THE BOEING COMPANY

SPACE DIVISION CHRYSLER CORPORATION

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MINUTES

MINUTES

of

SATURN MANUFACTURING REVIEW

MICHOUD ASSEMBLY FACILITY
NEW ORLEANS, LOUISIANA

TUESDAY - WEDNESDAY
MAY 24 - 25, 1966

SPONSORED BY:

MICHOUD ASSEMBLY FACILITY
DR. GEORGE N. CONSTAN, NASA MANAGER

CO-HOSTS

THE BOEING COMPANY
LAUNCH SYSTEMS BRANCH
MR. R. H. NELSON
GENERAL MANAGER

and

CHRYSLER CORPORATION
SPACE DIVISION
MR. H. D. LOWREY
PRESIDENT

FOREWORD

This publication contains a series of presentations, the results of a joint NASA/Saturn Manufacturing Review. They are written in the abstract form as a convenience to the reader.

A letter of invitation, included in this report, sets the background for the intent of this meeting.

Particular note should be made of the excellent representation, reflected in the List of Attendees, which is included in this publication as Appendix A.

If additional information is desired, relative to this meeting, contact should be made, attention Mrs. Gray (877-2187) with the Manufacturing Liaison Office, Manufacturing Engineering Laboratory, Marshall Space Flight Center, Huntsville, Alabama.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MICHOUD OPERATIONS
P.O. BOX 29300
New Orleans, La.
70129

IN REPLY REFER TO:

A Saturn Manufacturing Review is planned for May 24 and 25, 1966, at the NASA Michoud Assembly Facility, New Orleans, Louisiana, under NASA sponsorship and co-hosted by The Boeing Company and Chrysler Corporation. The objective of this review, as reflected in the attached agenda, is to promote interchange of space vehicle manufacturing technology and manufacturing systems information; and, thus help continue improvement of manufacturing development in the Aerospace Industry.

Presentations will be made by representatives of The Boeing Company, Chrysler Corporation, Douglas Aircraft Corporation, International Business Machines, Grumman Aircraft Engineering Corporation, McDonnell Aircraft, North American Aviation Divisions - S&ID, Rocketdyne, and LAD; and MSFC.

These presentations will cover a broad scope of recent manufacturing developments. Emphasis has been placed on presenting new material not covered in previous reviews of this nature.

Your attendance and/or representation will contribute in a major way to accomplishing the objective of this meeting.

Sincerely yours,

G. N. Constan

G. N. Constan
Manager

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AGENDA

SATURN MANUFACTURING REVIEW
MICHOUD ASSEMBLY FACILITY
NEW ORLEANS, LOUISIANA

TUESDAY - MAY 24, 1966

7:45 - 8:00	Pick up badges from table located in Hotel Lobby near bus exit. (Badge will be required for bus transportation and Plant admission.	
8:00	Board transportation at Roosevelt Hotel for Michoud Assembly Facility, NASA Auditorium, Bldg. 350, 2nd floor.	
8:45 - 9:15	WELCOME - Dr. George N. Constan, Manager NASA/Michoud Assembly Facility PERSPECTIVE - Mr. Werner R. Kuers, Director MSFC/Manufacturing Engineering Lab.	
9:15 - 9:30	Via Bus: Session "A" Participants go to Chrysler Chart Room, Bldg. 101, 2nd Floor. Session "B" Participants go to Boeing PCC Room, Bldg. 102, 1st Floor.	
9:30 - 9:40	Coffee	
	SESSION I	**SESSION II**
	Chrysler Chart Room, Bldg. 101, 2nd Floor - Chairman - J. S. Sheldon	Boeing PCC Room, Bldg. 102, 1st Floor - Chairman - F. L. Coenen
9:40 - 10:40	Out-of-Vacuum Electron Beam Welding P. G. Parks, MSFC	Space Vehicle Production and Attendant Requirements. John S. Sheldon, Chrysler
10:40 - 11:40	Problems Encountered in Manufacturing the Program Coupler Assembly. Ed Moles - Grumman	Contribution by Manufacturing to the Reliability Program. Otto Eisenhardt - MSFC

TUESDAY - MAY 24, 1966 - CONTINUED

	SESSION I	SESSION II
11:40 - 12:00	Break	
12:00 - 1:30	Lunch - Bldg. 351, Executive Dining Room	
1:30 - 3:00	Tour	
3:00 - 4:00	Weld Repair of Launch Vehicle Fuel and Lox Containers Etric Stone - DAC	Manufacturing's Role After the Spacecraft Leaves the Assembly Floor. W. Dubusker - McDonnell
4:10	Board special transportation for Roosevelt Hotel	
6:00	Dinner Meeting - Roosevelt Hotel	

WEDNESDAY, MAY 25, 1966

8:00	Board transportation at Roosevelt Hotel for Michoud Assembly Facility, Bldg. 101.	
	SESSION I	**SESSION II**
8:45 - 9:45	Induction Brazing Paul Kanzler - Grumman	A Method of Sequencing Operations and Reporting Technique Gerald Frazier - IBM
9:45 - 10:45	NC Contouring with a Punchpress W. D. Otto - Chrysler	Mechanical Machine Tool Utilization in Support of Manufacturing Reliability Arnold Graham - Rocketdyne
10:45 - 11:45	Service Module Radiator Panel Fabrication Jim E. McKee - NAA/Tulsa	Vehicle Project Administration - Tracy Wells - NAA/Apollo
11:45 - 1:15	Lunch - Bldg. 351 Executive Dining Room	
1:15 - 2:15	Bulge Forming J. A. Beasley - Boeing	Tool Experiment for Assembly, Maintenance, and Repair in Space. R. Schwinghamer - MSFC
2:15 - 3:15	High Energy Forming of Compound Contours and Complex Cross Sections Lou Frost - NAA/LAD	Weld Quality Assurance John Bodner - Boeing
3:15	Board bus front of Bldg. 101 for NASA Auditorium	
3:30 - 4:00	Summarization and Critique - Paul Maurer, MSFC	
4:00	Board special transportation in front of Bldg. 350 for Hotel Roosevelt or Lakefront Airport for Charter only.	
4:10	Depart	

PERSPECTIVE

by

Werner R. Kuers (MSFC)

I, too, want to welcome you to this Manufacturing Technology Review Meeting. It is a great pleasure for me to see the great interest in this meeting as evidenced by the fact that so many highly qualified men and many of the leaders in the aerospace industry in the field of manufacturing technology have made it possible to come here today. At this time, I want to thank all of those who made the arrangements and plans for this meeting. In this connection, I want to thank Michoud Operations, Dr. Constan and his associates, for sponsoring this meeting, and Mr. Paul Maurer and his people for all the effort of organizing it, and last, but not least, our hosts, The Boeing Company and Chrysler Corporation. My special thanks go to all of those who are going to make the presentations today for the work and effort connected with it.

Now, let me say a few words about the purpose of this Manufacturing Technology Review Meeting. As the title implies, we want to review and discuss together manufacturing techniques which are of special interest and importance to our Saturn/Apollo program. Some of the techniques, presented today, are innovations in manufacturing processes or equipment, some topics relate to specific experience in the application of generally known techniques to our specific tasks, and some deal with general ideas of controlling manufacturing efforts in our development program. All of the presentations have two things in common: (1) They represent the actual experience and knowledge of people who are daily involved in tasks of manufacturing space flight hardware, and (2) The information on manufacturing techniques presented here is new and cannot be found yet in the technical literature or reports in our libraries. In our space flight program, we just cannot afford to wait until new knowledge and techniques become known through regular reporting and literature channels to be applied to the hardware of our space flight program.

Therefore, this free exchange of information on new experience, gained in this program, and new developments in the area of manufacturing technology is of great importance for the total program. Finally, all of us are interested in one thing, that is: to make the lunar landing program a total success. Because of this, nobody can overlook any possibility to improve the quality and reliability of the hardware being produced at so many companies. The reliability requirements of these complex stages and spacecraft modules are really frightening if you consider that one failure of the tens of thousands components and structural elements can lead to a catastrophic failure of a mission. We must do more than is humanly possible by individual experts in the many engineering fields and manufacturing disciplines: We must jointly review our techniques and experience to make sure that all of the knowledge that is available has been utilized. I hope that this meeting is a step in this direction and will contribute to this interchange of experience in the area of manufacturing technology.

At the beginning of the guided missiles and space flight programs, you could very often read and hear about a "producibility barrier" in these programs. I do not believe that such a barrier exists today. There is such a tremendous amount of scientific data on materials and such great number and variety of equipment, measuring and control devices, manufacturing techniques, and processes available today that it should be possible to produce any hardware that a design engineer can come up with -- provided sufficient time is allowed for development of the manufacturing technique. And this is an important point: Very often we do not have this time in our programs to go through an orderly phase of development of the required manufacturing techniques and then start the manufacturing of flight stages. We have to telescope the activity of design engineering, process development, tooling, and fabrication of hardware in order to cut time and cost. Also, the development of manufacturing technology is progressing in our time so rapidly and new manufacturing processes or improvements are invented so fast, that only by timely exchange of such information can we hope that we stay up-to-date and produce the best and most reliable hardware for the program.

From my own experience and from observation of the activities at our contractor plants, I find that we have two basic problems in our development programs in the area of manufacturing and assembly: One is the application and development of optimum manufacturing techniques, and the second problem is in planning, organizing, and controlling the manufacturing operations in order to meet program schedule milestones. You will have noticed that some of the discussions today and tomorrow deal with topics of this second category. This is an area where we again can learn from each other and some new concepts and ideas on how to overcome such common problems like control of parts shortages, planning work-around operations, out-of-sequence installations, incorporation of late changes, etc., can only be helpful to the total program. I am sure we will have some interesting discussions on such topics during our meetings.

NASA/MICHOUD
SATURN MANUFACTURING REVIEW

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SESSION I-A

N67 12702

OUT OF VACUUM ELECTRON BEAM WELDING

by

P. G. PARKS (MSFC)

Electron beam welding has been removed from its empty cocoon and made portable and applicable in atmosphere.

The 15 KV-9KW unit which weighs only slightly over 200 pounds can be considered an automatic welding head. Application studies, mechanical properties, metallurgical quality of such alloys as 2219 and 2014 aluminum as well as maraging and high strength steels have shown unscoped potentials.

Demonstrated high current densities approximately 5×10^6 watts/cm^2, as compared to 5×10^9 watts/cm^2 for hard vacuum and approximately 1×10^4 watts/cm^2 for GTA welding does permit a significant improvement in welding efficiency. Operational accomplishment and results todate are illustrated by mechanical properties, metallurgical quality and procedure details in welding materials to 3/4-inch thickness and at speeds to 140 I. P. M.

In the mid 50's the U. S. industries became interested and active in the application of hard vacuum electron beam welding. By the beginning of the 60's, the hard vacuum E. B. welding systems, and its chambers had become an important factor in the small and difficult welding jobs.

Pieces had to be of a reasonable size in order to fit into the ever-present vacuum chamber.

The attractive joint properties of HVEB welds and the acceptance of the fact that a weld is a defect surrounded by sound metal resulted in several organizations searching for a way to operate the gun out of its cocoon.

The first productive effort was the result of work by R. E. Kutchera of the General Electric Large Jet Engine Departments, Evandale, Ohio. This Air Force funded program was continued with the Alloyd Corporation and then Hamilton Standard Division of the United Aircraft Corporation.

During 1964, the Westinghouse Research Corporation engineers completed a study designed at developing an electron beam welder aimed specifically for non-vacuum or OVEB welding. Early tests of these development results demonstrated advantage over the conventional arc processes, i. e., GTA, and GMA.

During June, 1965, a 3-phase contract was made between Westinghouse and NASA/MSFC Welding Development Branch. Phase I of the study was to demonstrate and evaluate the experimental equipment. With successful completion of this phase, Phase II was the construction of a light weight, portable non-vacuum electron beam welding head, manipulator and radiation proof enclosure.

Present status of this NASA funded program is illustrated by the premier showing of the demonstration film "Electron Beam Out of Vacuum As An Automatic Welding Head". The film characterized by the following word description provides an up-to-date report.

This is an electron beam operating in air, concentrating 350 times more heat in a given area than does the most efficient, conventional arc welding process. Concentrated energy means more welding with less overheated material, higher welding speeds, less stress, less cracking and less warping. Until recently these advantages were only available when the workpiece could be put into a vacuum.

This is the welder that produced the beam. Twelve kilowatts of beam energy 150,000 volts. It is a welder with full vacuum to non-vacuum operating flexibility. It is being demonstrated here as a non-vacuum welder and has the same portability and adaptability to large and small workpieces as a conventional inert gas arc welding head.

This unit was specifically designed for complete vacuum-to-non-vacuum flexibility and portability. It is not an adoption of an earlier limited purpose piece of electron beam equipment. The welder conditions 220-volt 400-cycle power to 150,000 volts do within this small tank. The resulting 250 pound unit hangs from a conventional side beam welding carriage. The welder can also be positioned horizontally by rotating the supports at these points. High voltage connections to the welding gun itself are made directly. No high voltage cables are required. Electrons are emitted from a sturdy tungsten rod about the size of a pencil lead. The rod is heated by bombardment of electrons from a tungsten filament. Such assemblies regularly achieve 97 hours mean-time between failure. After passing down the differentially pumped column, the electrons exit from this nozzle. A supply of pure helium gas also exists at the nozzle to keep dirt from being sucked up into the low pressure region of the gun. The pumping of the high pressure regions near the exit is accomplished through flexible attached here and here to mechanical pumps outside of the enclosure. The high vacuum regions are maintained by this small pump and the slightly larger pump on the left-hand side of the welder.

Simple, all purpose x-ray shielding is achieved by this lead-plywood enclosure. The welder observes the process through a lead glass window. The welding controls are in a console in front of him. Start-up controls are in the panel rack at the right hand side of the picture.

The welder is now ready to fuse 1/4 inch thick 2219-T87 material. The welding speed is 140 inches a minute. The aluminum is simply laid atop two pieces of stainless steel. Clamps are not required since longitudinal distortion is small even on this 4-foot long weld. The resulting freedom from distortion is more easily shown in this weld taken from an MSFC sponsored welding program. The upper bead contour is very smooth. Transverse distortion is not evident.

When auxiliary inert gas shielding is properly applied along with good cleaning produces freedom from porosity can be achieved as shown by these typical cross sections.

This specimen was run at 3.6 kilowatts at 20 inches per minute. 6 kilowatts of power at 60 inches a minute produces a similar cross section. A considerably narrower cross section is observed at 140 inches per minute using 8 kilowatts of power.

These 1/2 inch aluminum welds were made at 50 inches using 10 kilwatts of power.

All plates in this series of welds have remained flat without the use of restraint during the welding process. The narrowest weld is 185 thousandths of an inch at the widest portion. This compares favorably with 200 to 300 thousandths of an inch for a comparable inert gas weld in this thickness of material.

Heavy welding ferrous materials can also be accomplished. This is 3/4 inch steel is being welded at 9-inches per minute using 9 kilowatts of power. Potentially, the most attractive payoff from welding with the electron beam is the intense energy concentration to minimize metallurgical effects in a welded joint-effects that offset the attractiveness of today's high efficiency structural materials when they must be welded. As the weld leaves the plate the narrow, confined character of the non-vacuum electron beam operation can once again be observed. The Westinghouse welder has been designed to bring the advantages of EB welding to the maximum number of applications.

Todate it has been demonstrated by experimental procedure development that welds can be produced by the O. V. E. B. system to existing standards of metallurgical quality and physical properties.

Problems of weld refinement through a comprehensive investigation program is now in progress.

An interim report titled "Relationship Between Weld Quality and Non-Vacuum Electron Beam Welding Procedures", as well as future reports may be obtained by directing request to Mr. Floyd Bulette, MS-T. Referencing NASA Contract NAS 8-11929 "Light Weight Versatile Non-Vacuum EB Welding Unit".

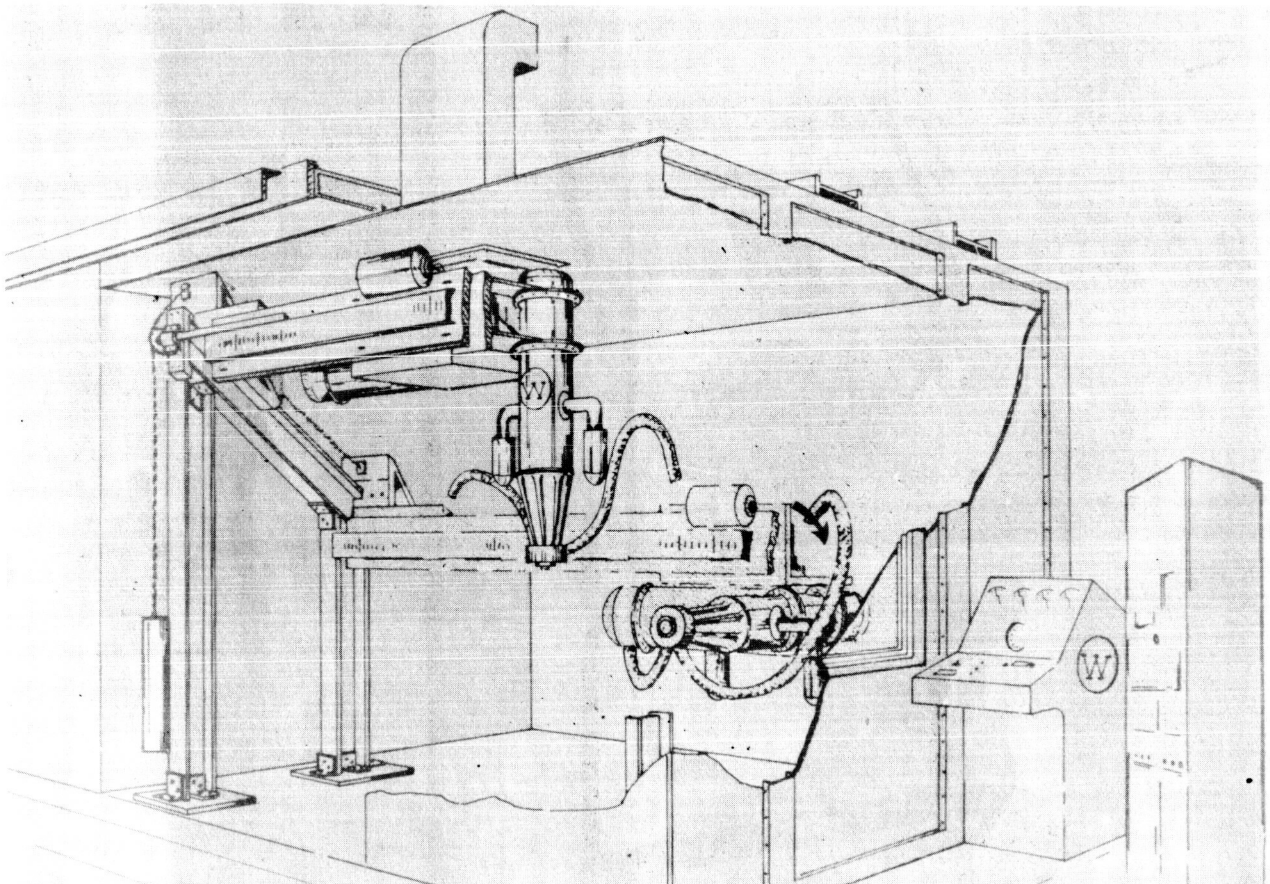

Figure 1 - Conceptual View of O. V. E. B. System

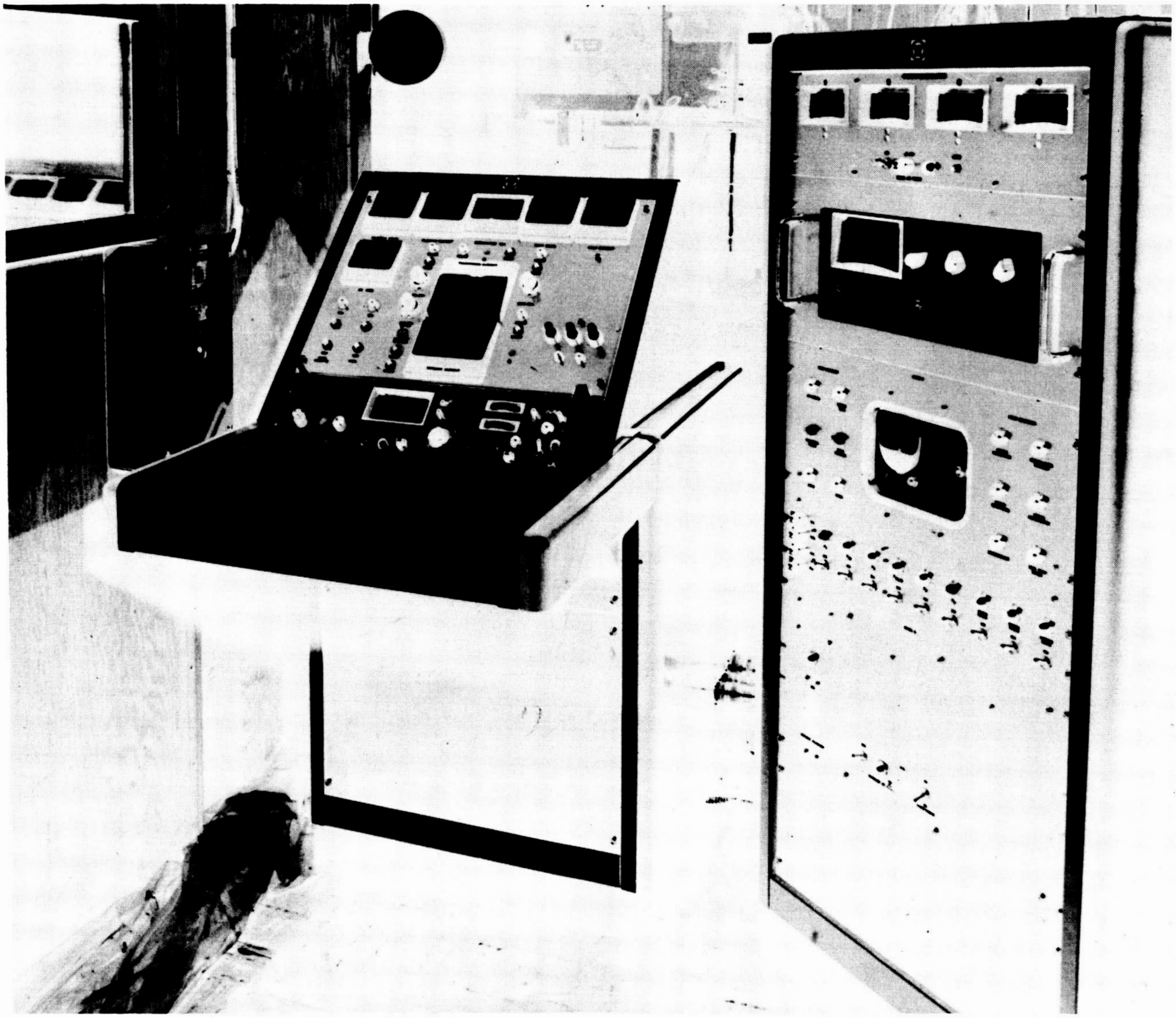

Figure 2 - Control Panels

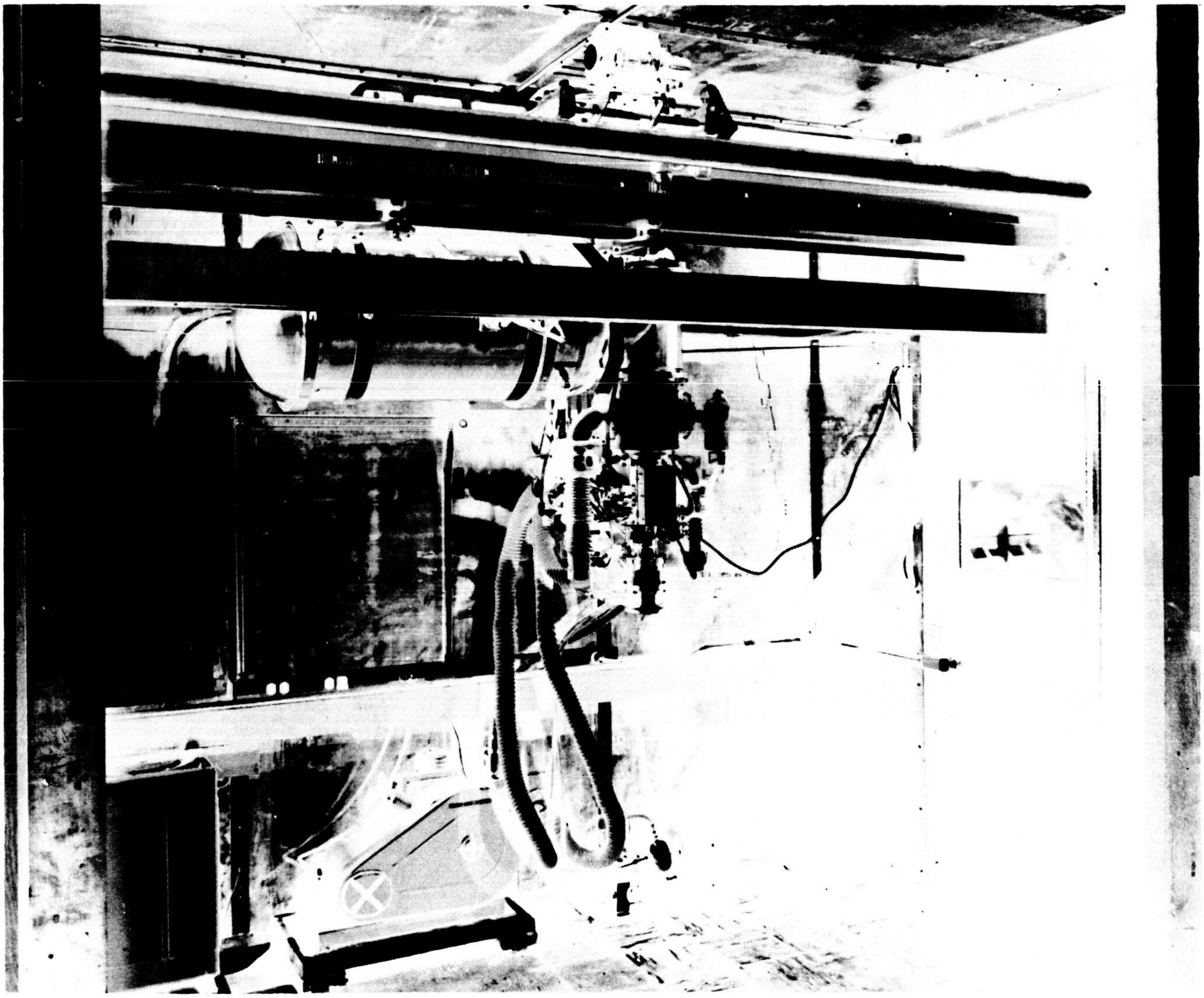

Figure 3 - Transformer and Gun

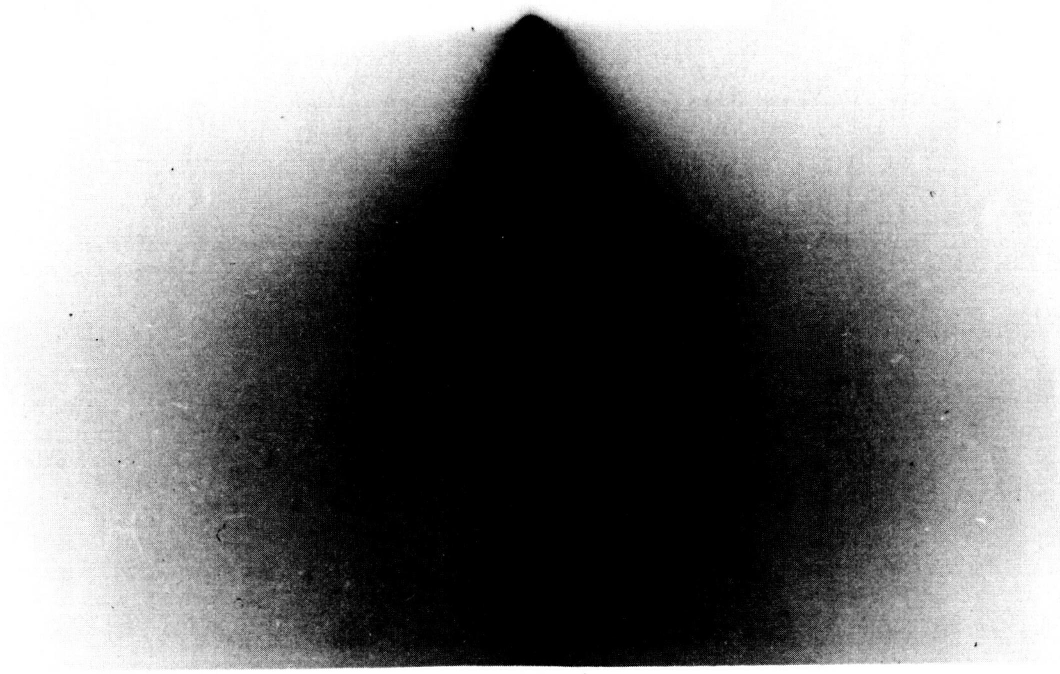

Figure 4 - Beam Stream in Atmosphere

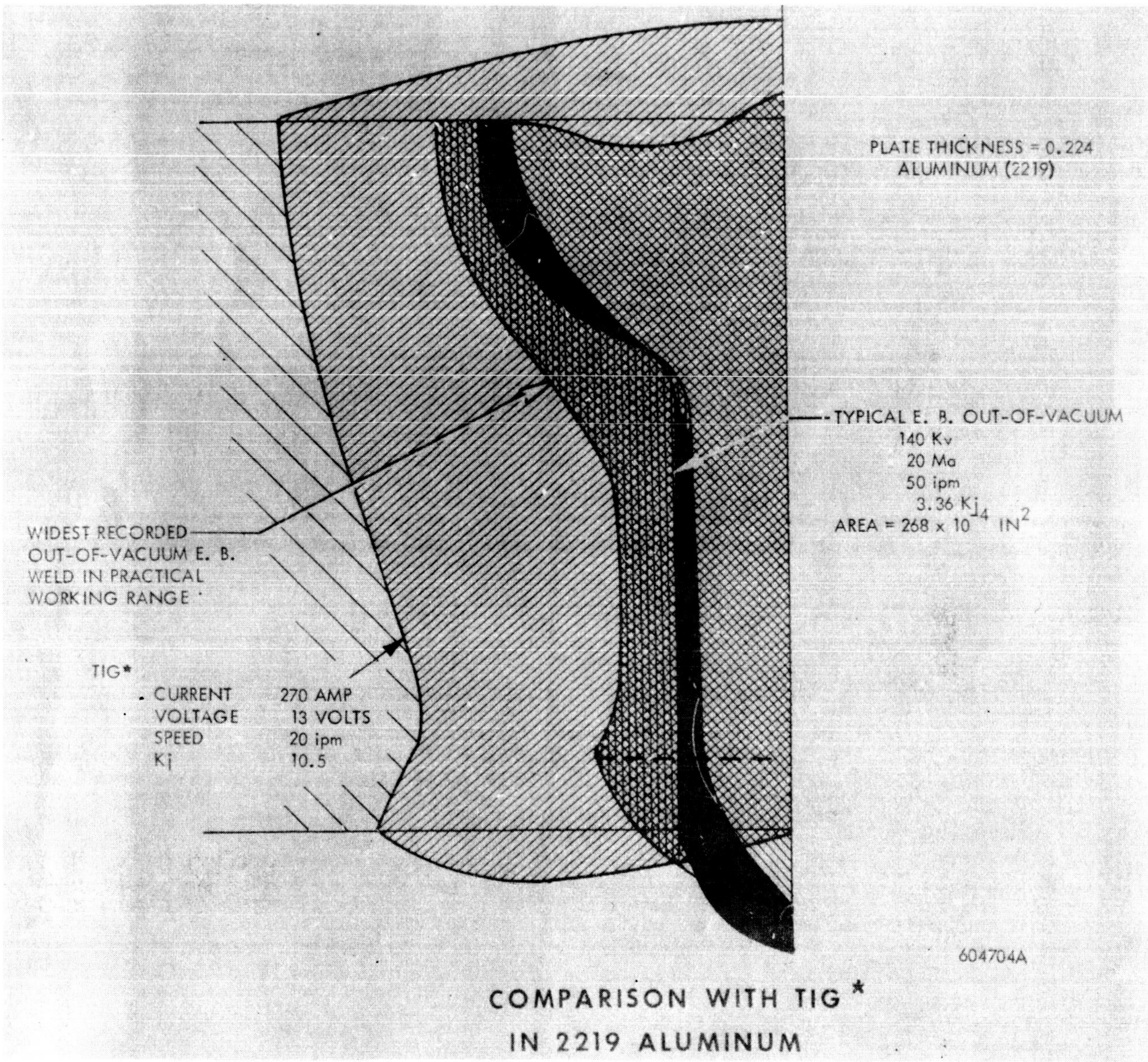

Figure 5 - Fusion Zone Comparisons TIG, VAC, EB, and O. V. E. B.

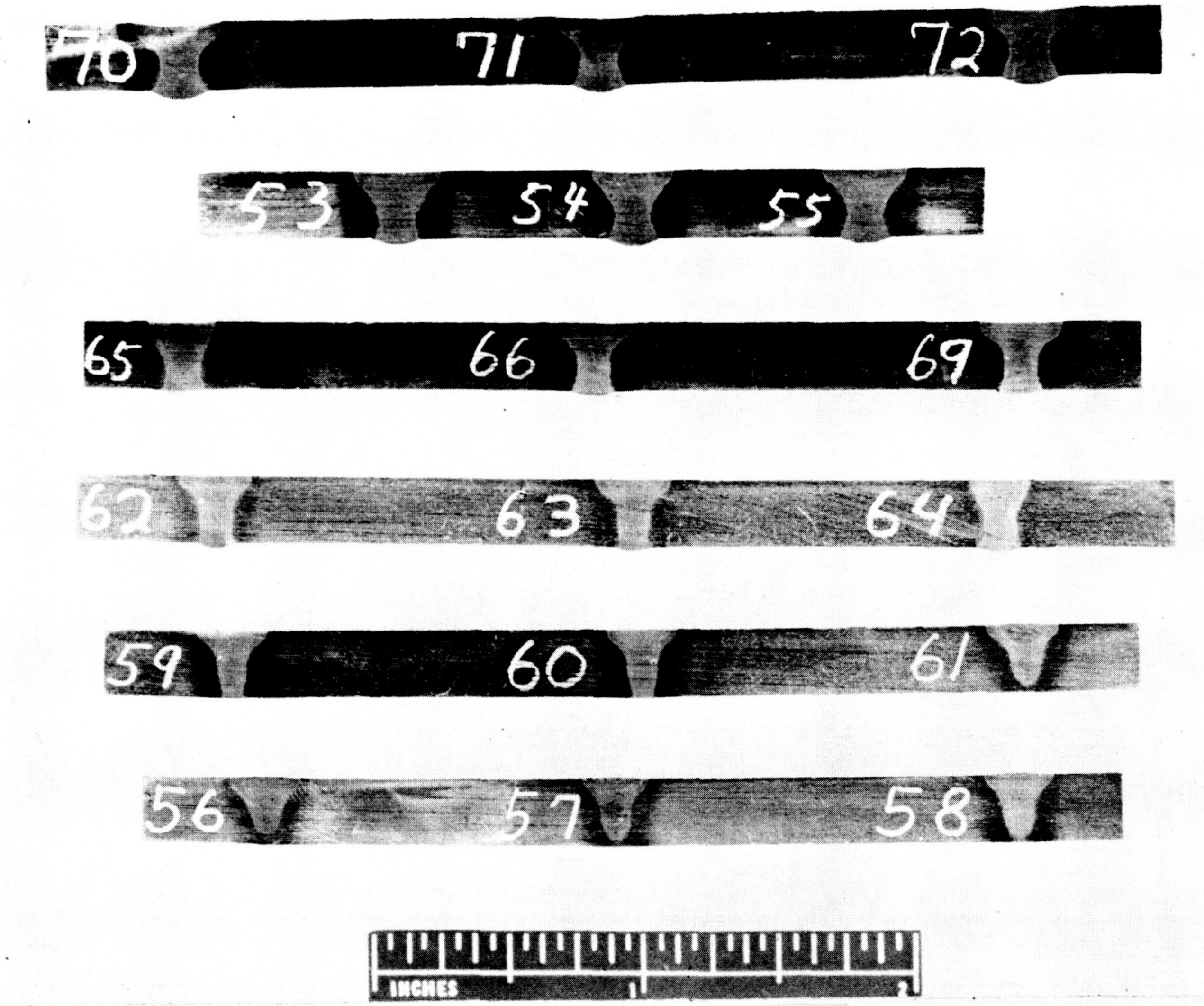

Figure 6 - O.V.E.B. Melt Patterns

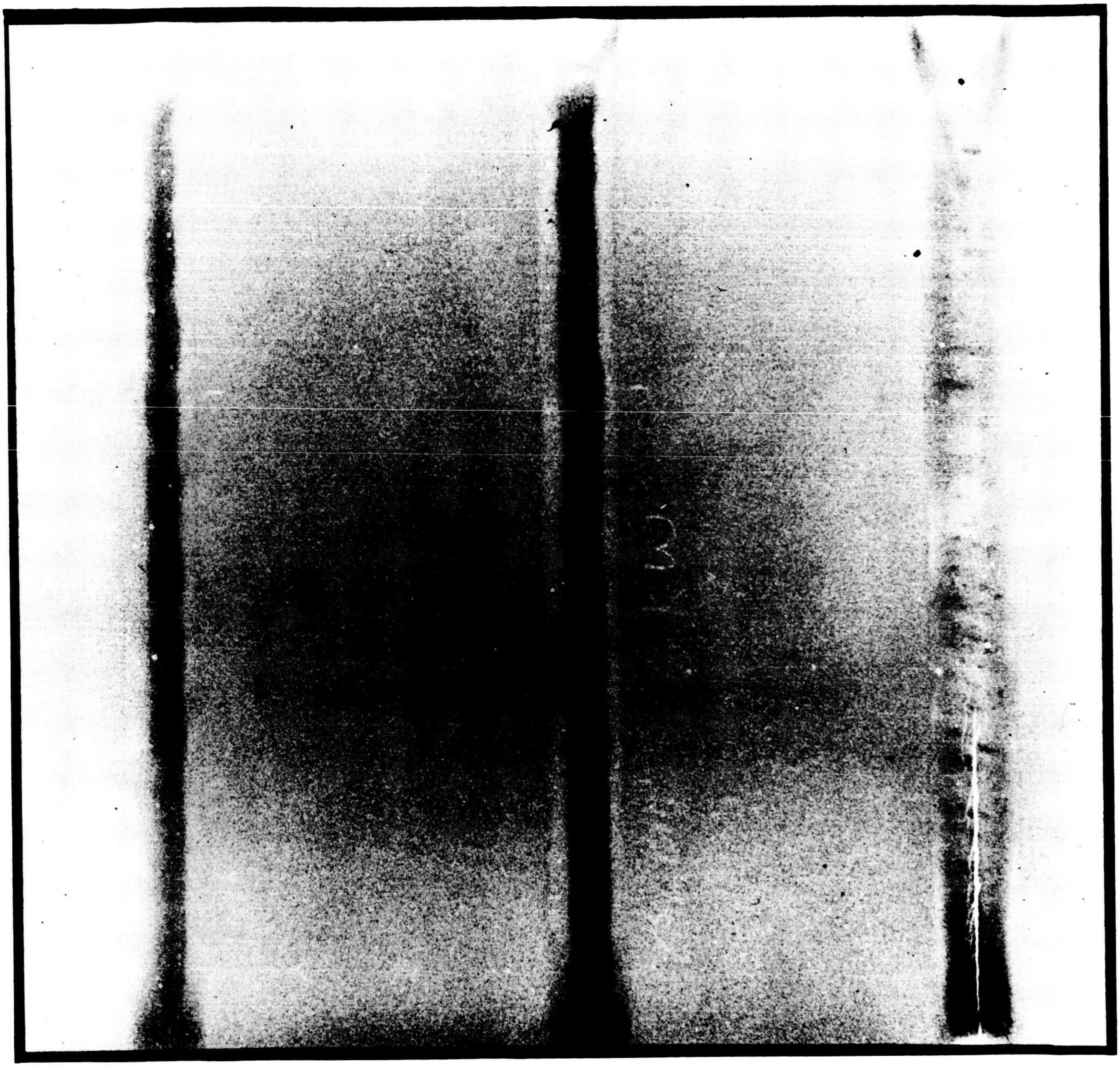

Figure 7 - X-rays of Varied Conditions

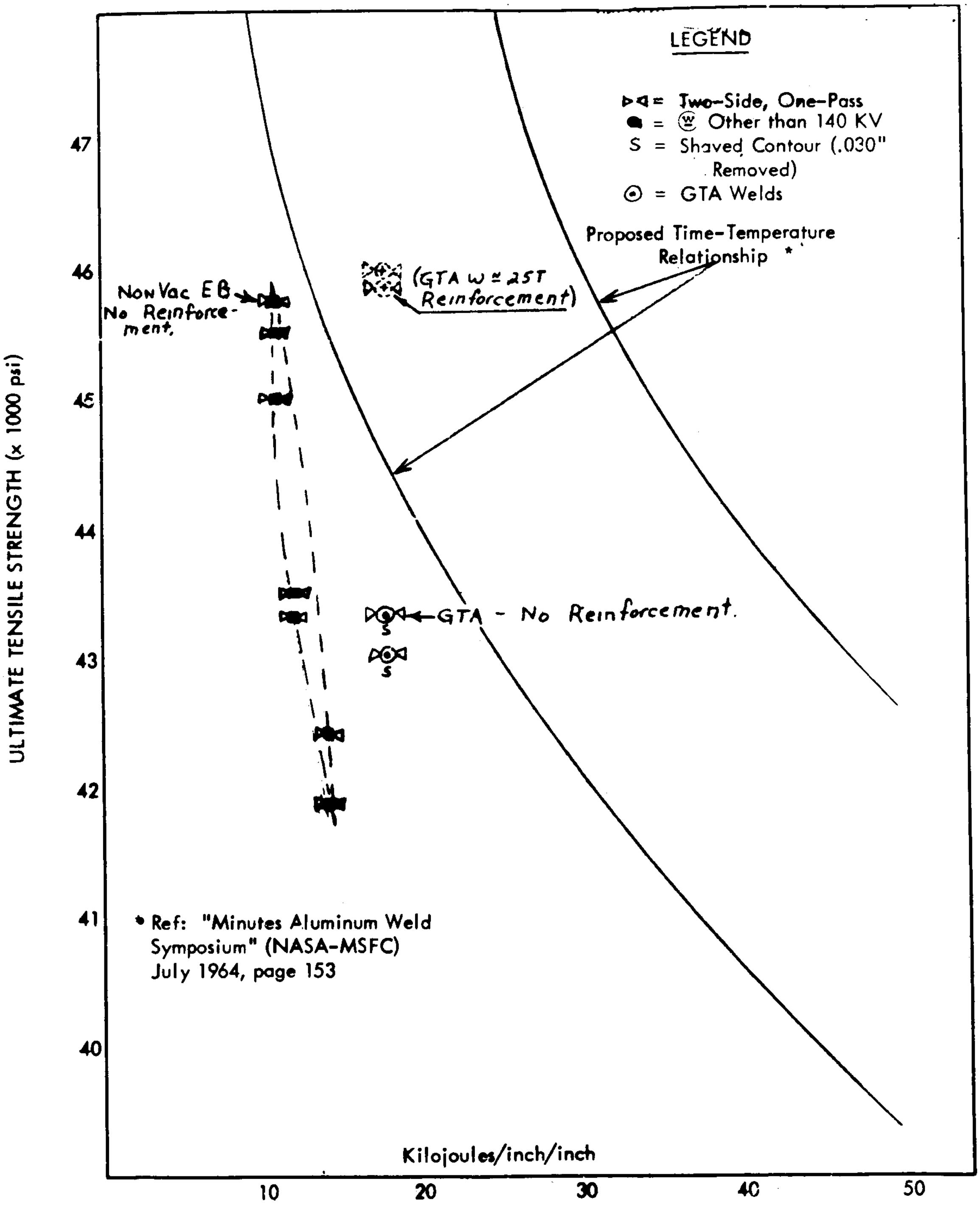

Figure 8 - Process Strength to Energy Relationships

SESSION I-B N67 12703

MANUFACTURING PROBLEMS ON THE LEM PROGRAM COUPLER ASSEMBLY

by

E. W. Moles (Grumman)

DEFINITION

The LEM Program Coupler Assembly (PCA) is part of the LEM Mission Programer. It accepts, processes and routes to the various Vehicle Sub-Systems, the commands from other assembly in the LEM Mission Programer. The other assemblies are the LEM Guidance Computer (LGC), the Program Reader Assembly (PRA) and the Digital Command Assembly (DCA). Simply stated, the PCA performs any of 256 distinct switching functions on remote command in the absence of the Astronauts, thereby, taking the place of the Astronaut during early flights. It consists of 17 modules of which 12 perform switching functions. Each module is about 5 x 6 x 1 1/2 arranged in a container to form a 6" x 8" x 30" assembly.

PRESENTATION

Mr. Moles utilized approximately twenty slides in support of his topic. Coverage of the subject has been condensed into the following abstract.

A description of the function and general arrangement of one LEM Program Coupler Assembly (PCA) was given. Detailed emphasis was placed on tooling, joining processes and manufacturing sequence employed in making the welded cordwood modules of which the PCA is partly composed. Processes discussed were Resistance and Percussive Arc Welding and Controlled Resistance Soldering. Examples of tooling and samples of welded cordwoods in various stages of completion were shown. A typical Manufacturing Operation Procedure was displayed showing matrix interconnection, component lead cutting and fitting, cordwood loading and module welding. A training program for operators and inspectors was described and specification highlights were commented upon.

CONCLUSION

The halfway point has been reached to what is assured to be a successful first production effort of Electronic Module Welding at Grumman. This success is a result of:

a. NASA schooling at Huntsville and plant visits.

b. Close producibility support of Design Engineering from the earliest stages.

c. In-plant training of Quality Control and Production personnel.

d. Recognition by Manufacturing Engineering of their responsibility to take as much of the "think" as possible out of the production operation by adequate and effective tooling.

e. Finally, close on-the-line support of Production by Manufacturing Engineering.

SESSION I-C

N67 12704

WELD REPAIR OF LAUNCH VEHICLE FUEL AND LOX CONTAINERS

by

Etric Stone (DAC)

This presentation covered the technical aspects of weld repair methods that are currently used with success on the structural membrane of welded aluminum fuel and liquid oxygen containers for the Saturn S-IVB Program.

The three principle categories of weld repair presented are:

a. Mechanized repair of the original weld accomplished in the same tooling and with the same equipment used for the original weld.

b. Out-of-position mechanized repair of the original weld utilizing special tooling and equipment developed for the repair.

c. Out-of-position repair which requires re-design of the weld joint and replacement of the defective weld.

The presentation described the process, testing, and quality requirements common to all three repair categories, as well as requirements specifically related to each. Through proper application of these weld repair procedures, the original design and integrity is retained.

It was emphasized that on any of the three types of repairs described in the above paragraph, complete testing of the proposed repair procedure was accomplished and evaluated prior to implementation. In categories "a" and "b" type repairs, for example, the necessary grind-out to remove the weld defect is simulated on a test panel. The reweld is then accomplished with particular attention directed to the stop and start points on the weldment. The test panel is then subjected to all necessary tests to insure that the proper strength requirements will be met by the proposed repair procedures. An example of category "c" type repairs was the necessary modification of the S-IVB jamb fitting weld. In this instance, full scale doublers were installed on five foot domes and completely tested in a special test fixture prior to the rework of the production hardware. It was explained that in this type of repair, a polyurethane adhesive system was utilized to seal the doublers, and the huck bolts were sealed with a silicone material. Also, a LOX compatible dynatherm material was utilized as a final covering on the inside surface of all LOX tank repairs.

SESSION I-D

N67 12705

INDUCTION BRAZING

by

Paul J. Kanzler (Grumman)

The engineering and manufacturing demands of the Lunar Excursion Module has placed GAEC in a leading position in the induction brazing field.

Presently, Grumman is extensively engaged in the Induction Brazing of this vehicle. This brazing is being done on 304L corrosion resistant tubular steel. The unions, or fittings, are the same material in the annealed condition. The braze alloy is 82 percent gold and ~~eighteen~~ percent nickel in composition and comes pre-placed in the beaded section of each fitting. The brazed joint concept used at Grumman utilizes capillary flow of the braze alloy in two directions to insure a greater surface area giving both additional strength and a more reliable seal.

The following diameters are being brazed with .016 of an inch wall thickness. These include 3/16, 1/4, 3/8, 1/2, 5/8, 3/4, and one inch. In addition .028 of an inch wall thickness is brazed on our 1/4 inch lines, .042 of an inch on our 3/8 inch lines and .057 on our 1/2 inch line which is our heaviest wall thickness. The one and one-quarter inch line has a wall thickness of .049 of an inch, one and one half inch are brazed with

.020 and .040 of an inch, one and three quarters of an inch utilizes both .020 and .049 of an inch and finally our two inch diameters are brazed with .025 and .049 of an inch wall thickness. This represents seventeen different combinations of joints brazed.

The fittings and tools were purchased from Aeroquip and the basic concept has been used by McDonnell Aircraft on the Gemini.

The primary differences in the process as it applies to Grumman include:

a. Two way flow of the gold alloy as opposed to one way flow.

b. The elimination of the port inspection holes.

c. The larger diameter brazing used at Grumman couples with the variety of different joint combinations as just described.

In diameter and frequency of braze joints this approximates a 3:1 ratio.

The success of out-of-position, varying engagement lengths, transistor joints, dead ended line, and mass attachments were discussed in detail. The heavier wall thickness fitting when using a transistor joint is desirable. Dead ended lines can be brazed if the argon is under no pressure. Components should be brazed one and one half inch from the edge of a fitting.

For convenience the cleaning cycle used to clean our tubing is:

Initially:

1. Cut to eight foot lengths.

2. Degrease.

3. Alkaline clean.

4. Dip in nitric acid/sodium sulphate solution.

5. Stock, cut to details, bend.

6. Degrease trichloroethylene.

Intermediate Clean:

7. Nitric acid/hydroflouric acid for fifteen minutes.

8. Nitric acid for a minimum of one hour.

9. Electro etch inspection mark.

10. Trichloroethylene.

11. Glass bead peen.

12. Solvent wipe, trichloroethylene.

Final Clean:

13. Ultrasonic clean for five minutes.

14. Freon flush internally and externally for two minutes in both directions.

15. Non-volatile residue and particle count to level "N"*.

16. Nylon bag - dry nitrogen.

17. Plastic bag - route cards affixed.

*Level "N" at Grumman is as follows:

0 to 5 microns	-	no count (unlimited)
5 to 15 microns	-	60 particles/100 milliliters of solution
15 to 25 microns	-	30 particles/100 milliliters of solution
25 to 50 microns	-	15 particles/100 milliliters of solution
50 to 100 microns	-	6 particles/100 milliliters of solution
100 microns	-	0 particles/100 milliliters of solution

Typical brazing parameters will be given on request.

SESSION I-E

N. C. CONTOURING WITH A PUNCH PRESS

by

W. D. Otto (Chrysler)

N67 12706

In early 1962, the Chrysler Corporation Space Division activated a portion of NASA's Michoud Operations in New Orleans to complete production on the Saturn I Booster, and to begin on Saturn IB.

A large variety of parts, short production runs, and relatively frequent design changes are typical of this type of work. Under these conditions, numerically controlled equipment is of considerable advantage. Since sheet metal components with many different shapes and hole patterns are common in a booster design (the largest sheet blank produced here was 48 x 30 x 0.187 in.) Chrysler-Michoud decided to use a numerically controlled punch press.

The initial application of the press (a Wiedematic A-15 turret punch press) was for sheet metal brackets that are rectilinear in both profile and hole pattern. The machine proved to be satisfactory; easy to program, accurate, fast, and showed a reduction in production manhours. But a problem still remained. Most sheet metal components on the booster have regular rectangular profiles, but because of the exterior shape and general configuration of the vehicle, a large number have more general contours or large radii. These parts posed a production problem: quantities were insufficient for conventional hard tooling (router templets and blank dies, for example); and complex part configurations made hand layout and trim methods too slow and costly.

Because of the production speed of the machine, it was difficult for the programming staff to maintain an adequate backlog of tapes for continuous production operations. So Chrysler decided to investigate the possibility of putting the more complex parts on an automatic press, while at the same time reducing programming time. The idea was sound: the machine was not overloaded, and accuracy tests showed that it would position within 0.003 in.

The technique for programming contours is not difficult - the NC programmer defines the part geometry as he would for any part programmed in APT, and then outlines the cutting sequence. However, the difference between the punching and mill cutting operations occurs at this point. Here the programmer must select punches that produce the desired periphery with a minimum number of steps, and the maximum possible edge condition.

Part costs have also been reduced. The versatility of the combination has virtually eliminated the need for tooling and layouts on flat-pattern sheet metal components of the Saturn Booster. This is true not only for the majority of the parts (which are made from aluminum) but also for materials such as fiberglass, phenolics, nylon, teflon, copper, and stainless steels.

SESSION I-F

ENVIRONMENTAL CONTROL SYSTEM (ECS) SPACE RADIATOR FABRICATION

by

J. E. McKee (NAA - Tulsa)

ECS space radiators are designed to dissipate the heat generated within the spacecraft using a water glycol coolant pumped through the radiator tubes. In addition to their function as a cooling panel, the space radiators serve as a structural component of the service module, i.e., the outer face heat of the 130° segment panels of the outer shell.

The unusual requirements and problems encountered are as follows:

1. Roll bonded panels 189 inches long (previous maximum length 125 inches)
2. Bi-gauge (not attempted before in material as thick as 0.066 - 0.120 and in 6061 alloy)
3. Inflation of 189-inch long panels (previous maximum length inflated; 100 inches)
4. Unequal inflation of tubes; i.e., a controlled distention ratio of 0.20 to 0.06 inch arc heights in relation to a common chord line
5. Stretching parts to contour without excessive collapse of tubes and without internal support

6. Sizing tubes internally

(a) to hold tolerance of $\pm$ 0.002 inch

(b) in tube length of 178 inches

(c) with 1100 aluminum - clad inner surfaces

(d) without galling

(e) with tube sheet formed on a 77 inch radius

(f) with tubes cambered (curved in plane of metal) as much as 15/32 inches.

A major portion of this presentation dealt with the expanding and sizing of the radiator tubes to exacting tolerances to meet the flow and pressure drop requirements of the system, as well as the chem-milling, contour stretch forming, welding of tube closures, and manifold adapters.

Highlights of the process including equipment and processess developed were viewed from 35 MM slides.

SESSION I-G

THE BULGE FORMING PROCESS

by

J. A. Beasley (Boeing)

The basic principles of the process are the application of hydraulic pressure to a sheet clamped over a female cavity that will produce the desired contour after the pressure is released. The concept was patented by the Verson Company many years ago; however, modifications have been made to the process. In the beginning, it was not considered necessary to pre-shape the cavity but only a supporting ring at the periphery of the part.

The gores for the Saturn first stage booster were bulge formed; however, the apex and base gore sections had to be bulge formed separately due to their size and varying design features.

The bulge forming tool design led to the use of pressure vessels of 1000 psig capability. The top and bottom halves were located together by 10 inch hydraulic cylinders which operated the toggles on the periphery of the tool. The basic structure was made of USS T-1 steel to meet the weight and stress restrictions of 35 ksi as measured in the T-1 structure. The forming cavity was placed in the upper half of the tool to further reduce the weight restrictions. The stress restrictions in the locking mechanisms were solved with SAE 4340 steel. The tools were proof loaded and cycled to confirm design and safety limitations.

Development of the bulge forming operation on gore sections showed that certain areas of the 2219-T37 aluminum sheets had excessive thin out due to the peripheral clamping procedure. Chemical milling of the simplest configurations to leave excess material solved the thin out problem. The second development phase for correction of thin out was pre-sculpturing and then forming the simplest configurations. The final step was to pre-sculpture all apexes and bases before the operation of bulge forming to the desired contour. The scrap rate has been 3% in forming 925 sections which includes all tool try out and development efforts on the .224 through .800 inch thick plates.

SESSION I-H

N67 12709

HIGH ENERGY FORMING OF COMPOUND CONTOURS AND COMPLEX CROSS SECTIONS

by

Lou Frost (NAA/LAD)

This presentation described the various high energy operations, techniques and accomplishments of the El Toro Explosive Forming Facility of the Los Angeles Division, NAA, Inc. A fifteen minute 16 mm movie showed typical hardware and operation. Additional detailed information was illustrated by use of 35 mm slides.

Daily production at El Toro included waffles, gores, dollars, and elbows for the Saturn S-II Program. Pressure bags for subsequent brazing of F-1, J-2, and H-1 tubular rocket engines were explosively formed to a waffled Ogive shape for Rocketdyne.

Many R&D programs are underway to form dish heads, hemispheres, wingskin, formed tube shapes, and architectural panels for buildings. Densification of powdered metal compacts of materials such as tungsten, molybdenum, beryllium, copper, and aluminum have resulted in theoretical densities around 95% and above. Experiments are proceeding to make densified shaped bodies other than the cylinder, rectangles, tapered and hollow cylinders made to date.

SESSION II-A

SPACE VEHICLE PRODUCTION AND ATTENDANT REQUIREMENTS

by N67 12710

John S. Sheldon (Chrysler)

Various managerial techniques are utilized in achieving the desired quality, scheduling and cost control through the integration and coordination of organizational elements to maintain flexibility in manufacturing a highly developmental end product.

Master schedules should include the proper time for release of engineering information to enable production's establishment of materials, tooling, and process requirements. From the initial receipt of information to the delivery of the end product, close cooperation between design and production, with engineering development sequence matching manufacturing sequence, is required to avoid delivery delay and unnecessary and expensive rework, as well as to obtain desirable technological results. Production operations should be scheduled in parallel rather than in a series sequence, with adequate check points in the schedule to monitor timeliness of inputs of engineering information, materials, tooling and processes. At the point in design development beyond which it is generally conceived that major changes will not occur, it is possible to program production parallel with further design development by delaying production decisions as long as possible, without compromising the program, in order to incorporate the latest and most successful state of the art.

Programming is the most important element in continuously exercising management authority in a complex organization to accomplish its objectives. Provision must be made for coordinating and balancing efforts of individual organizational elements to the rate of progress of the whole organization.

SESSION II-B

N67 12711

CONTRIBUTION BY MANUFACTURING TO THE RELIABILITY PROGRAM

by

Otto Eisenhardt (MSFC)

Management of the Manufacturing Engineering Laboratory initiated a reliability program combining employee motivation with defect analysis, defect cause elimination, tabulation, recording, and reporting. This program includes all manufacturing oriented employees of the Laboratory, whether skilled craftsman, planning, process, tooling or methods research engineer. To implement this program, a Reliability Office with functions specifically adapted to the need of manufacturing development for space vehicles has been established.

The following procedures were adopted and their use made mandatory to administer the reliability program. (Note: A group of slides were used by Mr. Eisenhardt to illustrate data supporting these procedures).

1. List of defect categories and code numbers.
2. Obtain acceptance of responsibility.
3. Determine operational function, area of occurrence and primary cause.
4. Locate and report defect trends to management. Request corrective action.

5. Code and enter into ADP system.

6. Prepare monthly defect analysis report to management.

7. Prepare organization performance charts.

8. Prepare trend charts by manufacturing discipline.

To attain the aspired reliability in space vehicle manufacture, we must make reliability an essential part of our daily thinking and work, and not a separate function. The most essential step however is to recognize that the human being and his attitude toward his job is the most contributing factor to success or failure of any reliability program. The supervisor is the gate through which the working employee can and must be reached. The initial evaluation of defects by the supervisor is such a gate. By making the supervisor immediately aware of any defect occurrence, he is motivated to initiate speedy corrective action. Recognition of the employee who conscientiously reports defects detected during the manufacturing cycle is another step toward attaining the goal. Calling to the attention of departmental groups of employees their standing in regards to defects per manhour enlivens the desire to improve individual and group performance.

In the future, more and more demands for excellence in reliability will be placed on manufacturing as we approach manned flights in the Apollo program, extended flight times and the performance of more demanding operations in space. Reliability will irrevocably be with us as long as we manufacture space vehicles and related systems.

Therefore, let us remember, reliability can only be achieved by an intense awareness, vigilance, and attention to details by every member of the team.

SESSION II-C

N67 12712

SPACECRAFT MANUFACTURING DIVISION'S RESPONSIBILITY AFTER THE SPACECRAFT LEAVES THE ASSEMBLY FLOOR

by

William Dubusker (McDonnell)

After the spacecraft has been assembled and tested in the Spacecraft Manufacturing Division at St. Louis, it is air transported to KSC. It could be assumed that the responsibilities of the St. Louis Facility would end at this point, but this most assuredly is not the case. The spacecraft hasn't really left the Spacecraft Manufacturing Division, it has merely changed geographical locations. Although the spacecraft is at a remote site over 1,000 miles away, the St. Louis Spacecraft Manufacturing Facility continues to monitor and support the launch preparation at KSC.

Under the project concept, highly qualified and experienced manufacturing personnel are transferred from St. Louis to KSC as the workload dictates to participate in launch system operations. Conversely, KSC personnel travel to St. Louis prior to shipment for familiarization with the spacecraft and to minimize indoctrinization time at KSC. Various modes of communication are used to notify KSC of the negotiated changes that must be incorporated prior to launch. Work instructions, engineering orders, and blueprints are instantaneously data-faxed to KSC for immediate action to eliminate mission delay. Since the fabrication and checkout facilities at KSC are limited, most new part fabrication, modification, and retesting of components is accomplished at St. Louis on an expedited basis.

SESSION II-D

N67 12713

A METHOD OF SEQUENCING OPERATIONS AND REPORTING TECHNIQUE

by

Gerald R. Frazier (IBM)

This technique was developed to provide various departments with daily status reports. It is based on parts availability, parts installation, sequence to assembly and parts status.

Inputs are required from Production Control, Purchasing, Manufacturing, Cost Engineering, and Manufacturing Engineering which are combined as they are related to each other by part number, find number, and installation sequence. This combination results in one set of information rather than a variety of sets which create different conclusions.

All parts are coded to a location on their top assembly and to sequence of assembly within that location. Various other information codes are also included for description and combination with data from other operating groups. This information is inputted by punched cards which can be manipulated on standard data processing equipment.

Implementation of the system can occur without increase in work provided the right format is used when each group performs its regular tasks. Engineering change activity has been facilitated by the main reports and numerous by-product reports as the current status of each part is known.

Several data systems are presently combined in this technique and will be put to more extensive and automatic use in the future. The key systems are:

1. Engineering Bill of Materials
2. Manufacturing Routing Parts List
3. Production Control Inventory Status System

N67 12714

MECHANICAL MACHINE TOOL UTILIZATION IN SUPPORT OF MANUFACTURING RELIABILITY

by

Arnold C. Graham (NAA/Rocketdyne)

In any Manufacturing concern the machine is a major partner in the reliability of the product. In a large plant with hundreds of machine tools, and a product-mix involving short-run, long-run, and one-piece orders, parts made from simple metals and newly developed alloys, and particularly where the end-product must be virtually free of all defects, the management of machine tools assumes a great magnitude of importance.

Rocketdyne, a Division of North American Aviation, has developed a system which utilizes their mechanized direct labor data collection system to provide the answers to the following questions:

1. What is the available manned-machine time of the plant?
2. What is the down-time for maintenance of this population?
3. What is the productive time?
4. What are the parts, orders and the quality inspection record for each product completed on machine tools?

The system which provides management visibility in this area is called Mechanized Machine Tool Utilization. The unique capabilities of this system, based on a man-machine relationship, permit Rocketdyne to take advantage of existing mechanized accounting records to produce low-cost reporting on each individual machine. Management use of the outputs of this system have changed the entire profile of action to eliminate marginal or unloaded machines, to trace part defects associated with equipment, to correct the often overlooked cause of scrap and rework, and to supplement general plant management.

SESSION II-F

N67 12715

VEHICLE PROJECT ADMINISTRATION

by

F. T. Wells, Jr. (NAA/Apollo)

NAA's S&ID Apollo Manufacturing operates within a complex environment where the product is still being developed, the production rate is relatively low, and design change is the order of the day. In order to emphasize the integrated "vehicle stack" aspect of manufacturing control in this environment, while preserving the benefit of normal product-type identification and control within the Work Breakdown Structure, Apollo Manufacturing has developed what is called Vehicle Project Administratration. This function, performed by a select group of highly qualified, management timbre, manufacturing personnel, provides constant surveillance of manufacturing progress and problems on a vehicle-by-vehicle basis.

Vehicle/Project Administration: (1) coordinates preplanning and replanning activities of shop, manufacturing engineering, planning and other affected functions; (2) maintains current schedule and cost performance data, for regular and special review with appropriate management levels; (3) solves (or gets solved) significant problems of immediate or potential schedule or cost impact; (4) frees senior manufacturing management from time-consuming stack-oriented interface chores which are of a relatively routine nature; and (5) is responsible for manufacturing fabrication Work Packages.

How Vehicle Project Administration works--its organizational location and make-up, its tools and its products--were the subjects of this discussion.

SESSION II- G

N67 12716

TOOL EXPERIMENTS FOR ASSEMBLY, MAINTENANCE AND REPAIR IN SPACE

by

Robert J. Schwinghamer (MSFC)

The future need for high power in space assembly, maintenance, and repair operations was pointed out, and the advantages of energy storage and the pulse power concept were discussed. A typical solar charged pulse power system was described, and some typical pulse power tools which already exist were shown. Applications for space assembly and maintenance and repair were considered. Experiments were described which were intended to develop apparatus and techniques for creating at will cohesion and perhaps even adhesion in vacuum environments of 10-9 Torr or less. The system will ultimately use magnetomotive force as the driving mechanism, and promises to be an ideal joining technique in space. Actual tool performance and operational simulation experiments were treated. Preliminary neutral buoyancy simulation studies of tool performance were also described. Conclusions were drawn, regarding ordinary hand tools, certain types of lanyards and tethers, large or complicated vehicle or structural assembly, maintenance and repair tasks, and the mechanical advantages associated with pulse, and ordinary power tools. Also included were comments denoting the benefits associated with neutral buoyancy immersion techniques in the development of space tools, tool systems and applications, and the contention was further made that working with the actual one-to-one ratio hardware, preferably under neutral buoyancy immersion conditions, constituted a decided advantage.

SESSION II-H

N67 12717

WELD QUALITY ASSURANCE

by

John J. Bodner (Boeing)

An assembly which contains twelve miles of critical weldment warrants a comprehensive system of integrity assurance. Such an assembly is the Saturn S-1C, every inch of weld therein being subjected to Quality Assurance evaluation.

Preliminary weld data, for a particular assembly, is gathered from laboratory trials conducted on equipment similar to that used in production. Emphasis is on consistency of results, radiographic quality, and physical properties. Wherever possible, welds are mechanized to reduce inconsistency.

Certification of welding procedures is conducted to demonstrate that a particular combination of operator, tooling, and settings will produce acceptable results. Any of these three factors remains certified unless undesirable trends are noted. Certification is performed by Manufacturing and monitored by Quality Assurance, to standards set forth by Engineering. Demonstration of this proficiency is done on simulated parts in production tooling. The certification parts are destruct tested to verify satisfaction of Engineering requirements. Records of certifications are maintained by Quality Assurance who monitor all operations to verify adherence to limitations. This certification procedure obviates the destruct testing of full size assemblies, the cost of which would be prohibitive.

Inspection techniques used for the evaluation of S-1C weldments are varied, the prime method being radiograph. The equipment and fixturing used in this program are necessarily adapted to the product. The gross size of welded assemblies usually requires that evaluation be made in the welded position. Quality Assurance has designed apparatus to provide rapid exposure processing (through the use of roll film and mechanized weld traverse), and provide read-out results in a minimum flow-time (by automatic film processing).

Evaluation of weld quality is done by Quality Assurance to MSFC specification standards. In those borderline cases, in which repair might cause problems in excess of those presented by the original defect, Engineering and NASA review the indications. Repairs are made by factory, on those items which are unacceptable to these three organizations.

Defect trend reporting is used to pinpoint areas of effort which are in or approaching, an out of control condition. When this situation becomes apparent, those organizations responsible for corrective action respond accordingly. In the interest of rapid reaction, this information is published weekly in graphic form and problem areas are described by text.

SATURN MANUFACTURING REVIEW

APPENDIX A

LIST OF ATTENDEES

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MICHOUD ASSEMBLY FACILITY
NEW ORLEANS, LOUISIANA

MAY 24 - 25, 1966

SATURN MANUFACTURING REVIEW
MICHOUD ASSEMBLY FACILITY
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