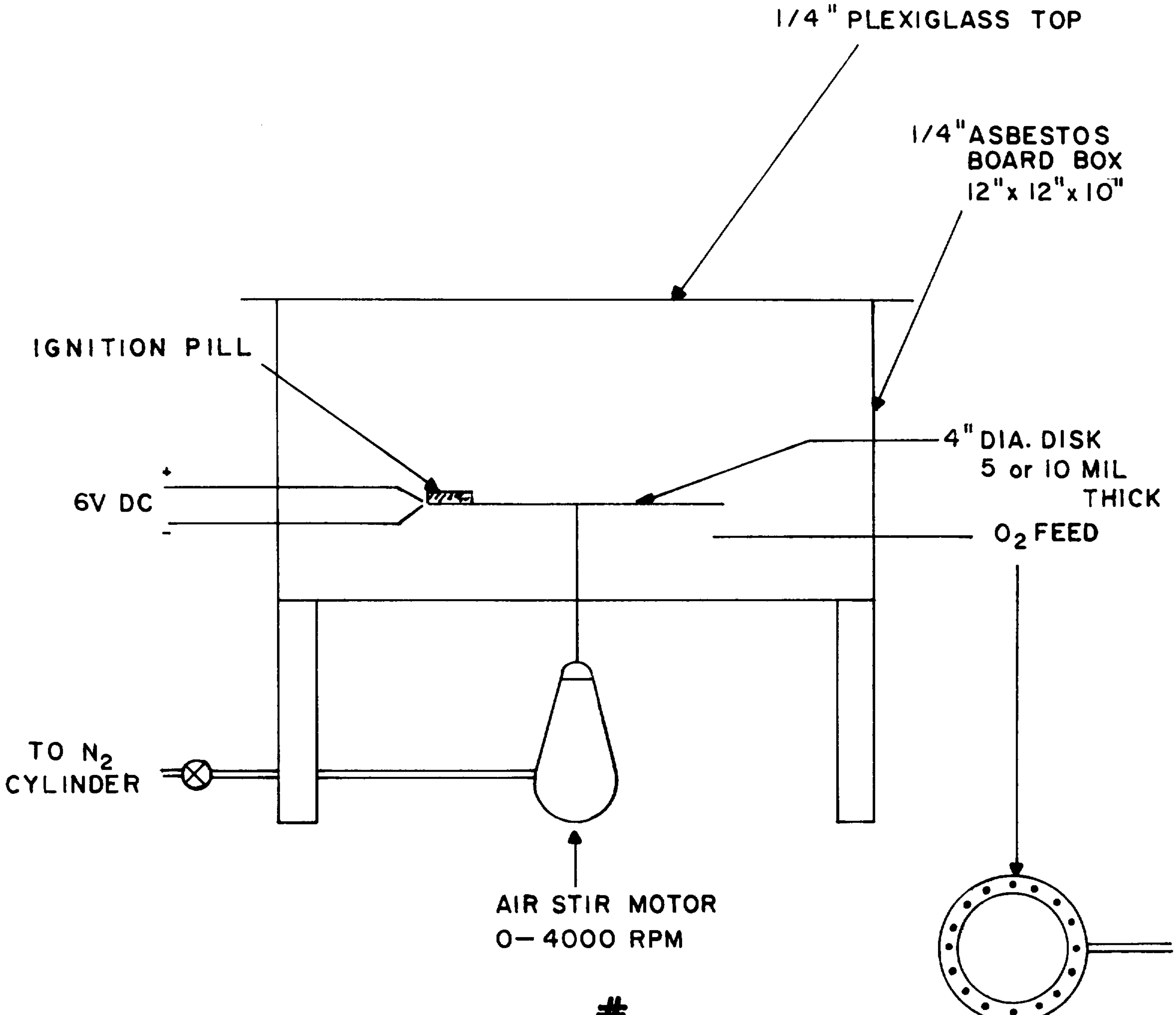


FIG. #3

APPARATUS #4

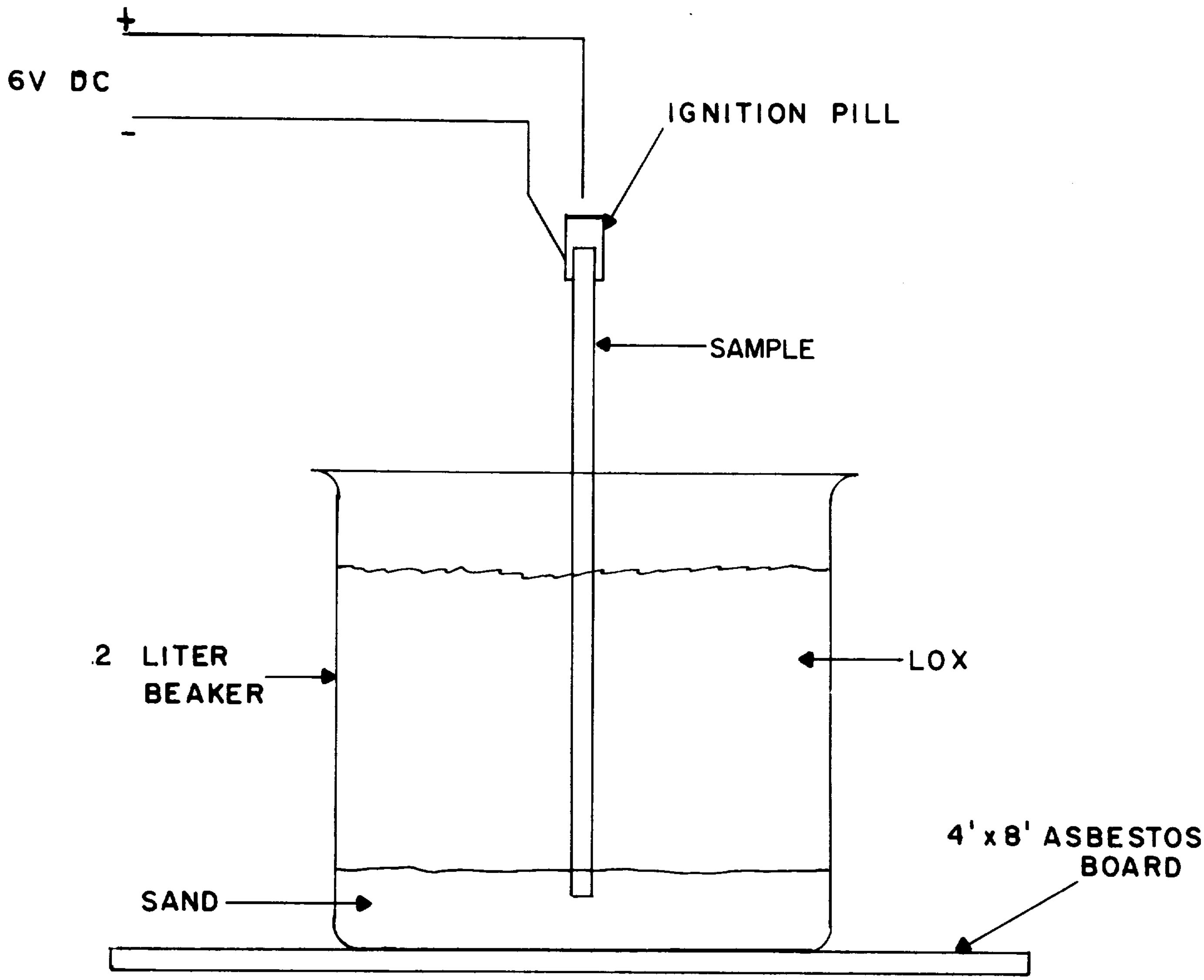


FIG. #4

There were a number of variations to this set-up before it got to the stage it appears in Figure 4. Initially samples were placed in the bottom of an 80 ml fire brick crucible filled with LOX. Next a 1/4" mild steel rod was heated to just below its melting point and thrust into the vapor space above the LOX. This resulted in the combustion of the rod causing a molten drop to fall into the crucible and onto the test piece. This molten drop would either cause ignition of the test specimen or solidify. From this it was decided that it might be possible to determine some combustion rates by going to an apparatus like the one shown in Figure 4 and using wire samples 6" or 8" long. This was not the case because the LOX vapor obstructed visual observation of start and finish of ignition.

Apparatus No. 5 (Figure 5)

Again as in Apparatus 2, the object of the set-up was to determine combustion rates of metals in the presence of 100% oxygen. This experiment (Figure 5) was run at near zero oxygen velocity, a 95 to 100% oxygen atmosphere, and in a horizontal position. The ignition method used was an ignition pill ignited by two electrodes and a 6 volt battery. The combustion rates, of all metals that burned in Apparatus No. 5, were higher than the rates in Apparatus No. 2, probably due to, both the higher oxygen concentration and the horizontal burning (see Table III for typical combustion rates). Aluminum was very difficult to ignite, and no rates were established. Different burning rates for the stainless steels tested were determined, thus allowing some comparison of burning rates and composition to be made. It appears, from the test results from Apparatus No. 2 and No. 5, and from the literature, that alloying steels with materials like magnesium and chromium will increase the burning rate somewhat, while alloying with materials like molybdenum and nickel will decrease the burning rate. Nickel and its alloys still resisted combustion in this apparatus. Nickel itself would not react at all, while monel and inconel did show signs of reaction with the oxygen. Hastelloy B was the only alloy to burn continuously. Its combustion rate was .08 in/sec.

IGNITION METHODS

Oxyacetylene Torch

The oxyacetylene torch was used initially because of the ease with which ignition of the sample could be obtained. Because of its high flame temperature, around 5000°F, the samples could be brought to ignition or melting temperature quickly. The problems involved in using the torch were:

1. The test chamber had to be open to the atmosphere so the torch could be brought close to the sample and then removed. This allowed the atmosphere around the ignition point to become diluted with air.

2. The high velocity of the combustion gas from the torch disturbed the atmosphere around the sample.

Ignition Pill

The ignition method was switched to the ignition pill because of the following reasons:

APPARATUS # 5

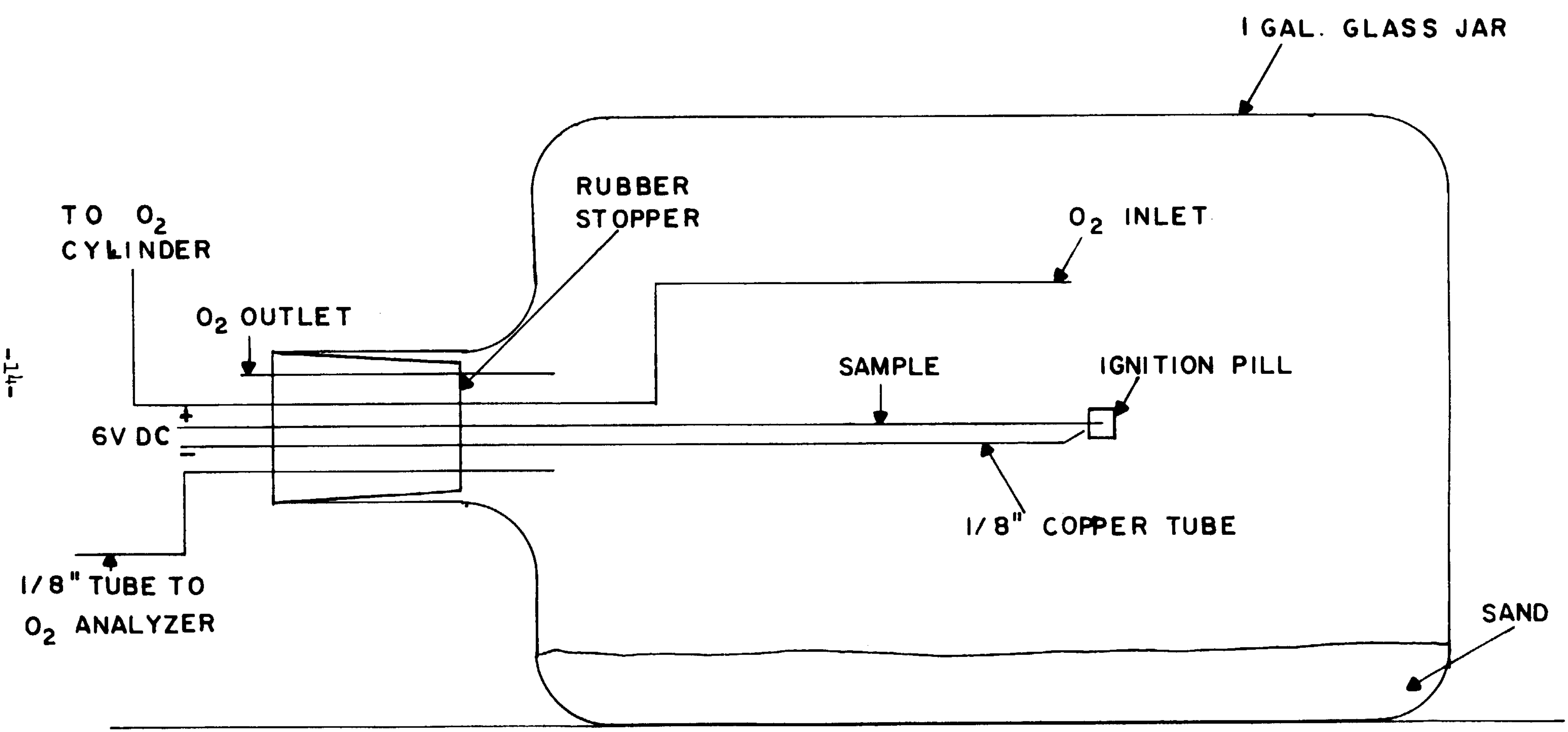


FIG. # 5

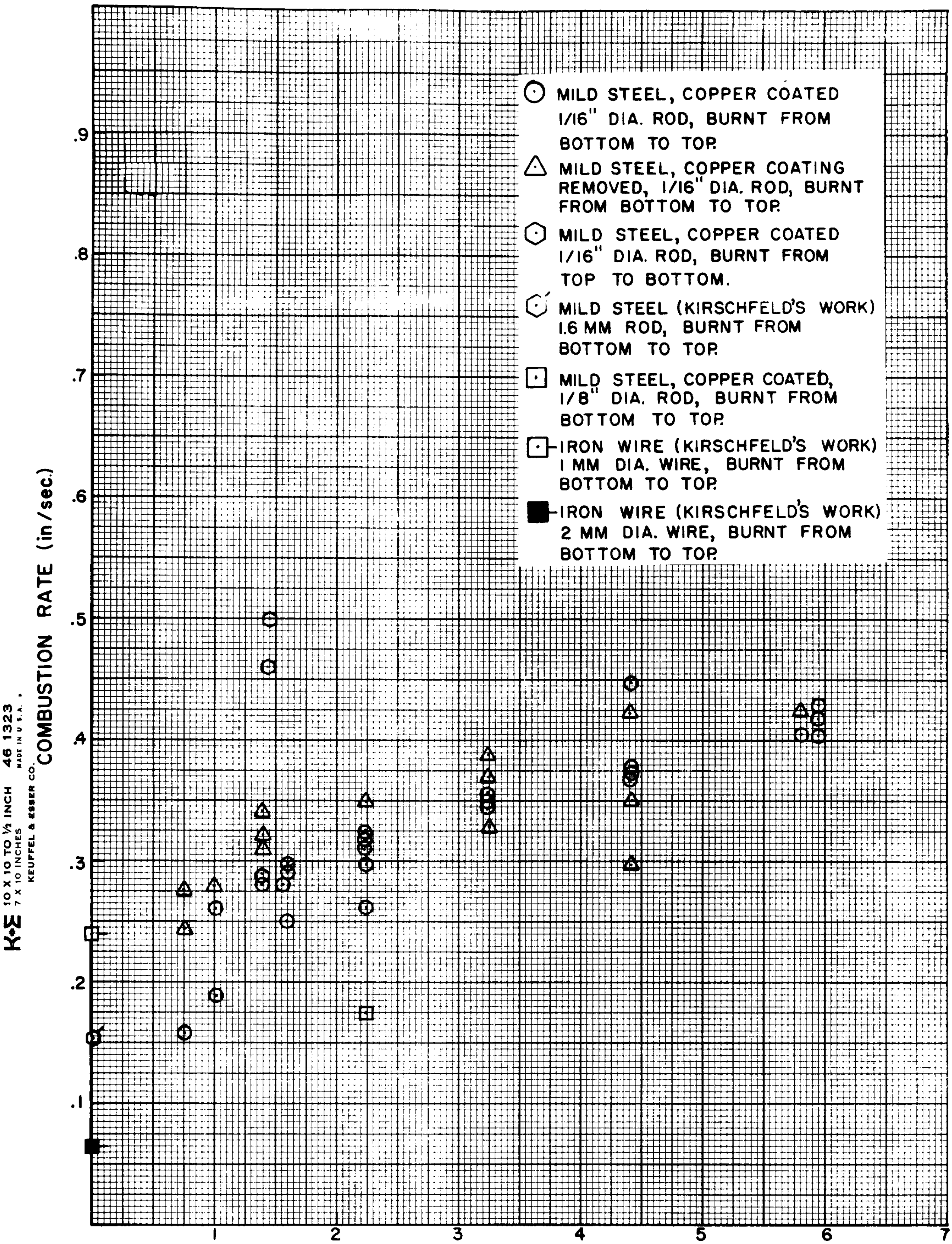


FIGURE 6 - O_2 VELOCITY (ft/sec.)

1. The system could be sealed off from the atmosphere thus enabling a higher oxygen concentration to be obtained.

2. A predetermined amount of material could be burned to cause ignition thus allowing a measurement of minimum heat input required to cause ignition. This was not done but future runs are planned to determine these values.

Three different ignition pills were used during the course of the experiments. The first one consisted of compressed steel wool in the shape of a wafer 1" in diameter by approximately 1/16" thick. The weight ranged from 2 to 5 grams. The wafer was made using approximately 5000 psi pressure. This size was abandoned for a smaller pill. The new pill was 1/2" in diameter and 3/16" thick weighing 2 - 4 grams. Three materials were used in making the second pill, steel, stainless steel and aluminum. Pills of each individual material and pills of 50-50 combinations of aluminum and steel, and aluminum and stainless steel were tested. The steel wool proved to be the best for igniting all metals except aluminum. A 50-50 pill of steel and aluminum wool worked best for igniting aluminum. In all cases the size of the pill appeared to be too large, that is, the amount of heat released was more than enough to cause ignition.

One problem related to the use of the pill was keeping the pill on the test sample after igniting it. The wafer pill was usually wrapped around the sample and secured with a piece of wire. With the smaller pill a hole was drilled in the pill and the metal sample forced through it. In some cases, after the pill was pushed on, a bend was put in the rod at the end to prevent the pill from falling off prematurely. The methods of attachment for both the large and small pill helped, but did not completely solve the problem. One possible method, which was not tried, is to support the pill with the test piece in it on a ceramic dish.

From the test results obtained it was felt that other methods of igniting the metals should be tried in future runs in an effort to try to pinpoint the ignition limits of metals in oxygen atmospheres.

DISCUSSION OF COMBUSTION PROCESSES

Metals and alloys when exposed to an oxidizing atmosphere undergo a chemical reaction with the oxidizer, forming an oxide film on the metal surface. When speaking of burning, and not just rusting or ambient oxidation, there are three possible ways in which this process can take place.

1. The combustion takes place only after the metal has melted and formed a molten oxidized drop which hangs on the end of the wire (experimentally observed). It has been noted that if at any time the liquid-phase disappears entirely from the rod the reaction will stop. This is a heterogeneous reaction, for which at least two phases are necessary: the liquid oxide phase and the oxygen vapor phase. Iron is one metal which exhibits this type of reaction.

2. Another way in which combustion can take place is for the metal to evaporate directly from the solid state, and react with the oxidizer. Magnesium because of its high heat of combustion exhibits this behavior.

3. The third possible way in which the combustion process can take place is by melting, evaporating from the liquid, and then reacting with the oxidizer. Aluminum behaves in this manner. It too has a high heat of combustion like magnesium, but it also has a lower vapor pressure than magnesium which makes it go through the liquid phase.

In general all metals tested to date, except aluminum, reacted with the oxygen from a molten droplet formed at the end of the test rod. The combustion would be initiated by the ignition pill thus starting the formation of the molten droplet. This droplet grew until it reached a critical size determined by the surface tension. Next it either dropped off as a molten oxide or explodes. In either case, fresh metal was exposed thus starting the process over again. Bartlett, Ong, Fassell and Papp (9) state, that the reason for this explosion or fragmentation in some metals is, once the boiling point of the metal is reached, metal evaporation will begin expanding the liquid oxide and provide a metal vapor film between the metal sphere and the oxide shell (Figure 7a). Excessively rapid expansion may lead to bursting of the liquid oxide bubble. In the case of aluminum the rate of reaction was so rapid that it was not possible to observe the combustion process.

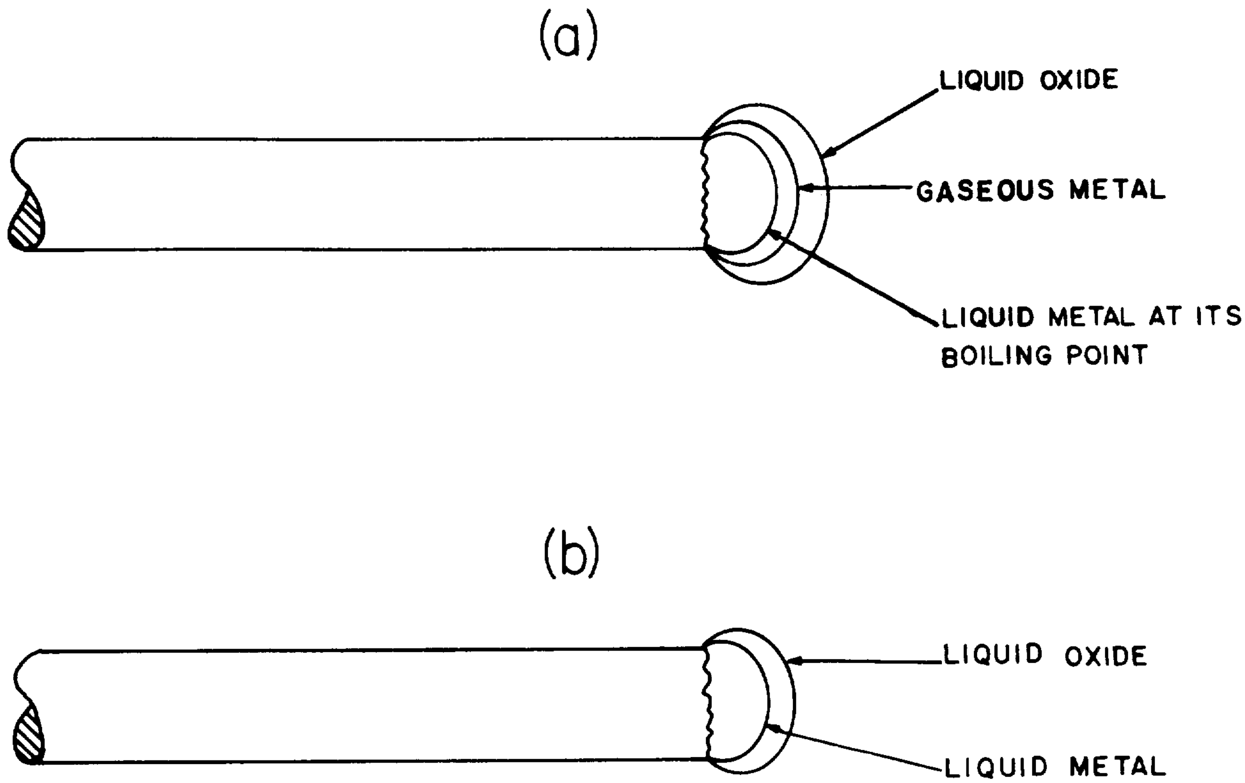
Glassman (10) summarized in four hypotheses the nature of metal combustion processes. These hypotheses are widely accepted by the investigators in this field. Our limited experimental work to date seems to confirm them or at least, has not contradicted them.

1. The boiling point of the metal oxide limits the flame temperature of the metal.

2. If the boiling point of the oxide is greater than the boiling point of the metal, steady state combustion will result in the vapor phase; and conversely, if the boiling point of the oxide is less than the boiling point of the metal, surface combustion will result.

3. Radiation plays a most important role in metal combustion.

4. The ignition phenomenon can be entirely different from the controlling steady state combustion phenomenon.



TYPICAL BURNING PATTERNS FOR METALS

FIG.# 7

REFERENCES

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2. APCI Laboratory Notebook No. 1603, pages 1 to 14.

3. Kirschfeld, L., "The Combustion Rate of Light Metal Wires in Oxygen", Metall 14, 1960, pp. 213-219.

4. Kirschfeld, L., "Combustion of Metals in Oxygen", Angewandte Chemie, Vol. 71, 1959, pp. 663-667.

5. White, E. L., and J. J. Ward, "Ignition of Metals in Oxygen", Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, DMIC Report 224, February 1, 1966.

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7. Nihart, G. J., and C. P. Smith, "Compatibility of Materials with 7500 PSI Oxygen", Union Carbide Corp., Tonawanda, New York, AD 608260 available CFSTI, 1964, pp. 94.

8. Bailey, B., "Technical Data Development For Cutting With Apachi Fuel Gas", APCI Technical Memorandum No. 120, October 17, 1968.

9. Bartlett, R. W., J. N. Ong, W. M. Fassell Jr., and C. A. Papp "Estimating Aluminum Particle Combustion Kinetics", Combustion and Flame, Vol. 7, No. 3, September 1963, Butterworth's London, p. 227-234.

10. Glassman, I., "Combustion of Metals. Physical Considerations", Progress in Astronautics and Rocketry, Vol. 1, Solid Propellant Rocket Research, 1960, Academic Press, New York, p. 253-258.

APPENDIX

1. "Spontaneous Ignition of Metals in Oxygen under Pressure", J. J. Jakowsky and E. W. Butzler, Bureau of Mines Report of Investigation, Serial No. 2521, September 1923.

This preliminary report deals with the effects of oxygen pressure on the ignition temperature and combustibility of iron, copper, brass and lead. A study was made of the relation between ignition temperature and pressure for iron, copper, and brass, which are the three materials usually employed, and for lead. The bomb was an old Parr calorimeter bomb which had been altered, as shown in Figure 2, to allow the wire (e) to be inserted, this wire comprising the material to be tested in the bomb. The wire was placed across the terminals of the bomb, and brought up to its ignition or melting temperature by passing a sufficient current through the wire. The greatest change in ignition temperature noted is in iron. At atmospheric pressure, iron in oxygen ignites at a temperature of approximately 930°C, while at a pressure of 2000 pounds per square inch the ignition temperature drops to approximately 600°C. Brass and copper behave very much alike, and differ considerably from iron, although at higher pressures brass in oxygen appears to ignite and burn more readily than copper. At atmospheric pressure, the brass and copper wires in oxygen severed at approximately their melting temperatures. Apparently, little or no oxidation takes place. Iron wire, however, behaved differently and burned at a temperature considerably below that of its melting point.

2. "Ignition in High Pressure Oxygen", M. Guter, The British Oxygen Co., Limited R&D Report, AD648612, June 1950.

Ignition temperatures in high pressure gas were determined by using a stainless steel bomb in which samples could be raised to the ignition temperature in a few minutes. The effect on ignition temperature of changes in total pressure, rate of heating, "aging", i.e. prolonged storage of material in oxygen under pressure, oxygen concentration, and the physical state of the sample were determined in the high pressure apparatus. A simpler apparatus called the "pot" ignition apparatus was developed for the rapid determination of ignition temperatures in oxygen at atmospheric pressure.

The many materials examined have been classified in the following five groups:

1. Lubricants, including thread sealing compounds.
2. Natural and Synthetic Rubber Hose Materials.
3. Polymers.
4. Valve Seat Materials.
5. Metals and Alloys.

Much detailed information is given on materials in groups 1 through 4, each group containing several materials.

None of the metals and alloys in Class V ignited in oxygen at 250 atmospheres when heated alone to 350°C. Copper, magnesium alloy and mild steel turnings ignited in the presence of a drop of oil if heated to about 200°C in oxygen at 250 atmospheres.

3. "The Iron-Oxygen Combustion Process - A Study Related To Oxygen Cutting", A. A. Wells, British Welding Journal, September 1955, pp. 392-400.

As often happens in research on an industrial process, it was found extremely difficult to make accurate measurements under the actual conditions of practical operation. It was therefore decided to make an experimental study with an apparatus specially designed for the purpose, in which a slowly rotating cylindrical bar of the material to be cut is moved end-ways into the oxygen jet; in this way the rate of cutting may be measured directly as the rate of feed of the bar into the jet. The report which follows describes results which have been obtained by this technique, and which appear to me to throw new light on a number of aspects of the problem, particularly concerning the effects of the composition of the metal to be cut and of the purity of the oxygen.

Measurements of the combustion rate between iron and oxygen are compared with calculations that determine the rate of diffusion of oxygen to the combustion face through a stagnant boundary layer of gaseous impurities. The thickness of this boundary layer is determined from a heat-flow analogue. With certain exceptions, it is concluded that the combustion rates for commercially pure reacting materials are mainly controlled by this diffusion mechanism.

4. "Combustion of Metals in Oxygen", A. V. Grosse and J. B. Conway, Ind. Eng. Chem. 50 (4), April 1958, pp. 663-672.

The basic aim of the work was to develop a technique for producing and utilizing high temperature sources. Combustion of aluminum yields a source of high intensity thermal radiation. Powdered metal-oxygen flames are highly effective in cutting through thick sections of concrete and ceramic materials.

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5. "Combustibility of Metals in Oxygen", Dr. L. Kirschfeld, Angewandte Chemie, Vol. 71, 1959, pp. 663-667.

The combustion speed of cylindrical Fe wires of different cross sections was measured at varying O_2 pressures. The combustion probably takes place between the gas phase and the melt occurring at the surface of the liquid slag droplets that are hanging on the wire and advance with the combustion. The Fe wire dissolves in the slag and migrates by diffusion to the surface of the slag droplet. Regardless of the cross section of the Fe wire, at constant O_2 pressure an equal Fe quantity is burned per unit of time. The reaction speed is inversely proportional to the cross section of the Fe wire and directly proportional to the square root of the O_2 pressure.

6. "Investigation of Ignition Temperatures of Solid Metals", W. C. Reynolds, National Aeronautics and Space Administration, Technical Note D-182, October 1959.

Summary

The ignition temperature of a solid metal is related through a thermal definition of ignition to the rate of oxidation and to the radiation and convection heat-transfer parameters. The mechanisms of oxidation are reviewed and the factors which influence ignition temperatures are discussed. Reasonable agreement between theoretical and experimental ignition temperatures is demonstrated. Experimental ignition temperatures for several metals are presented.

7. "Combustibility of Metals in Oxygen", Dr. L. Kirschfeld, phil. nat., From a lecture given at the Haus der Technik, Essen, Federal Institute for Testing Materials, Berlin-Dahlem, October 27, 1960.

Combustion of metallic materials as cause of destruction of high-pressure oxygen plants--Investigation of the laws and reaction mechanism in the combustion of metallic substances in oxygen from 1/8 to 100 atmospheres--Outlook.

8. "Combustion Rates of Ne- Heavy Metal Wires in Oxygen", Metall, Dr. L. Kirschfeld, August 1960, pp. 792-796.

The combustion velocity of cylindrical Cu, brass, and Zn wires in pure O was measured at variable pressures. Cu burns in the liquid phase on the surface of a drop of molten metal, but brass vapor comes directly from the solid alloy. With diminishing pressure combustion velocity of Cu and Zn decreases, but that of brass increases. All 3 metals burn by dissociation of O_2 into atmospheric O.

9. "The Combustion Rate of Light Metal Wires in Oxygen, Dr. L. Kirschfeld, Metall 14, 1960, pp. 213-219.

The combustion velocity of cylindrical Al wires, rolled Al ribbons, and flat Mg ribbons in pure O at variable pressures was measured. The Al probably burns over a drop of vaporized metal in the gaseous phase, and by superheating through high reaction temperatures phenomena similar to boiling often occur. The Mg probably burns in the gaseous phase after direct vaporization from the solid metal without formation of molten slag. Both metals probably burn by combination with atmospheric O after dissociation of O_2. The combustion velocity of Al decreases with falling O pressure, but that of Mg increases. The change in combustion velocity in both cases shows a linear dependence upon the square root of the O pressure.

10. "The Burning of Metals", P. L. Harrison and A. D. Yoffe, Proc. Roy. Soc. (London), Series A, Vol. 261, 1961, pp. 357-370.

A preliminary study has been made of the mechanism by which metals burn. Experiments have been carried out with wires of aluminum, iron, magnesium, molybdonum, titanium and zirconium in oxygen and oxygen + nitrogen mixtures. The rate of propagation of the combustion zone along the wire is dependent upon the oxygen pressure in the atmosphere, suggesting that combustion is largely controlled by gaseous diffusion through the atmosphere..

Some of the factors influencing the mode of burning and the reaction rates have been studied, and the temperatures attained under the given experimental conditions have been measured.

The mode of burning is determined by the relative melting and boiling points of the metal and its oxide. Metals with low boiling points such as aluminum and magnesium, burn in the vapor phase. Metals which have high boiling points, but which melt readily, burn at the surface of a molten oxide + metal mixture, provided the oxide also melts readily but has a high boiling point. Iron and titanium are examples of such metals. If, as with zirconium, the metal has a high boiling point and possesses a refractory oxide, a solid oxide film, which slows the reaction, can be formed on the metal surface. Metals such as molybdonum, which form oxides that readily sublime burn at the surface of the metal.

Color temperatures attained during the burning of iron, titanium and zirconium in oxygen were found to be higher the greater the pressure of oxygen. The temperatures were in the range 2600 to 3600°K and were highest for the metal with the greatest heat of oxidation when measured per gram of oxygen consumed.

The burning of a metal sphere to a molten oxide + metal mixture in a convection-free monomolecular gas has been treated theoretically. The variation of combustion temperature with oxygen pressure predicted by the theory agrees satisfactorily with that obtained experimentally.

11. "Ignition Characteristics of Metals and Alloys", L. E. Dean and W. R. Thompson, ARS Journal, July 1961, pp. 917-923.

The ignition characteristics of engine structural metals and alloys as influenced by the composition and pressure of the ambient atmosphere are of immediate interest to propulsion design engineers. Tubular test sections of the stainless steel, cobalt and nickel alloys, besides aluminum, copper and titanium were resistance heated in controlled atmospheres of oxygen, carbon dioxide and an equal mixture of these gases. Tube and gas temperatures obtained were correlated with color motion picture coverage of the manner in which the tube heated and failed. Stainless steels and cobalt alloys ignited within the melting point range of each material. Nickel alloys did not ignite until the melting point was reached. The rate of combustion increased with oxygen content. Stainless steels with a high nickel content appear most suited for applications at high temperatures in an oxidizing atmosphere.

12. "Ignition and Combustion of Aluminum Particles in Hot Ambient Gases", R. Friedman and A. Macek, Atlantic Res. Corp., WSS/CI Paper 61-21, September 1961.

Summary

Observations have been made of individual aluminum particles entrained in combustion gases under controlled conditions, at atmospheric pressure. Effects of ambient gas temperature and oxygen content and of aluminum particle size on ignition and subsequent combustion phenomena have been determined by flame photography and by microscopic examination of collected particles. Ignition occurs only when the ambient gases are above 2210-2360°K, this temperature being quite insensitive to free oxygen content and particle size. This result is consistent with an ignition theory which assumes a substantial change in the rate of the surface reaction at the melting temperature of alumina (2300°K). When ignition occurs, the delay time, which varies with the square of particle diameter, is in excellent agreement with simple heat-transfer calculations when the initial lag of the particle velocity relative to the gas is taken into account. Once ignition occurs, combustion phenomena are complex, involving unsymmetrical burning and fragmentation; a qualitative discussion is provided.

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13. "Combustion Rate of Light Metal Wires in Oxygen High Pressures", Dr. L. Kirschfeld, Metall, Vol. 15, 1961, pp. 873-878.

> The combustion velocity of cylindrical Al wires and Mg bands was measured in O from 1 to 100 atmosphere. In the case of Al a transition from one homogeneous gas reaction (probably Al_2O_3 formation) to another homogeneous gas reaction (probably AlO formation) occurs between 16 and 32 atmospheres. In the case of Mg transition from a gas reaction in which the transport phenomenon is velocity-determining to a reaction in which the chemical reaction velocity governs the total conversion occurs at 2-16 atmospheres.

14. "Investigations on Determination of Safe Operating Conditions for Steel Oxygen Piping", W. Wegener, Dipl.-Ing., Moderne Unfallverhutung, No. 6, 1962, From a lecture presented at the Haus der Technik Technology House in Essen, December 1961.

> Piping fires and their possible-causes--Current safety regulations and proposed modifications--Packing materials--Experimental investigations on permissible flowrate of oxygen.

15. "Influence of the Geometric Form on the Combustion Rate of Sheet Metal in Oxygen", Dr. L. Kirschfeld, Archiv f. d. Eisenhuttenw, Vol. 33, September 1962, pp. 617-621.

> Flat and bent specimens of 0.05% C steel strip and seamless tubing were used to study the effect of size and form of cross section on the rate of combustion of Fe in pure O at 1 kg./sq. cm. The rate of combustion increased proportionally to the increase in surface area, and was greatly influenced by the type of cross section.

16. Jackson, J. D., W. K. Boyd, and P. D. Miller "Reactivity of Metals with Liquid and Gaseous Oxygen", Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, DMIC Report 163, January 15, 1963.

> Of all the metals studied to date, titanium exhibits the greatest sensitivity to impact when immersed in LOX. In fact, its sensitivity approaches that of many organic materials such as greases and oils. Reactivity is observed in liquid oxygen and mixtures of liquid oxygen and liquid nitrogen at 20 ft-pounds until the LOX concentration is reduced to 30 per cent. Titanium can be partially protected from reactivity in LOX under impact by certain protective coatings, provided the coatings are not broken. Protection is given by electroless copper and nickel, possible aluminum, and to a lesser extent by Teflon and a fluoride-phosphate coating. Protection is also obtained by nitriding which adds a protective film to the surface, and by annealing which increases the thickness of the oxide film.

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Titanium exhibits no great reactivity in LOX when deformed by compression, by exposure of a fresh surface by machining or rupture, or by exposure of bulk titanium to high-pressure or high-velocity LOX.

In gaseous oxygen, titanium is highly reactive when a freshly formed surface is exposed at even moderate pressures. Under conditions of tensile rupture, a pressure of about 100 psig will initiate a violent burning reaction with titanium from about -250 F up to room temperature. Above room temperature, the pressure required to initiate the reaction is decreased somewhate. When 2 per cent HF is added as an inhibitor or 5 per cent argon as a diluent, the pressure must be increased about two fold at room temperature before reaction occurs. Titanium could not be made to react even at very high pressure when the oxygen content was 35 per cent or less.

When a titanium vessel containing LOX or gaseous oxygen is ruptured by a bullet, by a simulated micrometeoroid, or by other mechanical puncture, violent burning begins at almost 0 psig. If the vessel is not fractured by external impact, vibration, acoustic energy, thermal effects, or with slowly propagated cracks, such as fatigue cracks, no reactivity is noted.

When bulk titanium is heated in high-pressure oxygen, ignition and burning will occur at a temperature somewhat below its melting point. Similar reactions have been noted in CO_2. Ignition of titanium is also initiated under conditions of explosive or electrical shock.

The mechanism for the Ti-O_2 reaction is described as a reaction between a freshly formed titanium surface and gaseous oxygen.

Of other metals discussed, only zirconium shows similar reactions in oxygen. Stainless steels are found to exhibit almost no reactivity in oxygen under impact, rupture, explosive shock, or heating. Aluminum is similarly unreactive, but will ignite under conditions of high-explosive shock. Magnesium shows reactivity to explosive shock lying about midway between that of aluminum and titanium.

For high-pressure oxygen systems, stainless steel and Monel were found to be satisfactory.

17. "Combustion of Metals" George H. Markstein, AIAA Journal, Vol. 1, No. 3 March 1963 pgs. 550-562.

A comprehensive literature review of work on combustion of metals. Seventy-seven references are cited. The paper is primarily concerned with the aspects of metal combustion of special concern from the view of metal-fire prevention and from the use of finely divided metal fuel in propulsion.

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18. "Compatibility of Metals and Cryogenic Liquids", Jack L. Christian, James E. Chafey, Abraham Hurlich, James F. Watson and William E. Witzell, Metal Progress, Vol. 83, pp. 100-103 & 122, 124, April 1963.

We conducted tests to demonstrate whether a catastrophic titanium-oxygen reaction would result from accidental occurances when gaseous or liquid oxygen is contained in a thin walled titanium tank. The titanium sheet was fractured to expose a clean unoxidized surface while in contact with the liquid or gaseous oxygen. Comparison tests were made on type 301 stainless steel and 2024-T3 aluminum. The titanium-oxygen reactions appears to be initiated only by rapid fracture.

Neither stainless steel nor 2024 aluminum react when subjected to rapid fracture. Aluminum has been reacted with liquid oxygen in the standard falling-weight compressive impact test. However, the susceptibility to reaction is much less than for titanium.

19. "A Physical Criterion for Metal Ignition", A. M. Mellor and I. Glassman, (Princeton Univ., Princeton, New Jersey). Western States Sect. Combust. Inst., Paper WSS-CI 64-20, 1964, pp. 21.

The ignition of metals in oxidizing atmospheres was determined in terms of a transition temperature. The transition temperature is defined as the temperature at which the surface film on the metal becomes non-protective, and this predicts a minimum possible ignition temperature and the relative ease of ignition of a metal in an oxidizing atmosphere. Various means by which the surface film can become non-protective are discussed. Ignition tests off (1) Mg in atmospheres of O-Ar and O-CO_2; and (2) anodized Al in atmospheres of CO_2-Ar, H_2O vapor-Ar, H_2O vapor-CO_2, O-Ar, and O-CO_2 are described. The results of other exploratory investigations relating to the ignition of Al in atmospheres of air, O, O-CO_2; Mg in atmospheres of O; Ca in atmospheres of O; Mo in atmospheres of O; and U in atmospheres of O are correlated and explained by means of transition temperatures.

20. "Investigations on the Safe Flow Velocity to be Admitted for Oxygen in Steel Pipe Lines." W. Wegener, Report of the Bundesanstalt for Material-testing, (Report No. 6 of the Eng. Dept. and report No. 360 of the Eng. Committee of the Association of German Iron Workers), 1964.

Risks of fire caused by solid contamination in oxygen pipe lines and economic efficiency. Installation of trial sections. Measured values and fundamental data for calculating the velocity of flow. Experiments with straight and curved lines under severe conditions. Permanent trial section for oxygen of industrial purity. Conclusions to be drawn regarding fire risks with pipe lines and accessories.

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21. "Ignition and Combustion of Small-diameter Al Wires", D. K. Kuehl, Western States Sect. Combust. Inst., Paper WSS/CI 64-21, 1964, pp. 16

Application is described for the ignition and combustion of metals in gaseous oxidizers. Wires 2-4 in. long and 0.010-0.040 in. in diameter are heated electrically under gas pressures of 0.5-1000 psia. Temperature is determined by a calibrated photocell within $\pm$ 20°. Photographic and electronic equipment are utilized to record and analyze the combustion characteristics. Photographs of burning Al wires are shown and a theoretical discussion of the process is made.

22. "Compatibility of Materials with 7500-psi Oxygen", G. J. Nihart and C. P. Smith, (Union Carbide Corp., Tonawanda, New York). AD 608260. Available CFSTI, 1964, pp. 94.

A research program was conducted to develop ignition data on thread lubricants, thread sealants, fluorocarbon plastics, and metals. Spontaneous ignition temperatures were determined in both 2000-psi. and 7500-psi 0 for all the above materials except metals. The spontaneous ignition temperatures for these materials were found to be essentially the same in 7500-psi 0 and in 2000 psi 0. Only 3 of the tested lubricants are recommended for possible use in 7500-psi systems. None of the thread sealants are recommended. Glass-filled poly(tetrafluoroethylene) is usable only if tightly confined. The relative ease of ignition of metals and alloys was determined by promoted ignition methods in 0 at 7500 psi. Inconel alloy 600, brass, Monel alloy 400, and Ni had the highest resistance to ignition and combustion among the common alloys and metals. Of the materials tested, stainless steel and Al are the least satisfactory for use at 0 pressures at 7500-psi. A test system was constructed to evaluate the hazards in rapidly charging a 65 in^3 Ni-lined vessel with high pressure 0. A series of rapid charging tests up to as high as 8000-psi proceeded without incident. Electrostatic charges measured during the charging were negligible.

23. "Determination of the Burning Rate of Small Diameter Aluminum Wire", Charles William Friant, M.S. Thesis, Virginia Polytechnic Institute, Blacksburg, Virginia, June, 1964.

The following conclusions were drawn from the results of this investigation:

1. The burning rate of aluminum ant titanium can be determined using infrared sensitive photo conductive cells and electronic counting circuits.

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2. Under the conditions present during this investigation, 0.020" diameter aluminum wire will support sustained combustion over a range of oxygen mixtures from 90 per cent to 100 per cent.

3. Under the conditions of investigation, with mixtures below 90 per cent oxygen and above 70 per cent oxygen, ignition and combustion of 0.020" diameter aluminum wire will occur but the melting rate of the metal and subsequent formation of aluminum oxide exceeds the rate of vaporization to the extent that combustion is extinguished rapidly.

4. Under the conditions of investigation, for atmospheric mixtures below 70 per cent oxygen, the ignition and combustion of 0.020" diameter aluminum wire does not occur.

24. "Vapor-Phase Diffusion Flames in the Combustion of Magnesium and Aluminum", Progr. Astronaut. Aeron. 15, 1964.

Part I - Analytical Developments, T. A. Brzustowski and I. Glassman, pp. 75-117.

A quasi-steady vapor-phase diffusion flame theory is applied to the droplet combustion of Mg and Al. The two can burn in the vapor phase because their boiling points are lower than those of their oxides, whereas metal-O flame temperatures are otherwise limited to the boiling points of the respective oxides by the high heats of vaporization or of dissociation upon vaporization of the oxides (CA 58, 3263f). The theory is modified to consider flame radiation, mass transport of condensed oxides to the surroundings (but not to the droplet surface), and metal evaporation from the droplet. The theory also considers the diffusion of ambient oxidizer and of vaporized fuel to the flame zone, and heat transfer from the flame zone to the droplet surface and to the surroundings by conduction and radiation. The fraction of oxide vaporized in the reaction zone varies with ambient O concentration. The metal flames are non-adiabatic, owing to high flame emissivities resulting from the presence of condensed oxide in the reaction zone. Droplet surface temperatures can be hundreds of degrees below the metal boiling points, e.g. 300-800 or 100-200° lower for Al or Mg respectively, at 1-50 atmospheres. The flame zones lie very close to the droplets. Calculated evaporation consistencies of Mg and Al droplets are in the range of values observed with hydrocarbons, e.g., 0.002-0.040 cm^2/sec for 10-500 Mg droplets at 1-50 atmospheres and about half as much for Al, vs. 0.01-0.015 cm^2/sec for hydrocarbons under similar conditions. Burning rates and flame radii are readily calculated. The analysis ignores droplet-cloud interactions and unsteady effects, convective effects, particle trajectories, local O concentrations and thermodynamic conditions, and effects of chemical reactions other than oxide formation.

Part II - Experimental Observations in Oxygen Atmospheres, Ibid. pp. 117-158.

The region of validity of the analytical treatment was investigated experimentally. Al wires and Mg ribbons were burned under static conditions in dry O-Ar mixtures at 50 mm Hg ABS.-30 atmospheres. The amounts of O present were always in excess of stoichiometric requirements. The samples were ignited by resistance heating, at 17-40 or 37-72 amperes for Mg or Al, respectively. Mg ignited in the vapor phase above the ribbon; the initial flame speed was several cm/sec, e.g., $\sim$30 cm/sec in pure O at 1 atmosphere and 2 cm/sec in 20 mole % O at 75 mm-Hg ABS. Al ignited when the accumulated oxide coating melted and exposed liquid metal to the oxidizing atmosphere. Over the range of pressures and O concentrations studied, 9 regions were observed for Mg and 7 for Al, in which different combustion phenomena predominated. Maps of these regions are presented and discussed. Some of them are characteristic only of the experimental environment. The other regions are explained on the basis of photographic and spectroscopic observations and of the nature of the combustion products. The analytical model seems applicable to Mg ribbons over most of the range examined and to Al wires at low pressures. Wherever the model and the observed flame agreed, the predicted and observed flame variables also agreed. The scaling between particle size and pressure, as based on the analytical model, suggests that the vapor-phase burning mechanism may be significant for the ranges of pressure and particle size encountered in the combustion of metallized rocket propellants.

Part III - Experimental Observations in Carbon Dioxide Atmospheres, A. M. Mellor and I. Glassman, Ibid., pp. 159-176.

Al and Mg were burned in CO_2-O and CO_2-Ar mixtures, using the same procedures and analytical methods, over a narrower pressure range, e.g., 50 mm - 2 atmospheres. Anodized Al wires burning in CO_2-O exhibited the same combustion characteristics as those reported in O-Ar. The power required for ignition in CO_2-O decreased with increasing CO_2 concentrations and was a minimum in pure CO_2. When the same wires were burned in CO_2-Ar, cylindrical vapor-phase diffusion flames formed prior to the breaking of the electrically heated wire. The combustion characteristics of Mg were altered more appreciably by the presence of CO_2, e.g., the region of non-ignition was greater for CO_2-O than for O-Ar, and Mg would not burn in CO_2-Ar. These results are attributed to the ignition characteristics of Mg. The absence of any CO or CO_2 bands in the Al and Mg spectra indicate that the reaction mechanism in the flame is heterogeneous, as in metal-CO_2 surface reactions at lower temperatures.

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25. "Inflammability of Explosive Mixtures by Mechanically Produced Sparks", W. Fischer, Chem. Tech., 17(5), 1965, pp. 298-299.

A specially constructed application is described, consisting of a friction application with a counterbalanced anvil. The metal sample investigated is fastened on a wheel cast from construction-grade steel. The wheel is rotated by means of an electrical motor. This application is placed inside an explosion chamber with an 80 l. volume. The following gas mixtures were tested: CS_2 and air, C_2H_2 and H. Various samples of steel, bronze, Al, alloys, and metals covered with rust were investigated.

26. "Apparatus for Combustion Tests on Metals Under Oxygen Pressures Up to 200 atm, and the Combustibility of Iron Wire in High Pressure Oxygen", Dr. L. Kirschfeld, Archiv f. d. Eisenhuttenw, Vol. 36, November 1965, pp. 823-826.

The combustibility and rate of combustion of iron wire of 1 mm and 2 mm diameter in high-pressure O up to 200 atmospheres was studied by using a cylindrical steel pressure vessel with a volume of 3.8 l. The rate of combustion increases linearly with the square root of the O pressure. With iron wire of 1 mm diameter, evaporation of iron occurred at an O pressure 30 atm.

27. "The Effect of Water Vapor Upon the Burning Rate of Aluminum and Magnesium Wires", W. L. Proctor and C. H. Long, Western States Sect. Combust. Inst., Paper WSS-CI Vol. 66, 1966, pp. 35.

Tests of rate of burning of Al and Mg wires indicated that the rate increased slightly when small amounts of H_2O were present in atmospheres of O and N. Tests were made in a reaction chamber constructed of a 9 in diameter steel pipe 15 in long. O, N, and steam were supplied through the bottom. Lucite and glass slot windows were located in the side of the chamber. The test wires were supported vertically in the chamber. A W ignition coil with 3-5 turns was wrapped around the bottom of the test wire sample. Inside the W coil was placed a slightly smaller 0.020 in Al wire coil to keep the test sample from touching the W ignition coil. The progression of the flame was measured by 2 high-resistance CdS photoconductive cells placed 4.1 cm apart. Also a record of the burning was made on 16 mm film at 32 frames per second. The rate of burning of a 0.020 in diameter Al wire in a dry atmosphere of 92-98% O, balance N, increased almost linearly with increased O at speeds of 6.0-8.5 cm/sec. With 100% O_2, the rate was 11.5 cm/sec. In an atmosphere containing 2% H_2O and 92-98% O, the rates were 6.5-11.5 cm/sec. In an atmosphere containing

96% O and H_2O 0-3%, the rate was 7.4-10.3 cm/sec. Below 92% O, ignition of Al was difficult. Al wire 0.40 in diameter in dry atmosphere of 96-100% O burned at rates of 2.4-4.7 cm/sec. The rate of burning of a 0.030 in diameter Mg wire in a dry atmosphere of 50-100% O, the burning rates were 1.5-6.1 cm/sec. In an atmosphere containing 80% O and H_2O 0-3%, the rate was 2.2-3.4 cm/sec. At 50% O with 2% H_2O, there were no failures in ignition of Mg wire, whereas, in a dry atmosphere 60% of the runs resulted in ignition failure. With slight amounts of H_2O present, test runs of Mg wire were conducted as low as 28% O. The presence of H_2O seemed to stabilize combustion.

28. White, E. L., and J. J. Ward, "Ignition of Metals in Oxygen", Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio, DMIC Report 224, February 1, 1966.

Summary and Conclusions

The ignition of metals in oxygen and oxygen atmospheres was reviewed from the viewpoints of (a) methods that have been used to study behavior, (b) experimental values that have been obtained, and (c) the status of theories that permit the calculation of ignition temperatures.

While no clearcut definition of ignition temperature has been developed, it appears probable that a definite or an absolute ignition temperature does exist for a particular metal-oxygen system. In general terms, if the energy input as converted to heat is greater than the heat dissipation, a temperature will be reached at which ignition of the metal will occur. Practically, this temperature appears dependent on many factors some of which are relatively static (e.g., atmosphere, composition, purity, metal surface area and condition, etc.) and others that may be dynamic (e.g., pressure, impact, impact velocity, vibration, etc.). No standard test procedures or methods have been developed to evaluate the ignition temperatures of metals. The net result is that varying values have been reported for the same or similar metal-oxygen systems.

Despite these differences, the following generalizations can be offered on the basis of the experimental evaluations performed to date:

(1) All metals, with the possible exception of gold and platinum, can be expected to ignite in oxygen at some elevated temperature.

(2) Alloys of several systems have been shown to ignite in oxygen systems at relatively low temperatures and some at LOX temperatures if some external source of energy input is present. Generally, the presence of a fresh metal surface is also necessary to cause

ignition at these low temperatures. These ignition-sensitive alloy systems include the alloys of titanium, zirconium, thorium, uranium, lead, tin, and magnesium.

(3) A number of secondary energy input sources have been shown to cause ignition of these sensitive alloys in oxygen systems. These sources also probably produce a fresh metal surface and are identified as follows:

In Gaseous Oxygen

Electric spark
Puncture
Stress rupture
Explosive shock

In Liquid Oxygen

Mechanical impact
Explosive shock.
Puncture

(4) A number of other methods of secondary energy input and methods of exposing fresh metal do not produce ignition. These are as follows:

In Gaseous Oxygen

High-velocity flow

Low-cycle fatigue cracking

Impact on the outside of a container without puncture

High-velocity flow through a small orifice

Rapid pressurization

In Liquid Oxygen

Impact on the outside of a container without puncture

Rapid pressurization

Machining

Friction and galling

Tensile rupture

Mechanical vibration

Sonic vibration

Ultrasonic vibration

High-velocity flow through an orifice.

(5) An increase in pressure of a gaseous oxygen system tends to promote ignition at lower temperatures or with lower secondary energy inputs. The dilution of oxygen with an inert material, gaseous or liquid, tends to reduce sensitivity of metals in oxygen systems. However, propagation is not affected much until the dilution is very great, on the order of 90 percent inert gas or liquid.

(6) A number of alloy systems have been shown to be relatively insensitive to ignition in an oxygen environment either at high temperatures or at low temperatures with high secondary energy inputs. These alloy systems include: austenitic stainless steels, nickel alloys, cobalt alloys, copper alloys, and silver alloys. Alloys of these systems show the best service record and also show the least sensitivity in laboratory tests.

(7) Another group of alloys appears to be somewhat intermediate between the sensitive and insensitive groups cited in Items 2 and 6. This group includes aluminum alloys, the 400 series stainless steels, and carbon and low-alloy high-strength steels. These materials would be expected to find limited use in relatively nonsensitive applications.

A review of the theoretical analysis of the spontaneous ignition of metals in oxygen has shown the following:

(1) A theoretical model for the spontaneous ignition of massive metal in gaseous oxygen at high temperatures (above 1500 F) has been developed, based on low-temperature oxidation-reaction data and thermophysical property data.

(2) Several theoretical models for the calculation of ignition temperature of metal particles in gaseous oxidation have been developed that agree qualitatively. These models explain why particle radius is an important variable in powder combustion. Much of this work has been directed to the application of metal powder as a fuel.

(3) Practically no quantitative method is available for the calculation of ignition temperatures of massive metal in cryogenic oxidizers, such as liquid oxygen. Several good qualitative descriptions of the possible mechanism for massive metal-liquid oxygen reactions have been made. For this reason, the possible role

of shock loading and energy input sufficient to give local ignition temperatures has been considered and reviewed in this report.

In the development and discussion of theoretical calculational models, a number of thermochemical and thermophysical constants are required. Therefore, a literature search was made, and a compilation of data for these constants was given. The data included standard free energy of oxide formation as an extent of metal-oxygen reaction. Also, heat-capacity values, vapor-pressure data, and thermophysical properties of melting and boiling points were included. Thermal-conductivity values of metals and oxides were included when they could be found. Heats of metal-oxide formation were tabulated. These values, with heat-capacity data, were used in calculating temperature rise on reaction.

For those who may be interested in pursuing the theoretical-calculation ignition temperatures, this report also summarizes the following thermochemical and thermophysical data for most metals and their oxides:

(a) Standard free energy of formation
(b) Heat capacity
(c) Vapor pressure
(d) Melting and boiling points
(e) Thermal conductivity.

29. "Techniques for the Study of the Combustion of Metals", A. S. Gordon, C. M. Drew, J. L. Prentice, and R. H. Knipe, U. S. Naval Ordnance Test Station China Lake, California, American Institute of Aeronautics and Astronautics, New York, New York pp. 1-6, January 23-26, 1967.

Only small metal particles with high heats of combustion are of interest in propellants. The self-sustained combustion of metal occurs at nigh temperatures, making details of the process difficult to measure. High response instrumentation such as streak and high speed photography, and spectroscopic methods are employed to obtain information on the kinematics of combustion. Further combustion details are obtained by quenching the burning configuration which can be studied using optical and electron microscopy, including scanning electron microscopy. The experimental results point out shortcomings in the combustion model in current use. The mechanism of the ignition is of great importance, both in engineering practice and in research studies, since the products of preignition reaction can remain on the surface and affect the subsequent self-sustained burning. Ignition has been investigated using hot gases, electrically heated wires, and flash radiation. The physical properties of the metal and its products determine the mecahnism of the reaction. The greatest area of ignorance in metal combustion is the identification of reaction products and their properties as a function of temperature and composition of the environment.

30. "Combustibility of Metals in Oxygen up to 200 atm. Pressure", Dr. L. Kirschfeld, Metall, February 1967, pp. 98-102.

The results of older combustion experiments with Al wire are confirmed in new test apparatus up to 100 atm. of O. At 125 atm., the combustion velocity exceeds a maximum and then falls to that at 200 atm. In this range, transport velocity is probably limiting for the combustion velocity. Cu, brass, and Sn-bronzes burn up to 200 atm. of O partial pressure if they are ignited by hot primers. The reaction ceases in all cases if the slag lump sticks to the point of combustion. At high pressures, Zn wires burn with constant velocity over their entire length. At 1-atm. O pressure, the melting process requires a higher combustion velocity. Pure Co wires burn freely at higher O partial pressures, but slower than Fe. Ignition difficulties occur at lower partial pressures. Pure Ni wires could not be ignited at 0-200 atm. By intertwining with wires of other metals or alloying with these, Ni wire can also be burned in pure O.

31. "The Combustion of Metals", Final Report, July 1, 1964 to June 30, 1966. James G. Hansel, Arthur M. Mellor, and Harry F. Sullivan, Princeton University, Princeton, New Jersey, May 1967.

This research is concerned with the details of the interactions between metals and oxidizers which occur at elevated temperatures. A fundamental distinction between oxidation and self-sustained combustion permits detailed classification of the observed phenomena and lends insight into the appropriate ignition reactions as well. Earlier studies at Princeton revealed that certain fundamental criteria generally divided metals into two categories: those that burned by condensed phase reactions and those that reacted largely in the vapor phase. The research described herein involves metals of both categories. The condensed phase conbustion of molybdenum and tantalum was studied experimentally and the results compared with thermodynamic predictions as well as with the results of other investigators. Experiments with calcium have indicated that the generally accepted model of the structure of vapor phase metal diffusion flames may not be correct. This experimental finding allows other combustion models to be formulated which include heterogeneous reactions on condensed oxide particles and chemiluminescent radiation.

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32. "Combustibility of Steel and Cast Iron in Oxygen at Pressures of Up to 150 atms.", Dr. L. Kirschfeld, Archiv f.d. Eisenhuttenw, Vol. 39, 1968, #7, pp. 535-539.

The combustibility of structural materials which are used for pipelines, compressors, and other equipment in contact with O was studied. These included wire of plain C steel (C 0.05-0.96%), low-alloy steel (C0.11-0.15, Si 0.11-1.02, Mn 0.27-0.91, Cr 2.29-3.06, Mo 0.44-0.92%), and Cr-Ni steel (Cr 20-28, Ni 8-21%). Combustion tests were in a high pressure vessel of 3.81 vol. at O pressure of 1-150 atm. Cast iron rods (C 3.5%) were tested at an O pressure of 1-26 atm. Measurements of rates of combustion were compared with those of soft low C steel wire (C 0.04-0.07%). Plain steel with higher C content and low alloy steel burn at the same rate as low C steel. Cr-Ni steels burn more rapidly than low C steel but combustion of low C steel is slower at higher pressures due to evaporation of alloying elements. Combustion of cast iron is very slow and ceases at low O pressures, dense oxide fumes being formed due to the high C content of cast iron.

33. "Studies on Combustibility and Ignitability of Metal Tubing in Stationary and Flowing Oxygen", Simon, Verein Deutscher Eisenhütten-leute Bericht No. 140, 1968, pp. 116.

Introduction

Failures of fittings and pipelines have occurred during large-scale use of pure oxygen. Evaluation of available data on combustibility of metallic materials does not allow recommendations to be made relating to selection of suitable materials for service in oxygen systems.

In order to establish further data on combustibility of metallic materials, tests were made on tubing in 14 different metals to establish characteristics of ignitability and combustibility of the different materials.

Summary of Results

The object of the present research was the establishment of justifiable recommendations relating to which metallic materials are to be used preferentially for safety reasons in oxygen fittings, and which materials are to be avoided. In order to meet this purpose, tests were planned on tubing in 14 different materials and these were performed and evaluated. A final assessment of the materials in the light of their thermal,

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chemical and mechanical properties led to derivation of the required data. Evaluation was based particularly on the comparative properties of the materials under test, which characterized the method of investigation and the shape of specimens used; absolute assessment, based on the experimental results, did in general, not prove feasible.

The following viewpoints were considered in evaluation (Table 1):

1. What is the period t_{M1m} in which the critical tube surface temperature $_{M1K}$ (for the aluminum alloys t_{Mm} and $_{DK}$) is attained (Columns 3 and 4)?

2. What volume losses V_b are suffered by the materials on burn-through (Columns 5 and 6)?

3. What is the quantity of heat Q_{Kri} absorbed by the tube wall until the end of the period t_{M1m} (in the case of aluminum alloy t_{Mm} (Column 7)?

4. What is the dependence of the burn-through reaction on oxygen pressures P_{O_2} and tube wall thickness "s" (Columns 8, 9 and 10)?

5. What is the general combustion response (Column 11)?

The answers to these five problems do not give, for the various materials, a clear-cut positive or negative result; it is e.g., possible that a favorable thermal behavior is accompanied by unfavorable mechanical properties. The viewpoints of the separate evaluations must be assessed, as far as significance is concerned, and be summarized in an overall assessment of the material. This overall assessment applies for the given experimental conditions, during which the material preheated to the ignition temperature was exposed initially to stationary and subsequently flowing oxygen.

Table 1, Column 2, gives the order of merit in which the 14 materials, commencing with copper, are suitable for oxygen plant. Copper is the most suitable material because, in contrast to the remaining 13, no burn-through could be induced under the standard conditions of test. A high wall thickness has a severely inhibiting effect on ignition, since tubing with s = 5.0 mm could not be burned through, even at 40 atm. In addition, copper still retains good mechanical properties on heating.

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Among the group of materials which continue to burn only with external supply of heat (Nos. 1-12, Column 11), copper is followed by ferritic chromium steel (No. 2) and austenitic chromium-nickel steel (No. 3) which give the best results. It is true that these two materials have higher volume losses (bulk losses) V_m and V_b (Columns 5 and 6) than copper alloys (Nos. 4-8), but the critical temperatures M_{1K} (Column 4) are higher and the reaction period t_{M1m} is longer than for the copper alloys. Furthermore, for tubing having a wall thickness s = 5.0 mm (Column 10), burn-through is to be expected for Steels Nos. 2 and 3 only at a pressure of 40 atm., while the copper alloys lead to the expectation of a reaction at 16 atm., as shown for the material Rg 10. A higher wall thickness of tubing in the two steels has an appreciably greater effect in inhibiting ignition than found for the copper alloys. The above steels also lead to the expectation of better behavior at 10 atm than found for copper alloys (Column 8). Material 3 suffered only occasional burn-through at 10 atm, whereas, tubing in the copper alloy No. 7 always burned through at 10 atm, and a similar behavior is to be expected for Materials 4, 5, 6 and 8.

Within the group "copper alloys" brasses have more favorable V_m, V_b and T_{M1m} values (Columns 3, 5 and 6) than bronzes and gun metals, and are therefore, to be preferred. The differences between Materials 4-8 are, however, not significant.

Flake graphite iron (No. 9) is superior to spheroidal graphite iron (No. 10); the total volume loss V_m, the relative volume loss V_b, the temperature $_{MlK}$ and the absorbed heat Q_{Kri} are more favorable in Material No. 9 than in Material No. 10. In tubing of GGG 38 having a wall thickness of s = 5.0 mm, burn-through was always found at 16 atm, while similar tubing in GG 26 reacted only above 40 atm.

Among the group of materials which do not sustain combustion, the most unfavorable response was found in aluminum alloys: it proved possible to establish only the reaction period t_M and not values of t_{Ml}, but even with these values (t_M t_{Ml}), materials Nos. 12 and 13 have the shortest reaction period. Furthermore, the reaction temperatures $_{DK}$ are the lowest of all temperatures recorded. The total volume loss V_m is not particularly high, but the relative volume loss V_m, which is a better comparative parameter, is higher than that of all other materials, with the exception of Steels Nos. 13 and 14. Aluminum alloy tubing having a wall thickness s = 5.0 mm, will reliably burn through at 16 atm (Column 10). Increased wall thickness, therefore, does not reduce the danger of a burn-through reaction. A further disadvantage is that the volume loss V_m increases significantly with increasing oxygen pressure (Column 9).

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The least suitable from a safety point of view are unalloyed (No. 14) and low-alloyed steels (No. 13), since flowing oxygen initiates--once these two steels have been heated to the ignition temperature--a self-supporting combustion reaction. The volume loss (Column 5) is greater in the alloy steel 30 Cr Mo V 9 than found for the constructional steel St 35, because the St 35 tubing was expelled more frequently from the test stand during combustion and consequently had not been exposed for a similarly long period in the oxygen stream as had the alloy steel tubing; the alloy steel, however, reacted less frequently under conditions of secondary combustion than did the carbon steel, because the presence of chromium and molybdenum acted as combustion inhibitors. The unfavorable behavior of Materials Nos. 13 and 14 is further not reduced by the fact that St 35 tubing cannot be made to burn through at 10 atm (Column 9) and that reaction at a wall thickness s = 5.0 mm occurs only at 40 atm (Column 10). Furthermore, the extended heating-up period T_{Mlm} of the two materials (Column 3) and the high temperatures of reaction $_{Ml}K$ (Column 4) cannot hide the fact that these two steels exhibit the most vigorous reaction once combustion has initiated.

34. "The Inflammability and Combustibility of Metal Tubes in Quiet and Circulating Oxygen", Wolfgang Simon, Stahl und Eisen 88, No. 20, October 3, 1968.

This article is a condensed version of the item in this bibliography identified as "Studies on Combustibility and Ignitability of Metal Tubing in Stationary and Flowing Oxygen", Simon, Verein Deutscher Eisenhüttenleute Bericht No. 140, 1968, pp. 116.

35. "Experimental Determination of the Ignition Temperatures of Metallic Materials in the Presence of Gaseous Oxygen", L. Ya. Nesgovorov, Yu. A. Prozorov, and V. G. Kholin, Latv. PSR Zinat. Akad. Vestis Fiz. Teh. Zinat. Ser., Vol. 1, 1968, pp. 70-74.

An automatic recording device and the procedure for determining the minimum ignition temperature T_{ign} of structural steels under conditions approaching practical usage is described. In an atmosphere of 0 at pressures of 10^6 to 12 x 10^6 newtons/m^2, the specimens shaped as for tensile strength tests were heated for different lengths of time at temperatures up to the m.p. $T_{m.p.}$ and load up to the breaking load was applied. Ignition was observed visually or by moving pictures. The coefficient of workability (n - $T_{ign}/T_{m.p.}$) of steels EI696, EYaIT, and EI445P decreased linearly as the pressure increased. Ignition was associated with tensile rupture.

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36. "Materials Compatibility for Gaseous Oxygen Systems", Materials Testing Branch Analytical Laboratories Division SO-LAB-4, Room 1213, MSOB Kennedy Space Center, Florida, November 5, 1969.

For this reason, the Materials Testing Branch (MTB) conducted a literature search to ascertain the compatibility of materials for use in gaseous oxygen and oxygen enriched environments. This document, based on that literature search, includes information obtained by telecon with several companies and other government agencies in addition to those sources listed in the bibliography. However, a great amount of information has been generated by the companies which is generally treated as company confidential and was not made available for this report.

37. "Tribochemical Effects in Technology Ignition of Metal Combustion by Tribochemical Reaction", G. Heinicke and H. Hazenz, Technik, May 1969, pp. 313-319.

Extended protection against a tribochemically caused fire in oxygen plants can only be obtained through proper constructive measures, by choice of specific materials and an intense purification of the propelling gases to prevent the accumulation of fine particles or the forming of covering layers, especially on the inner walls of the compressors and other greatly stressed baffles. Oxygen plants are often washed with nitrogen before start-up to prevent fires. As the tests in article 3 show, with iron alloys at inert gas atmosphere, the chemical activity often increases, which on their part increase the combustibility of a number of metals by switching to oxygen. For this reason the flushing of oxygen plants should be conducted with air or with an oxygen-nitorgen-mixture, which still contains 10% oxygen. It was noted that with pre-grinding of manganese in air the combustibility of the obtained powder was reduced greatly in contrast to manganese which was not pre-ground. An important factor to consider is the prevention of corrosion in the interior of oxygen plants, because corrosion is practically always combined with the appearance of small particles. However, no aluminum lacquer may be used as corrosion prevention, because a high combustibility exists owing to the tribochemically released thermite reaction. Last but not least, the selection of materials also determines the combustibility in oxygen plants.

Practical experiences have shown that in consideration of these factors the combustibility is greatly reduced and it is possible to control the from a chemical point of view strong metastable systems. For complete quantitative comprehension of the causes leading to fires, an intensive research still has to be conducted in the future in the interest of increasing the safety of oxygen plants.

38. "Heterogeneous Reaction Processes in Metal Combustion", G. H. Markstein, Cornell Aeronautical Laboratory Inc., Buffalo, N. Y., 1969.

Metals burn predominantly, and in some cases exclusively, by heterogeneous reactions, since both the fuel and the products are usually in the condenser state. In metal combustion, transport processes exert at least a partially controlling influence, and the usual techniques of metal-combustion research are therefore not well suited for obtaining information on reaction kinetics. Current knowledge of rates and mechanisms of these reactions is therefore extremely limited. However, assuming a collision efficiency of 0.1, one can show that surface reaction rates becomes rate-controlling for characteristic dimensions less than roughly 40 mean free paths. A knowledge of reaction kinetics is therefore of interest if one is concerned with processes at the surface of small particles..

This paper deals primarily with the case of vapor-phase burning, in view of its importance in practical applications. In this case, heterogeneous reaction of metal vapor and oxygen (and possibly of volatile oxide species) may take place at the surface of growing oxide smoke particles, in competition with homogeneous gas-phase reaction followed by condensation. The relative importance of the heterogeneous and homogeneous reaction paths is currently the subject of some speculation and controversy. In this connection, a knowledge of the collision efficiency of the heterogeneous reaction would be of considerable interest. For the $Mg-O_2$ reaction, the author previously derived an average collision efficiency of 0.075, but this value cannot be regarded as very reliable. Results obtained by a recently developed method indicate larger values, probably exceeding 0.3.

The mechanism of the reaction of metal vapor and oxygen at the oxide is unknown. However, from analogy with chemisorption and catalysis oxide surfaces, it is suggested that electron transfer plays an important role, and, under some conditions, may become rate-controlling. Observations of luminescence and of anomalous electron emission during reaciton of Mg vapor and oxygen at the oxide surface have provided evidence for electronic excitation in the oxide layer.

39. "Burning Tests on Centrifugal Pumps for Liquid Oxygen" H. Bauer, W. Wegener, K. F. Windgassen, Kältetechnik-Klimatisierung, No. 4, 1970.

In order to clarify under which conditions fires or explosions in centrifugal pumps for liquid oxygen may occur, tests with pumps of aluminum, bronze and stainless steel alloys have been conducted. The test results have shown means against accidents.

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40. "Review of Factors Affecting Ignition of Metals in High Pressure Oxygen Systems", J. H. Kimzey, NASA-TMX-67201, October 28, 1970.

As a results of the Apollo 13 supercritical oxygen tank incident, a literature survey was conducted to determine the availability of data concerning ignition of metals in liquid or high pressure oxygen environments. This paper provides brief summaries of the reported data with emphasis being given to the effects of oxygen concentration; total pressure; convection, including zero gravity; oxygen percentage; and halogenated compounds on ignition.

Materials in contact with supercritical oxygen in the Apollo oxygen system include both metals and non-metals. Criteria for selection included the results of various tests, based primarily on mechanical impact. One such type is the drop test whereby 72 ft-lbs of energy are imparted against a striker in contact with the specimen submerged in liquid oxygen (LOX) at atmospheric pressure. Another test simulates meteorites puncturing a LOX tank. In some instances, successful usage for thousands of hours also reinforced the confidence in using specific materials.

41. "Fire tests on Centrifugal Pumps for Liquid Oxygen", H. Bauer, W. Wegener, and K. F. Windgassen, Cryogenics, June 1970, pages 241-248.

All the pump casing and impeller materials investigated here are combustible in oxygen. The quantity of heat liberated in combustion rises in the sequence: bronze, chrome-nickel steel, aluminum alloys (see Table 2), while the ignition temperatures become correspondingly lower. The fire hazard consequently increases in this order too.

The metallic abrasion particles resulting from catching inside the pump ignite more readily than the solid material (compare this with the section on ignition temperatures). Hence ignition starts preferentially on the abrasion particles. Consequently ignition may occur due to frictional heat when the temperature in the casing or impeller is still below the ignition temperature of the solid metal. This is one explanation for the brief temperature rises frequently observed in the tests, which occured when the gas phase or at least cavitation was present in the pump. It can therefore be assumed with certainty that the fires occurring in the aluminum and chrome-nickel steel pumps in the gas phase were triggered by burning abrasion particles. As the friction was steadily aggravated, these particles finally appeared in such high concentrations that ignition of the impeller and casing resulted. The non-appearance of fire in the bronze pump was due to the good thermal conductivity of this material, and the relatively low temperature of the burning abrasion particles resulting from the low combustion heat.

Bronze emerged favorably from the safety aspect, for despite high mechanical stressing leading to destruction of the impeller and fraction of the shaft, no fire occurred.

Chrome-nickel steel and aluminum alloys proved to be less suitable from the safety criterion, for fires were induced with both materials. Bronze casings and impellers provide the greatest security against fire and explosion damage.

42. "Recent Experimental Results on the Combustion of Aluminum and Other Metals", Marcel Barrere, Nations Aeronautics and Space Administration, Washington, D. C., July 1970.

The study of the combustion of metals has recently become important since they are used as a fuel in modern rocket propulsion systems. The ignition delay, burning time of metal particles, combustion efficiency, and the nature of the combustion products are considered in this paper. The first part is devoted to the experimental techniques used for the study of metal combustion. Metal particle combustion and the combustion of metal wires are considered. For the first group some static methods were developed, the metal particle being attached to a holder but the more widely used technique makes use of the metal particles in a flow. In the second group, ignition is simple and combustion is easy to study. The analysis of combustion phenomena is done by cinemicrography, freezing the combustion on cold plates, spectrography, etc. A critical study of these various techniques is presented. The second part is a synthesis of the experimental results showing for each metal and in particular for aluminum, beryilium, magnesium, and boron, the influence of various parameters, e.g., gas atmosphere, pressure and temperature, influence of surface conditions on the metal at ignition, etc. The nature of the deposits is also discussed. From these results some combustion models are proposed and are dealt with in the third part. The fourth part relates to a study of combustion in a heterogeneous environment, particularly when the metal is included in a propellant or in a solid fuel. The results are based on the study of the combustion of a metal in solid or hybrid propellant systems.

43. "Burning Tests on Centrifugal Pumps for Liquid Oxygen (II) H. Bauer, G.Klein, W. Wegener, K. F. Windgassen, Herrn, Kältetechnik-Klimatisierung, No. 4, 1971

Further to previous experiments new tests were carried out in order to clarify the risks of fire and explosion with liquid oxygen centrifugal pumps. These tests showed a range, in which low pressure pumps of aluminum alloys or stainless steel operate safely. However, the number of tests is not sufficient to delineate exactly an area of danger.

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OXYGEN DIFFUSION IN THE ATMOSPHERE FROM LIQUID OXYGEN POOLS

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INTRODUCTION

The ability to predict atmospheric oxygen concentrations near a liquid oxygen pool following either an accidental liquid spill or a planned disposal action may supplant direct measurements in determining if appropriate action need be taken because of excessive oxygen concentrations. Accordingly, this study was initiated to acquire pertinent data and to compare them with calculated values.

BACKGROUND

The subject of atmospheric diffusion is closely related to the problem of oxygen diffusion from liquid oxygen pools. In general, it applies to such cases as radiation pollution, dispersion of solids in the atmosphere, SO_2 pollution, etc., and involves long distances and considerable heights. In the case of oxygen diffusion from a liquid oxygen pool, only a relatively small area around and above the pool is of direct interest. Such specific interests have generally been considered under the subject of micrometeorology, a field which is concerned with the fine structure of atmospheric processes, particularly in the first few hundred feet above the earth's surface. For example, Sutton [1-3] has applied micrometeorology to the understanding and evaluation of what happens to practical matters in air pollution. Definitions of the terminology used in meteorology, as well as a detailed description of the major factors affecting atmospheric diffusion, can be found in the literature [2-7].

There is a large number of these factors, involving complex interrelationships. One of the most important factors is the wind, which determines the direction of movement of a diffusing gas and the rate of dispersion. This rate increases as the wind velocity increases. The velocity, type and degree of gustiness, degree of random fluctuation, and humidity are all involved in considerations of wind and influence the degree of dispersion taking place. The size and velocity of the eddies within a wind structure are themselves strongly influenced by atmospheric stability. Other important factors are the type of terrain, the general building arrangement, the air flow patterns and the temperature history in the vicinity of the pool. The list of factors can be increased almost at will. Some are of a more localized nature, such as cloud cover, small obstacles, local wind circulation, etc. Others are more general in nature, such as hurricanes.

In addition to these atmospheric factors, the characteristics of the sources of contamination are also important. These may be grouped in three classes: point source, line

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Symposium, p. 12-23, Chicago, Illinois, April 23, 1969

Moderator Cain: Next on our program is a talk on OXYGEN DIFFUSION IN THE ATMOSPHERE FROM LIQUID OXYGEN POOLS.

The author of this is Dr. Abraham Lapin, who is with Air Products & Chemicals, Inc., and has been with them since 1955, and is now the manager of their Product Engineering Department. Dr. Lapin.

OXYGEN DIFFUSION IN THE ATMOSPHERE FROM LIQUID OXYGEN POOLS

by A. Lapin & R. H. Foster
Air Products and Chemicals, Inc.

INTRODUCTION

It is of importance to be able to estimate the oxygen concentration in the atmosphere in the vicinity of a liquid oxygen pool, this pool being the result of either an accidental liquid spill or a planned disposal action.

While it is possible to measure oxygen concentrations after a spill or a dump has occurred, it is nevertheless desirable to be able to predict these concentrations in the immediate vicinity of the pool. Knowledge of this oxygen concentration will allow appropriate action to be taken if this concentration is considered excessive. Accordingly, this study was initiated to acquire such data and to compare them with calculated values. These data were obtained in the summer of 1966 and in the winter of 1967 at Nimbus, California.

BACKGROUND

The subject of atmospheric diffusion is closely related to our problem of oxygen diffusion from liquid oxygen pools. In general, it applies to such cases as radiation pollution, solids dispersion in the atmosphere, SO_2 pollution, etc. and involves long distances and heights. Our main area of interest, in the case of oxygen diffusion from a liquid oxygen pool, encompasses a relatively small area around the pool and only a few feet above it. This is covered under the subheading of micrometerology, a field which is concerned with the fine structure of atmospheric processes and particularly with what happens in the first few hundred feet above the earth's surface. Micrometerology is covered by Sir Graham Sutton (9, 10, 11)* and is used to understand and evaluate what happens to practical matters in air pollution. Definitions of the terminology used in meterorology as well as a detailed description of the major factors affecting atmospheric diffusion can be found in the literature (4, 5, 6, 7, 9, and 10).

The number of these factors is quite large, with complex interrelationships. One of the most important factors is the wind. It determines the direction of movement of a diffusing gas and the rate of dispersion which increases as the wind velocity increases. The wind involves several subfactors such as velocity, type and degree of gustiness, degree of random fluctuation, and humidity. All these influence the degree of dispersion taking place. The size and velocity of the eddies within a wind structure are themselves strongly influenced by atmospheric stability. Other factors which are also important are the type of terrain, the general building arrangement in the vicinity of the pool, the air flow patterns, and the temperature history at the location involved. The list of factors can be increased almost at will. Some are of a more localized nature, such as cloud cover, small obstacles, local wind circulation, etc. Others are more general in nature, such as hurricanes.

In addition to these atmospheric factors, the characteristics of the sources of contamination are also important. These may grouped in three classes: point source, line source, and area source, where the point and line sources have no area. These sources are further divided into instantaneous and continuous sources. The instantaneous source is essentially a "puff" of material which is created or rejected in a relatively short time. The continuous source is that one where the pollutant is continuously rejected into the atmosphere, such as at a factory chimney or a burning dump. In all cases, the atmospheric factors of immediate importance are the ones occurring at the place and the time at which the pollutant is created. In the case of continuous sources, there are important changes such as the diurnal and seasonal cycles which greatly affect the type and amount of dispersion taking place.

*Numbers in parenthesis refer to Bibliography.

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