Propulsion Test Handbook: MSFC & SSC

Draft 01

FOR REVIEW ONLY

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Preface

General Information
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Section 1.1: General Information

This Handbook was prepared to provide Propulsion Test Personnel a central source of fundamental reference material.

Section 1.2: The Testing Process

The Testing Process, which is a three-part process of pre-test activities, testing, and post-test activities, involves a collaborative effort from the mechanical, electrical, safety, and environmental disciplines in the test environment. Pre-test activities, testing, and post-test activities processes will vary, per test requirements; however, the content of this Handbook should cover basic procedures and standards that are shared across Centers.

Section 1.3: Chapter Overviews

The Mechanical chapter of this handbook focuses on test facility hardware and the accessories, tools, procedures, and handling of this hardware in propulsion testing. Identification and usage of items in this chapter include the following: test facility hardware and their connective devices, lubrication and packaging types, liquid propellants and other chemicals, rigging types, hand tools, and compressed bottles.

Further content TBD.

Pipe, Tube, and Fittings
Contents

Page

2.1: Introduction

Pipe and tubing are used for the transfer of fluids between vessels and other equipment. Pipe is distinguished from tubing by the fact that the nominal size refers to the approximate inside diameter of the pipe. The outside diameter of the various sizes of pipe is constant, and therefore, as pipe wall thickness increases, the flow passage must decrease in size. Pipe sections may be joined by screwed, welded, or flanged joints.

Tubing size is specified by outside diameter and comes in various wall thicknesses. The difficulty of obtaining good quality flares with 0.100 inch and heavier walled stainless steel tubing makes its use impractical. Tubing in use at the Field Laboratories varies in size from 1/8" to 2" in diameter. Tubing connections are made with MS or AN screwed fittings.

2.2: Selection of Pipe and Tubing

2.2.1: Pipe and Pipe Fittings

Tables 2-1 and 2-2 show allowable pressures for different kinds of pipe. The selection of pipe for a given installation should be based on these tables. The design pressure of the system should always be equal to or less than the allowable pressures shown in the tables.

Pipe fittings are designed to have a bursting strength that is not less than pipe of the same material and schedule number. Therefore, fittings should be selected with the same schedule number as the pipe that is to be used for a given service.

Where a fitting is stamped with a pressure rating by the manufacturer, this pressure represents the maximum allowable working pressure of the fitting.

Table 2-1. Maximum Allowable Working Pressure for Seamless Stainless Steel Pipe

Pipe Size		SEAMLESS UNTHREADED STAINLESS STEEL PIPE Pipe Schedule Number and Maximum Allowable Working Pressure, PSI					
NOMINAL	O.D.	5S	10S	40S	80S	160	XX
1/2	0.840	2860	3720	5000	#	#	#
3/4	1.050	2260	2930	4070	5720	#	#
1	1.315	1790	3090	3810	5270	#	#
1-1/4	1.660	1410	2410	3140	4380	5890	#
1-1/2	1.900	1230	2090	2820	3980	5770	#
2	2.375	980	1660	2380	3430	5640	#
3	3.500	840	1230	2260	3190	4800	#
4	4.500	650	950	1910	2770	4500	5860
5	5.563	700	860	1680	2480	4270	5210
6	6.625	580	720	1520	2390	4110	5020
8	8.625	450	610	1340	2110	3970	3820
10	10.750	440	540	1220	1680	3950	3480
12	12.750	430	500	1050	1410	3880	2900

NOTE:

1. Allowable working pressure in psi: from -325˚F to 100˚F.
2. Allowable stress = 20,000 psi (Safety Factor is 3.75) for ASTM A 312 seamless grade TP 304, 316, 321, ad 347.
3. Use 83% of table values for grades 304L and 316L.
4. No allowance for corrosion or mechanical weakness is included.

* The ANSI Piping Code references the procedures utilized by the ASME in determining the suitability of materials for use at lower temperatures, i.e., liquid hydrogen temperatures. The ASME Unfired Pressure Vessel Code establishes minimum impact resistance requirements and states that stainless steel types 304, 304L, and 347 are suitable and need not be further tested. Generally, any of the 300 series wrought annealed stainless is satisfactory, while 200 and 400 are not.

Table 2-2. Maximum Allowable Working Pressure for Seamless Carbon Steel Pipe

		SEAMLESS UNTHREADED CARBON STEEL PIPE					
Pipe Size		**Pipe Schedule Number and Maximum Allowable Working Pressure, PSI**					
NOMINAL	O.D.	5	10	40	80	160	XX
1/2	0.840	330	1100	2260	4050	6070	#
3/4	1.050	260	880	1930	3450	6010	#
1	1.315	210	1420	2100	3470	5720	#
1-1/4	1.660	170	1120	1810	2990	4430	#
1-1/2	1.900	150	970	1670	2780	4490	#
2	2.375	120	780	1470	2490	4600	#
3	3.500	260	640	1640	2550	4120	6090
4	4.500	200	490	1440	2280	3980	5310
5	5.563	330	490	1300	2080	3850	4780
6	6.625	280	410	1210	2060	3750	4660
8	8.625	210	370	1100	1860	3700	3550
10	10.750	250	350	1020	1810	3740	--
12	12.750	270	340	970	1790	3700	--

NOTE:

1. Allowable pressure in psi: from -20˚F to 100˚F.
2. Allowable stress = 20,000 psi (Safety Factor is 3) for ASTM A 53 or A 106 Grade B.
3. Use 80% of table values for Grade A.
4. A corrosion allowance of .050 inch is included in this table, which is typical for carbon steel lines exposed to weather or for buried installations. Where corrosion is not a factor, the higher values, which are obtained by the formula (omitting corrosion) may be used.

2.2.2: Flanges and Flange Fittings

Flanges and flanged fittings are rated for a primary service at a temperature in the range of 500 to 1,125˚ F. The rating also depends on the type of gasket. The majority of items at the field laboratories are rated at 100˚ F service temperature. Ratings of Standard ASA flanges are shown in Table 2-3.

Table 2-3. Pressure Ratings of ASA Standard Steel Flanges

MAXIMUM SERVICE PRESSURE RATING FOR ASA FLANGES AT 100˚ F, PSIG			
ANSI B16.5 Class	**Carbon Steel A 105**	**Stainless Steel A182 Type 304, 316, 321, 347**	**Stainless Steel A182 Type 304L, 316L**
150	285	275	230
300	740	720	600
400	990	960	800
600	1480	1440	1200
900	2220	2160	1800
1500	3705	3600	3000
2500	6170	6000	5000

NOTE: These are minimum ratings, based on usage of best type gasket.
When ordering weld-neck flanges, the bore corresponding to the ID of the pipe schedule to be used should be specified.

2.2.3: Flanged Pipe Connections

2.2.3.1: Standard ASA Flanges

The ASA standard flanges are suitable for use with pressure systems to 6,000 psi. Flanges are available in many types and facings as shown in Figure 2-1.

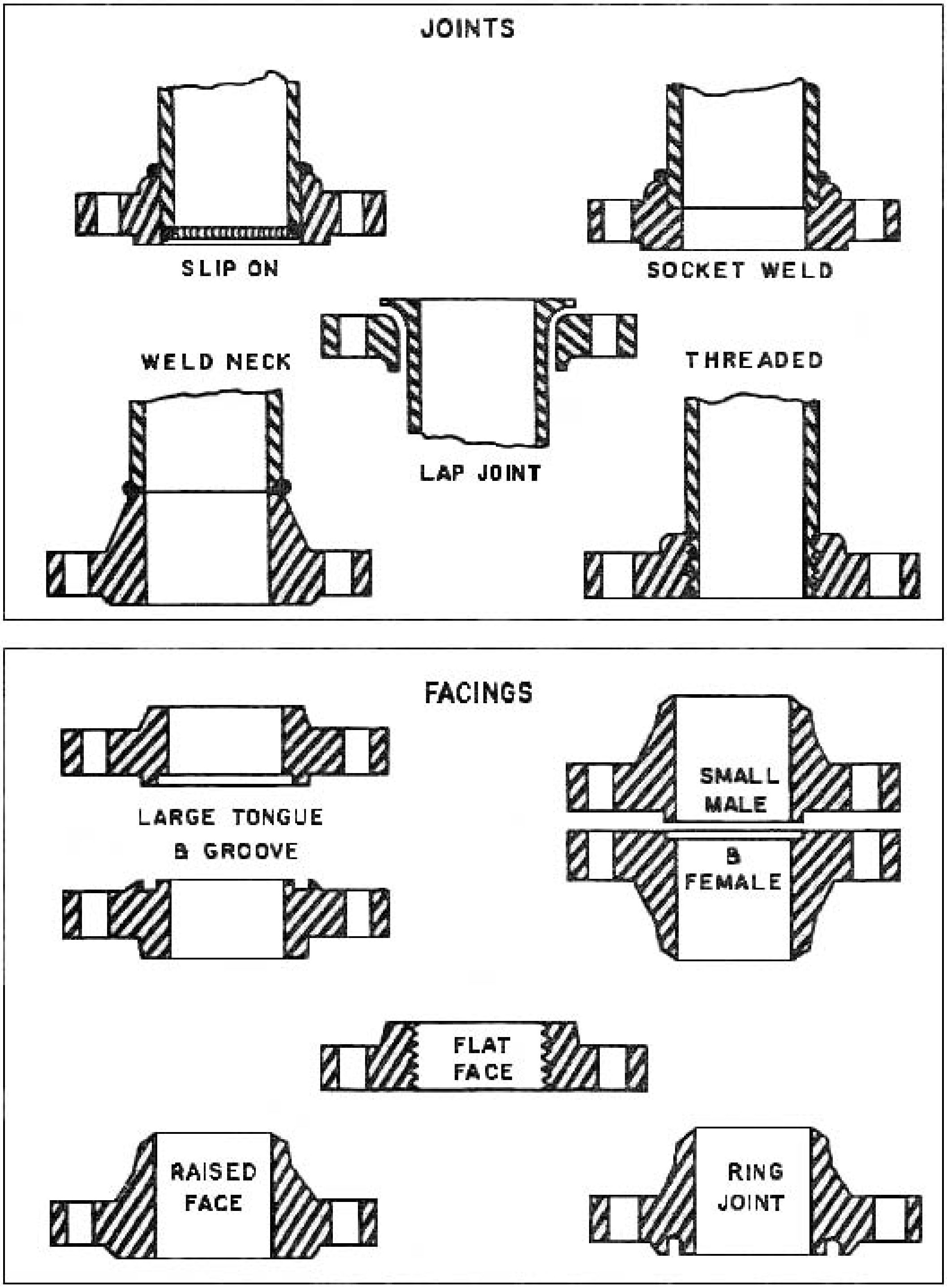


Figure 2-1. American Standard Flanges

2.2.4: High Pressure Flanged Fittings

For pressures above 6,000 psi, Grayloc type flanged fittings should be used.

2.2.4.1: General

Grayloc couplings offer a quick and sure means for joining the components of any piping system. They are leak tight on assembly, and they should remain leak tight even in the most extreme operating conditions.

As in the case with any precision made equipment, Grayloc connections should be handled with reasonable care. The following information is presented as a guide for proper care and installation of these connections. A few moments spent considering the points discussed will help insure their proper installation for maintenance-free service.

A complete Grayloc connection consists of the following components: (see Figure 2-2).

2 Grayloc Hubs
1 Grayloc Seal Ring
1 Set of Grayloc Clamps (consisting of two or three clamp segments, complete with studs and nuts)

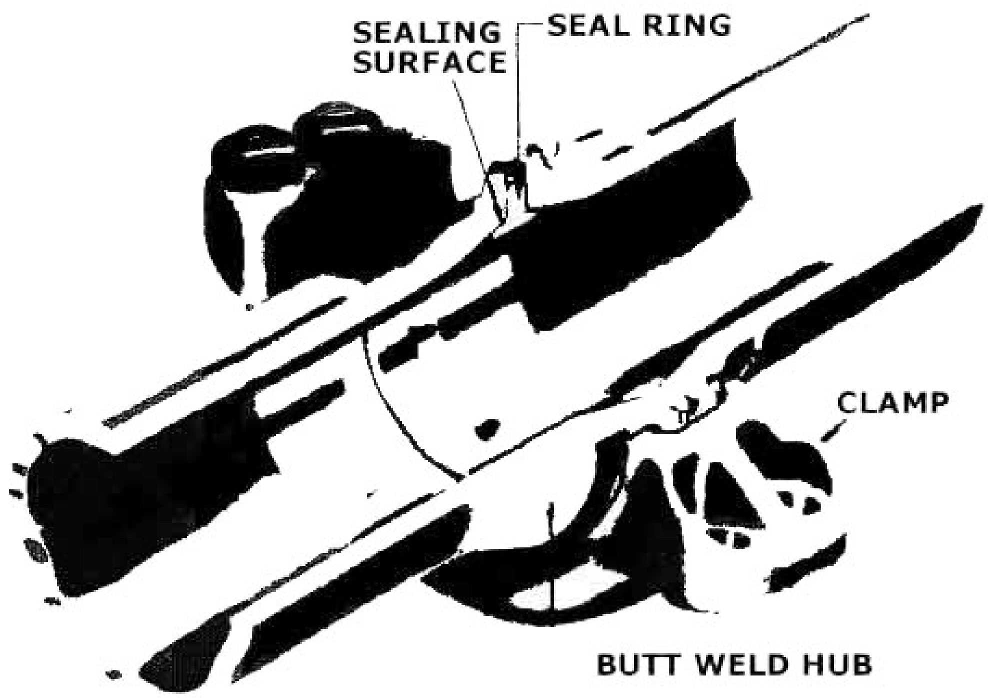
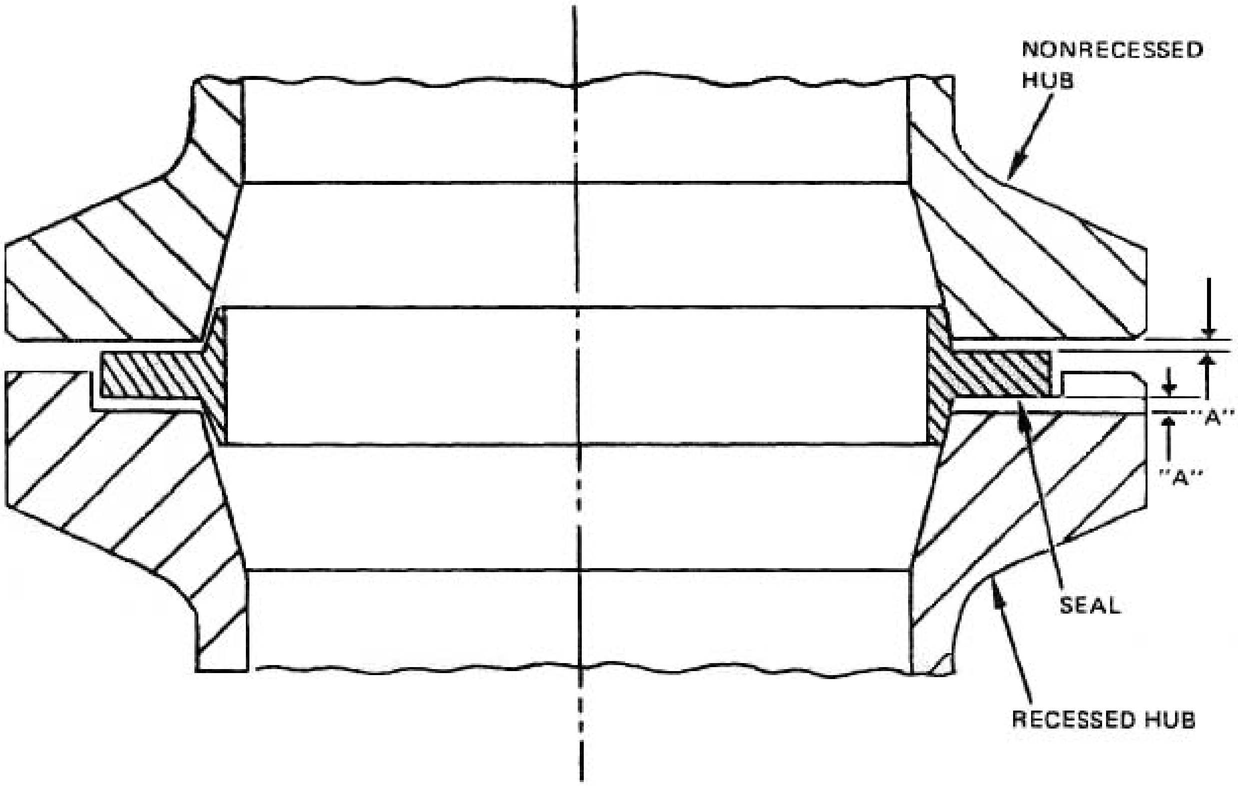


Figure 2-2. Typical Grayloc Connection

The Grayloc Seal Ring does not seat until the connection is fully tightened; therefore, a small clearance or standoff should be noticeable when the ring is placed into a mating hub ring seat. This standoff is the clearance between the hub face and seal ring. See Figure 2-3 for some representative minimal standoff dimensions. As the connection is tightened, the seal lips deflect, making contact with the hub sealing surface and the hub face shoulder against the ring rib. Even though the lip deflection is essentially elastic, and the lips return approximately to their original shape, it is recommended that a new seal be used upon a joint remake.



SEAT RING SIZE	"A" DIM. (MINIMUM STANDOFF DIMENSION)
14	.007
20	.006
25	.007
31	.007
34	.009
52	.012
62	.025

Figure 2-3. Minimum Standoff Dimension

2.2.4.2: Fabrication

The sealing surfaces of Grayloc hubs and rings should be protected throughout fabrication to avoid damage due to handling, heat scale and weld splatter.

Fabrication Alignment Tolerances

Grayloc hubs should be aligned with pipe or vessels. Unrestrained shop tolerances for this work are as follows:

a. Axial – Misalignment: ± .010" + thickness of seal rib. (See Figure 2-4.)*
**Allowances should be made for seal recesses.*

b. Radial – Misalignment: ± 0.10"

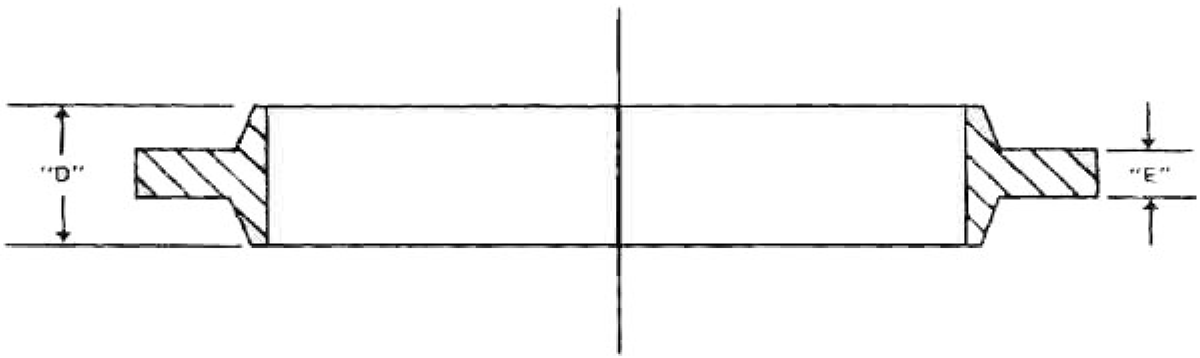
c. Angular – Misalignment: All hubs should be square with the axis of the pipe or equipment item by ± .010" and parallel with .010”.

In assembling piping, it should be noted that very rigid systems will require closer tolerance for proper assemblies than very flexible systems. Therefore, all short spool pieces should be made up first; longer, more flexible ones left for last.

Special note should be made of the seal width (Figure 2-4). The last joint in each section must be made within the fabrication tolerances, with provisions to insert or remove the seal.

In field fabrication, perfect alignment can be achieved by creating the connection and completing the system by the butt weld of the Grayloc hub to the pipe. In this work, it is necessary that the ground clamp of the welding machine be on the same side of the fitting on which the weld is being made (under no condition should the arc welding current be carried through the seal ring). Care must also be taken to see that the hub and seal element remain cool, to prevent stress relieving of the seal ring. Normal welding operations impose no problem.

GRAYLOC SEAL RINGS RIB AND SEAL WIDTH



RING SIZES	"D" DIM (SEAL THICKNESS)	"E" DIM. (SEAL RIB)
4 TO 11	.375	.125
14	.563	.250
20 TO 34	.750	.250
40 TO 52	1.000	.250
62 TO 102	1.375	.375

Figure 2-4. Grayloc Seal Rings Rib and Seal Width

<u>Preheat</u> — For the normal temperature range of preheat (200˚ F to 400˚ F), special protection against oxidation of Grayloc sealing surfaces is not required. If preheat above this range is required, the Grayloc ring seat should be protected.*

<u>Welding</u> — Welding is not allowed on Grayloc clamps or seal rings.

Protect the Grayloc ring seats from weld splatter during welding.*

If the inside weld bead requires grinding, extreme care must be taken not to damage the Grayloc ring seat by allowing the grinding wheel or grinding machine to come into contact with it.

<u>Stress Relieving</u> — When stress relieving is required, always protect the Grayloc sealing surfaces to prevent oxidation and scaling.* Beat treatment of any kind above 1,100˚ F should not be performed on finished Grayloc hubs.

***** NOTE:** *To prevent oxidation, scaling, or weld splatter damage to Grayloc ring seats, apply a coat of some protective product, such as Key Red-D-Mix (Manufactured by W-K-M Division, ACF Industries, Inc.)*

Sandblasting — Never sandblast a Grayloc ring seat, or the connection's effectiveness will be destroyed.

Protective Coating — Permanent protective coatings, such as metalizing or painting, which cannot be easily removed before assembly, should not be applied to the seal surfaces of either Grayloc rings or hubs.

2.2.4.3: Assembly

Assemble the Grayloc connection with the clamps in any position desired for accessibility.

Clean Seal Surfaces — All protective coatings and foreign matter must be cleaned from the hub sealing surfaces and from the seal ring before installation.

Grayloc connections should be assembled, clean and dry.

Alignment — Adjacent Grayloc hubs should be aligned so that the clamp segments can easily be engaged and can pull the hubs against the seal ring rib uniformly without excessive tightening of the clamps or springing of the piping system. The fabrication tolerances should be used in assembly. They are as follows:

a. Axial – Misalignment: ± .010" + thickness of seal rib (See Figure 2-4.)

b. Radial – Misalignment: ± .010"

c. Angular – Misalignment: All hubs should be square with the axis of the pipe or equipment item by .010" and parallel within .010".

Visual Inspection — A final visual check of the components before assembly will help locate any damage caused by accidents in transportation or handling during fabrication. High spots on the hub faces of clamp shoulders shall be filed smooth. Defects on the hub sealing surface require more careful attention. Light nicks and scratches may be removed by lightly polishing with fine steel wool. Deep scratches or indentations on the sealing surfaces that do not disappear when lightly polished are cause for component replacement.

Clamp Makeup — No special tools are required to make up a Grayloc connection. The Grayloc seal ring will not be damaged by overtightening; however, other components of the connection can be distorted by excessive tightening. Whenever possible, Grayloc clamp studs and nuts should be lubricated before tightening.

2.2.4.4: Maintenance

When Grayloc connections have been properly installed, they require no special maintenance during normal operations. See Table 2-4 for torque ranges.

CAUTION:
Never attempt to tighten the studs on a Grayloc connection while the assembly is under internal pressure or is carving large external mechanical loads.

Table 2-4. Two-Bolt and Four-Bolt Minimum and Maximum Torque in Ft Lbs

TORQUE FT. – LBS.				
Stud Bolt	**Two Bolt**		**Four Bolt**	
Size	**Minimum**	**Maximum**	**Minimum**	**Maximum**
3/8 – 16 UNC-2	12	16	6	8
5/8 – 11 UNC-2	60	80	30	40
3/4 – 10 UNC-2	100	130	50	65
7/8 – 9 UNC-2	160	210	80	105
1 – 8 UNC-2	240	330	120	165
1-1/8 – 8N-2	360	470	180	235
1-1/4 – 8N-2	500	670	250	335
1-3/8 – 8N-2	680	900	340	450
1-1/2 – 8N-2	800	1050	400	525
1-5/8 – 8N-2	1100	1450	550	725
1-3/4 – 8N-2	1500	2000	750	1000
1-7/8 – 8N-2	2000	2700	1000	1350
2 – 8N-2	2200	3000	1100	1500
2-1/4 – 8N-2	3200	4300	1600	2150
2-1/2 – 8N-2	4400	5900	2200	2950
2-3/4 – 8N-2	6000	8000	3000	4000

If scale or rust have formed on the sealing surfaces of the connection, it should be removed before assembly by lightly polishing with fine steel wool or by lapping.

CAUTION:
Never lap the Grayloc hub ring seat with a Grayloc seal ring, as this practice will damage both the ring seat and the seal ring.

The tapered seat in Grayloc hubs is machined to closely-controlled dimensional and surface finish tolerances. It is not recommended that field rework on this sealing surface be undertaken without detailed machining information and adequate gauging.

2.2.5: Tube and Tube Fittings Flared

Only annealed stainless steel seamless tubing should be used in the Field Laboratories. Table2-5 shows the allowable pressures for different kinds of tubing. The selection of tubing for a given installation should be based on this table. The design pressure of the system should always be equal to or less than the allowable pressures shown in the table.

Table 2-5. Maximum Allowable Working Pressure in PSI for Seamless Stainless Steel Fully Annealed Tubing (electronic copy version)

Wall Thickness Tubing OD	0.020	0.035	0.049	0.065	0.072	0.095	0.109	0.120	0.134
0.25	2817	5147	7515	----	----	----	----	----	----
0.375	1856	3341	4806	6581	7395	----	----	----	----
0.5	1468	2626	3755	5107	5720	7824	9108	----	----
0.75	972	1727	2451	3304	3686	4981	5800	6461	7326
1.0	727	1286	1819	2442	2719	3652	4235	4703	5310
1.25	580	1025	1446	1937	2154	2882	3335	3697	4164
1.5	481	849	1196	1599	1778	2372	2741	3035	3413
2.0	361	635	893	1192	1324	1761	2032	2246	2521

NOTE:
This will calculate the MAWP for tubing using B31.1 section 104.1.2 equation 4 as noted below.

P=(2SE(t-A)/(D-2y(t-A)

The MAWP shown accounts for 12.5% mill tolerance.

SE (psi)	20000	A312 TP304 seamless tube
A	0	
y	see table	see table
mill tol wall (%)	15	up to 0.5OD
mill tol wall (%)	10	>/= 0.5 OD
mill tol OD (in)	0.005	up to 1.5 OD
mill tol OD (in)	0.010	>/= 1.5 OD

Fittings are designed to be as strong as the strongest tubing of like material, which can be used with the fitting. In the size range from 1/8" through ¾", it is possible to make a system leak-tight up to 6,000 psi by use of copper seals and polished sealing surfaces. Sizes 1" and larger are more difficult to seal. Table2-6 indicates pressures that may be achieved in a carefully assembled system.

Table 2-6. Achievable Pressures in Carefully Assembled Tube Systems

TUBE SIZE, INCHES	PRESSURE, PSI
1	5,000
1 – 1/2	2,000
2	1,000

2.2.6: Tube Fittings

2.2.6.1: Flared Fittings

The AN/MS fitting consists of three pieces: a coupling nut (AN818), a sleeve (MS20819), and a male connector. The sealing occurs between the nose of the fitting and the inside of the flare on the tubing. AN819D aluminum sleeves are not used at the field laboratories since the aluminum work hardens and tends to crack. See Figure 2-5.

AN specifications and AN parts are—in many instances—being replaced by MS specifications and parts. In some cases the AN and MS parts are interchangeable. Check the Rocketdyne Standards Manual for applicable specifications.

Stainless steel and AN/MS fittings are structurally limited to the following pressures (based on a 4:1 safety factor):

1. 1/8" through 7/8" size – 6,000 psi
2. 1" through 1-1/4" size – 5,000 psi
3. 1-1/2" through 2" size – 4,500 psi

NOTE: System pressure limit is determined by associated tubing.

Tubing shall be flared to conform to AN or MS standards and checked accordingly for cracks, burrs, sharp edges, and concentricity. See Chapter 8, *Hand Tools*.

Where possible, tube and fitting material shall be alike to reduce the possibility of scratching, distortion, and galvanic corrosion associated with the use of dissimilar materials.

Where flares are damaged or otherwise defective, the flare shall be removed and a new flare made. Tubing shall not be reflared.

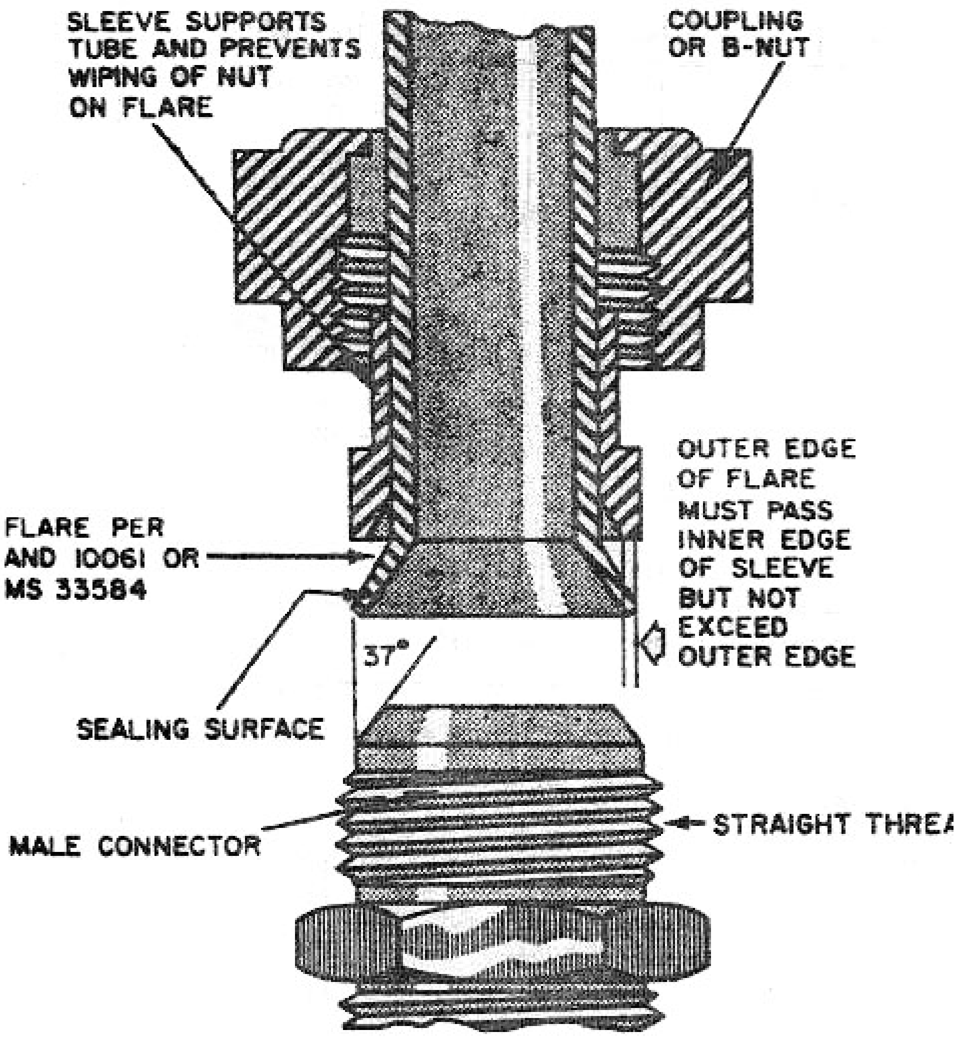


Figure 2-5. 3-Piece AN Flared Tube Fitting Per MS33656

2.2.6.2: AN and MS Fitting Threads

AN and MS fittings employ two types of thread: 1) the AN or MS straight thread that uses the American National Fine Thread Series and 12 thread series, and 2) the American Standard Taper Pipe Thread (NPT). The straight thread is always used for tubing fittings and often on other fittings. The NPT is used on fittings other then tubing fittings.

The two thread types are not identical, and though some of the sizes appear to be interchangeable, joining the two will form an imperfect joint. See Table 2-7.

Table 2-7. AN Fittings, Straight Thread Sizes (Per MIL-S-7742)

Tubing OD, inch	Fitting Dean No.	Fitting Thread Size*
1/8	2	5/16 – 24 UNF – 3B
3/16	3	3/8 – 24 UNF – 3B
1/4	4	7/16 – 20 UNF – 3B
5/16	5	1/2 – 20 UNF – 3B
3/8	6	9/16 – 18 UNF – 3B
1/2	8	3/4 – 16 UNF – 3B
5/8	10	7/8 – 14 UNF – 3B
3/4	12	1-1/16 – 12 UN – 3B
1	16	1-5/16 – 12 UN – 3B
1-1/4	20	1-5/8 – 12 N – 3B
1-1/2	24	1-7/8 – 12 N – 3B
1-3/4	28	2-1/4 – 12 UN – 3B
2	32	2-1/2 – 12 UN – 3B

*Diameter – Threads per inch – Thread type

2.2.6.3: AN and MS Fitting Designation

Fitting numbers are made up of the basic number followed by a dash number. See Figure 2-6 for images of tube fittings.

The basic number indicates the type of fitting.
Dash numbers indicate the size of fitting.

Fittings are made of four materials: steel, aluminum alloy, copper-based alloys, and corrosion-resistant steel. The following list shows the letter and number designations of all four materials:

No letter with dash number indicates steel.
The letter "D" with dash number indicates aluminum alloy.
The letter "B" with dash number indicates copper alloy.
The letter "C" with dash number indicates corrosion-resistant steel.
The letter "J" with dash number indicates 304SS.
The letter "K" with dash number indicates 316SS (to be used in water systems).

When the fitting steel or aluminum alloy only, the following applies:

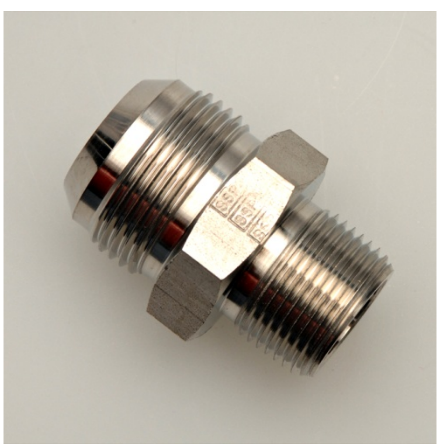
No letter with dash number indicates steel.
The letter "D" with dash number indicates aluminum alloy.

Tee

MS Tee

MS Tee

Elbow



Pipe to Tube Adapter

Bulkhead Union

Figure 2-6. Tube Fittings (1 of 4 Sheets)

AN Cross

Union

Swivel Tee

Swivel Elbow

Pipe Bushing

Pressure Plug

Figure 2-6. Tube Fittings (2 of 4 Sheets)

Pressure Cap

Reducer

TRTX Reducer

B-Nut and Sleeve

Jam Nut

Tubing Support Clamps

Figure 2-6. Tube Fittings (3 of 4 Sheets)

Spring Nut Washer

Pneumatic Filter

Figure 2-6. Tube Fittings (4 of 4 Sheets)

When the fitting is obtainable in copper alloy or aluminum only the following applies:
No letter with dash number indicates copper alloy.
The letter "D" with dash number indicates aluminum alloy.

AN fittings are colored for identification as shown in Table 2-8.

Table 2-8. Tube Fitting Color Code and Pressure Rating

Material	Color	Pressure Limit
Steel (Carbon)	Black	3,000 psi
Aluminum Allow	Blue	3,000 psi
Corrosion-Resistant Steel	Natural	6,000 psi
Copper Base Alloys	Natural Cadmium Plate	(not stocked)

Fittings have two types of connector thread ends, straight thread ends, and pipe thread ends.

2.2.6.4: RD Fitting Designation

Rocketdyne has found it necessary to design a number of fittings, which deviate in one way or another from the AN or MS Standard counterpart. The deviation might be that of the following:

- Finish
- Size
- Configuration
- Addition of lockwire holes
- Lubrication (Dry Lubed)
- Other deviations

The Rocketdyne design numbering system for fittings is shown in Figure 2-7. For further information refer to the Rocketdyne Standards Manual.

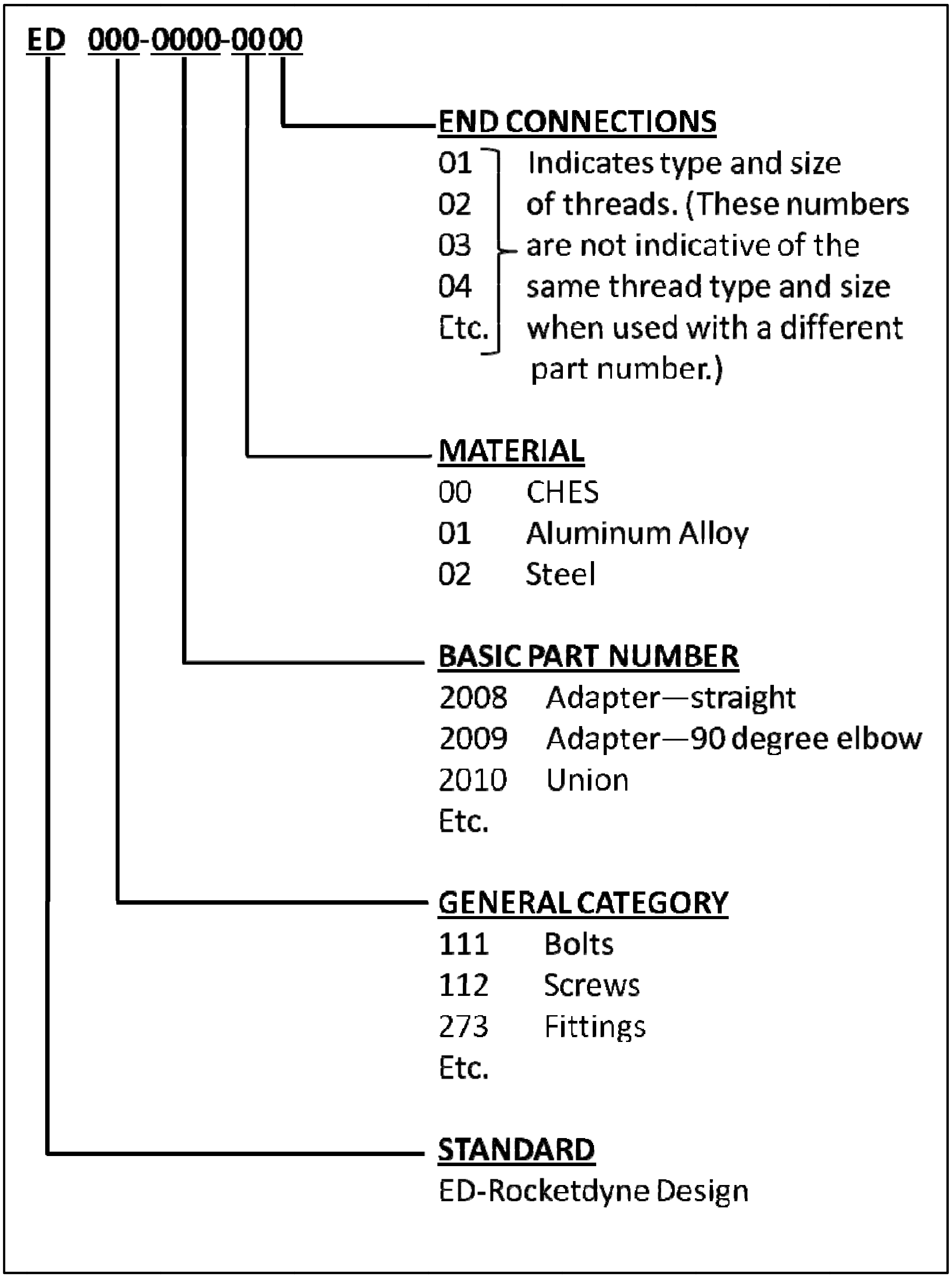


Figure 2-7. Rocketdyne Fittings Design Numbering System

2.2.7: Superpressure Tubes and Fittings

For pressures above 6,000 psi, superpressure tube and fittings should be used.

The pressure limitations on special high pressure fittings are shown in Table 2-9.

Table 2-9. Pressure Limitations on Special High Pressure Fittings

TUBING INCHES		FITTING PORT OPENING-INCHES	PRESSURE
9/16	-	5/16	20, 000 psi
9/16	-	1/4	60,000 psi*
3/8	-	5/32	60,000 psi*
1/4	-	1/6	60,000 psi*

* System Pressure Limit determined by associated tubing.

NOTE: Some Manufacturers rate tubing at pressures which cannot be confirmed by code formulae.

2.2.7.1: Superpressure Fittings

Superpressure, union-type fittings consist of four parts: a male tube, a female connection in valve or fitting, a gland nut, and an inner sleeve. The male tube has a 59 degree conical seating surface that mates with a corresponding 60 degree female conical seat in the body. The male tube an inner sleeve have left-hand threads; the land nut and opening in the valve or fitting body have right-hand threads. As the gland nut is slipped over the sleeve and screwed into the opening in the body, the sleeve is tightened on the tubing at the same time as the conical seating surfaces are sealed. A typical fitting is shown in Figure 2-8. See Chapter 8 for technique to cut cone.

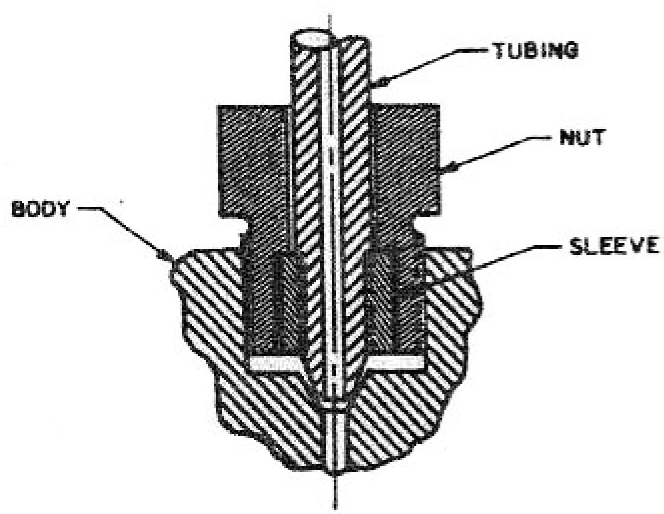


Figure 2-8. Superpressure Fitting

2.3: Pipe and Tubing Connections

2.3.1: Threaded Pipe Connections

The normal pipe threads used in the Field Laboratories are the following:

Standard Pipe Threads

NPT: American Standard - taper pipe threads
NPSL: American Standard - straight pipe threads (for loose fitting mechanical joints with locknuts)

Dry Seal Pipe Threads

NPTF: American Standard - taper pipe thread (for fuel and oil)

The dry seal threads have a closely controlled truncation of the crest and root of the threads to minimize spiral leakage in the joint.

2.4: Pipe and Tubing Installation

2.4.1: General

Installation of pipe and tubing should be done in a neat and orderly manner. Groups of parallel tubes should be aligned and uniformly spaced. Where possible a common rack or strut should be provided to support the entire group of tubes. Similarly, pipe should be run in an economical manner between the start and finish point. Where several pipes are run in the same location, they should be parallel and at the same elevation so that a common pipe rack may be used to support them. It is not necessarily economical to run diagonal lines between two points, since the layout must allow piping expansion and contraction. By judicious layout of a system, it is usually possible to provide flexibility without the need of flexible hose or expansion joints, minimize connections and fittings, provide heat shielding by use of structural members, and optimize drainage of the system.

2.4.2: Piping Expansion and Flexibility

When a piping system expands (or contracts) under the influence of a change in temperature of the contained fluid or surrounding atmosphere, each individual run increases (or decreases) in length. If only one point of the line were kept in a fixed position when the line is expanding, growth radially outward from this point could take place with perfect freedom and no stresses would be set up. Actually, however, piping systems have more than one fixation; they are nearly always restrained at their terminal points by the equipment they connect, and often also at intermediate points by anchors, guides, stops, rigid hangers or sway braces; these restraints develop resistance to expansion and thereby put the line under stress and cause it to deform.

Cryogenic lines may be cooled to temperatures as low as -423˚ F when subjected to liquid hydrogen. Table 2-10 shows the contraction that would occur in a 10-foot length of metal line when cooled from 70˚F to -423˚ F.

Table 2-10. Contraction of 10-Foot Length of Tubing at -423˚ F

Material	Contraction, Inches
Stainless Steel	0.37
Copper	0.4
Aluminum	0.48

Longer lines will have a proportionately greater contraction. If the line is not flexible enough to provide this contraction, the material will be permanently distorted, and may possibly fail. Every installation must be evaluated on the basis of its normal service. If the line is heated, it will expand rather than contract.

Table 2-11 shows some typical Field Laboratory service conditions, and the expansion or contraction that would be expected.

Table 2-11. Estimated Expansion or Contraction of a 10-Foot Length of Pipe

Type Systems	Inches	
	Contraction	Expansion
5,000 psi GH_2 Blowdown line	0.1	
Liquid Oxygen	0.34	
Compressor Discharge (Carbon Steel)		0.2
Hot GN_2 at 350˚ F (CRES)		0.3

2.4.3: Tubing Supports

Recommended maximum spacing for rigid line tubing assemblies is given in Table 2-12. Tubing supports in a test area, or where subjected to vibration, should be placed adjacent to fitting such as unions, tees, etc., in addition to the spacing given in Table 2-12. Supports should be placed as close to bends as possible.

Valves and similar components, which are not supplied with mounting holes, may be supported by the tubing, provided a tube support is pieced as close as possible on each side of the component.

Straight tubes should not be used between two rigid connections, because of the high stresses imposed when the tube expands or contracts. Supports must be located to allow for expansion and contraction

Tubing assemblies must be supported to prevent undesirable stresses and consequent weakening of the system. In addition, proper support minimizes the danger of recoil and line whip in the event of tubing failure caused by excessive pressure.

Where tubes of different diameters are connected, average spacing may be used. Supports should be placed as close to each side of valves, regulators, etc., as practical. Overhang should be minimized by placing supports as close to bends as conditions will allow.

Table 2-12. Maximum Rigid Tubing Support Spacing

	LOCATED IN TEST AREA AND/OR SUBJECT TO VIBRATION, INCH		NOT IN TEST AREA NO VIBRATION, INCH	
Tube OD, Inch	**Aluminum**	**Stainless Steel**	**Aluminum**	**Stainless Steel**
1/4	14	16	48	48
5/16	15	18	48	48
3/8	17	20	48	48
1/2	19	23	60	72
5/8	22	26	60	72
3/4	24	28	60	72
1	27	30	84	108
1-1/4	29	32	84	108
1-1/2	31	34	84	108
2	36	38	84	108

NOTE:
1. Tubing supports in a test area, or where subjected to vibration, should be placed adjacent to fittings such as unions, tees, etc., in addition to the spacing listed in the table.
2. Valves and similar components which are not supplied with mounting holes may be supported by the tubing, provided a support is placed as close as possible on each side of the component.
3. Where tubes of different diameters are connected, average spacing may be used.
4. Overhand should be minimized by placing supports as close to bends as possible.

2.4.4: Pipe Supports

Supports must be fabricated and assembled to permit the free movement of piping, caused by thermal expansion and contraction or by other causes.

Spacing of supports must prevent excessive sag, bending and shear stresses in the piping, with special consideration given to those piping sections where flanges, valves, etc., impose concentrated loads. Where calculations are not made suggested spacing of hangers or supports for piping operating at 100˚ F and lower are given in Table 2-13.

Table 2-13. Maximum Pipe Support Spacing

Nominal Pipe Size (Inches)	**MAXIMUM SPAN (FEET AT 100˚ F)**		
	Stainless and Carbon Steel	**Aluminum Alloys**	**Copper**
1	8	8	5
1-1/2	9	9	6
2	10	10	6
2-1/2	12	11	7
3	13	12	8
3-1/2	14	12	8
4	15	14	9
5	16	15	10
6	18	16	10
8	19	17	11
10	22	18	13
12	23	20	14

2.4.5: Bend Radii of Tubing

Tubing installations requiring bends must be accomplished with minimum distortion and constriction of the tubing. See Chapter 8, *Hand Tools*. A satisfactory bend is one which decreases tubing OD less than 6 percent. Minimum bend radii will yield satisfactory bends when accomplished with the proper tools and methods. See Table 2-14. Attempts at tube bending with improper tools or by incorrect methods will result in constricted sections of bend with a reduction of fluid flow. Such incorrectly bent sections should not be installed.

Table 2-14. Minimum Tube Bend Radii

Minimum Bend Radii for Stainless Steel and Aluminum Alloy Tubing
(All measurements in inches)

Tube OD	Wall Thickness	Inside Bend Radii	Radii to Center of Tube
3/16	any	5/8	23/32
1/4	any	3/4	7/8
5/16	any	3/4	29/32
3/8	Through 0.022	1-1/2	1-11/16
	over 0.022	1	1-3/16
1/2	Through 0.028	1-3/4	2
	over 0.028	1-1/2	1-3/4
5/8	Through 0.028	2-1/2	2-13/16
	over 0.028	1-3/4	2-1/16
3/4	Through 0.028	3	3-3/8
	over 0.028	2-1/2	2-7/8
7/8	Through 0.035	3-1/4	3-11/16
	over 0.035	2-3/4	3-3/16
1	Through 0.035	3-1/2	4
	over 0.035	3	3-1/2
1-1/8	Through 0.035	4	4-9/16
	over 0.035	3-1/4	3-13/16
1-1/4	Through 0.035	4-1/2	5-1/8
	over 0.035	3-1/2	4-1/8
1-1/2	Through 0.035	6	6-3/4
	over 0.035	4	4-3/4
1-3/4	Through 0.035	7	7-7/8
	over 0.035	5	5-7/8
2	Through 0.035	7	8
	over 0.035	6	7
2-1/2	Through 0.049	9	10-1/4
	over 0.049	7	8-1/4
3	Through 0.049	11	12-1/2
	over 0.049	9	10-1/2
4	Through 0.065	12	14
	over 0.065	10	12

2.4.6: Pipe Threads

The moat commonly used pipe thread in this country is the American Standard Taper Pipe Thread, also known as National Pipe Thread (NPT).

A variation of the NPT is the Dryseal thread used on pipe threaded AN and MS parts. These threads are completely interchangeable and will mate without interference. Dryseal pipe threads (NPTF) (the F indicates fuel) permit less leakage than American Standard Taper Pipe Thread (NPT). However, either can be made to seal with the other. A sealing compound must be used when either of the threads is not Dryseal.

2.4.6.1: Thread Assembly

It is advisable to lubricate all pipe threads before assembly (see Chapter 5.0, *Lubricants, Gaskets, Seals, and Packaging*). When any tapered threads, except Dryseal pipe threads, are mated a sealer or a thread compound must be used. The thread compound must be compatible with the fluid in the line.

It is important that the threads of both parts of screwed pipe joints be thoroughly cleaned before they are joined. The lubricant reduces the friction, allowing the two parts to be pulled up further and resulting in a more effective pipe joint.

Apply lubricant in streak across the male threads only. See Figure 2-9.

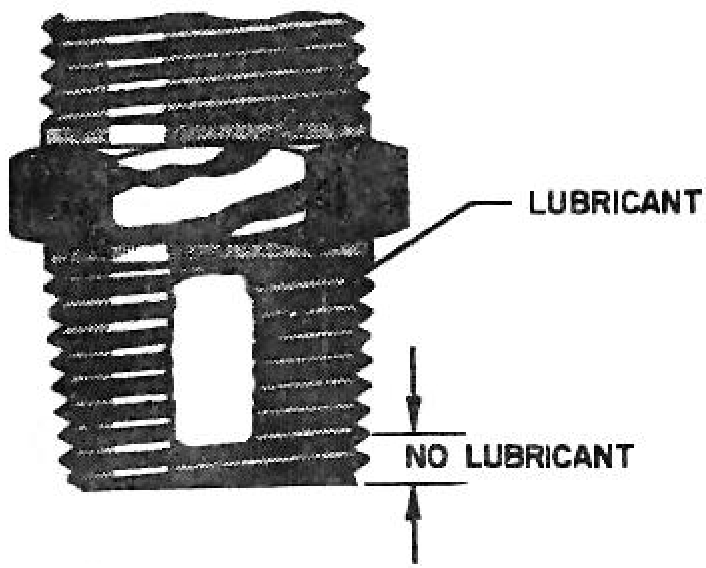


Figure 2-9. Apply Lubricant in Streak Across Male Threads Only

Alternate Method Using RB0140-002 Teflon Tape. Wrap tape around external thread in direction used for loosening the thread, stretching over threads slightly so that it conforms to the shape of the thread. Do not overlap the engaging thread end. Overlap the starting turn by approximately 1/2 inch and break tape. Assembly of threaded joint can then be made. When reworking threaded surfaces, remove all old tape from the threads. For NPTF 1-inch and larger, use two identical wrappings side by side.

2.5: Autoclave

2.5.1: AE SlimLine Connections: Medium Pressure

2.5.1.1: Application

Application: 10,000, 20,000, and 30,000 psi coned and threaded connections

At any pressure from vacuum to 30,000 psi, AE SlimLine coned-and-threaded connections offer no compromised reliability even under rigorous thermal and pressure cycling. A more compact version of the original AE High Pressure coned-and-threaded connection is particularly suited to installations, which must be assembled and disassembled repeatedly with no loss of reliability. Available in orifice sizes 0.109” thru 0.688” OD tube sizes ¼” through 1”.

2.5.1.2: Design Considerations: Why Coning and Threading?

Because of dissimilar angles between the body and tube cone, tube **CONING** provides **line contact sealing** along the perimeter of a contact circle, thus reducing sealing contact area to its practical minimum. Small seal areas provide high seal stresses at low seal loads, producing a reliable seal and less likelihood of leakage.

THREADING supplies **positive backup support** with the collar threading directly onto the tubing to form a positive, integral retaining surface. No possibility of imperfect bite or swage as might be possible in a compression sleeve type of connection. When the gland nut I threaded into the connection, the tubing is locked securely in place.

Re-Makes. Since the threaded glands are not captive to the tubing, but held on by the collar, AE SlimLine connections can be assembled, disassembled, and reassembled repeatedly, with no loss of reliability. These connections are used with cold worked valve and fitting bodies, which can withstand many repeated sealings.

Thermal Cycling. Unlike swaged, bite-type or coned-and-threaded connection employing compressed ferrules, AE SlimLine coned-and-threaded connections can take repeated thermal cycling under pressure with no loss in reliability.

Pro-Rated Systems. AE Medium Pressure Valves, Fittings, and Tubing with AE SlimLine connections provide a fully-engineered, pre-rated SYSTEM of components that go together hand-in-glove the first time they are assembled. They are not over sensitive to abuse or careless assembly. No special gauges or gadgets are needed to check the connection—weep holes in every joint permit fast visual inspection for leakage.

Materials. AE’s standard gland and collar material is Type 316 stainless steel.

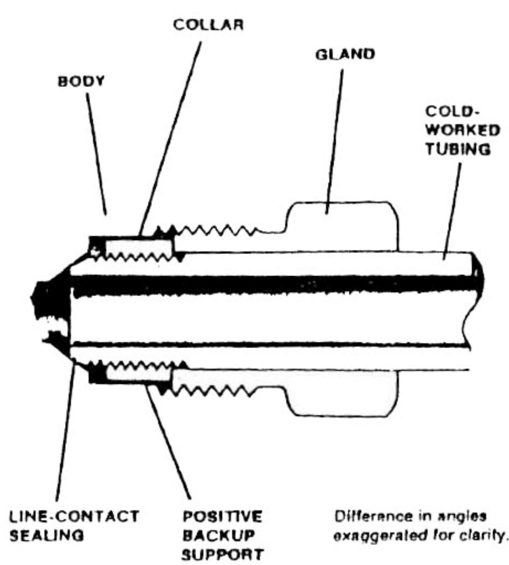


Figure 2-10. AE SlimLine Coned and Threaded Connection

2.5.2: AE High Pressure Coned and Threaded Connections

2.5.2.1: Application

Application: For pressure to 150,000 psi

AE High Pressure connections are refinements of the original coned-and-threaded joint, which has been the standard connection in high pressure technology since its development by an agency of the U.S. government better than 50 years ago. It offers the same design and reliability advantages as the AE SlimLine connection described on the preceding page, plus pressure handling capabilities, which have been applied successfully at pressures of more than 200,000 psi. Tube sizes ¼", 3/8", 9/16", and 5/15" outside diameter are available.

2.5.2.2: Design Considerations: High Sealing Stress—with Moderate Torque

The design principle employed in AE High Pressure and SlimLine connections provides the high sealing stresses necessary for high pressure metal-to-metal seals with only moderate gland torque requirements. (Torque values are listed in Table 2-19.) This is achieved by mating a male cone machined on the tubing, in a manner closely approaching a true line contact, with a female cone machined to a slightly larger included angle in the connection. Positive mechanical support for this contact is provided by a collar threaded onto the tubing, which is supported by a gland threaded into the connection.

Every Joint a Union Joint. With AE High Pressure and AE SlimLine connections, every joint is a union connection. Thus valves, fittings, and accessories can be inserted or removed from a pressure system or the system can be altered or expanded, in a fraction of the time—and cost—that may be imposed by welded, screwed, flared, or other types of systems. Connections can be made and re-made repeatedly providing reliable, leak-tight fluid systems every time.

Like the AE SlimLine connection, AE High Pressure connections offer excellent thermal cycling capabilities. And also like SlimLine, they provide fully-engineered, pre-rated systems of correlated components. They are not over-sensitive to abuse or careless assembly and weep holes in every joint permit fast visual inspection for leakage.

Materials. AE's standard gland and collar material is Type 316 stainless steel.

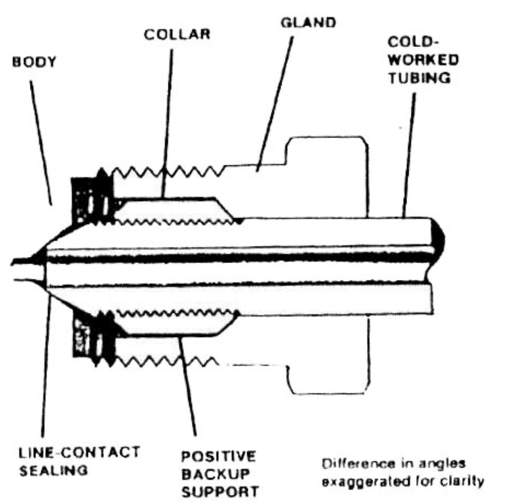


Figure 2-11. AE High Pressure Coned and Threaded Connection

2.5.3: Coning and Threading Operation Instructions

2.5.3.1: Cutting and Preparing Tubing for Coning and Threading Operations

A. Tubing should be measured accurately and cut to length. See Table 2-15 for an allowance for engagement (assembly). An additional 1/16” finish allowance is required per side to square up tube ends. This total allowance is the additional tubing length needed, per end, after measurement of fitting to fitting distance. **Note:** Tubing lengths greater than four feet (4’) should be supported at machine level during coning and threading operations to avoid damage or excessive wear to tooling and machine. Tubing should also be kept concentric to the threading dies and coning blades.

Table 2-15. Extra Allowance for Engagement

Connection Type	Tubing Size OD x ID	Engagement Allowance
SF 250 CX	1/4 x .109"	.55"
SF 375 CX	3/8 x .203"	.69"
SF 562 CX	9/16 x.312"	.84"
SF 562 CX	9/16 x .359"	.84"
SF 750 CX	3/4 x .438"	1.00"
SF 750 CX	3/4 x.516"	1.00"
SF 1000 CX	1 x .438	1.44
SF 1000 CX	1 x.562"	1.44"
SF 1000 CX	1 x .688"	1.44"
F 250 C	1 /4 x .083"	.50"
F 312 $C1_1 50$	5/16 x.062"	1.25"

B. Remove burr from tubing inside diameter and outside diameter after cutting.

C. Proceed with coning operation.

ILLUSTRATION #1

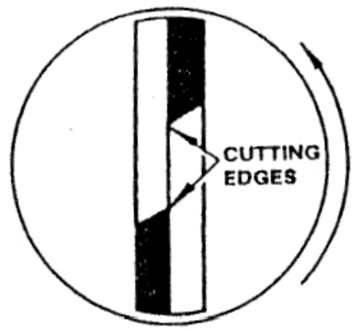


Figure 2-12. Illustration 1: Cutting Edges

NOTE: For coning and threading operations requiring more than one size tubing, it is advisable to have extra holders with a set of cutting blades installed for each size tubing being coned.

D. Select appropriate collet. Each tubing outside diameter size has a collet to match. See Table 2-16 for collet part numbers.

Table 2-16. Collet Tooling Part Numbers

Tube Size OD x ID (In.)	**Collet Only**	**Cutters Only**	**Die Chasers**	**Complete**
1 /4 x.109	AEGCTM 4C	201 A-3058	AEGCTM 4D	AEGCTM 4X
1/4 x .083	AEGCTM 4C	202A-3058	AEGCTM 4D	AEGCTM 4
5-16 x .062	AEGCTM 5C	203A-30 8	AEGCTM 6D	AEG CTM 6X
3/8 x .203	AEGCTM 6C	204A-3058	AEGCTM 6D	AEGCTM 6X
3/8 x .125	AEGCTM 6C	205A-3508	AEGCTM 6D	AEGCTM 6
9/16 x .359	AEGCTM 9C	206A-3058	AEGCTM 9D	AEGCTM 9XX
9/16 x.312	AEGCTM 9C	207A-3058	AEGCTM 90	AEGCTM 9X
9/16 x.188	AEGCTM 9C	208A-3058	AEGCTM 9D	AEGCTM 9
3/4 x .516	AEGCTM 12C	209A-3058	AEGCTM 120	AEGCTM 12X
3/4 x .438	AEGCTM 12C	210A-3058	AEGCTM 12D	AEGCTM 12
1 x .688	AEGCTM 16C	211 A-3058	AEGCTM 16D	AEGCTM.16X
1 x .562	AEGCTM 16C	212A-3058	AEGCTM 16D	AEGCTM 16
1 x .438	AEGCTM 16C	213A-3058	AEGCTM 16D	AEGCTM 16XX

2.5.3.2: Coning Operation

A. Insert appropriate collet and cutting blades for desired tubing size.

B. Engage coning feedwheel with sleeve (P/N: 201A-3066), rotate feedwheel three [3] turns to ensure thread engagement.

NOTE: When coning ¼” tubing, rotate feedwheel on sleeve until it bottoms out and then rotate <u>back</u> three [3] turns.

When feedwheel is not in use, or intended to remain stationary, place chained hook through spokes to keep wheel immobile.

C. Rotate feedwheel until you see the cutting blades extend approximately ¼” through the hole in the sleeve (Item #24). Insert tubing into collet until it is flush against the blades. Now back tubing up about ¼” and tighten the collet nut with the spanner wrench. Start the machine and advance the blades via the feedwheel slowly. When the blades start to cut (as seen through hole in sleeve), rotate feedwheel the number of turns indicated in Table 2-17. Each turn of the feedwheel advances the tube 1/16”.

NOTE: 304 SS tubing will require a slower blade feed rate than 316 SS. The rate of turning the feed wheel for 304 SS is approximately 1/4 that of 316 SS.

Table 2-17. Required Feedwheel Rotation for Coning Operation

Type of Connection	**Diameters**		**Number of Feedwheel Turns**
	OD	**ID**	
SM 250 CX	1/4"	0.109"	2.0
SM 375 CX	3/8"	0.203"	2.0
SM 562 CX	9/16"	0.312"	2.5
SM 562 CX	9/16"	0.359"	2.0
SM 750 CX	3/4"	0.438"	3.0
SM 750 CX	3/4"	0.516"	2.5
SM 1000 CX	1.00"	0.438"	5.0
SM 1000 CX	1.00"	0.562"	4.0
SM 1000 CX	1.00"	0.688"	3.0
M 250 C	1/4"	0.083"	2.0
M 312 r 150	5/16"	0.062"	3.0
M 375 C	3/8"	0.125"	2.5
M 562 C	9/16"	0.188"	4.0

D. At completion of turns, hold feedwheel stationary for ten [10] revolutions of cutting blades. This squares and finishes the coned end of the tubing.

NOTE: To insure proper sealing of a coned connection, it is necessary that the finished coned has a square end, which is perpendicular to the center line of the tubing. The critical finish for coned connections is on the leading edge of the cone. The transition point where the cone meets the square end of the tube must be free of burrs and tool marks (see “General Information”, pages 2 and 3).

E. Reverse feedwheel smoothly until tubing is disengaged from cutting blades. Turn machine off, loosen collet nut and remove the tubing. Inspect the cone for proper finish.

2.5.3.3: Threading Operation

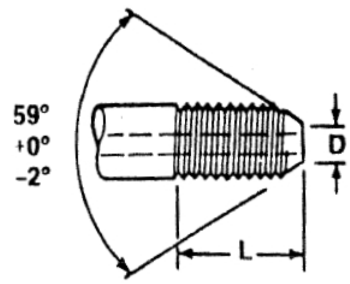
A. Select collet and die chasers for tubing connection desired. See Table 2-16 for collet and die chasers.

B. Install die chasers in die head. (See Figure 2-17 [Illustration 3]).
   1. **Trip die head into open position.** Push back on trip yoke arms causing head to trip into open position.
   2. **Open die head for chaser insertion.** Press stop lever in adjusting ring with an implement, allowing springs to force back the trip flange into extreme open position.
   3. **Insert chasers into die heads.** No. 1 chaser in No. 1 slot, No. 2 chaser in No. 2 slot, etc., pushing chasers in until the pins in the chasers are firmly held in the chaser spring plungers. A slight click tells when each chaser seats properly.
   4. **Close die head into cutting position.** Pull trip flange forward, being sure to continue the forward motion after the stop lever snaps into locking position and until head locks into cutting position.

C. Setting Die Head
   1. To check alignment of chasers, obtain a previously machined piece of tubing and attempt to screw the piece into the die head. If the piece does not go in smoothly, loosen adjusting ring binding screw, using a 5/32" hex key. Then, by means of a pin inserted into the hole of the adjusting ring, turn until the desired thread size is obtained. Tighten adjusting ring binding screw before cutting a thread. Repeat this procedure until the piece smoothly screws into the die head the entire length of the thread.
   2. Using sample piece of tubing, install appropriate collet in pivot arm holder. Rotate pivot arm and extend tubing until it bottoms in gauge button. Tighten collet with spanner wrench.
   3. Rotate pivot arm back, apply oil to chasers and tubing, position tubing, position tubing in chasers and start the machine. Apply pressure to pivot arm to start threading. After threading has begun, machine is self-feeding.
   4. When machine is tripped the die head, turn off the machine and check tubing thread length. See Table 2-18 for correct threaded length. To adjust threaded length, use knurled adjusting know on trip device under the die head.
   5. Check the thread fit by using the proper collar for tubing. Adjust die head for each chaser size if required.

NOTE: Chasers are ground in matched sets of four [4] chasers, available in sets only. Chasers may be reground in sets if required, after use.

Table 2-18. Thread Lengths



Male Thread Connection Type	Dimensions (Inches)				
	Tubing Size O.D.	x I.D.	D	L (Max.)	(lefthand) National Fine
SM 250 CX	1/4"	0.109"	0.141	0.344	1/4"-28
SM 375 CX	3/8"	0.203"	0.250	0.438	3/8"-24
SM 562 CX	9/16"	0.312"	0.406	0.500	9/16"-18
	9/16"	0.359"	0.438	0.500	9/16"-18
SM 750 CX	3/4"	0.438"	0.562	0.625	3/4"-16
	3/4"	0.516"	0.578	0.625	3/4"-16
SM 1000 CX	1"	0.438	0.562	0.906	1" -14
	1"	0.562"	0.719	0.781	1" -14
	1"	0.688"	0.812	0.781	1" -14
M 250 C	1/4"	0.083"	0.125	0.562	1/4"-28
M 312 C150	5/16"	0.062"	0.125	0.687	5/16"-24
M 875 C	3/8"	0.125"	0.219	0.750	3/8"-24
M 562 C	9/16"	0.188"	0.281	0.938	9/16"-18

D. Operation After Setting Die Head
1. When the die head has been properly adjusted and sample tubing is produced with proper thread length and fit, proceed with threading operation of tubing. Proceed with threading operation by fitting tubing loosely in collet and rotating pivot arm until tubing aligns with gauge button. Bottom tube in gauge button hole and tighten collet with spanner wrench.
2. Rotate pivot arm back, position tubing in chasers. (Apply some lubricant [oil] to the chasers and tubing prior to starting the machine.) Start the machine and apply pressure to pivot arm to start threading. After threading has begun, machine is self-feeding.
3. When pre-set length has been threaded, the trip yoke is actuated and will automatically open the die head. Then, turn off the machine.
4. Loosen the collet nut and remove the tubing.

NOTE: The coning and threading machine is furnished with a lubrication pump. This is used to supply cutting fluid to the points of cone cutting and threading. A sufficient supply of cutting fluid shall be maintained during machining operations for successful coning and threading.

An optimal thermostatically controlled immersion heater is available for use in cold weather.

Cutting fluid should be Sunicut 442[1] or equivalent.

E. To Remove Chasers

> ***CAUTION:***
> ***Unplug the machine before proceeding.***

To unlock the head, press the stop lever to allow trip flange to move to the rear, and pull the chasers out with fingers. Chaser spring plungers prevent chasers, before removal, from falling into chips and oil. Chaser removal is done without taking the die head from the machine.

2.5.3.4: Assembly and Make Up of Coned Connections

A. After coning and threading operations, use Figure 2-13 (Illustration 2) and Table 2-19 for properly connecting and torquing coned connections.

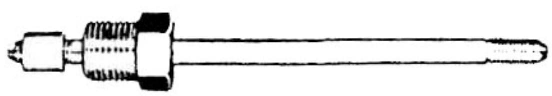


Figure 2-13. Illustration 2: Assembly and Makeup of Connection

1. Slip gland on tubing as shown and thread collar on tubing until one [1] to two [2] threads are exposed between collar and cone.
2. Insert tubing in connection, engage gland and tighten “finger-tight”.

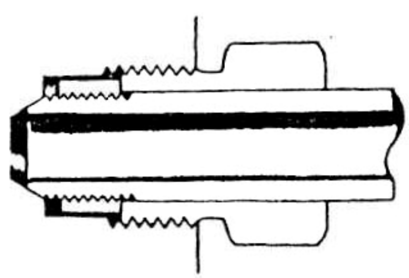


Figure 2-14. Completed AE SlimLine Connection

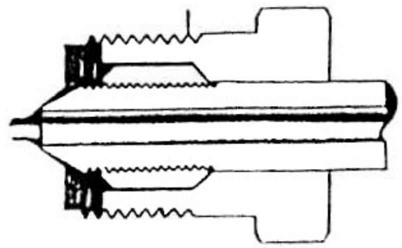


Figure 2-15. Completed AE High Pressure Connection

3. Tighten gland to specific torque.

Figure 2-19. Torque Requirements for Coned Connections

Connections	**Gland Nut Sizes**	**Required torque Ft-Lbs.**
5F 25UX	112"	20
3F 375 GX	5/8"	30
SF 562 CX 10	7/8"	55
SF 562 CX 20	7/8"	55
SF 750 CX 10	1-3116"	75
SF 750 CX 20	1-3116"	90
SF 1000 C X 10	1-3/8"	125
S F 1000 C X 20	1-3/8"	150
SF 1000 C X 30	1-3/8"	150
F 250 C	5/8"	25
F 312 C150	11/16"	70
F 375 C	13/16"	50
F 562 C	1-3/16"	110

2.5.4: Recommended Spare Parts

Drive Belt, P-1754
Holder (Cone Cutters), 201A-4231
Tooling (See Table 2-20.)

Table 2-20.Recommended Spare Parts

Tubing Size OD x ID (Inches)	P/N Collet	P/N Cutters	P/N Die Chasers	P/N Complete Set
1/4 x .109	AEGCTM 4 C	201A-3058	AEGCTM 4 D	AEGGTM 4 X
1/4 x .083	AEGCTM 4 C	202A-3058	AEGCTM 4 D	AEGCTM 4
5/16 x .062	AEGCTM 5 C	203A-3058	AEGCTM 6 D	AEGCTM 6X
3/8 x .203	AEGCTM 6 C	204A-3058	AEGCTM 6 D	AEGCTM 6X
3/8 x .125	AEGCTM 6 C	205A-3058	AEGCTM 6 D	AEGCTM 6
9/16 x .359	AEGCTM 9 C	206A-3058	AEGCTM 9 D	AEGCTM 9 XX
9/16 x .312	AEGCTM 9 C	207A-3058	AEGCTM 9 D	AEGCTM 9 X
9/16 x .188	AEGCTM 9 C	208A-3058	AEGCTM 9 D	AEGCTM 9
3/4 x .516	AEGCTM 12 C	209A-3058	AEGCTM 12 D	AEGCTM 12 X
3/4 x .438	AEGCTM 12 C	210A-3058	AEGGTM 12 D	AEGCTM 12
1 x .688	AEGCTM 16 C	211A-3058	AEGCTM 16 D	AEGCTM 16 X
1 x .562	AEGCTM 16 C	212A-3058	AEGCTM 16 D	AEGCTM 16
1 x .438	AEGCTM 16 C	213A-3058	AEGCTM 16 D	AEGCTM 16 XX

NOTE: See Drawing #50-290 for additional parts not required as spare parts

2.5.5: Service

2.5.5.1: General

Little Giant Pump Instructions

NOTE: IMPORTANT – READ CAREFULLY for better service and longer life.

The pump, which you have just purchased, is of the highest quality workmanship and material. It has been engineered to give you long and trouble-free service. Like any other piece of mechanical equipment, a little attention will help to keep it in perfect operating condition for a long time.

2.5.5.2: Information and Suggestions

A. Your unit is factory-serviced with oil. It does not need to be lubricated ever.

B. Be sure not to let the unit freeze in the winter, as it may distort or break the case.

C. DO NOT CONNECT THIS UNIT TO VOLTAGE OTHER THAN SHOWN ON THIS UNIT. IF YOU ARE IN DOUBT, PLEASE HAVE YOUR SERVICE PERSON CHECK. THE WARRANTY DOES NOT COVER UNITS BURNED OUT BY HIGH VOLTAGE CURRENT.

D. DO NOT LET THE UNIT OPERATE DRY. It is designed to be cooled by either sitting in liquid or circulating liquid through the head. If used in a cooler, it should be connected to a separate switch so that the cooler can be operated without water if desired. You can damage your unit and cause it to fail by letting it run without any cooling medium.

2.5.5.3: Service Instructions

Very little service will be required by your pump. If for any reason the unit should fail to operate, follow the suggestions listed below:

Disconnect pump from electric current. Try it at another electrical outlet to make sure current is getting to the unit; if it does not start:

A. Remove screen and three [3] front screws as indicated by arrows on sketch. See Figure 2-16. (DO NOT REMOVE OTHER SCREWS, WHICH MAY BE EXPOSED.) You can then remove the pump head.

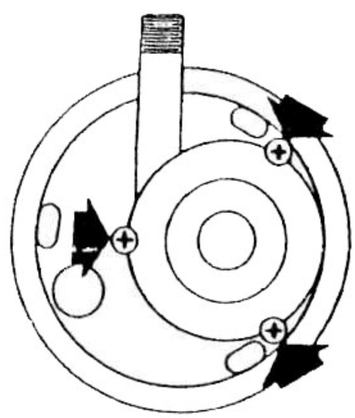


Figure 2-16. Pump Front Screws

B. Lightly clean any corrosion or debris, which may have clogged the impeller. Use a brush and penetrating oil and LIGHTLY scrape. Do not scratch the painted surface.

C. Turn the impeller by hand to make sure it is free. Plug the unit in to see if the impeller will turn. If it does, replace the front, and the unit should operate as good as new.

FOR ANY REASON THESE OPERATIONS DO NOT RESTORE THE UNIT TO FULL SERVICE, CALL YOUR DEALER OR SERVICE TECHNICIAN.

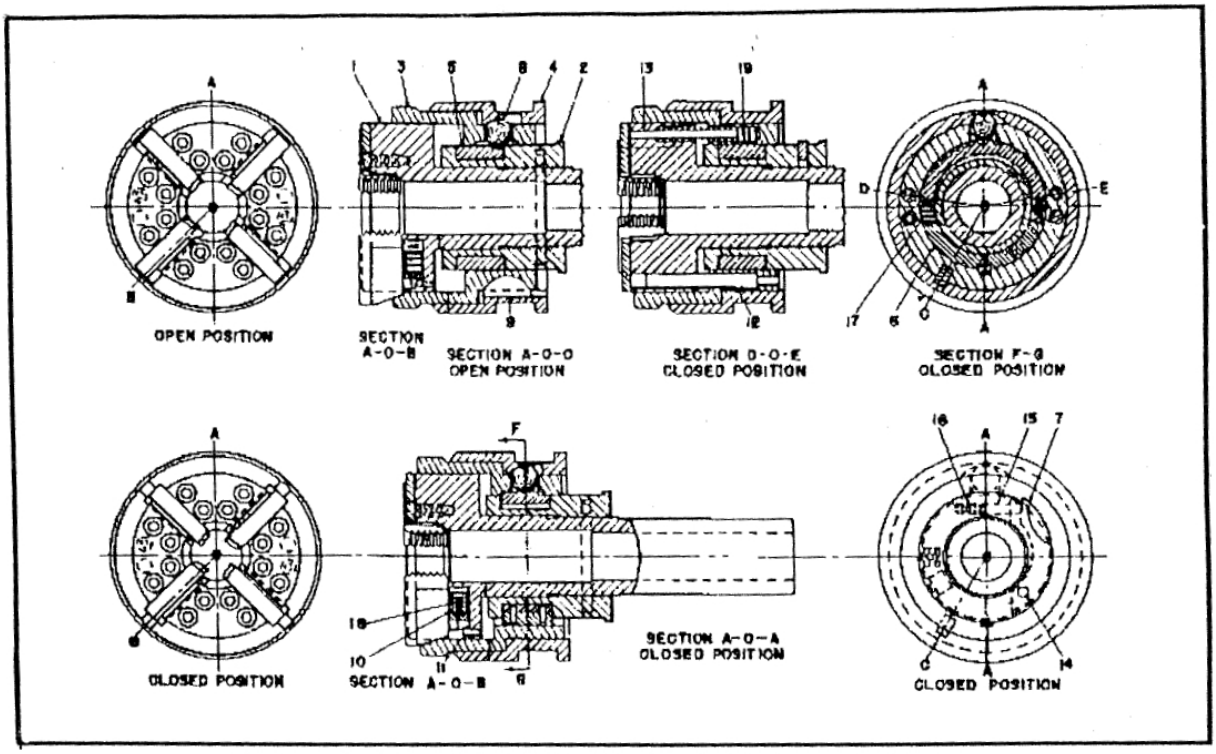
DO NOT, IN ANY CASE, OPEN THE SEALED PORTION OF THE UNIT OR REMOVE SCREWS, OTHER THAN SHOWN BY THE ARROWS ABOVE.

DO NOT CUT THE ELECTRIC CORD ON THE UNIT WHEN REMOVING IT. DISCONNECT FROM ITS REGULAR CONNECTION.

VIOLATIONS OF THESE PROVISIONS WILL VIOLATE THE WARRANTY ON THE UNIT.

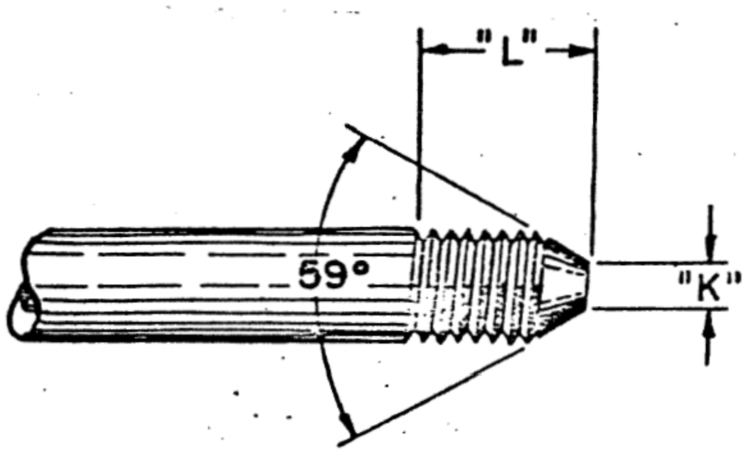
CONDITIONS. This unit is designed to circulate water, light oils, and other mild liquids. It will operate under more severe conditions, also, but the warranty in such cases will be subject to approval by the factory.

CONNECT TO THE SAME SERVICE VOLTAGE AS SHOWN ON THE PUMP.



1 – Skeleton with front plates and front plate screws
2 – Adjusting ring with binding shoe and set screw
3 – Closing sleeve
4 – Trip flange
5 – Pawl
6 – Segment with key
7 – Stop lever
8 – Ball
9 – Woodruff key
10 – Chaser spring plungers
11 – Chaser spring plunger retaining screws and lock washers
12 – Closing sleeve guide pins
13 – Closing sleeve spring pins
14 – Stop lever pivot pin
15 – Stop lever spring pin
16 – Stop lever spring
17 – Pawl springs
18 – Chaser springs
19 – Closing sleeve springs

Figure 2-17. Illustration 3: Open and Closed Position of the Die Head



Size	"L"	"K" Diameter
1/4" Tubing	9/16"	1/8"
3/8" Tubing	3/4"	7/32"
9/16" x 3/16" Tubing	15/16"	9/32"
9/16" x 5/16" Tubing	15/16"	11/32"

Figure 2-18. Tube End

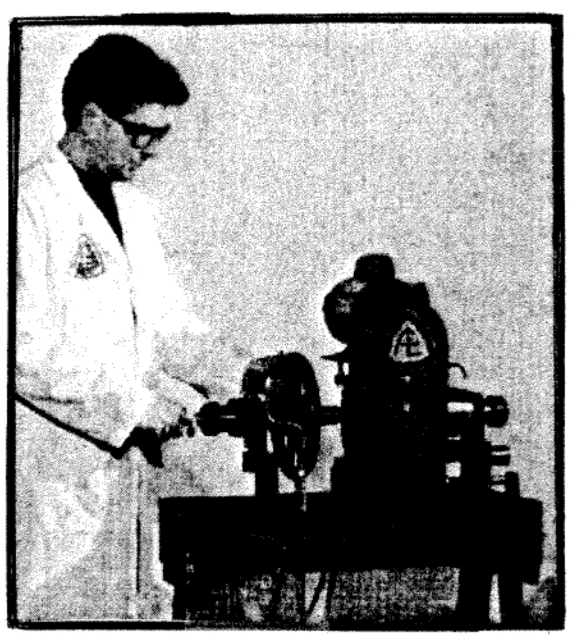


Figure 2-19. Medium Pressure Tubing Machine

2.6: Cleaning

Cleaning of components at the SSFL, which are to be installed in plumbing systems, is controlled by established procedures and must be rigidly followed to maintain system integrity.

Prior to the installation of components—including piping and tubing assemblies—into a system, the components shall be cleaned to meet the requirements of the applicable procedure. The requirements, specified by these procedures, are conveyed to the mechanic by use of the EWR. When the component has been installed and the EWR item is initialized, the intent of the procedure has been implemented.

2.7: Proof Test

Prior to assembly of a piping or tubing system, the system components that are to be subjected to internal pressure shall be proof tested per the requirements of the field laboratories procedure (FLP) No. 405. The FLP requires the component to be permanently marked, either etched or stamped, with the maximum working pressure (MWP), and date. The MWP and date must appear on the component before it is installed in a system.

2.8: Leak Test

Following the proof test, the system or component shall be leak tested as specified by the EWR.

2.9: Identification of Systems

All facility piping and tubing systems shall be uniformly identified. This includes all tubing and piping systems installed for the purpose of conducting pressurants, propellants, hydraulic fluids, cleaning fluids, water, steam, air, vents, and vacuum from one location to another. Electrical conduit is also included.

2.9.1: Proof Test Identification

New piping and tubing systems requiring proof test, shall have an embossed tag in a clearly visible location, indicating the date of the test and the maximum working pressure (MWP). In addition, nominal pipe size, pipe schedule, material, grade (if applicable) and whether it is ERW or seamless pipe, and date of installation shall be shown.

The above information shall be shown on any piping component where it is possible to change from one pipe size to another. The marking should be in the form of an embossed metal tag or band stamped with the appropriate information. The pipe shall not, in any form or manner, be stamped or disfigured. However, stamping on flanges is permissible.

All systems or lines, whether painted or not, shall be identified with color coded tapes in accordance with Table 2-21 and 2-22. The size of the tape shall be determined by Table 2-22.

Table 2-21. Basic Identification of Piping and Tubing Systems

Category No.	Category	Color	Requirement for Continuous Skull and Crossbones on Border of Tape
1	Fuels and other flammable materials (see note 1)	Yellow	Hydrazine; UDMH
2	Oxidizers (see note 2)	Green	Liquid or gaseous fluorine; NTO; IRFNA; CTF; oxygen difluoride
3	Inert Materials (see note 3)	White	None
4	Reclaimed, industrial, chill, or cooling water (see note 4)	Brown	All water in this category
5	GN_2, helium, high-pressure steam (see note 5)	Gray	None
6	Fire protection systems (see note 6)	Red	None
7	Anesthetics and harmful materials (see note 7)	Blue	None

Notes:

1. Includes: acetylene, trichloroethylene, ethyl alcohol, ammonia, butane, flushing oil, lube oil, GH_2, hypergol, hydraulic oil, pickling oil, vacuum oil, waste oil, all rocket fuels, vents.
2. Includes: fluorine gas, halogen fluoride, hydrogen peroxide, oxygen rag, all rocket oxidizers, vents.
3. Includes: breathing air, compressed air, argon gas, calcium chloride solution, LN_2, refrigeration suction and discharge, steam under 15 psig, vacuum, water systems (deionized, distilled, drinking, filtered, hot, microfilter, soft, well).
4. Includes: supply and return chill water, supply and return cooling water, industrial water, reclaimed water.
5. Includes: nitrogen gas, helium, steam above 15 psig.
6. Includes: sprinkler lines, sprinkler risers, fire extinguisher systems.
7. Includes: caustic soda, chromic acid, hydrochloric acid, sulphuric acid.

Table 2-22. Required Tape Width

	Polyester (Mylar) Tape Black Print on Specified Color	
Diameter of Piping or Tubing and Location	2-1/4 Inch-Wide Tape 1/8-Inch Lettering	9-Inch-Wide Tape 1/2-Inch Lettering
2 Inches or under-all locations	X	
Over 2 inches-all locations	X	Optional – Existing stock may be used

2.9.1.1: Location of Color-Coded Tape

If the tube or pipe is not more than 24 inches long and the entire length of the tube can to seen from some central location, the tape shall be applied midway along the tube or pipe length.

Tubes or pipes longer than 24 inches shall have the tape applied at:

- Outlet valves
- Connections

- Changes in direction of piping and tubing runs. (If either the upstream or downstream side of the tubing bend is not visible from one location, apply the tape upstream and downstream of the bend.

- Intervals of 125 feet on long runs or at shorter intervals as necessary to ensure proper and adequate identification.

If the tubing or piping passes through more than one test cell or bulkhead, additional tape shall be applied so that the line is readily identifiable in each cell or an each side of the bulkhead.

Tapes shall be applied tightly with at least 1-1/4 turns, but not more than 2 turns around the tubing or piping.

2.9.1.2: Direction of Flow Identification

Direction of flow shall be indicated by directional flow tape on all tubing and piping (except as indicated under Exceptions) at the following locations:

- Outlet valves

- Connections

- Changes indirection of piping and tubing runs. (If either the upstream or downstream side of the tubing bend is not visible from one location, apply the tape upstream and downstream of the bend.)

- Intervals of 125 feet on long runs or at shorter intervals as necessary to ensure proper and adequate identification.

Exceptions:

- Valve actuation tubing
- Instrumentation tubing
- Fire extinguishing systems

2.9.1.3: Pressure Identification

All systems containing compressed gas or steam above 15 psig shall be marked with the system operating pressure. The location of the pressure-indicating tapes shall be as indicated above. Listed below are current Rocketdyne stock numbers of pressure-indicating tapes for commonly used pressures. The Rocketdyne Standards Manual contains a section on tapes with additional stock numbers for other pressures.

Table 2-23. Pressure-Indicating Tapes for Commonly Used Pressures

PRESSURE, PSI	ROCKETDYNE STOCK NO.
120	RD172--0018-0120
150	RD172-0018-0150
350	RD172-0018-0350
750	RD17 2-00].8-07 50
3000	RD172-0018-3000
5000	RD172-0018-5000

2.9.1.4: Electrical Conduit Identification

Electrical conduit shall be identified with electrical conduit-identifying tape (currently Rocketdyne Stock No. RD172-0022-0001). The location of this tape shall be in accordance with the Section 2.9.1.1, "Location of Color-Coded Tape".

Conduit not requiring identification:

- Conduit installed in control centers
- Conduit Installed in the ECS
- Flexible conduit (e.g., Plica)
- Conduit installed in pretest buildings and T-houses
- Conduit installed in E.L., I.L , and cascade stations

2.9.1.5: Instrumentation Controls Tubing

Instrumentation control tubing shall be identified with instrumentation controls identifying tape. The location of this tape shall be in accordance with the paragraph titled "Location of Color-Coded Tapes".

2.9.2: Installation of Flanged Fittings

A wide variety of pipe flanges and couplings are used at the Field Laboratories. Care must be used to assure that the flanges match the facing of the equipment to which it is connected, and to assure that the proper gasket is used.

Flange faces should mate evenly and should not be bent-to-match with the flange bolts. The flange bolts can cause distortion and permanent damage to the flange if they are not loaded evenly.

Flat face flanges and full gaskets must be used with cast iron pump flanges to prevent cracking of the pump flange.

Flange facing should be protected during installation to prevent scratching and possible leakage.

2.9.3: Installation of AN and MS Fittings

It is absolutely necessary that open ends of tubing and fittings be kept capped until they are connected into the system. IF they are disconnected at any time, they must be capped at once. Expensive units can become contaminated or permanently damaged by dirt and chips if this is not done.

Immediately prior to installation of fittings, lubricate the sleeve bearing outer surface and the male threads of fittings by applying a thin coating of prescribed compound. Do not allow the compound to coat the inside of the tube or flare. See Figure 2-20.

Place the tube in position, making certain that it is not scratched during installation, and see that the tube flares or tube ends meet the fittings squarely and fully. Never use an AN nut to draw the tube to the fitting as the flare or sleeve might be spun off or damaged.

Using fingers only, start the nut on the fitting and turn it until flares or sleeves are firmly seated. Never use a wrench until the nut is finger-tight.

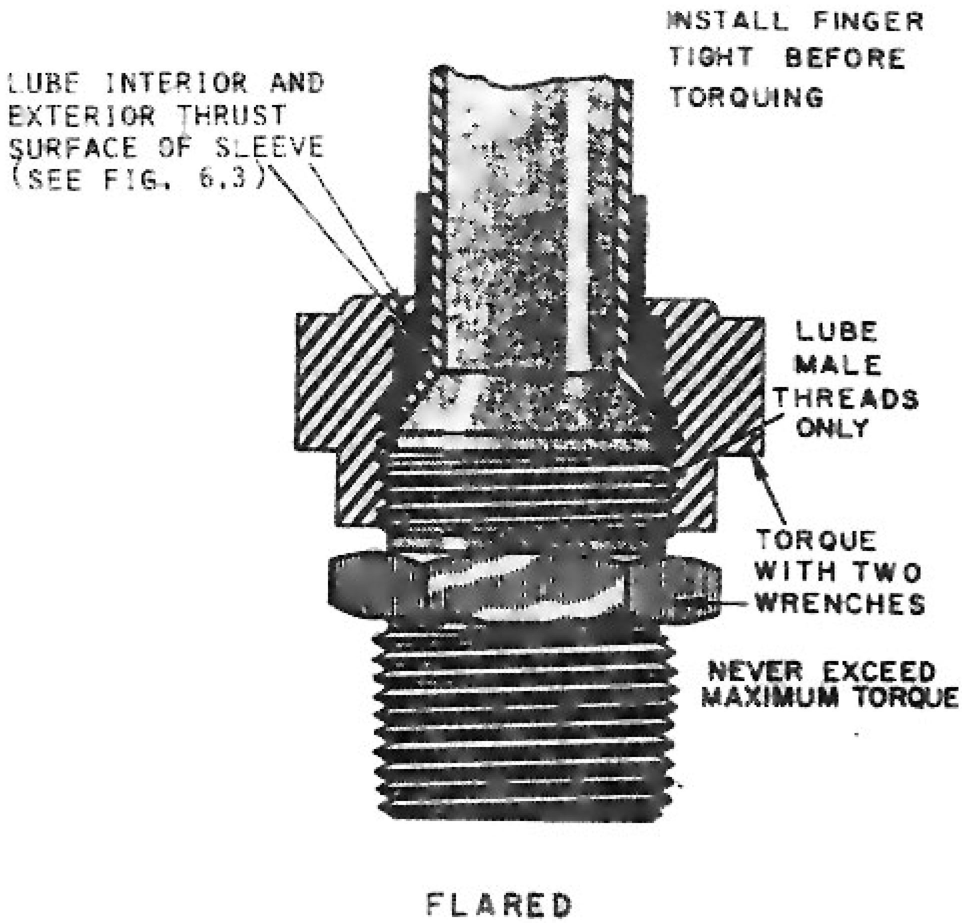


Figure 2-20. Installation of Tube Fittings

After the nut is firmly in place, tighten the AN nut with a torque wrench, using the values shown in the torque tables. Use a second wrench on the hex of the body to counteract the torque of the wrench on the nut. See Figures 2-21 through 2-24 and Table 2-24.

If the fitting leaks, correct the defect if possible, and replace if necessary.

NOTE: Do not tighten the AN or MS nut over the maximum torque recommended. Never attempt leak correction with pressure in the system.

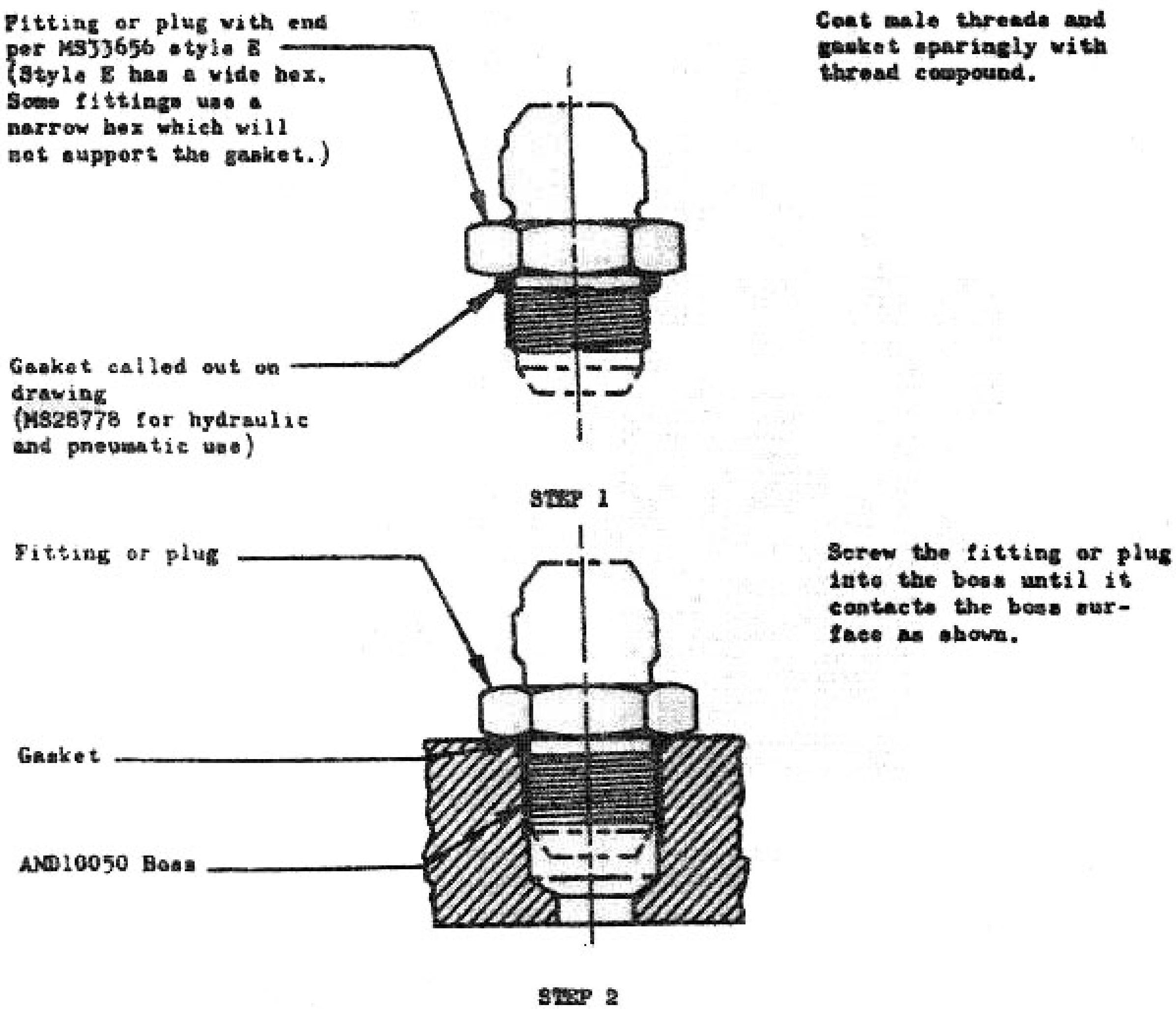
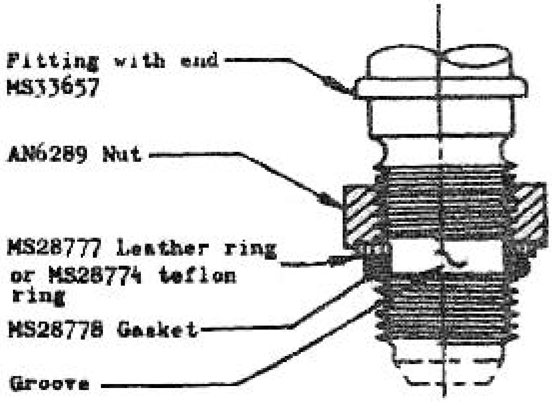
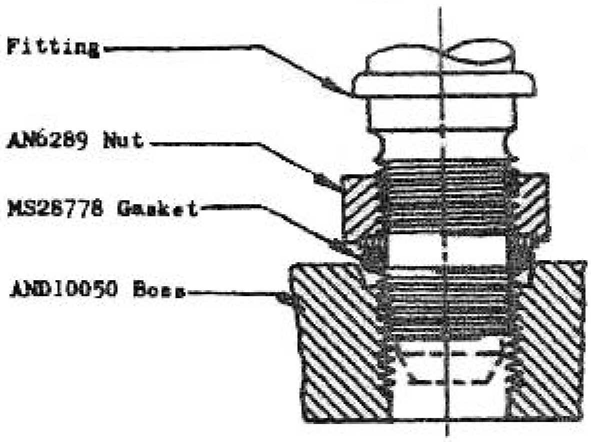


Figure 2-21. Installation of MS33656 Style E Fitting End Into AND10050 Boss



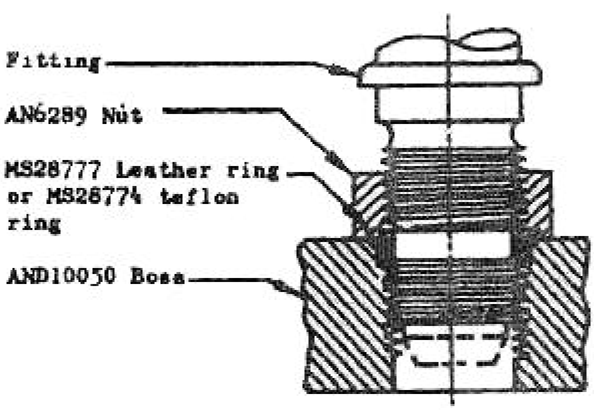
STEP 1

Coat male threads, MS28777 leather ring or MS28774 teflon ring, and MS28778 gasket sparingly with applicable thread compound and assemble as shown in step 1. If the leather ring is used, have the smooth (hair side) against the gasket. Work the MS28777 leather ring or MS28774 teflon ring into the counterbore of the AN6289 nut; then turn the AN6289 nut down until the MS28778 gasket is pushed firmly against the lower threaded section of the fitting.



STEP 2

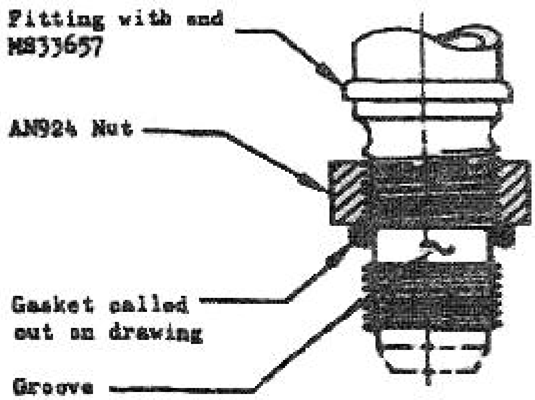
Install the fitting into the AND10050 boss and, at the same time, keep the AN6289 nut turning with the fitting until the MS28778 gasket contacts the AND10050 boss, as shown in step 2. This point can be determined by a sudden increase in torque. With the fitting in this position, put a wrench on the AN6289 nut to keep it from turning and, at the same time, turn the fitting in 1-1/2 turns. Position the fitting by turning it <u>in</u> not more than one additional turn.



Step 3

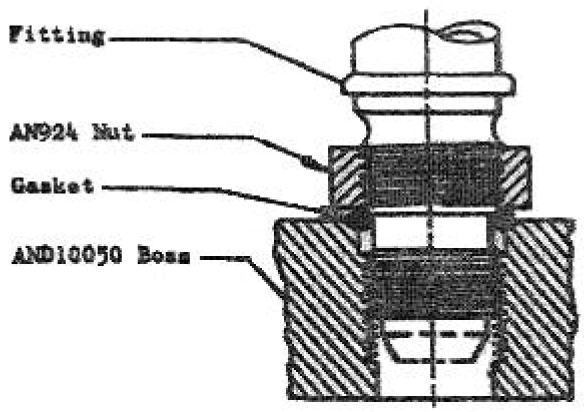
Hold fitting and turn AN6289 nut down tightly against AND10050 boss, as shown in step 3. Slight extrusion of the MS28777 leather ring or MS28774 teflon ring is not detrimental at the initial installation, but they shall not be reused at any re-installation of the fitting in the boss.

Figure 2-22. Installation of MS33657 Fitting End Into AND10050 Boss in Hydraulic and Pneumatic System



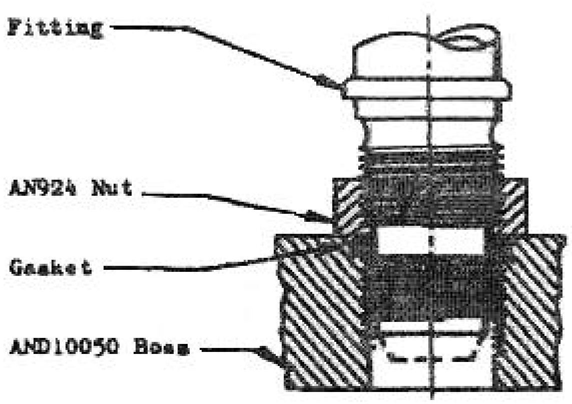
Step 1

Assemble AN924 nut on fitting end and run all the way back to clear fitting groove. Coat male threads and gasket sparingly with thread compound. Assemble gasket in groove. Hold gasket firmly against the top threaded section of the fitting and run nut down until it contacts the gasket.



Step 2

Assemble the fitting into the AND10050 boss and, at the same time, keep the AN924 nut turning with the fitting until the gasket contacts the boss. The point can be determined by a sudden increase in resistance.



Step 3

Continue to screw the fitting into the boss for another 1/4 turn. Keep the AN924 nut turning with the fitting to prevent cutting the gasket with the fitting thread. Position the fitting by turning the fitting and nut by not more than one additional turn. Hold fitting and turn AN924 nut down tightly against the AND10050 boss. Torque to proper value.

Figure 2-23. Installation of MS33657 Fitting End Into AND10050 Boss in Other Than Hydraulic and Pneumatic Systems

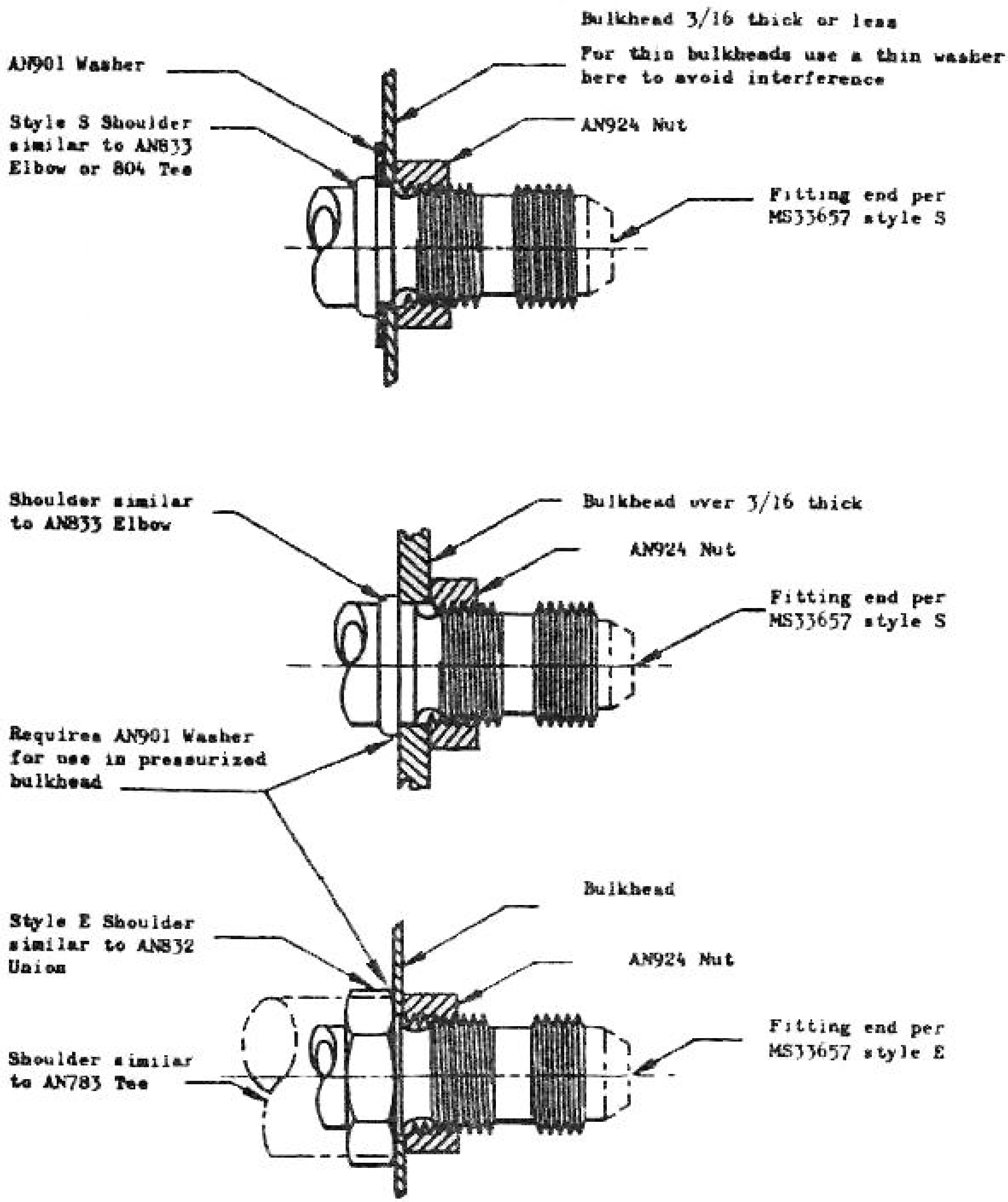


Figure 2-24. Installation of MS33657 Fitting Ends Through Bulkheads or Brackets

Table2-24. Hole Diameters for Bulkhead Fittings

	Fitting	Bulkhead Hole Diameter					
	Thread	Single Sheet		Multiple Sheet		AN901 Washer	AN924
Tube Size	**Diameter**	**Fraction**	**Decimal**	**Fraction**	**Decimal**	**(.0508 Thick)**	**Nut Size**
1/4	7/16	15/32	.469	1/2	.500	-4A	-4D
5/16	1/2	17/32	.531	9/16	.562	-5A	-5D
3/8	9/16	19/32	.954	5/8	.625	-6A	-6D
1/2	3/4	25/32	.781	13/16	.812	-8A	-8D
5/8	7/8	29/32	.906	15/16	.934	-10A	-10D
3/4	1-1/16	1-3/32	1.094	1-1/8	1.125	-12A	-12D
1	1-5/16	1-11/32	1.344	1-3/8	1.375	-16A	-16D
1-1/4	1-5/8	1-21/32	1.656	1-11/16	1.688	-20A	-20D

Note: Use AN901 dural washers (maximum temperature 400˚ F) for both pressure and nonpressure applications. The 2W17 washer is used for temperatures over 400˚ F through 1,200˚ F (nonpressure). Dural washers are used on the nut side if bulkhead thicknesses are below the minimum thickness specified. In a pressure application, these washers must be replaced when the fitting is removed.

2.10: Vacuum Piping

2.10.1: General

Vacuum systems which provide a condition of almost complete lack of atmosphere are widely used in providing vacuum insulation and providing environmental chambers for space simulation. Because of the special and sometimes extreme requirements of vacuum system components, a brief coverage is made.

2.10.2: Operating Vacuum Pressure and Units

The most familiar unit of pressure or vacuum is the millimeter of mercury (mm of Hg); however, it is now called the torr. Some of the commonly used vacuum pressure units are listed in Table 2-25.

Table 2-25. Vacuum Conversion Units

Atmosphere	Altitude (Feet)	PSIA	torr (mm of Hg)	Microns of Hg (μ)
1	0	14.7	760	760,000
0.068	6.1×10^{4}	1	52	52,000
1.32×10^{-3}	1.5×10^{5}	1.93×10^{-2}	1	1,000
1.32×10^{-6}	3.1×10^{5}	1.93×10^{-5}	10^{-3}	1
1.32×10^{-9}	5.2×10^{5}	1.93×10^{-8}	10^{-6}	10^{-3}

To be effective, insulation systems must operate in the following ranges:

- Powder- Vacuum 10^{-2} torr
- Super Insulation 10^{-4} torr
- Hard Vacuum 10^{-3} to 10^{-6} torr

The degree of vacuum attainable depends on the type of pump used. Ranges of pumps are as follows:

- Mechanical 10^{-3} to 10^{-4} torr
- Diffusion (backed by mechanical) below 10^{-3} torr

2.10.3: Vacuum Systems

In vacuum systems, there are three important factors to consider (see Figure 2-25):

1. The importance of providing lines which are as short and large in diameter as possible. As a rule the system pressure drop should not exceed 20 percent of the desired operating pressure. Line size becomes extremely important at pressures in the 1 to 10^{-3} torr, since gas flow which is viscous at pressures above 1 torr changes to a diffusion type flow at pressures below 10^{-3} torr. In this range line sizes must be large to get any pumping speed at all.

2. The desirability of incorporating into the system sufficient vacuum tight valve and gage connections to permit "trouble shooting" analysis when operating pressure cannot be maintained. In this respect vacuum gages should be placed where they will measure the systems pressure rather than the pressure near the pump. It is also possible to get a higher pressure than true system pressure if a vacuum gage is located in a branch line near a pin hole leak.

3. The necessity of eliminating leaks to an extent far beyond the requirements of ordinary pipe. To the novice, a system that is not scrupulously clean may appear to leak because it may take considerable time to pump out oil or dirt (with a relatively high vapor pressure) from construction.

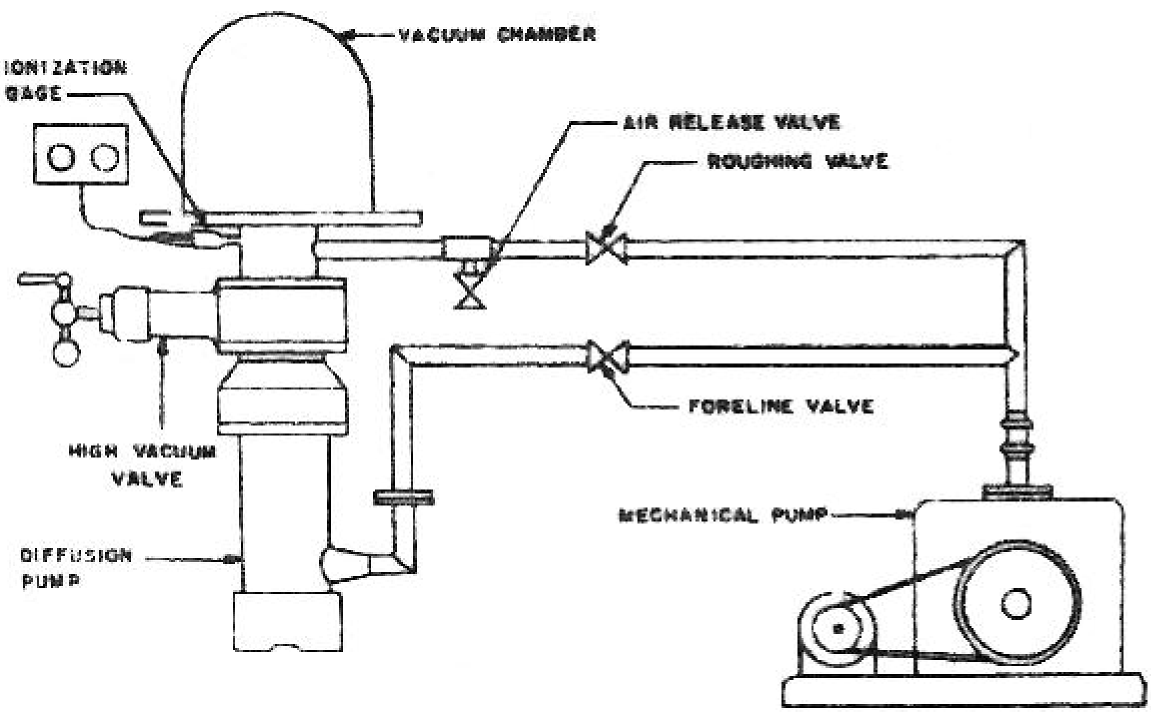


Figure 2-25. Typical Vacuum Pumping System

2.10.4: Piping Components

2.10.4.1: Pipe

Nearly all the common structural metals may be used for vacuum lines. Stainless and carbon steel and aluminum are widely used. Ordinary carbon steel is not often used in vacuum insulation lines where the part becomes cold (low temperature embrittlement); but it is often used for the outer room temperature enclosure.

2.10.4.2: Pumps

Mechanical Pumps are included in most vacuum systems to rough-evacuate the system in the range from atmospheric to 10^{-2} torr. These pumps are of two general types: the rotary vane and the rotary piston.

The most common cause of poor performance of a mechanical pump is contamination of the oil with a volatile substance such as water. Moderate contamination can be removed by pumping air for several hours.

Most pumps have check valves which prevent flow of oil into the vacuum system when the pump is stopped. However, these sometimes leak, so it is safest to close the valve between the mechanical pump and the rest of the system and have a valve to let air into the mechanical pump when it is stopped. To avoid damage to large pumps with oil separation reservoirs it is advisable to turn the pump over by hand before turning on the motor so that any excess oil in the working volume of the pump is gently discharged into the reservoir.

Diffusion Pumps are most frequently used in pressures below 10^{-3} torr. Since this type of pump cannot discharge to atmosphere, mechanical pumps are required to reduce the pressure to the operating range of the diffusion pump. The mechanical pump removes about 99.99 percent of the gas while reducing the pressure to 10^{-1} torr or less. The remaining pressure from 10^{-3} torr or lower is removed by the diffusion pump discharging into the mechanical pump.

The lowest pressure attainable by the diffusion pump is determined in part by the vapor pressure of the oil at the temperature of available cooling water. Oil diffusion pumps should never be opened to the atmosphere when the oil is hot, as this might cause decomposition of the oil.

2.10.4.3: Valves

Vacuum valves differ from more conventional valves in the following characteristics:

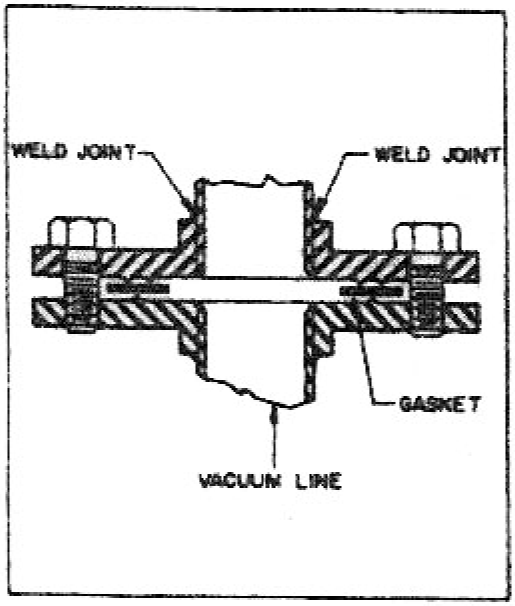
- Freedom from Leakage. Conventional packing on stems has been proven entirely unreliable from a leakage standpoint. Vacuum valves use either a bellows, an O-ring, or a diaphragm as a stem seal.

- Minimum Flow Resistance. The criteria for conventional valves (absence of excessive pressure drop through the valve is insured if full area equal to port area is maintained through entry section of the valve) is only a minimum criterion for vacuum valves. Obstructions in the line of flow are not permitted, and the valve port should be completely uncovered. The latter requires a stem lift approximating the diameter of the port.

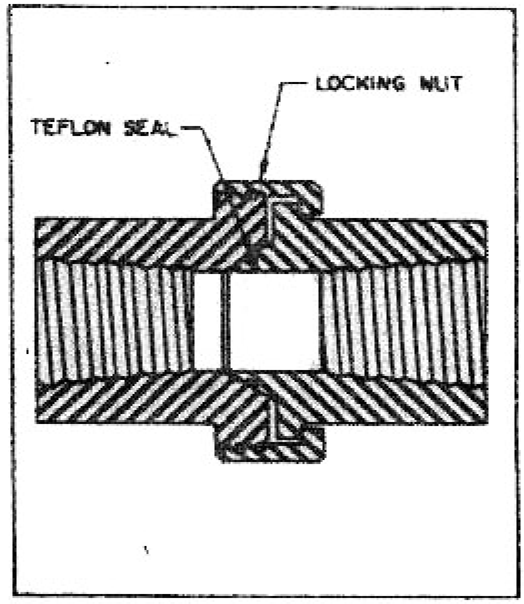
- Absence of Outgassing. In vacuum systems outgassing of volatile materials from sealing and lubricating greases and organic sealing materials cannot be tolerated. Greases are used sparingly, or not at all, in vacuum valves and where used, are special vacuum greases of low vapor pressure. Rubber-like materials—although gassy—are so efficient as sealers, that they are used in the majority of vacuum valves.

2.10.4.4: Gaskets and Seals

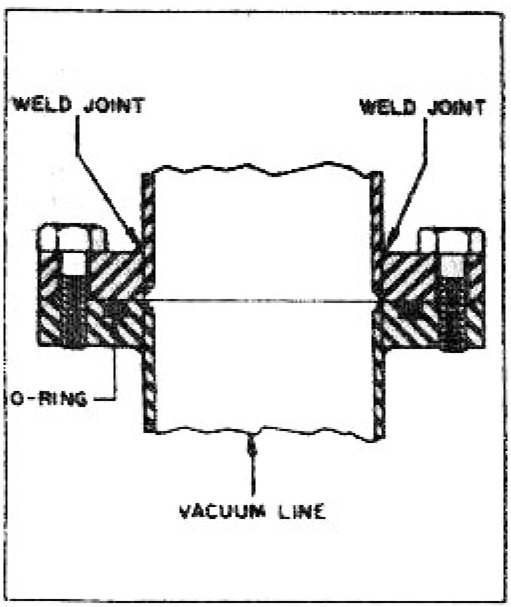
One of the most widely used vacuum seals is the O-ring, made of neoprene, butyl rubber, or Teflon. Gaskets made of soft metals such as lead, copper, or aluminum may be used over a wider temperature range than O-rings due to their lower expansion and contraction. Typical seals are shown in Figure 2-26. Also see Chapter 5, “Lubricants, Gaskets, Seals, and Packaging”.



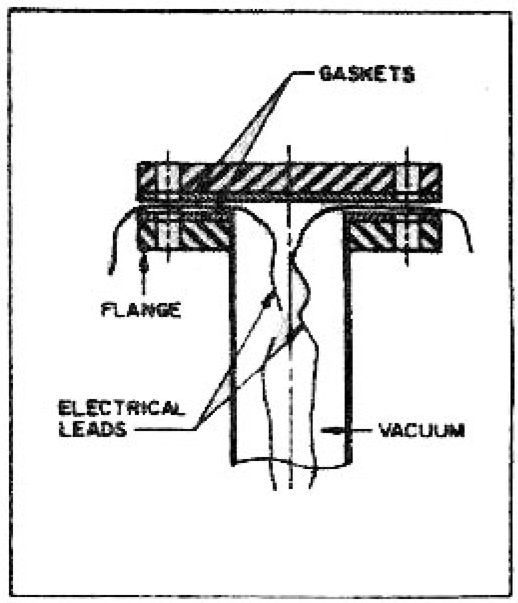
Vacuum Flanged Fitting With Gasket



Threaded Vacuum Line Fitting



Vacuum Flanged Fitting With O-ring



Vacuum Flange Fitting for Electrical Leads

Figure 2-26. Typical Vacuum Seals and Gaskets

2.10.5: System Leak Repair

Leaks in joints that are kept at room temperature are sometimes sealed by painting with a varnish such as Glyptal.

Leaks in gaskets usually require renewing or re-greasing the gasket. Where soft metal gaskets are used, a leak can sometimes be cured by annealing the gasket.

2.10.6: Leak Detection Tests

The most sensitive, reliable, and convenient instrument used for leak detector tests is the helium mass spectrometer leak detector. A typical setup for leak detection is shown in Figure 2-27. After the equipment being leak-tested has been evacuated, helium is sprayed over the outside of the equipment. If a leak is present, helium will enter the equipment and be transferred to the mass spectrometer by its vacuum pump. The cold trap shown is provided to protect the mass spectrometer from volatile substances that may be evolved by the test object. The mass spectrometer indicates any helium ions present inside the equipment. Leaks as small as 10^{-10} cubic centimeters per second can be located by use of this procedure. When spraying the helium over the outside of the equipment, it is important to start at the top of the equipment because helium, being light, will rise, so that a leak may apparently be discovered at the bottom of the equipment when the helium is actually entering through a leak higher up.

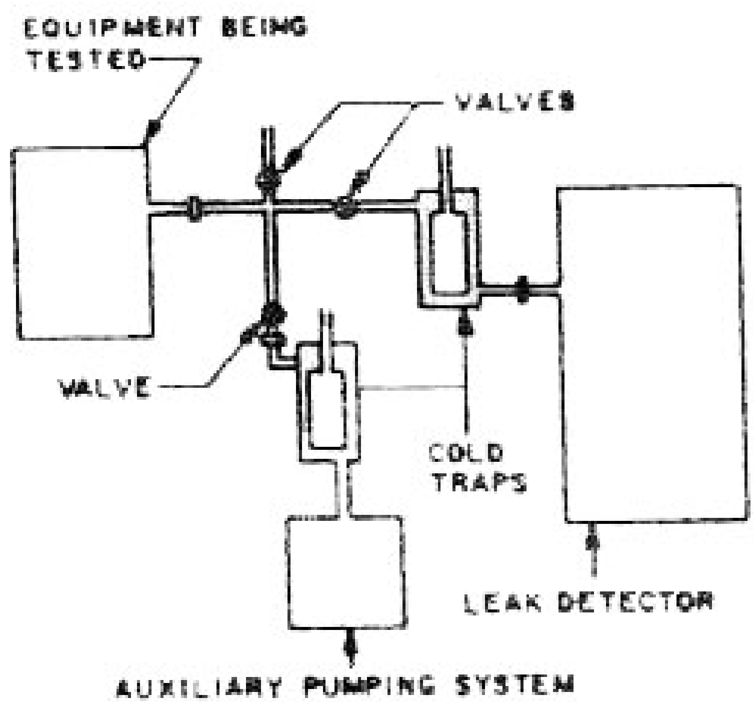


Figure 2-27. Leak Detector Test Setup

Another, more sensitive, method of using the helium mass spectrometer is to completely enclose the equipment being tested in a hood or enclosure and fill this area with an atmosphere of pure helium. This method will not show the specific, location of the leak but will localize it to a small area. A joint or suspected leak area may be tested by wrapping the joint or covering the area with a blanket of rubber or other airtight flexible material. Insert small tube under the blanket. Seal the edges of the blanket to the system with tape and induce helium.

The third method of using the helium mass-spectrometer is to fill the area being tested with helium at a pressure greater than atmospheric and use a sniffer probe that is connected to the leak detector. The sniffer is a fine valve at the end of a probing tube that admits gas very slowly so the leak detector can be kept in its operating range of 10^{-1} torr. This method is not as sensitive as the two previous methods because a large amount of air is always taken into the probe along with the small amount of helium escaping from the leak.

Valves and Regulators
Contents

3.1: Introduction

3.1.1: Equipment Laboratory Procedures

All valves procured for use at the Field Laboratories pass through the Equipment Laboratory (E.L.) for inspection, lubrication, and identification. At the same time, they are hydrostatically or pneumatically proof-tested to 1-1/2 times their maximum working pressure (MWP). A metal tag is then attached to the valve to designate a specific use. A valve should not be used for service other than that specified.

All valves at the Field Laboratories are rated at 100˚ F and the maximum working pressure at this temperature is stamped on the valve body. This maximum working pressure incorporates a safety factor of 4. The pressure marked on the valve should never be exceeded.

A Qualified Equipment List compiled by Equipment Engineering gives pertinent information on valves and other components suggested for use at the field laboratories.

3.1.2: Valve Rules

1. All valve repairs and adjustments must be performed by Qualified personnel.
2. Relief valves are tagged with check due dates and must be checked annually.
3. High-pressure hand valves are precision instruments and care should be exercised to avoid damage by over-tightening.
4. Valves should be used only under the pressure and service conditions stamped on the valve body.
5. Packing gland nuts and flange nuts should not be tightened while the system is pressurized.
6. Safety wires should never be cut and the lead seal should never be removed from valves by other than qualified personnel.

3.1.3: Valve Nomenclature

The following illustration (Figure 3.1) shows the parts of a typical valve. Terms in common use include:

Trim — The plug and seat combination. Metal to metal, O-ring to metal, and soft seat are common applications.

Plug — The movable portion which contacts the seat to form a seal. Different shapes are used to produce different opening characteristics.

Seat — The orifice through which the fluid flows. It is either all metal or is metal with a plastic insert which contacts the plug (soft seat).

Stem — The connector between the actuator and the plug.

Body — The main part of a valve. The part to which lines are attached by means of flanges or threaded bosses. (AN, and MS straight threads and NPT threads are in use.)

N.C. Normally closed (valve). A valve that is closed when de-energized.

N.O. Normally open (valve). A valve that is open when de-energized.

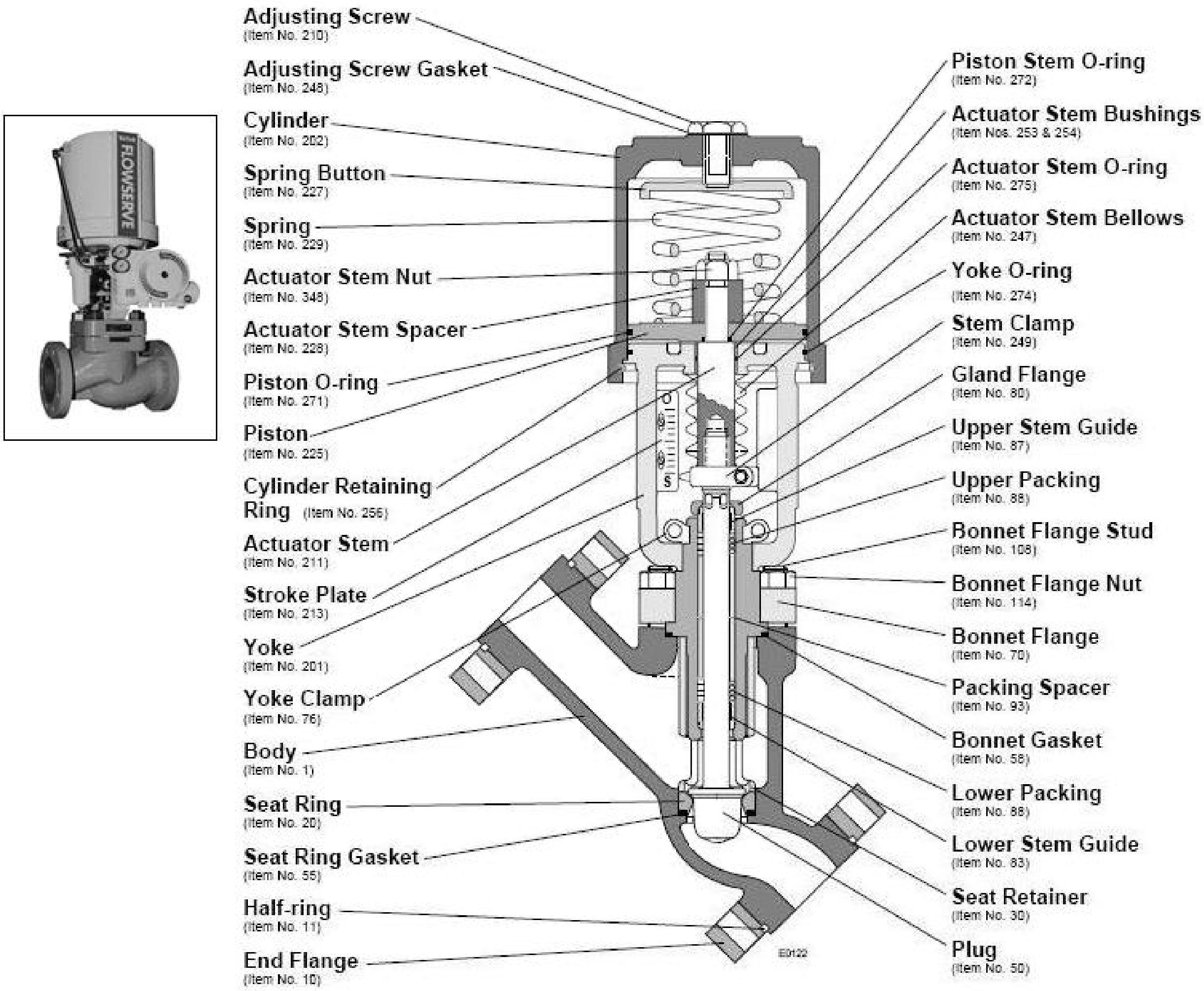


Figure 3-1. Typical Globe Valve

3.2: Valve Types

The many pneumatic and hydraulic systems used at the Field Laboratories require many types of valves. Each valve type has some characteristic which makes it suitable for a particular service. The different valve types vary in operation and the care required for reliable service.

The following descriptions and illustrations represent the most used valves, their particular characteristics, and any special precautions necessary for reliable operation.

3.2.1: Gate Valve

The major advantage of a gate valve is that it allows unrestricted fluid flow. The valve gate seals by a wedging action. (See Figure 3-2.)

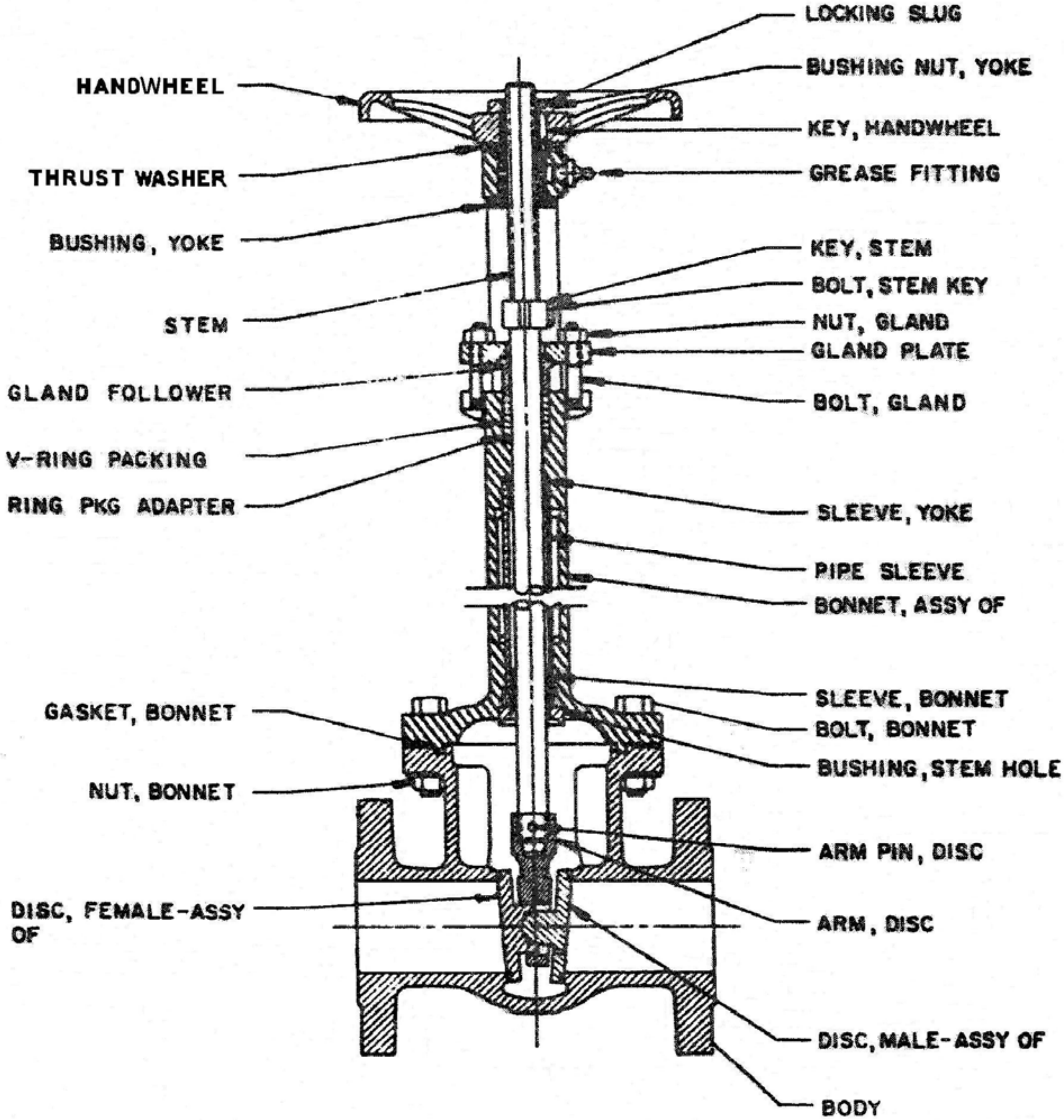


Figure 3-2. Gate Valve

Gate Valve (Grove Seal O-Rings)

This gate valve uses Kel-F O-rings and a parallel-sided gate rather than the usual Kel-F to metal seat and wedge gate to form the seal. The use of neoprene O-rings makes it unusable in liquefied gas service because of the low temperatures involved. This valve is in the 6,000 psi pressure range. Sealing is independent of shutoff forces. (See Figure 3-3.)

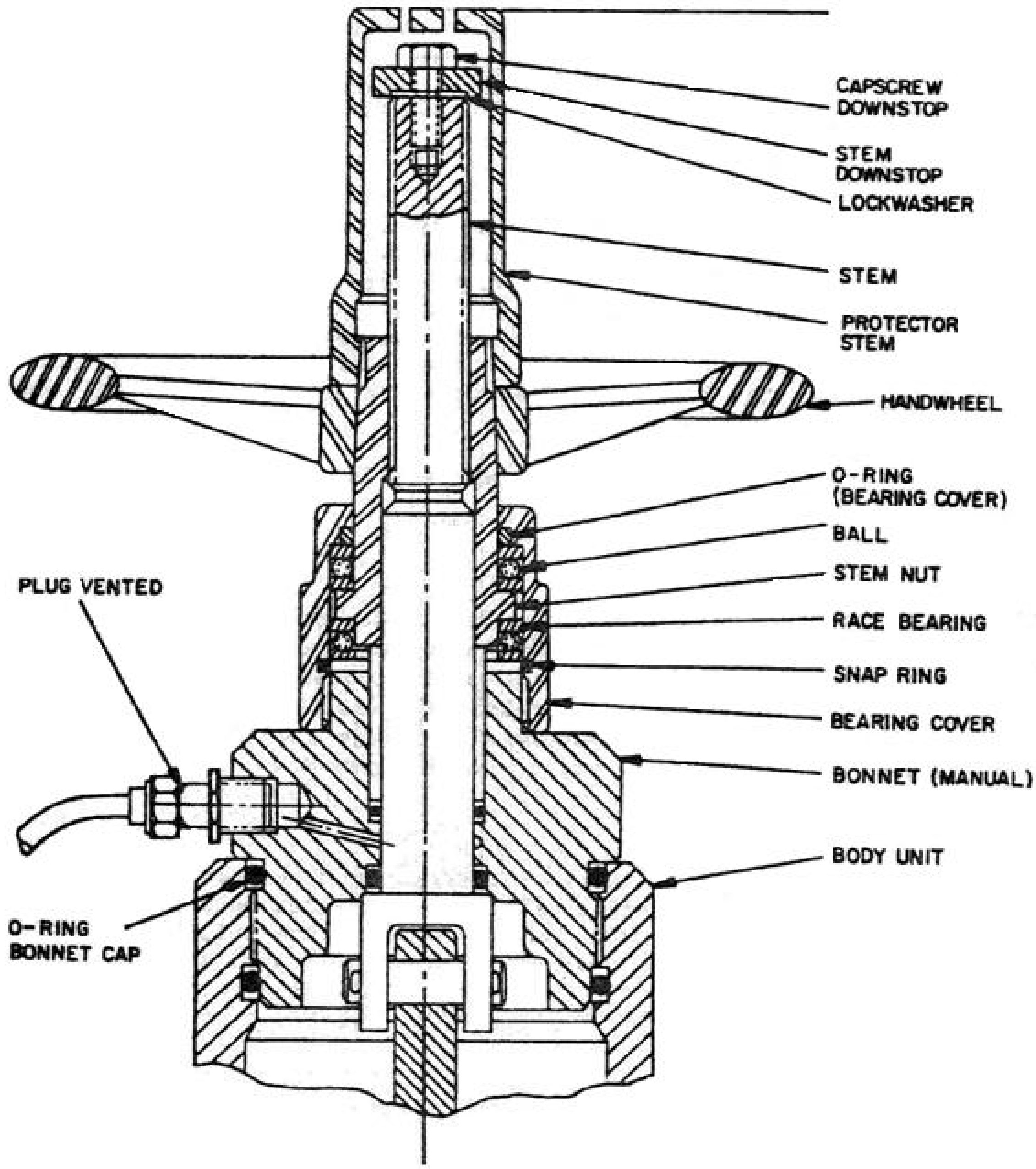


Figure 3-3. Manual Operating Mechanism Gate Valve (Grove Seal O-Ring)

3.2.2: Globe Valves

3.2.2.1: Anin

The Annin Company manufactures a globe valve, which is furnished in a variety of sizes, trim, connections, and operating pressures. Stem packing is normally of chevron Teflon. Some valves use metal to metal trim, but a metal plug and a Kel-F soft seat are more common. Operation of this valve is effected by a non-rising manual handle or by a pneumatic cylinder, either of which can be attached to the basic valve. There are two types of pneumatic cylinders, normally closed (N.C.) and normally open N.O.). The Annin pneumatic cylinders are limited to 150 psi maximum pressure (normal operation is in the 120 to 135 psi range to allow relief valves to be set at 150 psi), and Domotors to 100 psi. Annin valves can have high pressure cylinders, such as Miller cylinders.

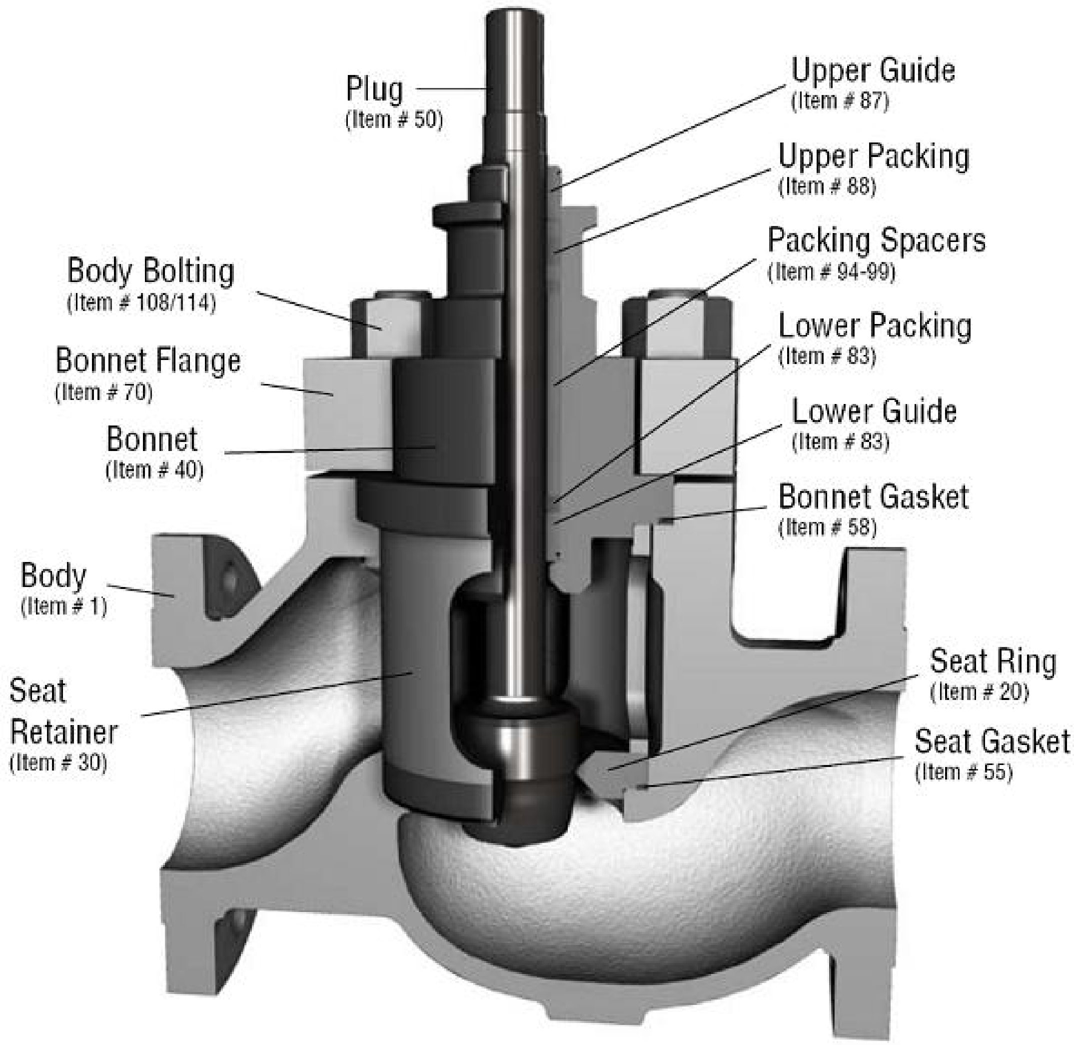


Figure 3-4. Standard Glove Valve

3.2.2.2: Seat Seal Valve (Grove)

The Grove T series (see Figure 3-5) is typical of this type of globe valve. Sealing of the seat seal valve is effected by an O-ring, rather than by the standard trim of plug and seat. Further tightening after the O-ring has entered the seat will cause a metal plug to contact the seat. Tightening beyond this point may result in seat damage, and damage is certain if strong hand pressure is exerted on the valve handle. Damage to the seat causes scuffing of the O-Ring seal. The Grove T series comes in 1/4, 3/8, and 1/2-inch sizes for working pressures up to 6,000 psi.

In addition to the O-ring seat seal, an O-ring seal is used around the stem, eliminating stuffing box difficulties.

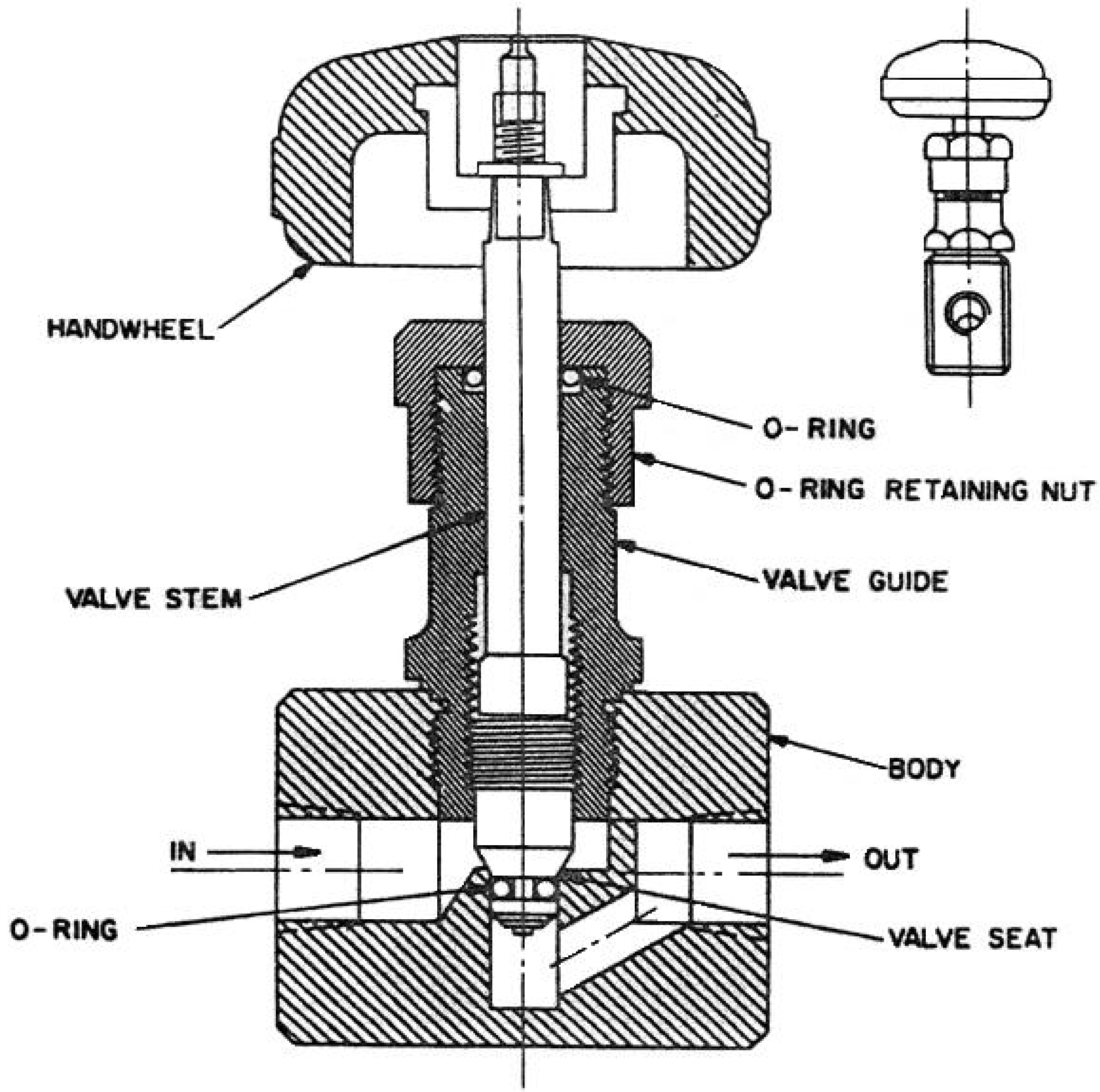


Figure 3-5. Seat Seal Valve

3.2.2.3: Needle Valve

This valve is a modification of a globe valve and is designed for high-pressure use (10,000 psi). The stem is tapered to form a plug, and the seat is built with a very small plug contact area. This small contact area is the trim results in high seating pressure from a relatively small force on the stem. Any undue force applied to the valve handle will damage the trim. Two-finger shutoff is sufficient for this type of valve. (See Figure 3-6.)

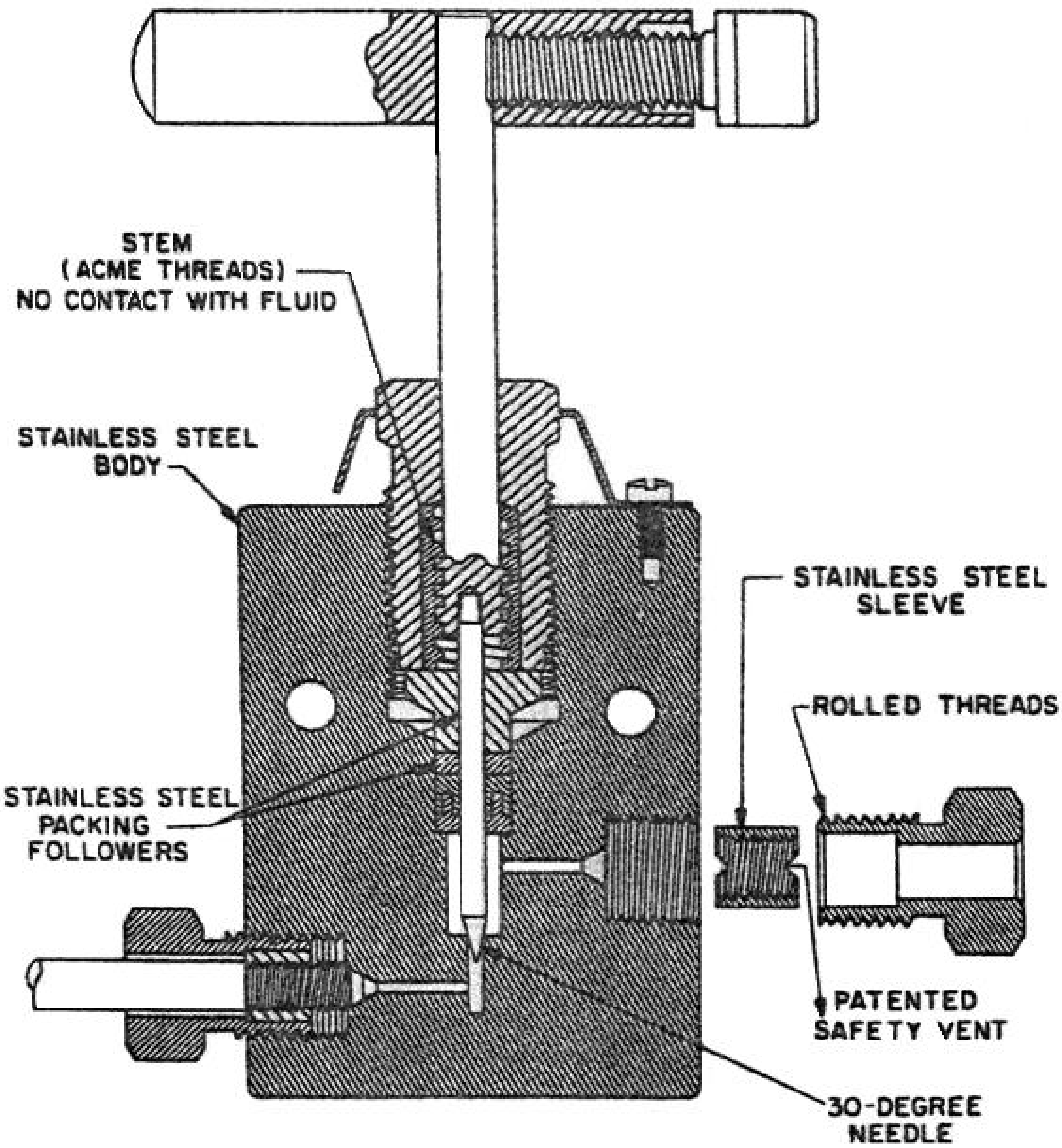


Figure 3-6. Needle Valve

3.2.3: Solenoid Valves, 3-Way

Solenoid valves are actuated by electrical energy. A direct-acting solenoid valve is one in which the opening and closing are controlled only by the solenoid. A pilot-operated solenoid valve is one in which the solenoid controls the flow of a small portion of the fluid which is in turn used to operate the main valve. The pilot-operated valve, however, requires a certain minimum fluid pressure before it will open or close (usually 30 psi).

3.2.3.1: Marotta

This solenoid valve is a direct-acting valve and is opened or closed completely by the action of the electric solenoid (28 V.D.C.). There are two inlet/vent ports and one outlet or cylinder port. Whether this valve is N.C. or N.O. depends on how the inlet pressure is plumbed. Energizing the solenoid closes one fluid path and opens the other. The Marotta MV-74P and KV-543 models are examples of this type of valve. (See Figure 3-7.)

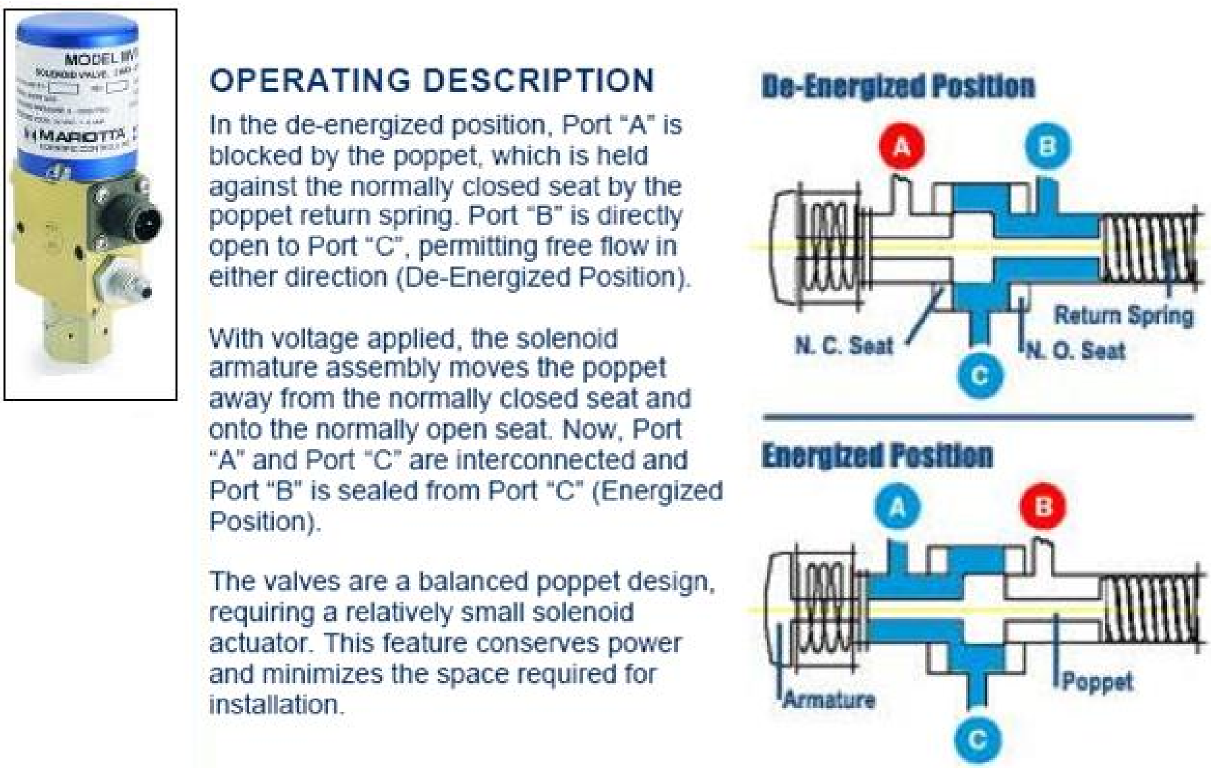


Figure 3-7. Solenoid Valve, 3-Way (Marotta)

3.2.3.2: Barksdale

The Barksdale solenoid valve is pilot-operated It uses a solenoid to control fluid flow to a piston, which opens or closes the valve. This valve is limited to 230 psi and is used to control flow to the Annin pneumatic cylinders. The Barksdale is furnished in two types, N.O. and N.C.

3.2.4: Solenoid Valves, 4-Way (Barksdale 4-Way)

The 4-way type valve can be used in place of two 3-way valves for control of a pneumatic air cylinder-operated valve. The ports are arranged so that one set is venting while the other is pressurizing.

3.2.5: Expansible Tube Valves

The Grove Flexflo is an example of the expansible tube type of valve. It is designed to be operated by pressure from the upstream supply pressure, a solenoid valve being used to control the upstream fluid pressure, which actuates the Flexflo valve. The pressure is equal on both sides of the expansible tube, but greater area is exposed to fluid pressure on the outside surface. The valve will stay closed while control pressure is on. Venting the control pressure allows the tube to expand and the valve to open. (See Figure 3-8.)

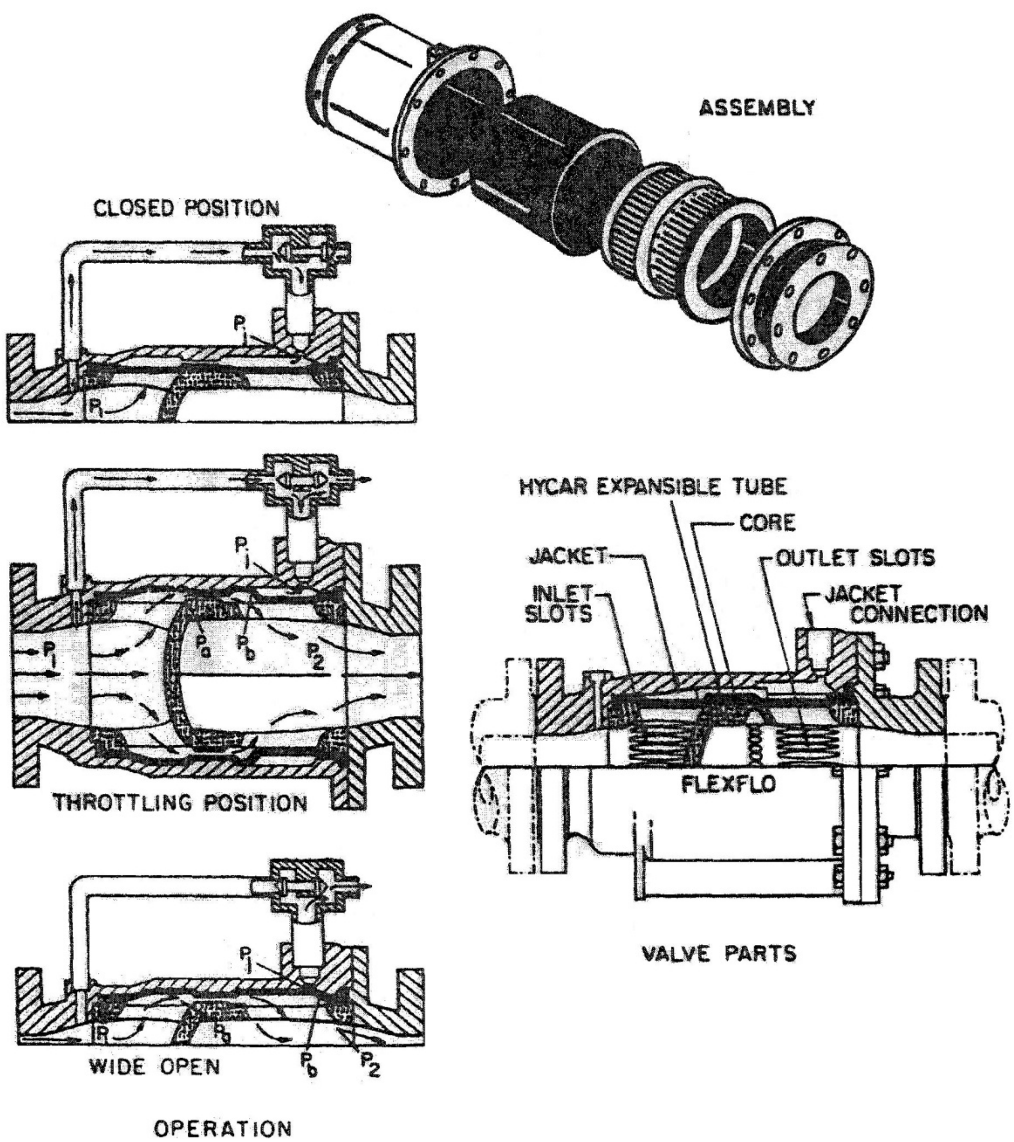


Figure 3-8. Expansible Tube Valve (Grove Flexflo)

3.2.6: Check Valves

Check valves operate on differential pressure and allow flow in one direction only. All restrict flow to some extent. The most common check valves used are the Split-Flapper type and the Poppet type.

3.2.6.1: Split-Flapper Type

The Split-Flapper type consists of two semi-circular discs hinged to a pin. Flow through the valve in the forward direction moves the discs, parallel to the flow stream and into the center of the valve. This type is more common in the larger sizes (3" and up) and has the advantage of minimum pressure drop per given size. (See Figure 3-9.)

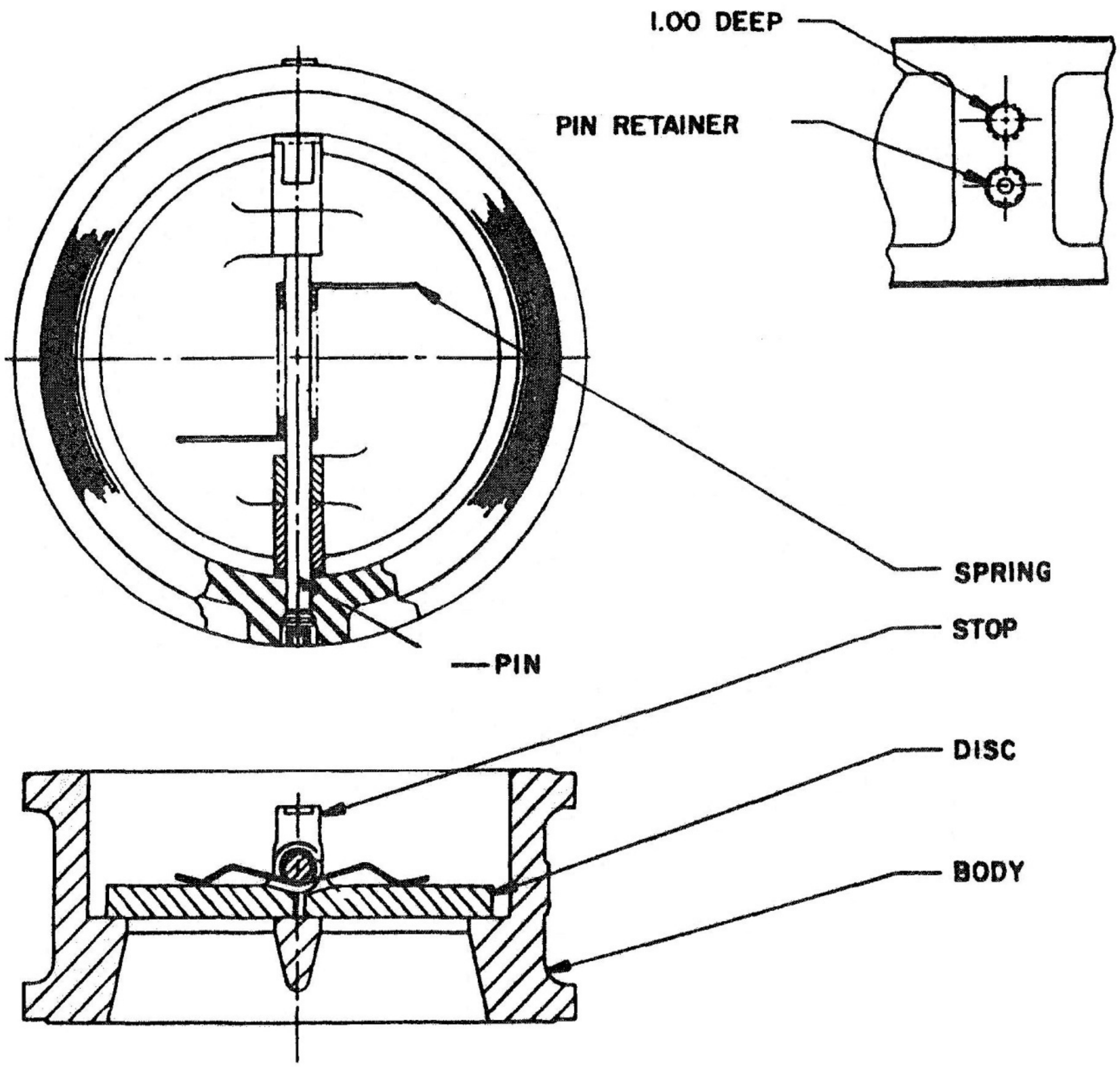


Figure 3-9. Check Valve (Split Flapper Type)

3.2.6.2: Poppet Type

The Poppet type consists of a sliding poppet, which is closely guided in the valve body and the head of which seals against an O-ring or metal seat. Flow through the valve in the forward direction forces the poppet off the seat and permits flow around the poppet and through the valve. Because of close tolerances within the valve, contamination or dirt can cause sticking and leakage. (See Figure 3-10.)

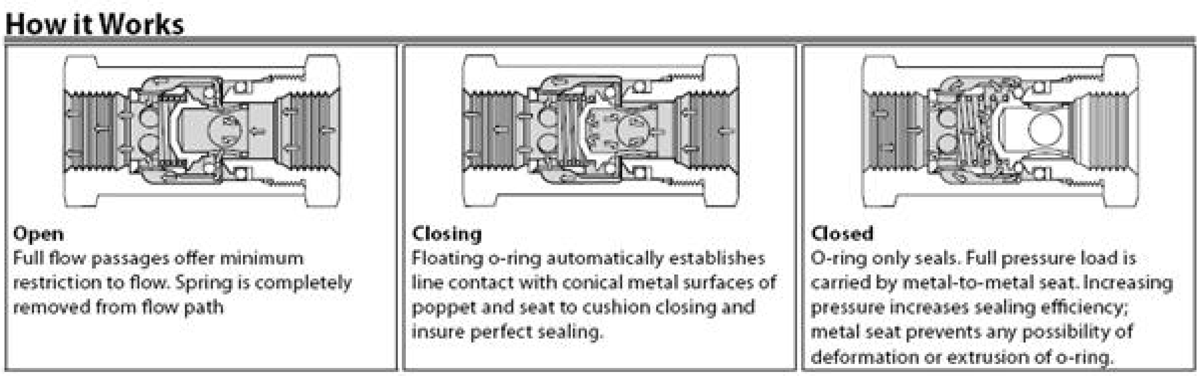


Figure 3-10. Check Valve (Poppet Type – Original image has been replaced with this one.)

3.2.7: Relief Valves

The typical direct operating relief valve utilizes a preset spring load to prevent valve opening. The valves have a set pressure tolerance of 2 psi for set pressures through 70 kpsi, and 3 percent for set pressures over 70 psi. They must reseat before the pressure falls below 90 percent of set pressure. The trim consists of O-ring, plastic or metal seat and metal nozzles. (See Figure 3-11.)

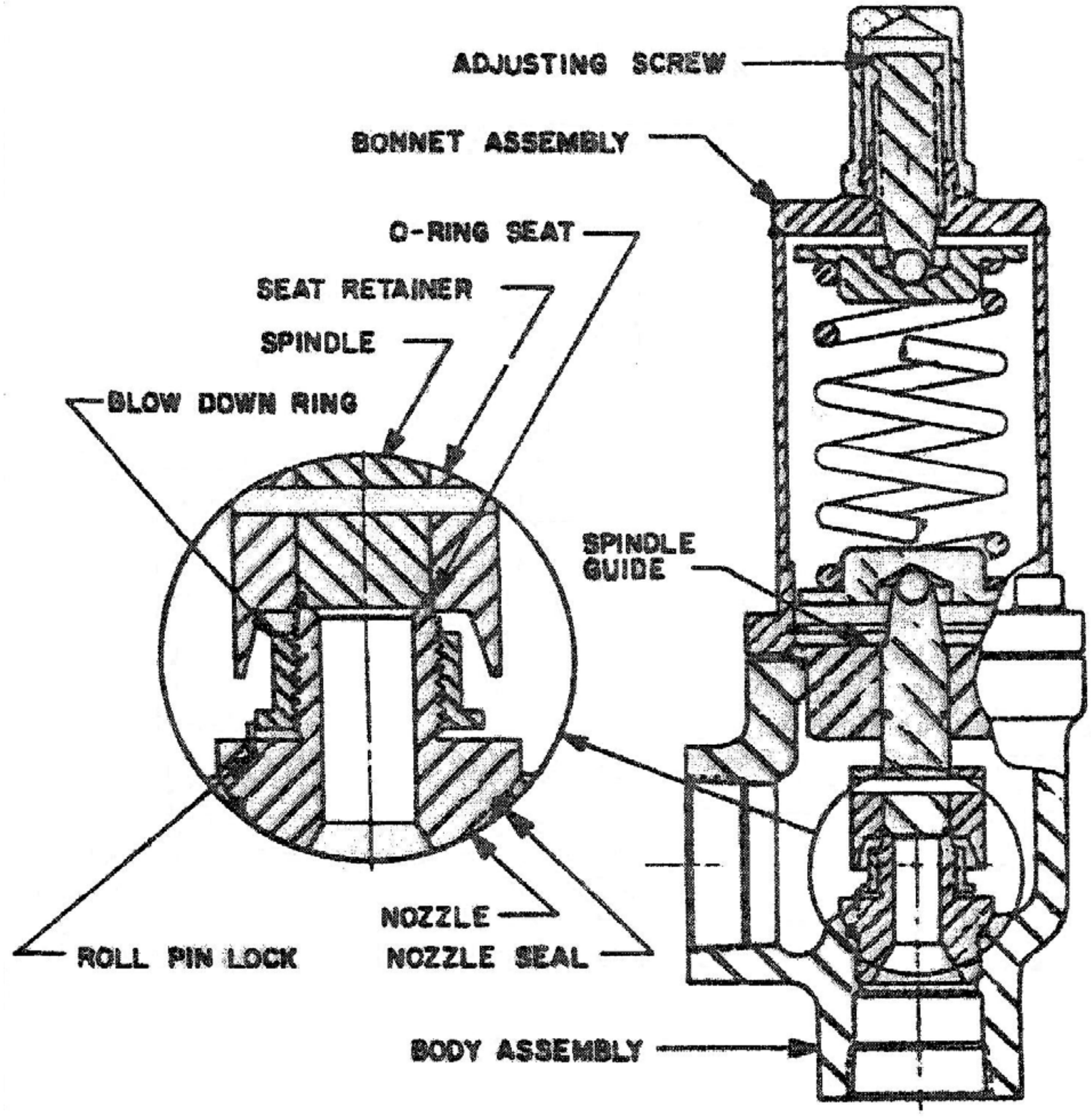


Figure 3-11. Relief Valve (Direct Acting)

The pilot-operated relief valve (AGCO) differs from the direct acting relief valve primarily due to the application of a separate direct operating relief valve (pilot) for control of pressure forces acting on the main valve piston. (See Figure 3-12.)

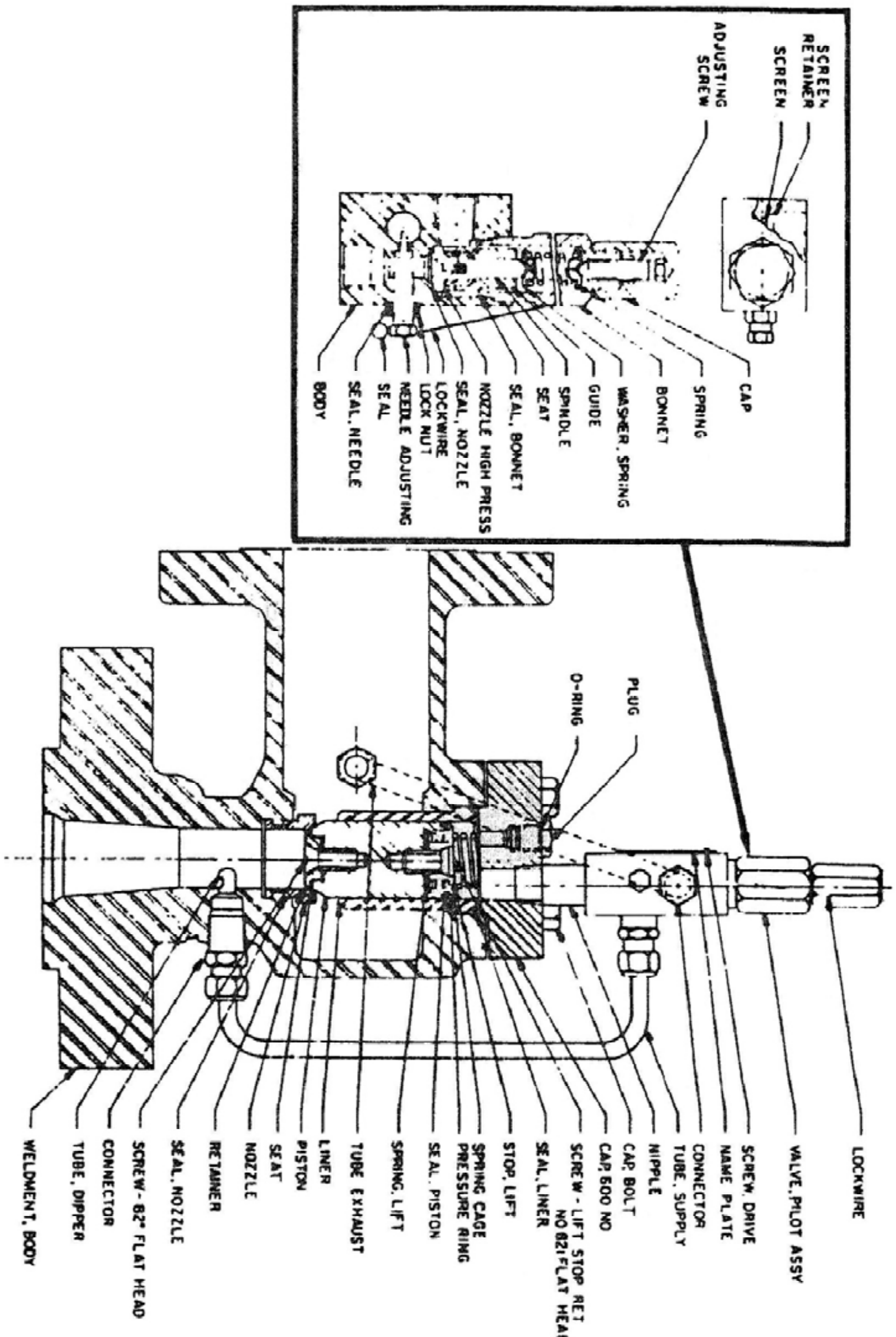


Figure 3-12. Pilot Operated Relief Valve (AGCO)

3.2.8: Ball Valves

Ball valves are used as shut-off valves in lines where a low pressure drop across the valve is desired. The ball valve, like the gate valve, allows unrestricted fluid flow with the additional advantage of eliminating the turbulence usually caused by the large body cavity of the gate valve. However, some ball valves tend to leak at low inlet pressures, due to the fact that the ball "floats" between two seat seals. There is no means of stopping seat leakage by tightening down the handle as with a globe or gate valve. (See Figure 3-13.)

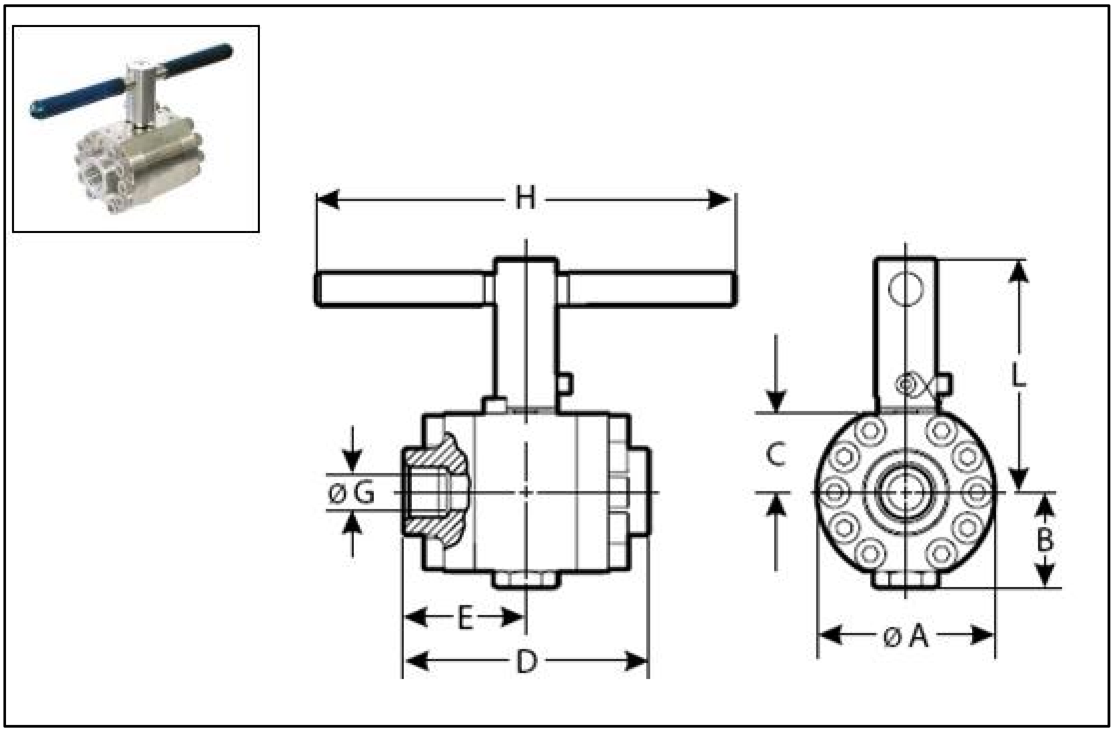


Figure 3-13. Ball Valve

3.2.9: Burst Diaphragms

The burst diaphragm or safety head is a device used to prevent excessive pressures or to allow flow at a predetermined pressure. The diaphragms are fragile and care must be used on installation to prevent creases, bends, or cuts; and clamping surfaces must be kept free of dirt or grit. Diaphragms are installed so that pressure is against the concave side. Since they are rated at a particular temperature (usually 72˚ F), the burst pressure must be redetermined for use at other temperatures. Burst diaphragms should be operated at 66 percent of the design burst pressure for normal burst diaphragm life. Vent lines must be positioned so that fluids are carried away from personnel. (See Figure 3-14.)

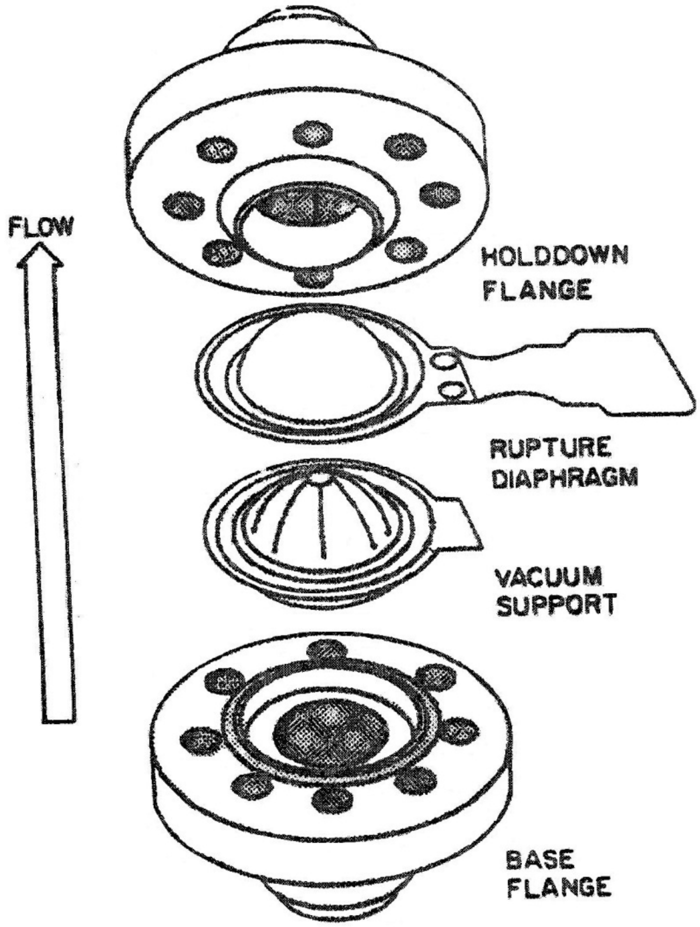


Figure 3-14. Burst Diaphragms

3.3: Pressure Regulators and Pressure Regulation Systems

3.3.1: General

An orifice regulates flow under dynamic conditions, but it does not function under static conditions. Automatic valving incorporating a diaphragm and plug to regulate pressure under dynamic or static conditions is a satisfactory method used in most mechanical regulators. This is accomplished by varying the flow area.

3.3.2: Large Volume Pressure Regulator (Grove Dome)

This regulator is of the diaphragm type and is made in three basic sizes (series 200, 300, 400) with additional valve trim variations in each series. The dome, which controls the pressure on the diaphragm, can be either internally loaded or externally loaded. External loading is usually with a Grove small volume hand regulator. This allows easy setting of the downstream regulated pressure. In operation the trapped pressure within the dome moves the large flexible diaphragm, forcing the reverse acting plug off its seat. The supply pressure entering the regulator is then permitted to flow through the open valve and into the reduced pressure line. An internal sensing passage transmits this pressure to the underside of the diaphragm. When the delivered pressure in the downstream line approximates the loading pressure in the dome and the unbalanced forces are equalized, the plug is closed. With the slightest drop in downstream pressure, the pressure trapped in the dome instantly forces the plug open, allowing sufficient flow to return the delivered pressure to the set point. (See Figure 3-15.)

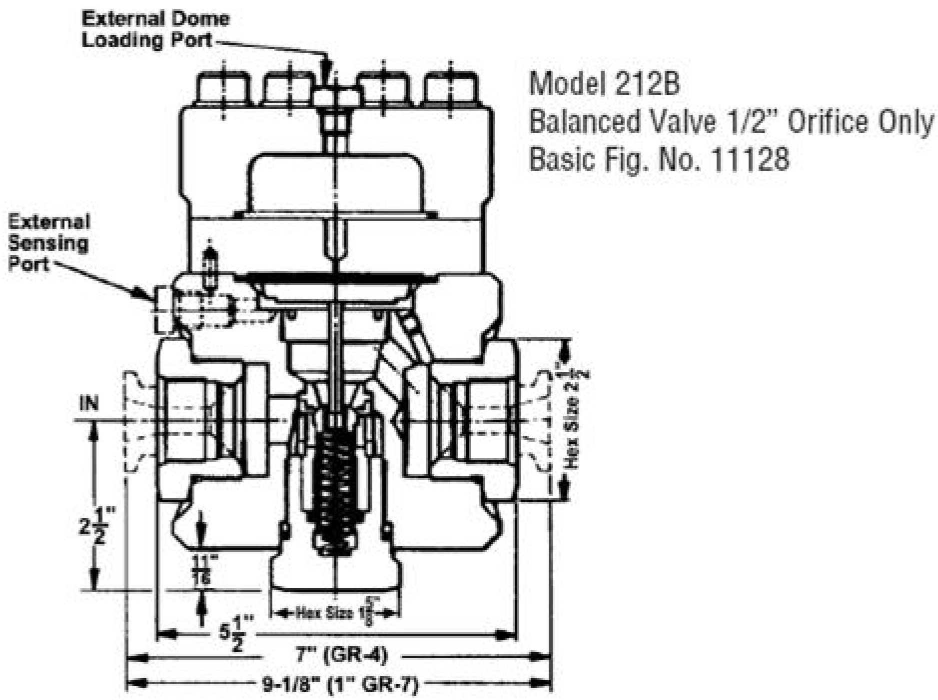


Figure 3-15. Regulator

3.3.3: Small Volume Pressure Regulator (Grove Handloader)

The Grove small volume high pressure regulators, or "handloaders" as they are familiarly known, are most commonly used to maintain a constant pressure within the domes of the grove dome regulators. The pressures coming from these regulators are subject to temperature variations. The handloader is stocked in several models, which determine the inlet and outlet pressure ranges. Inlet pressures are either 3,000 psi or 6,000 psi, while the regulated pressure is available in a wide variety of ranges from 0 to 6,000 psi.

In operation, as compression in the spring is increased by manually turning the handwheel, the inlet valve is forced from its seat, thereby, admitting pressure to the diaphragm chamber and outlet line. When this pressure on the diaphragm produces a force equal to the adjusted spring compression, the diaphragm rises, thus closing the inlet valve. When the spring force is reduced by turning the handwheel counter clockwise, pressure in the diaphragm chamber is greater than the spring force, the diaphragm assembly and relief valve seat rise, opening the relief valve and thus reducing the outlet pressure.

The sensitivity of this handloader is a function of the bleed adjustment, which corrects minor deviations beyond the scope of the main diaphragm spring. This bleed is adjustable by a small screw under the acorn nut. (See Figure 3-16.)

The bleed should be a minimum consistent with good regulation. Excessive bleed will consume large quantities or GN_2 over long periods of time.

NOTE: HANDLOADERS SHOULD NOT BE USED IN GASEOUS HYDROGEN SERVICE. THE HYDROGEN BLEED PRESENTS A FIRE HAZARD.

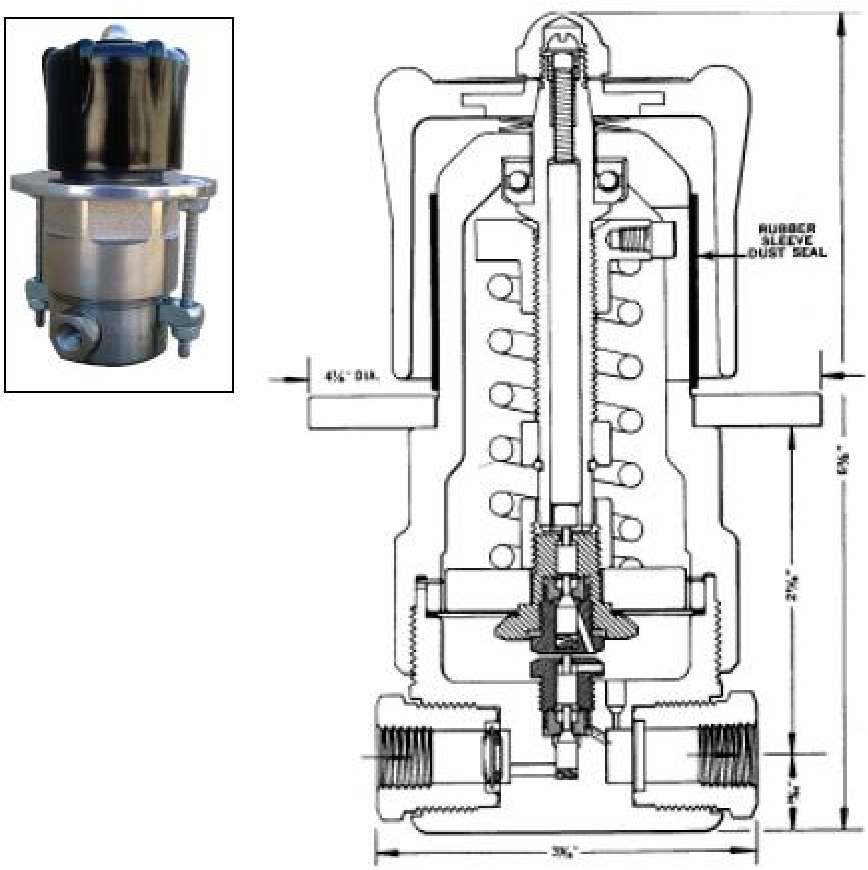


Figure 3-16. Handloader

3.3.4: Pressure Regulator (Grove Mity Mite)

Model 94-RR is a reducing and relief valve available in 1/4-, 1/2, and 1-inch end connections for inlet pressures to 6000 psi and outlet pressures to 5,000 psi. The operation of this regulator is similar to the dome regulator with the addition of a relief port, which will vent off downstream pressure in excess of the static loading. This regulator measures only 2-3/4 by 3-1/4 inches. The Mity Mite is also available without the relief feature for inlet pressures to 10,000 psi and outlet pressures to 6,000 psi. (See Figure 3-17.)

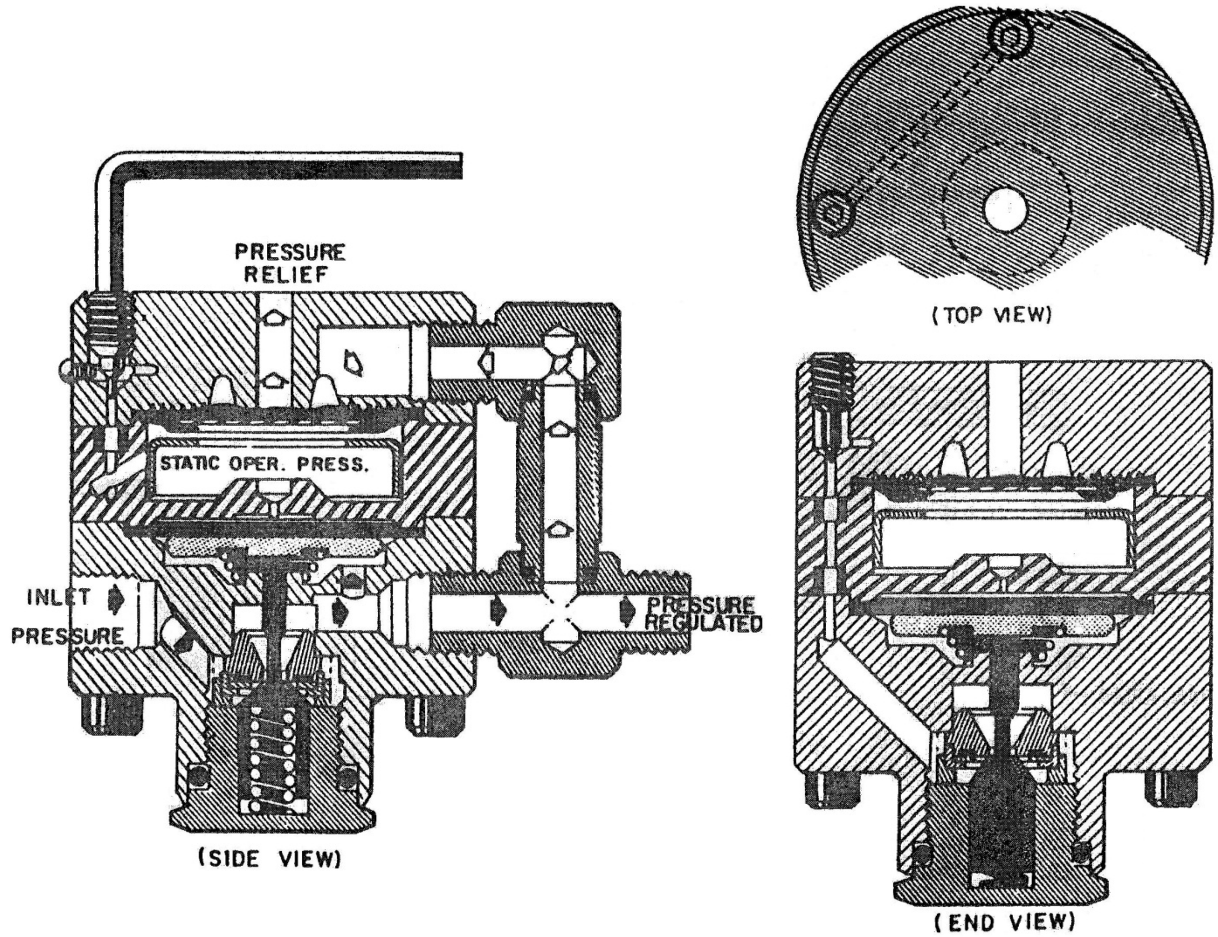


Figure 3-17. Pressure Regulator (Grove Mity Mite)

3.3.5: Pressure Regulation System

The small volume pressure reducing and relief regulator regulates the static pressure to the dome of the large volume regulator. The pressure in the dome actuates the large volume regulator valve, which maintains a constant pressure downstream of the regulator. Increasing dome pressure opens the large volume regulator valve and increases downstream pressure. Decreasing dome pressure closes the large volume regulator valve but will not decrease the downstream regulated pressure. To decrease downstream regulated pressure, the manual vent valve must be opened.

It is important to note that only the downstream pressure gauge indicates the regulated pressure. The dome loading pressure gauge does not read regulated pressure. (See Figure 3-18.)

The three-way solenoid valve shown between the small volume regulator and the large volume regulator (Figure 3-18), may or may not be plumbed into a system. The three-way solenoid is used for remote control of a regulation system.

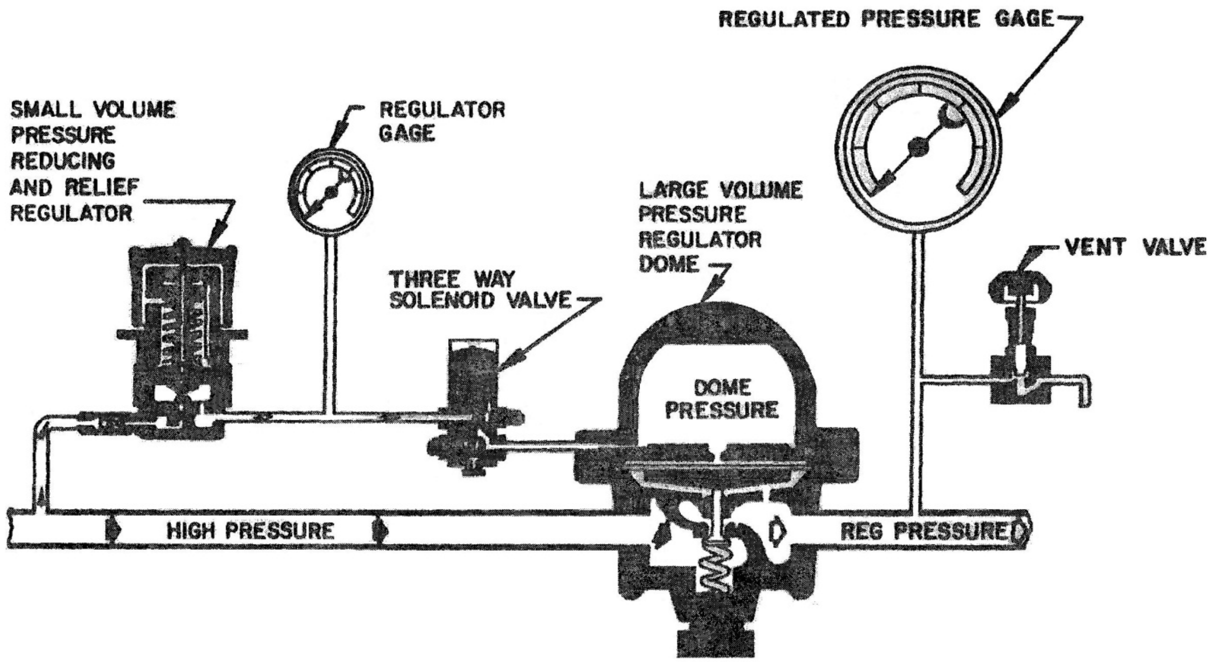
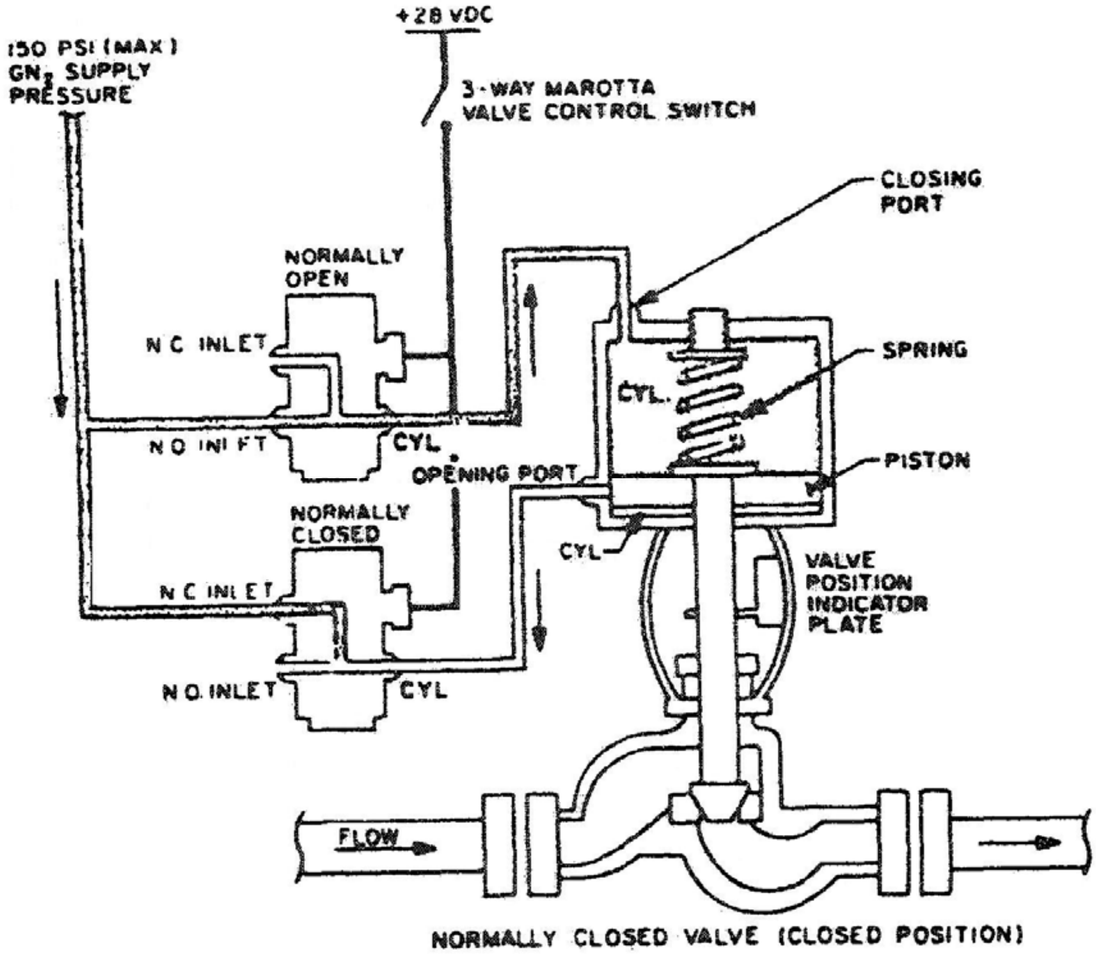


Figure 3-18. Pressure Regulation System (Pneumatic Panel)

3.4: Control Valve Installation

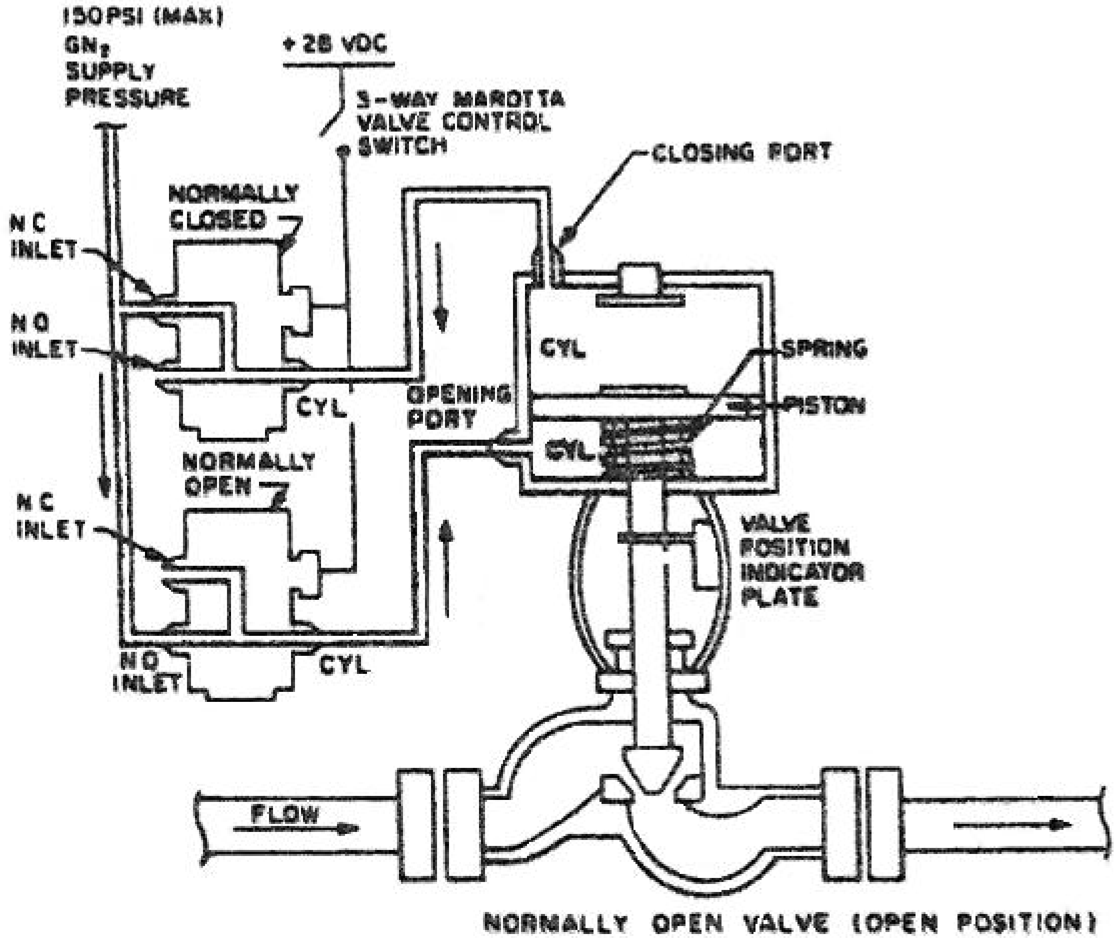
Figures 3-19, 3-20, and 3-21 show typical usage of regulated pressures in the control plumbing of an Annin valve installation, and its operation, with the use of two three-way solenoid valves and one four-way solenoid valve.



The opening and closing control valves for the Annin valve installation shown below are plumbed as follows:

- The Normally Open (N.0.) - 3-way control valve (Marotta) is plumbed to the Annin valve closing control port.
- The Normally Closed (N.C.) 3-way control valve (Marotta) is plumbed to the Annin valve opening control port.
- The two 3-way control valves are operated with one switch. By closing the switch the Annin valve is opened, by opening the switch the Annin valve is closed.
- When the Annin valve is in the closed position (as shown), the opening control pressure below the piston is vented to atmosphere through the normally closed control valve's normally open port.
- When the Annin valve is open, the closing control pressure above the piston will be vented to atmosphere through the normally open control valve's normally closed port.
- This Annin valve is plumbed Fail Safe Closed. In case of an electrical power failure, the Annin valve will return to the closed position. In case of GN_2 control pressure failure, the spring installed above the piston in the Annin valve will return the Annin valve to the closed position.

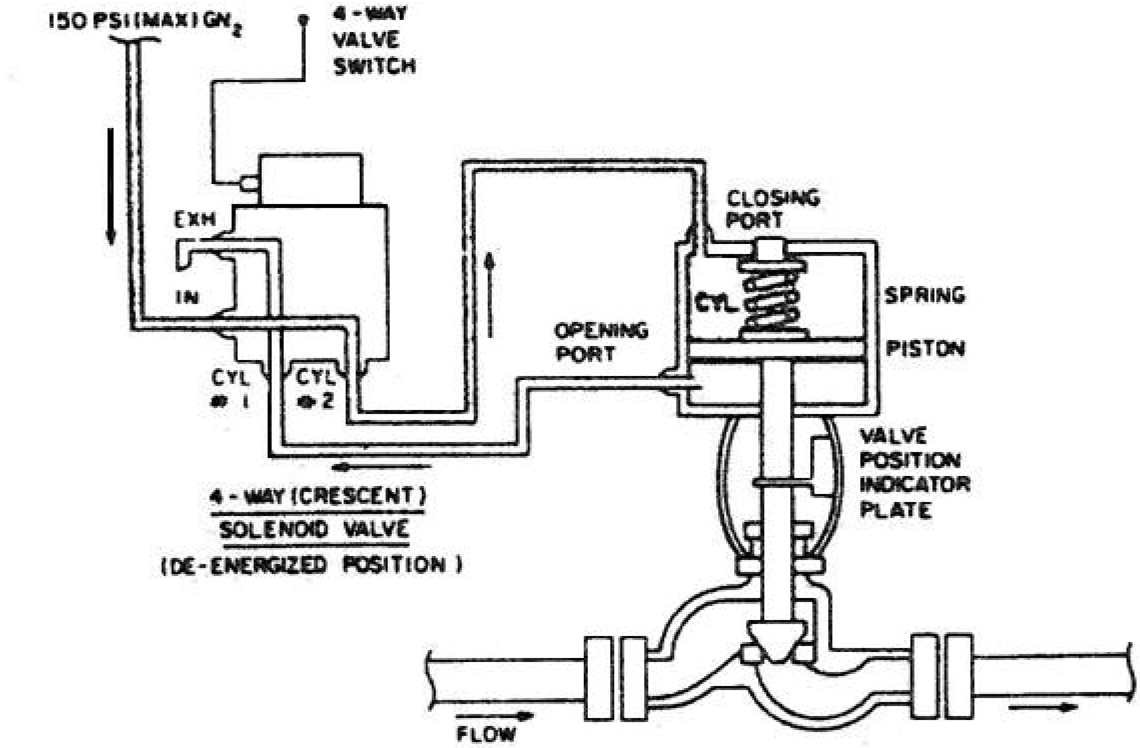
Figure 3-19. Relationship of Annin and Solenoid Control Valves (Fail Safe Closed)



The opening and closing control valves for the Annin valve installation shown below are plumbed as follows:

- The Normally Open (N.O.) 3-way control valve (Marotta) is plumbed to the Annin valve opening control port.
- The Normally Closed (N.C.) 3-way control valve (Marotta) is plumbed to the Annin valve closing control port.
- The two 3-way control valves are operated with one switch. By closing the switch the Annin valve is closed; by opening the switch the Annin valve is opened.
- When the Annin valve is in the open position (as shown), the closing control pressure above the piston is vented to atmosphere through the normally closed control valve's normally open port.
- When the Annin valve is closed, the opening control pressure below the piston will be vented to atmosphere through the normally open control valve's normally closed port.
- This Annin valve is plumbed Fail Safe Open. In case of an electrical power failure, the Annin valve will return to the open position. In case of GN2 control pressure failure, the spring installed below the piston in the Annin valve will return the Annin valve to the open position.

Figure 3-20. Relationship of Annin and Solenoid Control Valves (Fail Safe Open)



The Crescent Pilot-operated 4-Way Solenoid Valve requires a minimum operating pressure of 30 psi. It is used to control a pneumatically-operated valve in place of two 3-Way control valves.

The opening and closing control pressures for operation of the Annin Valve are plumbed as follows:

- A supply pressure of 150 psi (Max.) is plumbed to the IN port on the 4-Way valve.
- The 4-Way valve in a de-energized state with pressure up will have a flow path from the IN port to the CYL. #2 port.
- The 4-Way valve in an energized state with pressure up will have a flow path from the IN port to the CYL. #1 port.
- The 4-Way valve CYL. #2 is plumbed to the closing control port on the Annin Valve, so that with pressure up and the 4-Way valve de-energized, a constant supply of pressure is holding the Annin Valve closed.
- The 4-Way valve CYL. #1 is plumbed to the opening control port on the Annin Valve so that with pressure up and the 4-Way valve de-energized, the opening control pressure is vented to atmosphere through the Exhaust port on the 4-Way valve.
- When the 4-Way valve is energized, the pressure in the CYL. #2 is vented to atmosphere through the Exhaust port and CYL. #1 is opened to pressure. When the 4-Way valve is energized, the Annin Valve will open if plumbed as shown.
- This Annin Valve is plumbed Fail Safe Closed. In case of an electrical power failure, the Annin Valve will return to the closed position from an open position. In case of GN2 control pressure failure, the spring installed above the piston in the Annin valve will return the valve to the closed position.

Figure 3-21. Annin Valve (Closed Position)

Fasteners
Contents

Page

4.1: General

Bolts are generally used to fit through a hole rather than to thread into one. Bolts are classified by size, configuration, and tensile strength under an MS specification heading. MS is the Military Standards symbol for a specification standard. Make certain that the bolts to be used and installed are the ones called out on the drawing (or other document). Do not substitute bolts unless authorization has been secured from the responsible engineer.

Anytime a deviation from a drawing (or other document) is to be made, it shall be made only with an EWR from the responsible engineer or supervisor.

Screws are generally used in applications where they are screwed into a threaded hole rather than through a clearance hole. Screws are also categorized and identified by MS numbers. Care must be taken to use the recommended configuration, size, and strength for a particular job.

Nuts are generally used to secure or immobilize some component or assembly. The MS prefixes, as well as other means of identification, are used to classify nuts at Rocketdyne.

Washers are generally used as a seat for bolt heads and nuts. The function of a washer may be to keep a bolt or nut from unthreading, to act as a spacer, or serve as a device which will allow a bolt to be stressed to its proper torque value with a minimum of frictional resistance.

Pins are used in fastening parts together. Pins are usually designed for close fit and may be designed to be forced into contact with mating parts.

Safety wiring is a method of securing nuts, bolts, screws, and other fasteners to keep them from vibrating or shaking loose. Methods of securing fasteners are accomplished in a number of ways, such as safety wiring and tack welding.

4.2: Installation of Fasteners

All threaded parts shall be installed as shown on the drawing. Lubrication shall not be used (except as shown on the drawing) where both threaded parts are bare corrosion-resistant steel. Tightening shall be accomplished by rotating the nut if possible.

Excessive tightening of nut will overstress the fastener, causing distortion or stripping of the threads, while insufficient tightening results in loose joints. Fasteners which have been bottomed or the threads otherwise damaged shall be replaced.

Bolts used with self-locking nuts and inserts must be without cotter pin holes in threaded shank.

Bolts and screws shall run free enough to engage the threads of threaded parts by hand, without using a wrench.

CAUTION:
There have been mishaps caused by substituting bolts of a different (and weaker) material, even though the correct size bolt was used. Do not interchange bolts made of different materials. Deviations to the drawing (or other document) shall be made only with authorization from the responsible engineer and shall be conveyed by EWR.

4.3: Fastener Head Styles

Some typical fastener head styles are shown in Figures 4-1 through 4-3. For more detail see the Standards Manual.

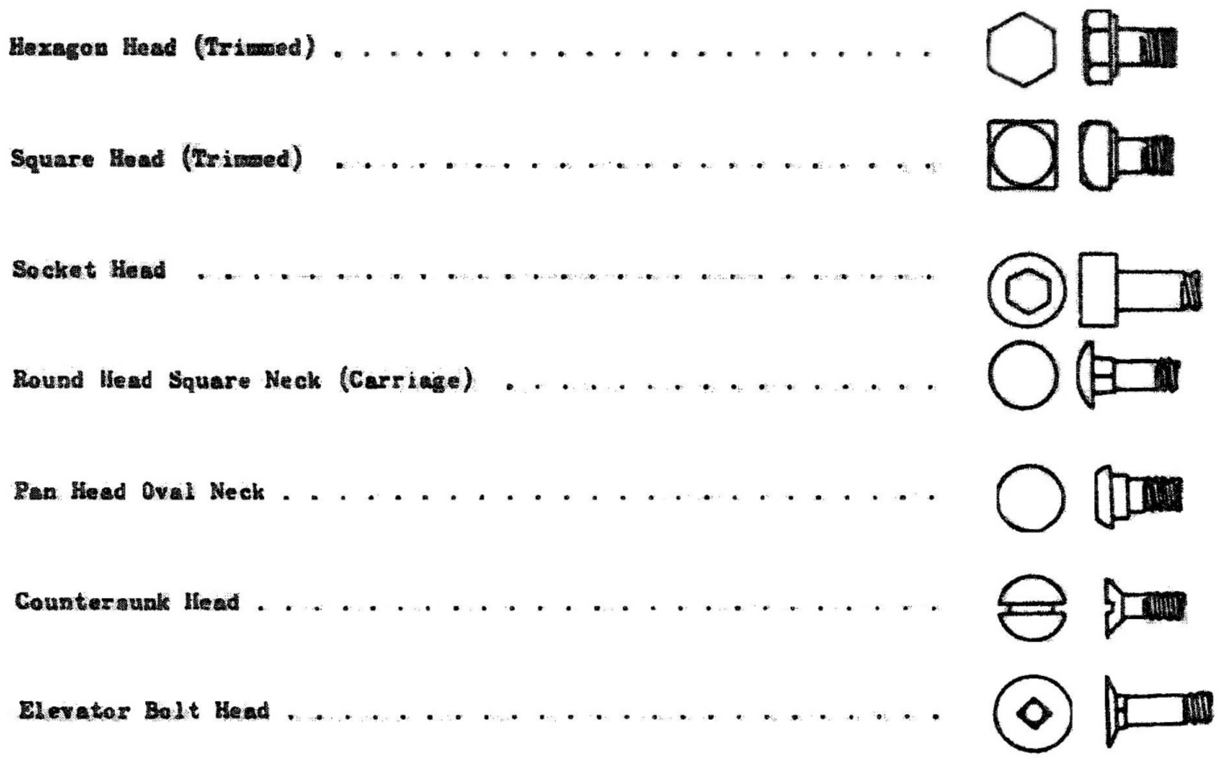


Figure 4-1. Fastener Head Styles: Bolt and Cap Screw Heads (Sheet 1 of 3)

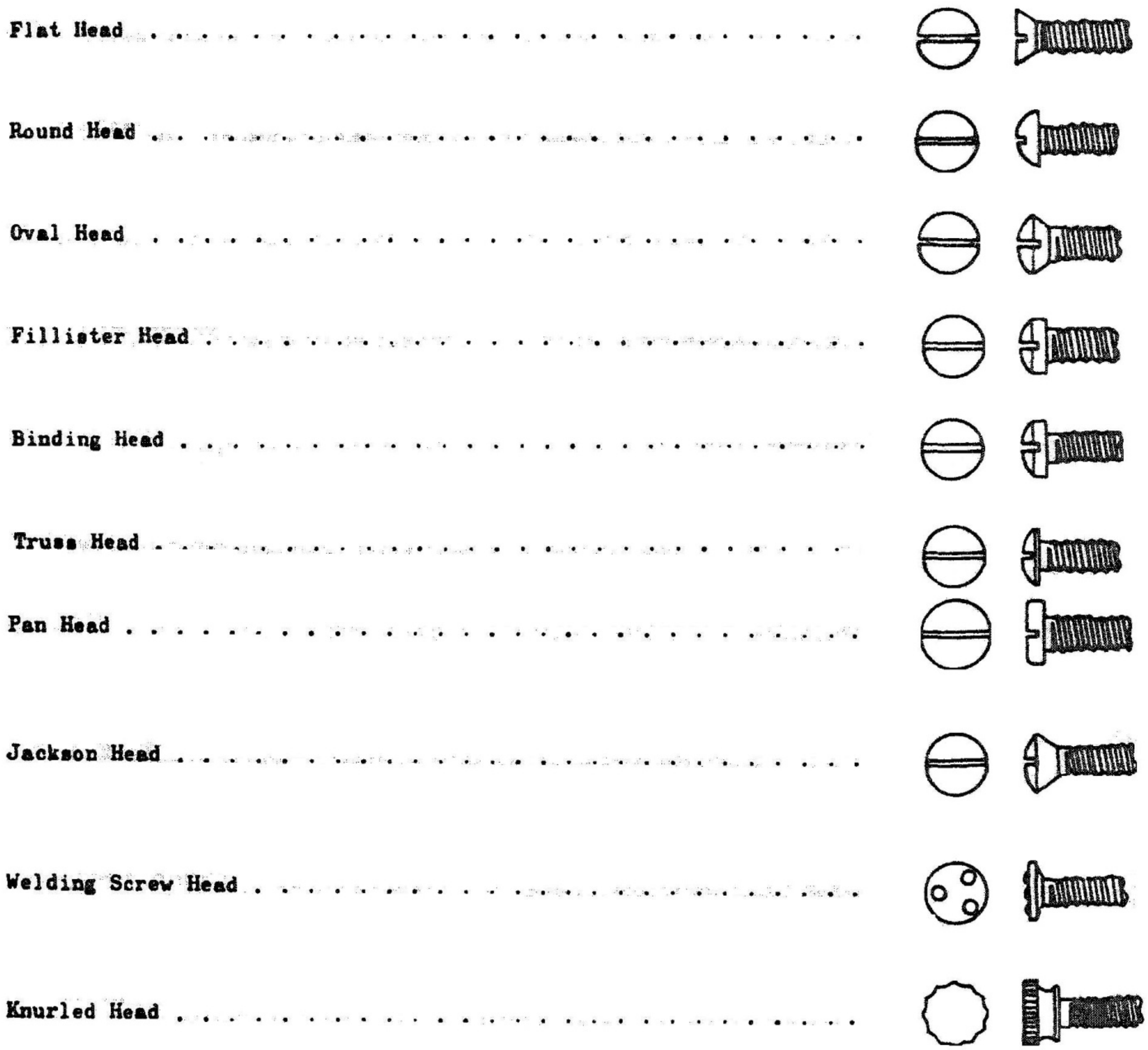


Figure 4-2. Fastener Head Styles: Screw Heads (Machine, Wood, Tapping, Stove Bolts) (Sheet 2 of 3)

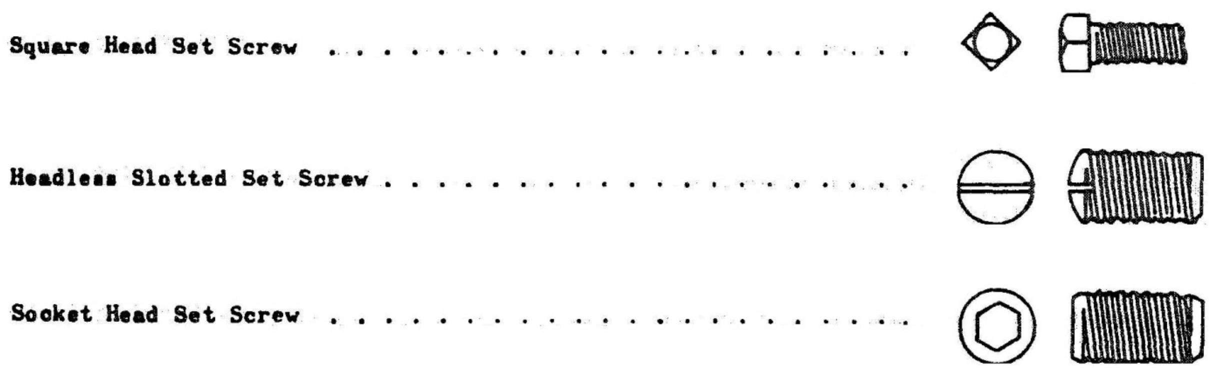


Figure 4-3. Fastener Head Styles: Set Screw Heads (Sheet 3 of 3)

4.4: AN Bolts

Bolt numbers consist of a basic number followed by a dash number. Basic numbers indicate the type, diameter of shank, and thread size. Dash numbers indicate the length. As bolt lengths are not consistent between AN designations, the specific AN designation should be consulted for the dash number of the length required. Complete tables of AN designations are available in the Standards Manual. Basic numbers and dash numbers of both are interpreted as follows:

AN4-10	1/4" diameter, 1-1/32" long, with cotter pin hole
AN5-7A	5/16" diameter, 3-1/32" long, without cotter pin hole (undrilled)
AN5H-6A	5/16" diameter, 27/32" long, drilled head, without cotter pin hole

4.5: AN Screws

Screw numbers consist of the basic number followed by two dash numbers. The basic number indicates the head shape. The first dash number indicates the diameter of the screw. The second dash number indicates the length of the screw.

The absence of a letter before the first dash number indicates a carbon steel screw. The letter "C" before the first dash number indicates a corrosion-resistant steel screw. The letters "DD" before the first dash number indicates an aluminum alloy screw.

The letter "R" between the first and second dash number indicates a recessed head. The absence of a letter between the first and second dash number indicates a slotted head screw.

Screw head markings, such as dashes or crosses, indicate screw material. The symbols used vary among the different screw types. Consult the Standards Manual for specific information.

Example:

AN507 – 428 R 20

- 20 — Second dash number - length
- R — Recessed head (absence of letter indicates slotted head)
- 428 — First dash number - diameter
- AN507 — Basic screw type

4.6: AN Nuts

Nut numbers consist of the basic number followed by a dash number. Basic numbers indicate the type of nut; dash numbers indicate the diameter in 1/16ths. Nuts are steel unless otherwise coded (except AN341).

The addition of the letter "C" before the dash number indicates corrosion-resistant steel. The letter "D" before the dash number indicates aluminum alloy. The absence of a letter before the dash number indicates carbon steel. The letter "L" after dash number indicates a nut with a right-hand thread. The letter "R" after dash number indicates a nut with a right-hand thread. A complete list of nuts and their specifications can be found in the Standards Manual. This numbering pattern does not apply to Rocketdyne Standard Nuts.

Example:

AN315 C 7 R

- R — Right-hand thread
- 7 — Dash number - - nut size
- C — Material - - corrosion –resistant steel (absence of letter indicates carbon steel)
- AN315 — Basic nut type

4.7: Washers

Washers are available in a variety of types, sizes, and materials. Washer numbers consist of basic number, which indicates the type of washer, followed by a dash number, which indicates the size of the washer. Additional letters before the basic number or before or after the dash number refer to variation of shape, material, or thickness. The symbols used vary among the different washer types. Consult the Standards Manual for specific information.

Example:

AN935-10L	Steel lock washer for #10 bolt (light)
AN936B10B	Bronze washer, external teeth, for #10 bolt
2W17-416M	Corrosion-resistant steel washer .032 thick for 1/4" diameter fastener
MS20002C8	Countersunk washer with 1/2"' nominal ID

4.8: Pins

Pin types and sizes are identified by part numbers. The part number consists of the basic number followed by one or two dash numbers. The basic number indicates the type of pin; for flat head pins, it also indicates the length. If there are two dash numbers, the first dash number indicates the diameter and the second dash number indicates the length.

Example:

AN380-4-4	Steel cotter pin, 1/8" diameter, 1" long
AN392-7	Flat head steel pin, 1/8" diameter, 7/32" grip

MS dash numbers are not consistent and have no special meaning outside of the context of their use for a given part. Consult the Standard Manual for specific performance.

4.9: Applying Fasteners

4.9.1: Safety Wiring

Where lockwire is specified and aluminum seals are shown on the drawing, each lockwire pigtail shall be sealed.

Lockwire and cotter pins shall be installed only one time; destroy if removed for any reason. Avoid sharp bends (kinks) and picking in both lockwire and cotter pins.

Lockwire shall be as short as possible and attached in the most direct manner. The double-twist method of safety wiring shall be used as the common method of safety wiring. The single-wire method of safety wiring may be used on small screws in a closely spaced closed geometrical pattern (triangle, square, rectangle, circle, etc.), on parts in electrical systems and in places that are difficult to reach that would make the single-wire method more advisable.

When safety wiring widely spaced multiple groups by the double-twist method, three units shall be the maximum number in a series. When safety wiring closely spaced multiple groups, the number of units that can be safety wired by a 24-inch length of wire shall be the maximum number in a series.

Parts shall be safely wired in such a. manner that the safety wire shall be put in tension when the part tends to loosen. A pigtail of 1/4 to 1/2 inch (3 to 6 twists) shall be made at the end of the wiring and shall be bent back or under (in a direction to increase the tension) to prevent it from becoming a snag. If an attach point to the structure is required (as when safetying a single bolt), it shall be made only where shown on the drawing.

Safety wire shall always pass around the fastener head except on MS type internal wrenching tapered head bolts, in which case the wire shall pass over the head. Figure 4-4 illustrates typical examples of these two variations. In safety wiring Mullin grooved-head type screws, the safety wire shall pass around the head and be contained within the grooves provided.

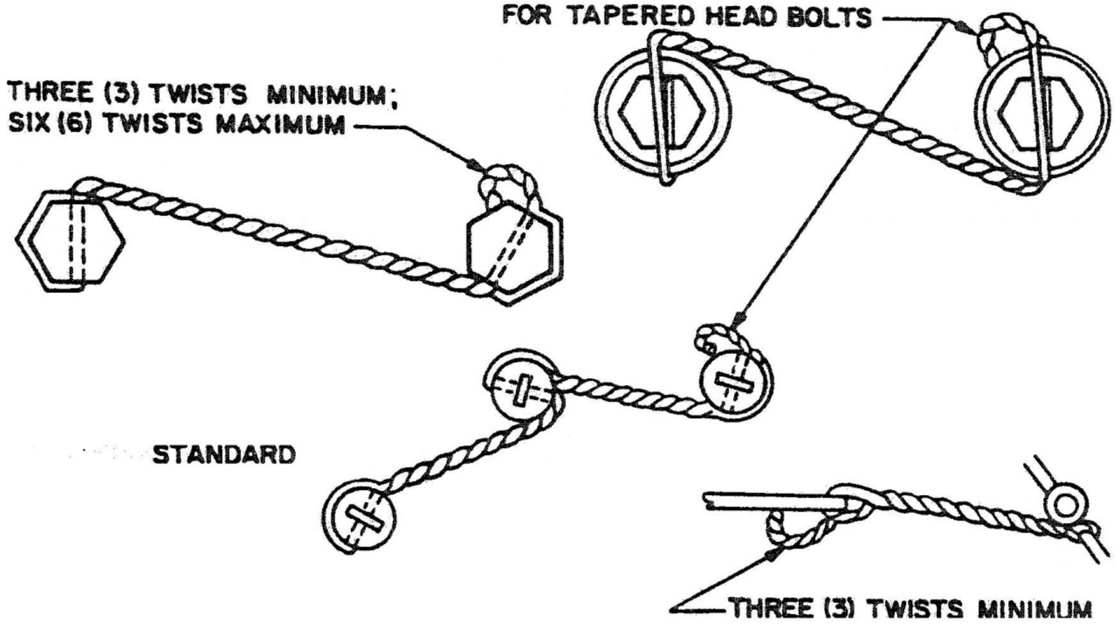


Figure 4-4. Lockwiring

4.9.2: Cotter Pins

There are two methods of installing cotter pins. (1) Where one end of the cotter pins goes over the top of the nut and (2) where ends go around the flats of the nut (see Figure 4-5). The first method is preferred and should be used whenever possible, except for human safety precautions, interference with clothing or equipment, and flat head pins.

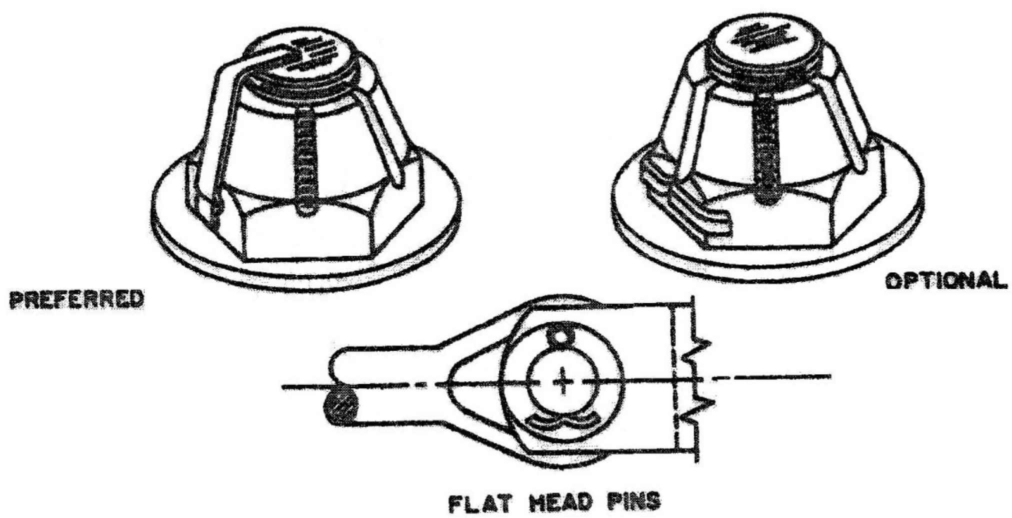


Figure 4-5. Pin Installation

4.9.3: Allowable Tilt Under the Head of Bolts and Screws

Maximum acceptable tilt under the head of bolts and protruding head screws and the maximum acceptable gap under the head of flush head fasteners shall not exceed 0.005 inch. (See Figure 4-6.)

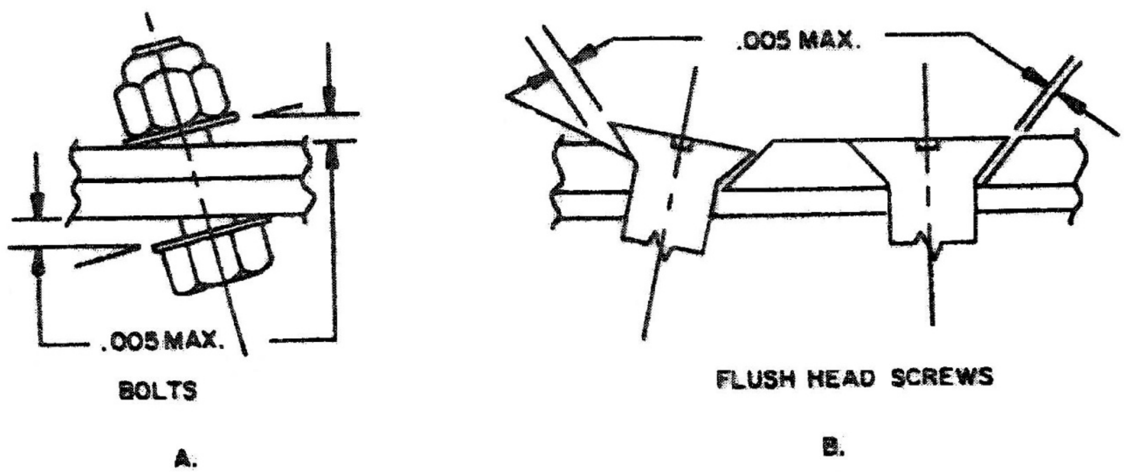


Figure 4-6. Allowable Tilt Under Head of Bolt

4.9.4: Location of Bolt Holes

Bolt heads shall be fully bearing on material. (See Figure 4.7.)

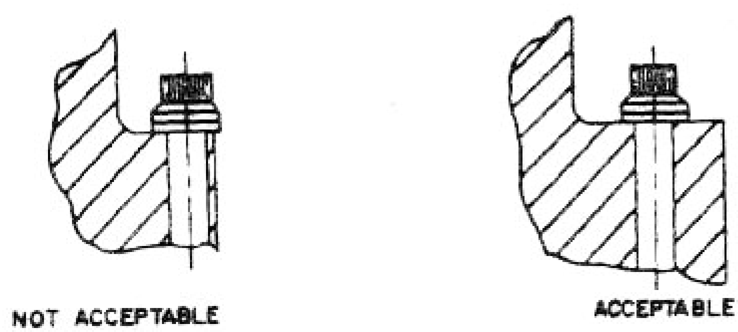


Figure 4-7. Location of Bolt Holes

4.10: Rod Installation (Push Pull)

In push-pull rod installation, the threaded end of the rod should extend into the rod end until at least one-half of the inspection hole in the rod end is filled. (See Figure 4.8.)

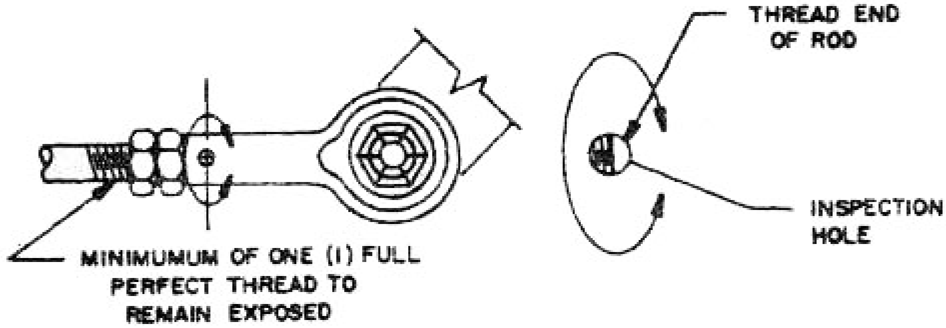


Figure 4-8. Push Pull Rod Application

4.11: Castellated Nuts

4.11.1: Securing

When securing castellated nuts, the center of the hole in the fastener shall not extend beyond the end of the nut. (See Figure 4-9.)

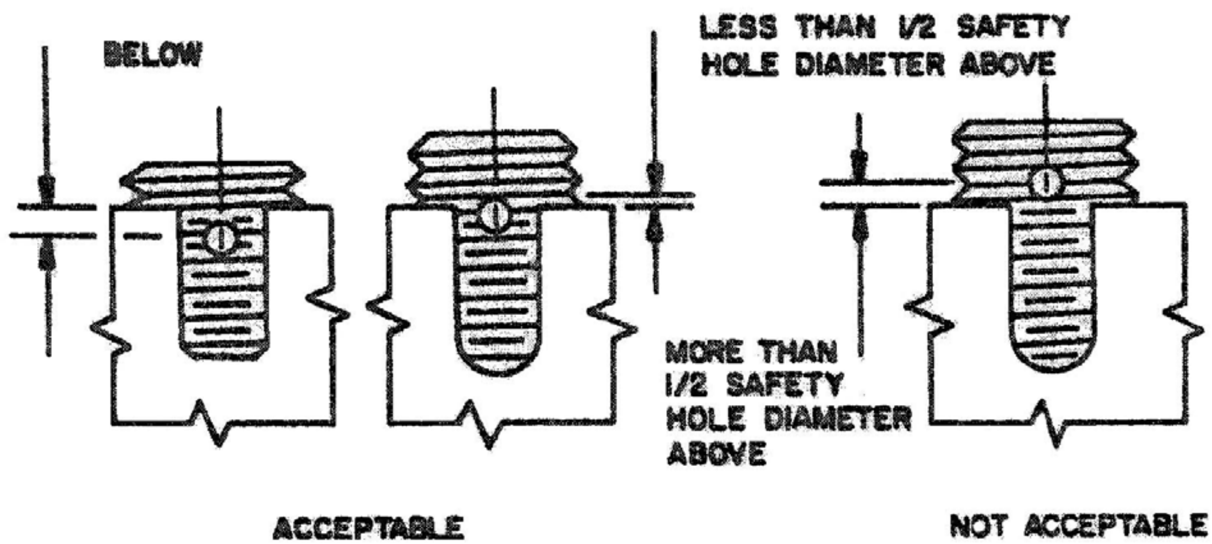


Figure 4-9. Castellated Nut Application

4.11.2: Securing Lock Washers

When feasible, a minimum of two tabs of any lock washer shall be bent over for locking purposes, one in each direction. If the tab is not at a direct right angle to the surface over which it is to be bent, extreme care must be taken to make the bend in the direction tending to tighten the adjustment. Backing off on the adjustment to suit the tabs is not permitted. Installation is illustrated in Figure 4-10.

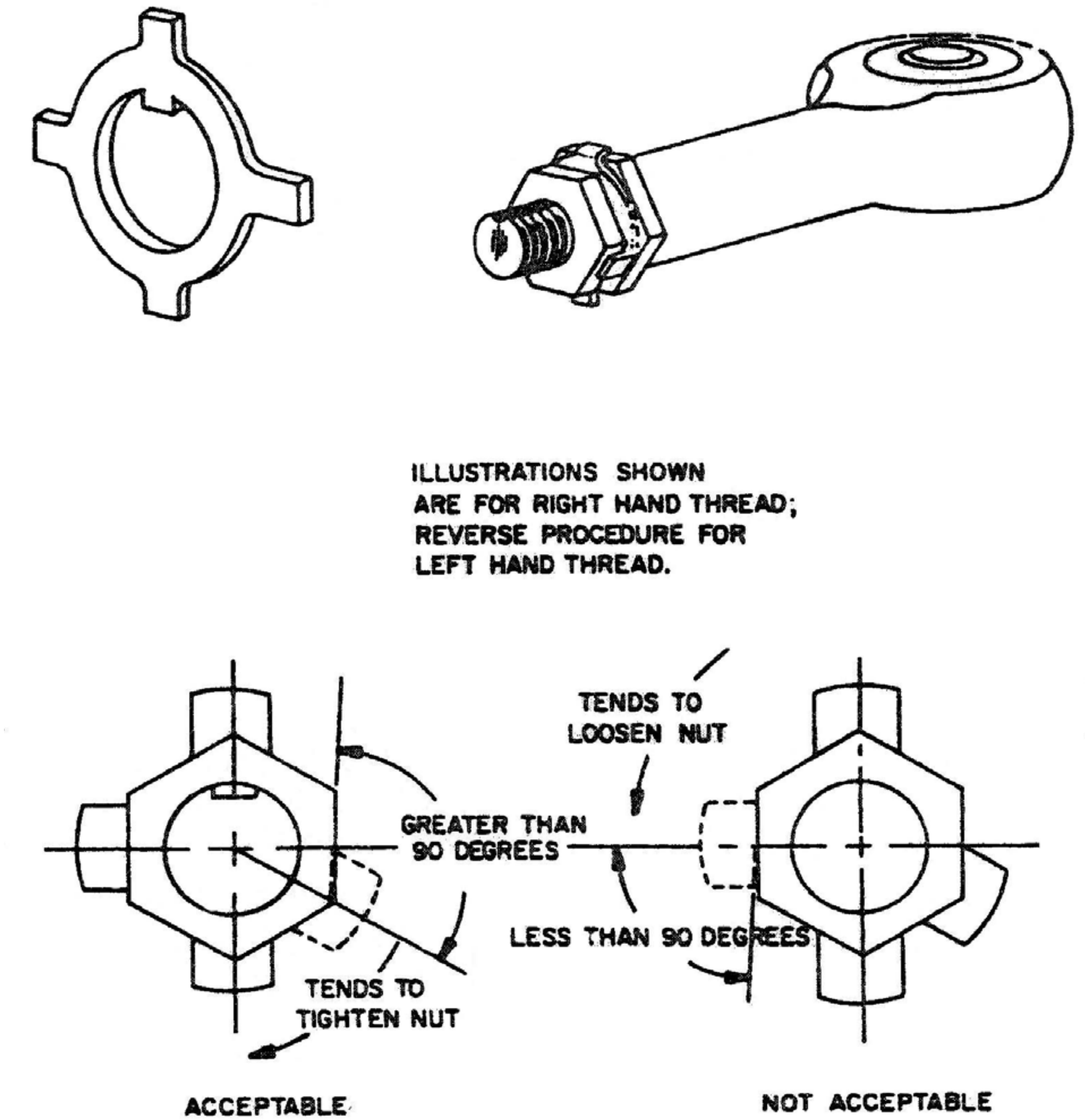


Figure 4-10. Lockwasher Application

4.11.3: Counter-Sunk Washer Application

Installation of countersunk washer with high tensile bolt is shown in Figure 4-11.

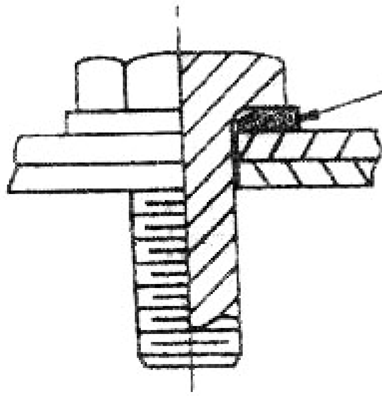


Figure 4-11. Countersunk Washer Application

4.12: Torquing

4.12.1: General

Torque is a rotational force applied to bolts or coupling nuts to produce tension between two connecting elements. Proper torque produces sufficient tension in fittings to produce a seal-tight joint. The tension force created by torquing must be greater than the forces produced by fluid pressures, which tend to separate the elements. In addition, tension forces created by torquing must be sufficient to conform the mating surfaces into close contact to prevent fluid leakage.

4.12.2: Torquing Tube Fittings

Torque values listed on the drawing or work order should be used. The torque values listed in Tables 4-1 and 4-2 should be utilized in all cases not covered by specific drawings or work orders.

The correct torquing procedure is to initially torque to the values listed in Table 4-1 and retorque to the same values 15 minutes after initially torquing and leak check the system.

The torque values given are based upon the presence of a smooth, scratch free uniform, tubing flare. See Section 8, *Hand Tools*, for instructions in preparing a flare.

Table 4-1. Flared Tube “B” Nut Torque Values

FLARED TUBE “B” NUT TORQUE VALUES IN INCH-POUNDS*						
Tube O.D. Inches	**6061-0 and 5052-0 AL Alloy Tubing**		**6061-T6 AL Alloy Tubing**		**Stainless (CRES) Steel Tubing**	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
1/8	20	25	---	---	---	---
3/16	25	35	30	70	---	---
1/4	40	65	70	80	300	360
5/16	60	80	70	120	---	---
3/8	75	125	130	180	600	740
1/2	150	250	300	400	830	1020
5/8	200	350	430	550	1230	1510
3/4	300	500	650	800	1660	2040
1	500	700	900	1100	2070	2530
1-1/4	600	900	1200	1450	2230	2730
1-1/2	600	900	1550	1850	4750	4850
1-3/4	700	1000	2000	2350	4750	4850
2	800	1100	2500	2900	4750	4850
*For combinations of tempers or materials use the applicable values shown for the material of the tubing flare. Where aluminum alloy nuts or fittings are used with steel tubing, torque values for 6061-T6 tubing shall apply.						

Table 4-2. Recommended Torque Values for Tube Fittings

RECOMMENDED TORQUE VALUES (IN INCH/LBS)											
For Gasketed Alum or Steel Fittings*								**For Jam Nuts and Fittings Without Gaskets****			
Nom. Tube O.D.	**Fitting Thread Size**	**AN924 Nut AN815 Union**		**AN814 Plug**		**AN6289 Nut**		**Aluminum (Lb. In.)**		**Steel (Lb. In.)**	
		Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
1/8	5/16 – 24	25	35	10	16	25	35	35	50	--	--
3/16	3/8 – 24	50	75	30	40	50	75	65	80	70	90
1/4	7/16 – 20	55	80	40	65	75	100	90	105	110	130
5/16	1/2 – 20	75	100	60	80	90	120	105	125	140	160
3/8	9/16 – 18	100	150	80	120	150	200	125	145	225	275
1/2	3/4 – 16	180	230	150	200	200	250	240	280	400	450
5/8	7/8 – 14	250	350	200	350	275	400	330	370	550	650
3/4	1-1/16 – 12	420	600	300	500	450	650	540	660	800	960
1	1-5/16 – 12	600	840	450	600	650	900	840	960	1000	1200
1-1/4	1-5/8 – 12	720	960	600	720	800	1000	960	1200	--	--
1-1/2	1-7/8 – 12	840	1080	600	800	900	1100	1200	1440	--	--
*For use with 0-Rings and aluminum, asbestos, leather, Teflon, etc., gaskets or washers. **For combinations of materials (either jam nut, fitting, or boss) use the lowest applicable values shown.											

4.12.3: Torquing Flanged Fittings

4.12.3.1: Torquing Method

Torquing of multibolt applications of bolted flanges or any bolted joint to apply an evenly distributed axial load to seals, gaskets, etc., shall use a bolt cross-torquing procedure as outlined below: This procedure shall be used where a definite method of torquing is not shown on the drawing, and may be used regardless of the number of bolts used in the joint.

Cross torque all bolts following a numerical sequence similar to the patterns shown in Figure 4-12 and continue as shown until all bolts are torqued to one third of the total torque to be applied. Repeat this procedure torquing the bolts in one-third increments until the total specified torque is obtained.

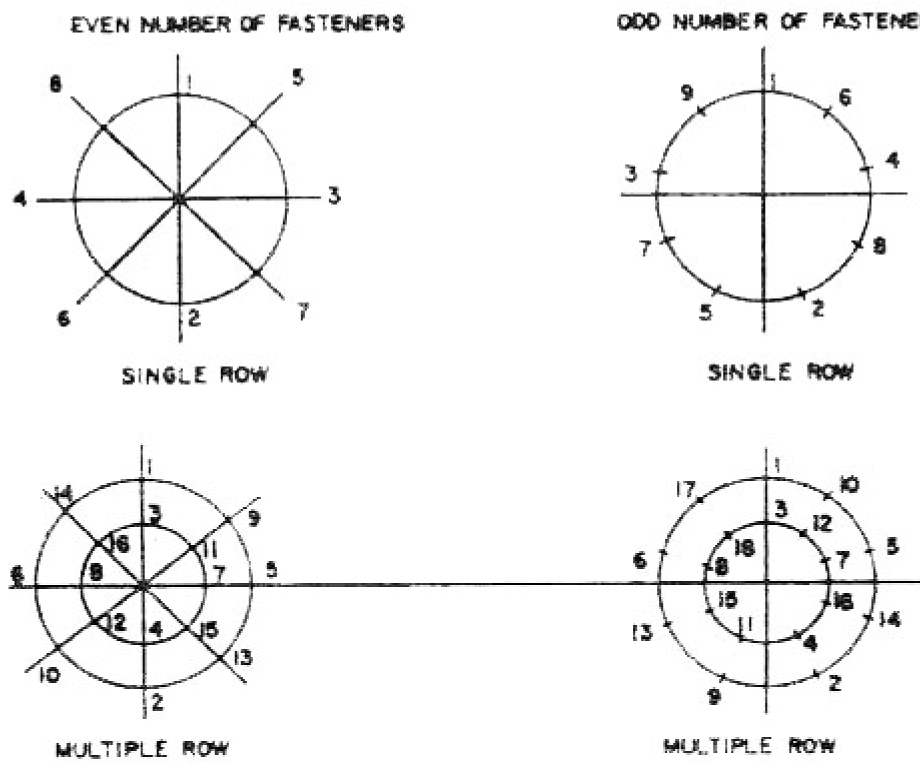


Figure 4-12. Method of Cross Torquing

4.12.3.2: Torque Values

Torque values listed on the engineering drawing, EWR or specification must be used.

The total installation bolt force must be great enough to properly seat the gasket. This force comes from the actual tightening of the bolts and is not a design value. As an example, the ASME Code for Unfired Pressure vessels gives design bolt stress values ranging from 7,000 to 20,000 psi depending on the bolt material. In actual practice the bolts are stressed on installation from 15,000 to 60,000 psi depending on the size of bolt and method of tightening.

The ASME Code procedures take into account the operating temperature while gaskets are installed at ambient temperature. A design stress of 20,000 psi does not allow for joint stress decay at operating temperature. At installation the bolts are actually stressed to a much higher value.

The following torque values may be used where the torque is not specified:

1. Aircraft Type Nuts and Bolts – Use values listed in Tables 4-3 and 4-4.

2. Standard ASA and Grayloc High Pressure Carbon Steel Systems – The ASTM 193 bolt-stud and ASTM 194 nut combination is recommended. Stress in bolts for various loadings is tabulated in Table 4-5. These values are for lubricated bolts (non-lubricated bolts have an efficiency of approximately 50 percent of well lubricated bolts). Where possible, it is recommended that the initial bolt stress be approximately 45,000 psi.

3. Machine bolts and Cold Rolled Steel Stud Bolts – Vaned listed in Table 4-6 are for lubricated bolts.

4. Stainless Steel Standard ASA and Grayloc Flange Bolts should be torqued from 15,000 to 20,000 psi tensile stress.

Table 4-3. Torque Values for Tightening Nuts

Torque Values in Inch-Ounce (1) for Tightening Nuts (2) (3)						
Bolt Stud or Screw Size	**Torque Values For Shear Bolts**		**Torque Values for Tensile Bolts**			
	55,000 To 89,000 psi	**90,000 psi and Up**	**55,000 To 89,000 psi**	**90,000 To 124,000 psi**	**125,000 To 159,000 psi**	**160,000 psi and Up**
0-80	2 - 2.5	5 - 6	3.5 - 4.5	8 - 10	10.5 - 13	14.5 - 18
1-72	4 - 5	9.5 - 12	6.5 - 8.5	15.5 - 20	20 - 25.5	28 - 35.5
2-56	6 - 7.5	14 - 17.5	10 - 12.5	23.5 - 29	30 - 37.5	41.5 - 52
2-64	7 - 8.5	16 - 20.5	11.5 - 14.5	26.4 - 34	34.5 - 43.5	47.5 - 60.5
3-48	9 - 11.5	21.5 - 26.5	15.5 - 19	35.5 - 44.5	46 - 57	63.5 - 79.5
3-56	10.5 - 13.5	24.5 - 31.5	17.5 - 22.5	41 - 52	53 - 67	73.5 - 93
4-40	13 - 16	30 - 37	21.5 - 26.5	50 - 61.5	64 - 79.5	89 - 110
4-48	15 - 19	35.5 - 44.5	25 - 32	59 - 74.5	75.5 - 95.5	105 - 133
5-40	19 - 24	45 - 56.5	32 - 40	75 - 94	96.5 - 120.5	133.5 - 167.5
5-44	21.5 - 27	50 - 63	35.5 - 45	83 - 105.5	106.5 - 135.5	148 - 188
6-32	24 - 29.5	56 - 69	40 - 49.5	93 - 115	120 - 148	166.5 - 205.5
6-40	29 - 36.5	67.5 - 85.5	48 - 61	112.5 - 142.5	144.5 - 183.5	201 - 255

Notes: (1) To obtain values in inch pounds, divide inch-ounce values by 16.

(2) When it is necessary to tighten the fastener from the head side, the torque shall be within ±10 percent of the high side of the selected torque range listed in Table 1, unless otherwise shown on the drawing.

(3) Maximum torque values are to be used only when materials and surfaces being fastened together have sufficient area, thickness, or strength to resist breaking, warping or other damage; e.g., no attempt should be made to reach the maximum torque value when bolting through very thin sections of glass, plastic or metal.

Table 4-4. Torque Values for Tensile Fasteners

Bolt, Stud or Screw Size	(4) Shear Type Nuts 125,000 psi and Up		Torque Values for Tensile Fasteners								Bolt, Stud or Screw Size
			55,000 to 89,000 psi		90,000 to 124,000 psi		125,000 to 159,000 psi		160,000 psi and Up		
	In.-Lb	Ft.-Lb	In.-Lb	Ft.-Lb	In.-Lb	Ft.-Lb	In.-Lb	Ft.-Lb	In.-Lb	Ft.-Lb	
8-32	8- 11		5- 6		11- 14		14- 18		19- 24		8-32
8-36	9- 12	(1)	5- 6	(1)	12- 15	(1)	16- 20	(1)	22- 28	(1)	8-36
10-24	12- 15		7- 8		15- 19		20- 25		28- 35		10-24
10-32	14- 18		8- 10		19- 24		24- 30		33- 42		10-32
1/4-20	31- 39	(5)	17- 22	(5)	40- 50	(5)	52- 65	(5)	72- 90	(5)	1/4-20
1/4-28	36- 47		20- 26		47- 61		61- 75		85- 110		1/4-28
5/16-18	63- 80		35- 45		80- 105		105- 135		145- 180		5/16-18
5/16-24	71- 90		40- 51		90- 120		120- 155		160- 210		5/16-24
3/8-16	110- 140		62- 80		145- 180		180- 230		250- 330		3/8-16
3/8-24	125- 160		70- 90		160- 210		210- 280		290- 390		3/8-24
7/16-14	180- 230		100- 130		230- 300		300- 380		420- 530		7/16-14
7/16-20	200- 260		110- 145		250- 330		330- 430		460- 600	35 50	7/16-20
1/2-13	270- 350		150- 190		350- 450		450- 580		630- 810	50 65	1/2-13
1/2-20	310- 410		170- 230		400- 530		520- 680	40 55	720- 950	60 80	1/2-20
9/16-12	400- 510		220- 290		520- 670	40 55	670- 860	55 70	920-1190	75 100	9/16-12
9/16-18	450- 590		250- 330		580- 770	45 65	750- 990	60 80	1040-1380	85 115	9/16-18
5/8-11	550- 700		300- 390		710- 910	60 75	910-1180	75 95	1270-1630	105 135	5/8-11
5/8-18	620- 830	50- 70	350- 460		810-1070	65 90	1040-1380	85 115	1450-1920	120 160	5/8-18
3/4-10	960-1240	80-100	530- 690		1250-1610	105 135	1600-2080	130 170		185 240	3/4-10
3/4-16	1080-1430	90-120	600- 790	50 65	1400-1850	115 155		150 195		200 270	3/4-16
7/8-14		140-190	960-1270	80 105		185 240		240 310		330 440	7/8-14
1-12		210-290	1450-1930	120 160		280 370		360 480		500 670	1-12
1-14		210-290	1460-1960	120 160		280 380		360 490		500 680	1-14
1-1/8-12		310-410		170 230		400 540		520 690		720 960	1-1/8-12
1-1/4-12		430-580		240 320		560 750		720 970		1000 1350	1-1/4-12

Notes: (1) To obtain value in foot pounds, divide inch-pound values by 12.

(2) When nuts are to be secured with cotter pins or lockwire, tighten the nut to the low side of the selected torque range and if necessary continue tightening until the next slot aligns with the hole. Nuts shall not be backed off to obtain alignment.

(3) When it is necessary to tighten the fastener from the head side, the torque shall be within ±10 percent of the high side of the selected torque range unless shown on the drawing.

(4) Values to be used with nuts designated as shear type nuts. (AN 316 and AN 320)

(5) Recommend use of wrenches graduated in inch-pounds for these fasteners.

(6) Above values apply only at ambient temperatures of -65˚ F through 165˚ F.

Table 4-5. Torque Values for Machine Bolts and Cold Rolled Steel Stud Bolts

Data for Use With Machine Bolts and Cold Rolled Steel Stud Bolts Load in pounds on Bolts and Stud Bolts when Torque Loads are Applied									
Nominal Diameter of Bolt	Number of Threads	Diameter at Root of Thread	Area at Root of Thread	Stress					
				7,000 psi		15,000 psi		30,000 psi	
Inches	per Inch	Inches	Sq Inch	Torque Ft Lbs	Compression Lbs	Torque Ft Lbs	Compression Lbs	Torque Ft Lbs	Compression Lbs
1/4	20	.185	.027	1	203	2	405	4	810
5/16	18	.240	.045	2	338	4	675	8	1350
3/8	16	.294	.068	3	510	6	1020	12	2040
7/16	14	.345	.093	5	698	10	1395	20	2790
1/2	13	.400	.126	8	945	15	1890	30	3780
9/16	12	.454	.162	12	1215	23	2430	45	4860
5/8	11	.507	.202	15	1515	30	3030	60	6060
3/4	10	.620	.302	25	2265	50	4530	100	9060
7/8	9	.731	.419	40	3143	80	6285	160	12570
1	8	.838	.551	62	4133	123	8265	245	16230
1-1/8	7	.939	.693	98	5190	195	10380	390	20760
1-1/4	7	1.064	.890	137	6675	273	13350	545	26700
1-3/8	6	1.158	1.054	183	7905	365	15810	730	31620
1-1/2	6	1.283	1.294	219	9705	437	19410	875	38820
1-5/8	5-1/2	1.389	1.515	300	11363	600	22725	1200	45450
1-3/4	5	1.490	1.744	390	13080	775	26160	1550	52320
1-7/8	5	1.615	2.049	525	15368	1050	30735	2100	61470
2	4-1/2	1.711	2.300	563	17250	1125	34500	2250	69000

Table 4-6. Torque Values for ASTM 193 and ASTM A194 Nut and Bolt Combinations

Data for Use With ASTM A193 Bolt-Stud and ASTM 193 Nut Combination Load in pounds on Stud Bolts when Torque Loads are Applied									
Nominal Diameter of Bolt	Number of Threads	Diameter at Root of Thread	Area at Root of Thread	Stress					
				30,000 psi		45,000 psi		60,000 psi	
Inches	per Inch	Inches	Sq Inch	Torque Ft Lbs	Compression Lbs	Torque Ft Lbs	Compression Lbs	Torque Ft Lbs	Compression Lbs
1/4	20	.185	.027	4	810	6	1215	8	1620
5/16	18	.240	.045	8	1350	12	2025	16	2700
3/8	16	.294	.068	12	2040	18	3060	24	4080
7/16	14	.345	.093	20	2790	30	4185	40	5580
1/2	13	.400	.126	30	3780	45	5670	60	7560
9/16	12	.454	.162	45	4860	68	7290	90	9720
5/8	11	.507	.202	60	6060	90	9090	120	12120
3/4	10	.620	.302	100	9060	150	13590	200	18120
7/8	9	.731	.419	160	12570	240	18855	320	25140
1	8	.838	.551	245	16530	368	24795	490	33060
1-1/8	8	.963	.728	355	21840	533	32760	710	43680
1-1/4	8	1.088	.929	500	27870	750	41805	1000	55740
1-3/8	8	1.213	1.155	680	34650	1020	51975	1360	69300
1-1/2	8	1.338	1.405	800	42150	1200	63225	1600	84300
1-5/8	8	1.463	1.680	1100	50400	1650	75600	2200	100800
1-3/4	8	1.588	1.980	1500	59400	2250	89100	3000	118800
1-7/8	8	1.713	2.304	2000	69120	3000	103680	4000	138240
2	8	1.838	2.652	2200	79560	3300	119340	4400	159120
2-1/4	8	2.088	3.423	3180	102690	4770	154035	6360	205380
2-1/2	8	2.338	4.292	4400	128760	6600	193140	8800	257520
2-3/4	8	2.588	5.259	5920	157770	8880	236655	11840	315540
3	8	2.838	6.324	7720	189720	11580	284580	15440	379440

4.12.4: Torque Wrenches and Their Use

Several torque wrench types are shown in Figure 4-13. Their use and limitations are:

1. Research has proved that is physically impossible for any mechanic to tighten a series of nuts or bolts to an equalized pre-determined tension with ordinary wrench equipment.

2. Torque wrenches are precision tools; they should not be subjected to abuse or misuse.

3. Do not put the torque wrench at the bottom of your tool chest and pile tools on top of it. A special storage place is supplied for it; always put it there when you are finished with it.

4. Never use a torque wrench to break nuts loose. It is not a working wrench but a precision tool used to obtain accurate measuring.

5. Torque readings should be taken only while tightening the fastener. Do not overtighten and then loosen to the desired torque value.

6. Never jerk a torque wrench. Force must be applied slowly for an accurate indication of the torque being applied to a fastener.

7. Do not attempt to use a torque wrench to tighten a fastener to a higher value than the maximum value shown on the torque wrench indicator.

8. All bolts and studs should be cleaned thoroughly before being tightened. The "thread drag" caused by rusted or dirty threads makes it impossible to torque accurately.

9. Sockets and/or adapters must be installed fully on the nut or bolt. Maintaining a slight inload on the wrench will lessen the changes of damage to the fastener.

10. All torque wrenches must receive a periodic calibration to compensate for wear, and should not be used after the void date shown on each wrench.

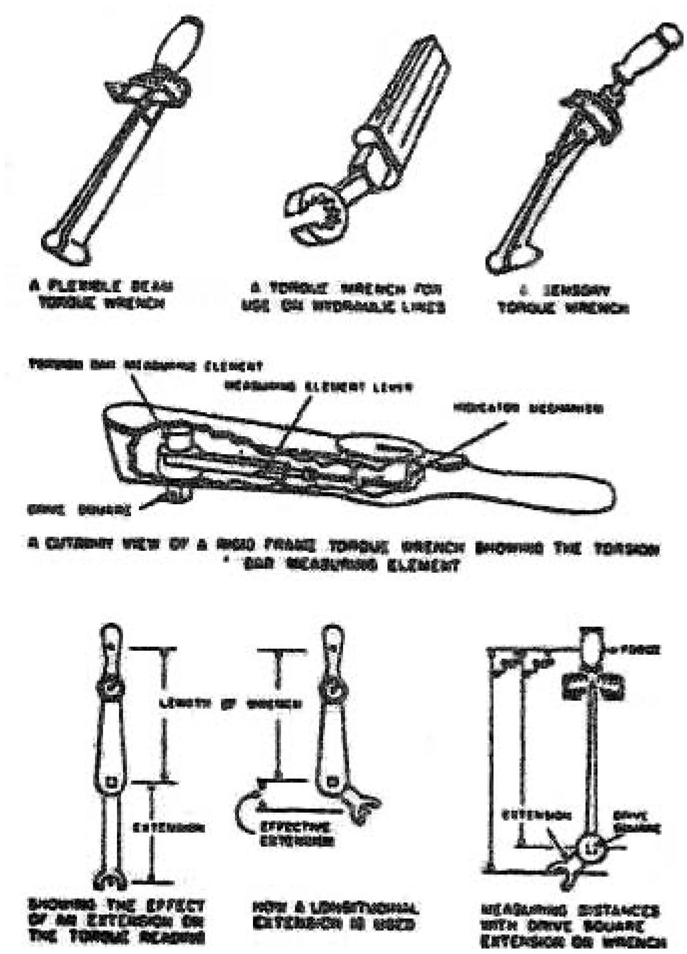


Figure 4-13. Torque Wrenches

4.12.5: How Adaptors Affect Torque

1. To understand why some extensions and adapters change or alter the torque at a bolt, a brief explanation of what is meant by "torque" and how it is measured should prove helpful. Theoretically, "torque" is the movement of a system of forces around an object which tends to produce twist or torsion. A wrench acts as a lever when force is applied, and the amount of torque produced upon the bolt is dependent upon the length of the wrench and the amount of force applied.

2. In Figure 4-14 the lever length of the wrench from the center of the nut to the center of the hand applying the force is represented by "L". The applied force is indicated by "F". Since torque "T" is the product of the applied force multiplied by the effective lever length, it can be calculated by using the formula: T = F × L.

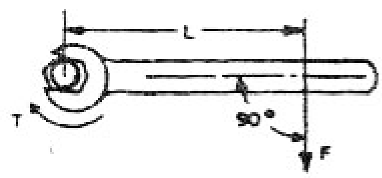


Figure 4-14. Wrench Without Adaptor

3. Because the applied force usually is measured in pounds, while the lever length is measured in inches or feet, the resulting torque is measured in inch-pounds or foot-pounds. Thus if "L" is one foot and "F" is 30 pounds, "T" equals 30 foot-pounds.

4. As shown in the figure above, "F" must be applied at a 90 degree angle to the lever. When the force is applied in any other direction, a lesser torque than that calculated is exerted by the wrench.

5. A torque wrench has a built-in device which indicates to a mechanic when he has exerted the desired amount of torque on a bolt or nut. A reading on a dial is made directly in foot-pounds or inch-pounds. However, when adaptors which add lever length or used with torque wrenches, the wrench no longer reads true, and corrections must be made.

6. If an adaptor or extension attached to the square drive, which changes the length of the torque wrench, the readings on the dial will not give the actual torque. A simple formula, however, enables one to figure out what the dial should read for a pre-determined torque using any adaptor (Figure 4-15).

Formula: $S = \frac{T \times L}{L + E}$

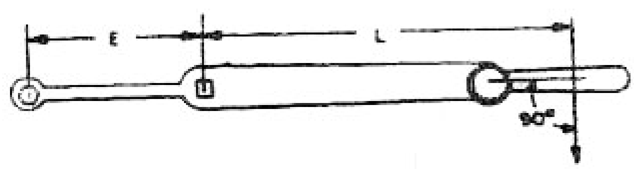


Figure 4-15. Wrench With Adaptor Attached to Square Drive

7. The letters in the formula have the following meaning:

T = Torque desired (actual torque)

S = Dial reading. This is the unknown factor. You want to know what it should be when you use an adaptor.

L = Distance from the square drive for the torque wrench to the center of the operator's hand on the handle of the torque wrench. The pull must be at right angles to the centerline of torque.

E = Extended length of the adaptor parallel to the handle. Measure this from the bolt to the square drive of the torque wrench and use only that distance with is parallel to the torque wrench.

Example: L = 12"
E = 3"
S = Unknown
T = 360 In. lbs

$$S = \frac{T \times L}{L+E} \quad \text{or} \quad S = \frac{360 \times 12}{12+5} = \frac{4320}{15} = 280 \text{ in lbs}$$

$$288 \div 12 = 24 \text{ ft lbs}$$

8. The example explained above gives a very simple conversion using a straight extension. However, there are many types of adaptors and extensions. A few are shown in the following figures, but in each case it is obvious that only the added extension from the square drive of the torque wrench increasing its length will change the readings. It is also well to note that n extension which is perpendicular to the torque wrench, regardless of length not affect the readings.

9. It is difficult to get accurate readings if universal joints are used and, therefore, an adaptor should be used instead, whenever possible. If it is absolutely necessary to use a universal joint, the formula should be used to figure the corrected torque.

10. This handle extension does not affect the dial reading although it does increase the torque. No correction is necessary because factor "E" is not changed. (See Figure 4-16.)

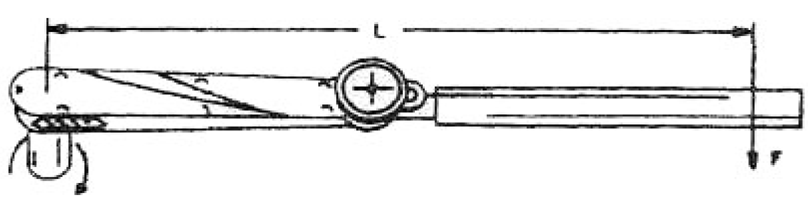


Figure 4-16. Adaptor Attached to Handle End of Wrench

11. This adaptor doubles the length and leverage of the torque wrench. The dial will read only ½ of the torque. Note “L” and “E” are equal. (See Figure 4-17.)

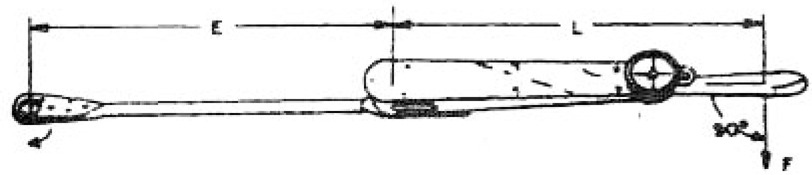


Figure 4-17. Adaptor Attached to Square Drive (Correct Measurement)

12. This adaptor or wrench affects the dial reading. Factor "E" is involved and therefore a correction is necessary. Note that "E" is not the length of the adaptor but only the increase in length parallel to the torque wrench. (See Figure 4-18.)

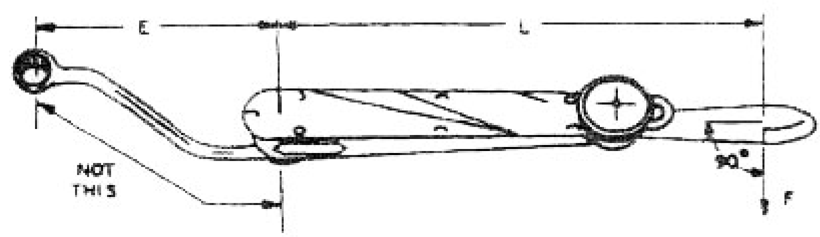


Figure 4-18. Adaptor Attached to Square Drive (Incorrect Measurement)

13. Here again we have a wrench which adds length. Note that only the distance parallel to the torque wrench is used to get Factor “E” (See Figure 4-19.)

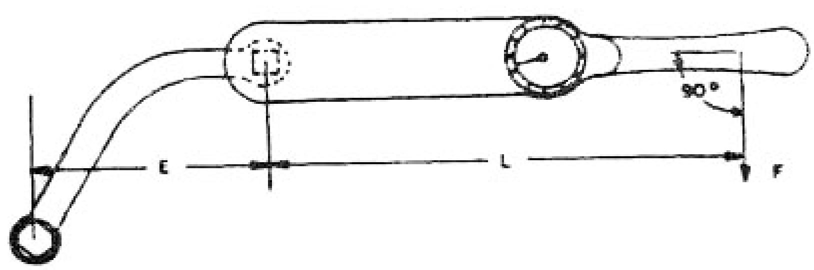


Figure 4-19. Adaptor Attached to Handle End of a Box End Wrench

Lubricants, Gaskets, Seals, and Packaging
Contents

5.1: Lubricants (Definitions and Functions)

The general term lubricants includes the following specific terms functions:

1. Lubricant — a material used to reduce friction between threaded devices or sliding surfaces

2. Sealant — a material used to effect a seal between two surfaces

3. Antiseize — a material used to allow easy disassembly of threaded parts

4. Thread Compound — a compound used with NPT joints to perform the function of sealant, lubricant, and antiseize

5.2: Application of Lubricants

5.2.1: Thread Lubricant Application

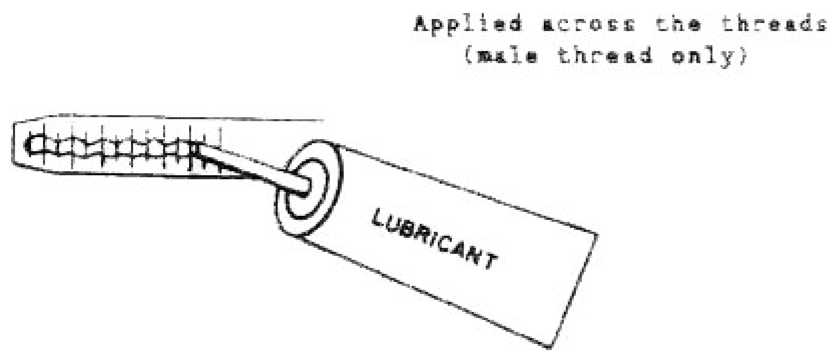


Figure 5.1 Thread Lube Application

The number of application points will vary with the size of the fitting. (See Table 5-1.)

Table 5-1. Lubricant Application

Thread Diameter, inch	No. of Applications Points	Approx. Width of Streak, inch
Up to 1/2	1	1/8 to 1/4
Over 1/2 and up to 1	1	3/8
Over 1 and up to 1-3/4	2	1/2
Over 1-3/4 through 2-1/2	3	1/2

The application points stall be equally spaced around the thread circumference where more than one application point is needed.

5.2.2: Tube Fitting Lubricant Application

Lubricate interior and exterior thrust surface of tubing sleeve (see Figure 5-2).

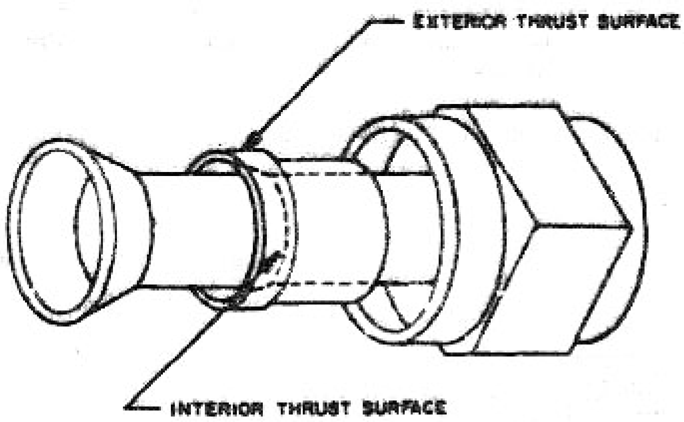


Figure 5-2. Lube Application to Tube Fittings

5.2.3: Dynamic O-Ring Lubricant Application

1. Pack one-quarter the distance around the groove with the required lubricant prior to installing the 0-ring (see Figure 5-3).

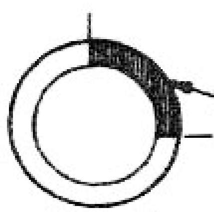


Figure 5-3. Lube Application to O-Ring Grooves

2. Spread lubricant evenly within the groove. This may be accomplished by hand or by installing the O-ring and then rotating it several times around the groove.

3. Additional lubricant may be applied to the mating surface. Globules of grease on the mating surface must be wiped off.

4. O-ring lubrication for hydraulic fluid or oil should be accomplished by dipping the O-ring in the fluid before installation.

5.2.4: Static Seal Lubricant Application for Greases and Oils

1. Apply lubricant to dry static O-rings. Distribute uniformly over the surface of the O-ring and remove excess by drawing the O-ring through the finger tips.

2. If lubricating material is needed to retain a static O-ring in its groove while installing a mating part, the amount of material should not exceed 10 percent of the total volume of the groove.

3. Flat seals used between flat surfaces without grooves should be coated on both sides with the sealing compound. Excess globules of the sealing compound shall be wiped off.

4. 4 Sealant for flat mating surfaces, without a gasket type seal, should be spread uniformly on both surfaces. Wipe off excess prior to joining the parts.

5. Flexitallic gaskets should be thoroughly wetted on both sides with the sealing compound. Sealant should be worked into the gasket grooves with moderate finger pressure.

5.2.5: Application of Dry Powdered Lubricant (Such as Molykote Type Z Powder)

1. Metal parts must be vapor degreased.

2. Nonmetallic parts must be cleaned by immersion in RB0210-002 mild alkaline cleaning solution.

3. Parts should <u>not</u> be touched by bare fingers after cleaning. Clean cotton gloves should be worn.

4. Dry powdered lubricants should be applied as soon as possible after cleaning.

5. Lubricant should be rubbed onto the surface to be lubricated with a clean, lint-free nylon cloth.

6. Excess lubricant should be removed.

7. Sliding surfaces should be thoroughly coated during installation.

5.2.6: RB0120-017 Dispersion Application for Naflex, Flange Seals, and Washers

1. Dispersion must be mixed prior to use.

2. Drawings should specify the method of application.

   Application Method I

   1. Apply with lint-free nylon cloth or nylon brush to the sealing surfaces of the grooves or flanges.

   2. Use a light touch, applying in one continuous stroke.

   3. Allow to dry for 5 to 7 minutes.

   4. Apply a second coat.

   5. Immediately install seal or washer and assemble while the dispersion is still damp.

Application Method II

Follow the same procedure as for method I, except apply the dispersion only to the gasket, seal, or washer rather than the groove, flange, or mating surfaces.

Application Method III

Follow the procedure for method I, except apply dispersion to all contacting surfaces. Use only one coat and install while dispersion is still damp.

5.3: Gaskets

5.3.1: General

Application of gaskets depends on three main factors: compatibility of the gasket material with the fluid, ability to withstand the pressure temperature system, and the relationship of total installation bolt force to gasket seating stress and hydrostatic end force.

5.3.2: Flat Gaskets

Several types of flat gaskets and their limitations are listed in Table 5-2.

Table 5-2. Flat Gaskets in Use at the Field Laboratories

Johns-Manville (number 76)	A general use sheet gasket of rubber compound and asbestos composition. Will handle Kerosene, water and LN_2.
Teflon	Polytetrafluoroethylene sheet suitable for gasketing in applications from -423 F for extended periods of time. Suitable for use with LOX, hydrogen peroxide (H_2O_2), alcohol, and other fluids. Extensively used for soft seats in valves. It has limited flexibility at LOX temperatures. Teflon gaskets tend to extrude if overtightened. Teflon forms toxic vapors when burned.
Kel-F	An expensive, partially chlorinated fluorocarbon gasket material for use from -423 to 390 F. Suitable for same use as Teflon, but with better flexibility at low temperatures. Kel-F forms toxic vapors when burned.
Spiral Wound Gaskets	A very strong high pressure gasket composed of alternate bands of stainless steel and Teflon, Kel-F, or asbestos.
Metallic Gaskets	Manufactured of various metals for such high temperature and pressure uses as turbine exhausts. Usually soft copper with or without a chrome plating.
Flurogold (or) Flurogreen	Same general characteristics as Teflon except it has glass fiber strands incorporated for strength and reduced cold flow properties.

5.3.3: Ring Joint Gaskets

These gaskets are available in the oval or octagonal cross-section. They are made of soft carbon steel or stainless steel. Nigh-pressure gas and cryogenic systems are equipped with this type gasket.

5.3.4: Pressure-Energized Gaskets

The Naflex and Pneuflex seals are the two common gaskets in use at the Field Laboratories. Since the fluid pressure tends to provide the seal, only light bolt loads are required. Metallic pressure-energized seals have a "U" shaped cross-section with relatively flexible members that are deformed by the flange. The fluid pressure inside the "U" acts on the flexible member to produce a contact stress at the seal contact interface.

Because of the relatively high-cost and the surface-finish requirement, it is essential that cleanliness and careful handling be exercised with this type seal.

NOTE: All gasket types should be carefully handled to prevent damage to sealing surfaces. Most gaskets depend on a hair-line seal and only a slight scratch or nick may cause leakage.

Comments

1. Do not use serrated flange surfaces against spiral wound gaskets.

2. Use Fluorogold (glass filled Teflon) whenever possible for LH_2 systems having concentric serrated flanges.

3. Bolts must be cross torqued to effect even gasket loading and to prevent over-compression of gasket sections.

4. Bolts must be torqued to values specified for proper gasket loading.

5. Gaskets must comply with designer or manufacturer's standards. Gaskets not in compliance due to previous installation shall not be used. Substitutes will not be made without proper engineering consideration.

5.4: Seals

5.4.1: Boss Sealing Recommendations for Hot-Gas and Cryogenic Applications

The following seals are recommended in a preferred order:

1. Temperature range 500˚F to 1000˚F:

    - NATORQ P/N VD261-0123 - XXXX (silver plated)
    - Harrison "K" P/N 12100 AA (gold plated)

2. Temperature range -423˚F to 500˚F:

    - Harrison "K" P/N 12100 CR (Teflon coated)
    - NATORQ P/N VD261-0123 - XXXX

3. All service bulkhead application:

    - NATORQ VD261-0006 - XXXX

4. Transducer applications limited to low-torque values and high temperature:

    - Harrison "K" P/N 12100 AA (gold plated)

5. Transducer applications limited to low-torque values and cryogenic temperature:

    - Harrison "K" P/N 12100 CR (Teflon coated)

5.4.2: Boss Sealing Limitations for Hot-Gas and Cryogenic Applications

The following limitations and recommendations are made for boss seals:

1. Recommended increased torque values for the above seals used in conjunction with standard fittings are as shown in Table 5-3.

Table 5-3. Increased Torque Values for Boss Seals

Fitting Dash Size	**Tube Diameter, inch**	**In.-lb**	**Ft-lb.**
-4	1/4	300	25
-6	3/8	600	50
-8	1/2	840	70
-10	5/8	1250	104
-12	3/4	1680	140
-16	1	2100	175

2. Do not use AN900 series copper crush washers or AN901 series asbestos filled copper gaskets in AN10050 boss seal applications.

3. Do not use elastomer O-rings above or below their rated maximum temperatures—not even for a short time.

4. In applications where Photocon transducers are applied in AN10050 threaded boss ports, the torque requirements are limited by the transducer and must comply to the manufacturer's recommendations.

5. Boss seals should never be reused unless they can be leak-checked per system pressure requirements. Retorquing is permissible provided that the seal fitting combination has not been subjected to zero torque conditions, which disrupts the original continuity between the contacting surfaces. In this situation, leak-check after retorquing.

6. The use of bulkhead fittings is not recommended for high-temperature or cryogenic applications; however, in special installations where bulkhead fittings must be incorporated, elastomer O-rings should be replaced with metal NATORQ bulkhead seals, VD261-0006-XXXX.

7. Teflon O-rings are not recommended for cryogenic or high-temperature applications. The cold flow properties of Teflon combined with a non-captivating seal cavity will allow the initial seal preloading to relax.

5.4.3: O-Rings

5.4.3.1: Basic Principle

An O-ring seal is a means for closing off a passageway, preventing an unwanted escape or loss of fluid. The seal consists of an O-ring installed in a gland (groove), see Figure 5-4. An O-ring is exactly that, a circular ring in which the glastomeric material has a section that is virtually a circle. The gland is a cavity into which the O-ring is placed.

The combination of these two elements comprise an O-ring seal. The flight tight seal is accomplished by the O-ring deforming into the leak path.

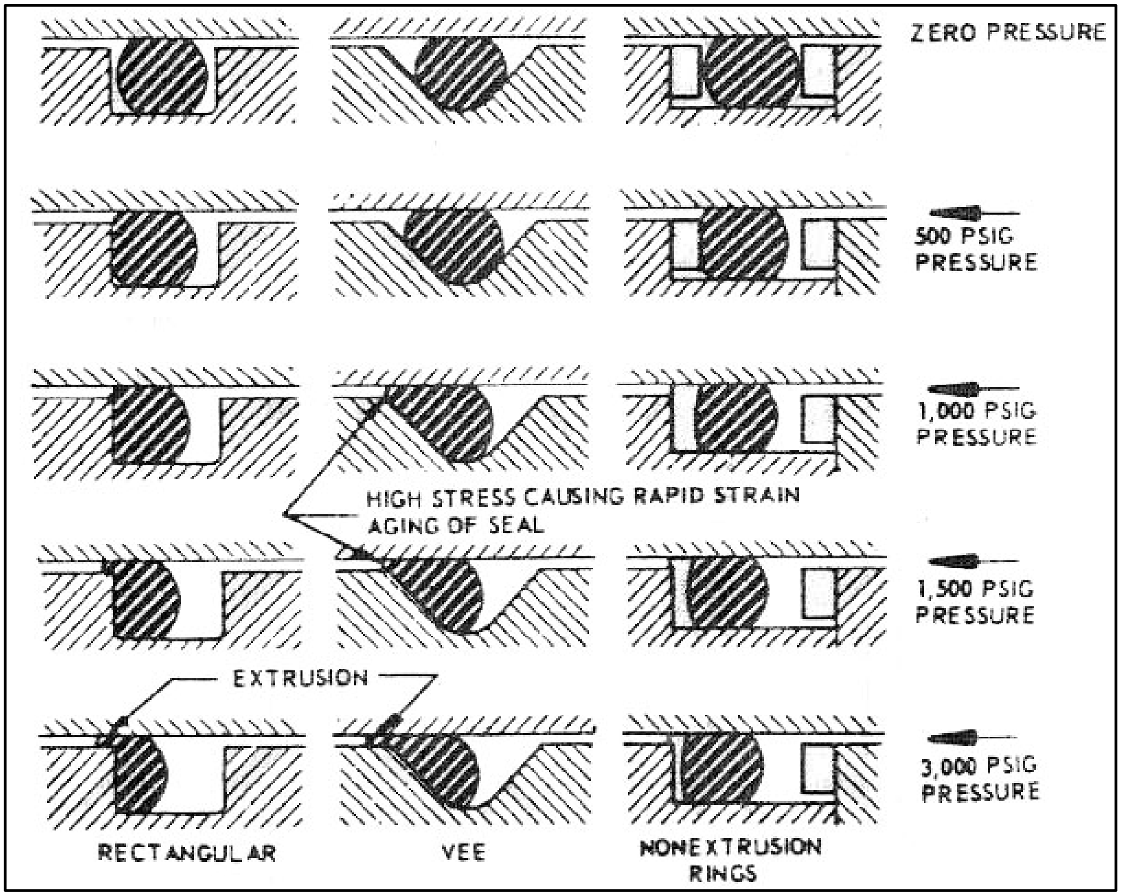


Figure 5-4. O-Ring Extrusion

The O-ring seal should be considered as an incompressible, viscous fluid having a very high surface tension. Whether by mechanical pressure from the surrounding structure or by pressure transmitted through hydraulic fluid, this extremely viscous fluid is forced to flow in the gland to produce zero clearance or a positive block to the flow of the less viscous fluid being sealed.

The O-ring absorbs the stack-up or tolerances of the unit, and its memory maintains a sealed condition.

Figure 6-7 illustrates the permeation that the O-ring takes at various pressures.

General

1. Used as moving and nonmoving seals.
2. Manufactured in many different sizes and from a variety of materials.
3. Must be compatible with system fluids and pressures.
4. In general, different types of O-rings are not interchangeable.
5. O-rings are stocked at the field laboratories.
6. Buna-N O-rings are not suitable for use at cryogenic temperatures.
7. Beware of O-ring shelf life. Do not use outdated materials.

8. Compatibility.

5.4.3.2: Standard O-Ring Part Numbers for Facility Equipment

All SSFL stocked O-rings have primary grouping according to their material. The only stocked compounds are as follows:

COMPOUND NO.	MATERIAL	DUROMETER
N304-75	Buna-N	75
N507-90	Buna-N	90
N545-45	Buna-N	45
V747-75	Viton	75
V709-90	Viton	90
T	Teflon	
S469-40	Silicone	40
S604-70	Silicone	70
B318-70	Butyl	70
E515-80	Ethylene Propylene	80

The above listed compounds are Standard Parker numbers. All other types of O-rings (i.e., MS, AN, ES, NAS, etc.) are no longer stocked, as they are not required for maintenance of facility equipment.

All in-house O-rings have been re-identified to appropriate standard Parker compounds as outlined below.

The following table lists former specifications and their current Parker compound replacement.

Parker Compound	Former Specification			
N304-75	AN6227B	AN6230B	MS2B775	MS29513
	MS29512	PSI-30-5	MS9021	MS9020
	N506-65	N674-70	N602-70	N219-7
	N519-7			
N507-90	AN6290	MS28778	N552-90	N183-9
N545-45	N299-50			
V747-75	SR275-70	77-545		
B318	RD262-4007-XXXX		B496-70	B591-8
	RD262-4012-XXXX		SR613-75	
S604-70	S451-70			
Teflon	RD262-4013-XXXX		RD262-3003-XXXX	

All specifications (i.e., MS, NAS, RD) dash numbers except "AN," convert directly into the Parker (2-) dash number. For example, RD262-4007-0118 converts into Parker size 2-118.

The AN to Parker conversion is as follows:

AN6227B Size	Parker Size	AN6227B Size	Parker Size	AN6227B Size	Parker Size	A6227B Size	Parker Size
1	2-006	23	2-218	45	2-342	66	2-439
2	2-007	24	2-219	46	2-243	67	2-450
3	2-008	25	2-220	47	2-344	68	2-451
4	2-009	26	2-221	48	2-345	69	2-452
5	2-010	27	2-222	49	2-346	70	2-453
5	2-011	28	2-325	50	2-347	71	2-444
7	2-012	29	2-326	51	2-348	72	2-445
8	2-110	30	2-327	52	2-349	73	2-446
9	2-111	31	2-328	53	2-425	74	2-447
10	2-112	32	2-329	54	2-426	75	2-448
11	2-113	33	2-330	55	2-427	76	2-449
12	2-114	34	2-331	56	2-428	77	2-450
13	2-115	35	2-332	57	2-429	78	2-451
14	2-116	36	2-333	58	2-430	79	2-452
15	2-210	37	2-334	59	2-431	80	2-453
16	2-211	38	2-335	60	2-432	81	2-454
17	2-212	39	2-336	61	2-433	82	2-455
18	2-213	40	2-337	62	2-434	83	2-456
19	2-214	41	2-338	63	2-435	84	2-457
20	2-215	42	2-339	65	2-436	85	2-458
21	2-216	43	2-340	65	2-437	86	2-459
22	2-217	44	2-341	66	2-438	87	2-460

**should be “24” rather than “14”?? yellow highlight: same number & off by one??

AN6230B Size	Parker Size	AN6230B Size	Parker Size	AN6230B Size	Parker Size	A6230B Size	Parker Size
1	2-223	14	2-236	27	2-249	40	2-262
2	2-224	15	2-237	28	2-250	41	2-263
3	2-225	16	2-238	29	2-251	42	2-264
4	2-226	17	2-239	30	2-252	43	2-265
5	2-227	18	2-240	31	2-253	44	2-266
5	2-228	19	2-241	32	2-254	45	2-267
7	2-229	20	2-242	33	2-255	46	2-268
8	2-230	21	2-243	34	2-256	47	2-269
9	2-231	22	2-244	35	2-257	48	2-270
10	2-232	23	2-245	36	2-258	49	2-271
11	2-233	24	2-246	37	2-259	50	2-272
12	2-234	25	2-247	38	2-260	51	2-273
13	2-235	26	2-248	39	2-261	52	2-274

Fitting O-rings (formerly AN6290, MS28778, MS29512, etc.) appear as 3-9XX, where “XX” represents the fitting size in 16ths of an inch. Example: AN6290-8 converts to 3-908.

AN6227B O-Rings (MS28775 Equivalent) (2-XXX)

AN6227B O-rings (packing O-ring hydraulic) are designed for hydraulic service (Ref. MIL-P-5516). They are suitable for moving or nonmoving seals. The usual application is with hydraulic pistons, valve stems, or other installations

involving reciprocating, rotary, or oscillating movement. Provisions must be made for lubrication when they are installed as moving seals in pneumatic systems. AN6227B O-rings are not designed for use with fittings.
These O-rings are furnished in a range of various cross-section widths and diameter sizes to fit standard O-ring gland dimensions per MIL-P-5514. For use with pressures from 1,500 to 3,000 psi, the gland design has provisions for backup rings of leather, Teflon, Kel-F, or other materials to prevent extrusion of the O-ring (see Figure 5-4, O-ring Extrusion). AN6227B dash numbers do not represent size increments but must be chosen according to the required ID and the cross-sectional width of the groove dimension.

AN6227B O-rings can be identified by two or three colored dots on the outer diameter, the number and color of the dots varying between manufacturers. They are supplied in Buna-N material.

Rectangular grooves as established in MIL-P-5514 must be used for AN6227B O-ring installation. Care must be taken not to scratch or pick the O-ring. Lubrication compatible to the system should be employed. AN6227B O-rings are not dimensionally the same as AN6290 O-rings in comparable sizes, and AN6227B O-rings are not acceptable substitutes for AN6290 O-rings in the fitting applications. AN6227B O-rings require AN6246 backup rings for pressure drops from 1,500 to 3,000 psi.

AN6230B O-Rings (MS82775 Equivalent)(2-XXX)

AN6230B O-rings (gasket O-ring hydraulic) are designed for nonmoving gasket applications in hydraulic service (MIL-P-5516). This O-ring is comparable to AN6227B but is limited to static applications. It is furnished in ID dimensions of 1-5/8 inches through 4-5/8 inches and is available only in a 1/8-inch cross-section size. AN6230B dash numbers are not comparable to AN6227B or AN6290 dash numbers.

Installation of AN6230B O-rings is the same as AN6227B O-rings, except that for pressures from 1,500 to 3,000 psi, the AN6230B O-ring requires an AN6244 backup ring.

MS28778 O-Rings,(3-9XX)

MS28778 (Gasket-straight thread tube fitting, boss) O-rings are required for gasket applications on AND10056 and AND10057 straight thread tube fittings in AND10050 bosses for port connections of pumps, valves, and other units in hydraulic and pneumatic systems (see MIL-P-5510). They are also used with three-piece tube fittings for mounting in straight thread bosses.

Installation of an O-ring with a fitting requires the fitting to have a hex shoulder of sufficient width to cover the entire O-ring. Some AN fittings are not suitable for use with O-rings. For use with AND10057 bulkhead flared tube connections in pneumatic or hydraulic systems to 3,000 psi, the installation required an AN6289 nut and AN6291 leather rings.

Manufacturers now carry color-coded O-rings which allow for easy identification. The following is a list of base polymers and their corresponding colors.

Ethylene Propylene	Purple	Neoprene	Red
Fluorocarbon	Brown	Nitrile	Black
Fluorosilicon	Blue	Silicone	Rust

The O-ring part number should continue to be checked to verify what the material actually is, since most O-rings still are black. (See Table 5-4.)

Table 5-4. O-Ring Properties by Number

PART NUMBER (1)	PART NUMBER (2)	MATERIAL	HARDNESS. SHORE A	TEMPERATURE RANGE. F	PROCUREMENT DOCUMENT	USAGE
MS9071	MS9020	BUNA N	65	10 TO 225	AMS 7271	PETROLEUM BASE FUEL, LOW TEMPERATURE RESISTANT
MS9068		SILICONE	70	80 TO 450	AMS 3304	AIR AND GASES. STATIC SEALS ONLY
MS28775		BUNA N	75	65 TO 225	MIL P-25732	MIL – H – 5606 HYDRAULIC FLUID (REPLACES AN6227 AND AN6230 FOR NEW DESIGN)
	MS28778	BUNA N	90	65 TO 225	MIL P-5510	MIL-H-5606 HYDRAULIC FLUID (REPLACES AN6290 FOR NEW DESIGN)
MS29513	MS29517	BUNA N	70	60 TO 200	MIL P-5315	HYDROCARBON FUELS
MS29561	NAS617	BUNA N	70	65 TO 225	MIL-R-1362, TYPE 1	SYNTHETIC LUBRICANTS
M83248/1		FLUOROCARBON	75	30 TO 400	MIL-R-83428, CLASS 1	HIGH TEMPERATURE, FLUID AND COMPRESSION SET RESISTANT
	M83248/2	FLUOROCARBON	90	30 TO 400	MIL-R-83428, CLASS 2	HIGH TEMPERATURE, FLUID AND COMPRESSION SET RESISTANT
RD262 4015	RD262 3006	BUIY 1	70	65 TO 165	S10130RB0077	SHORT TERM EXPOSURE TO NTD AND HYDROGINE TYPE FUELS
RD767 4016		FLUOROSILICONE	70	80 TO 350	OSI RD262 4016	OIL AND FUEL RESISTANT
	RD262 3007	FLUOROSILICONE	70	80 TO 350	OSI RD262 3007	OIL AND FUEL RESISTANT

(1) O-RINGS IN THIS COLUMN ARE FOR USE IN RADIAL FACE SEAL GLANDS.
(2) O-RINGS IN THIS COLUMN ARE FOR USE IN BOSS SEAL APPLICATIONS.

text was hard to read, need to double check entire table content

Conical Seals

It is necessary to utilize an annealed copper or aluminum conical seal in Facility tubing connections (1/4-inch size optional) to insure a leak-free connection. See Figure 5-5.

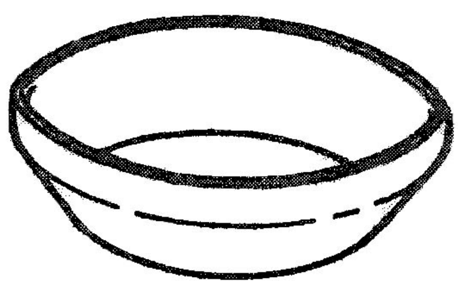


Figure 5-5. Typical Conical Seal

5.5: Good Practice Tips

1. Do not use a lubricant if doubt exists concerning its compatibility in the system.

2. Lubricants must be compatible with all downstream materials in fluid systems.

3. Lubricants contaminated with dirt, grit, metal chips, or other foreign matter must be discarded.

4. Use lubricants from original marked cans only. Do not return excess to the container.

5. Some lubricants have a shelf life. Be aware of the date on the container.

6. Avoid excessive lubrication. Lubricants should be applied in a streak across male threads. The amount of lubricant depends on thread size. Follow application procedures in the appropriate process specification.

7. Do not lubricate female threads or flares. Interior and exterior thrust surfaces of the tubing sleeve must be lightly lubricated to prevent galling during torquing of B-nuts.

8. Do not apply lubricant to the end of a fitting.

5.6: Packaging

5.6.1: Items Requiring Packaging

When components are fragile, have an irregular configuration or sharp projections, have a close tolerance on surface finishes or surface flatness or total alignment, and/or have a weight in excess of 1 pound, additional physical protection to the bagged or capped component may be required. Packaging should be indicated on the drawing, specification, or engineering work request.

5.6.2: Packaging Methods

Where specific requirements are not called out on the controlling document, the following methods are recommended:

1. Package the component in a container selected, so the component will not occupy more than three-fourths of any container dimension. Locate the component centrally within the container and secure to the container base or completely block the component in position with cushioning material.

2. For a suitable alternate, the component may be wrapped with a cushioning material (Table 5-5). Cushioned items should be packaged in a suitable snug-fitting, rigid or semi-rigid container. Oversized containers may be used when additional cushioning materials are used to prevent movement of the component within the container.

Table 5-5. Selection of Cushioning Wrap Materials

SELECTION OF CUSHION WRAP MATERIALS
(Minimum Thickness, Inches)

Part Weight, lbs	Polyurethane Foam	Folyethylene Foam
Less than 7	1/2	1/8
7 to 10	1	1/4
10 to 15	–	3/8
15 to 20	–	1/2

NOTE: Sheets of different thickness may be combined to obtain the required thickness.

Liquid Propellants, Pressurants, and Solvents
Contents

Page

6.1: Important Notices Prior to Work

NOTES:

1. The engineering work order, drawing, or the latest process specifications should be consulted prior to the selection of compatible materials (metals, nonmetals, and lubricants) to be used in a propellant system.

2. The safety clothing data and other PPE used for propellant handling is subject to revision at any time. Your supervisor will notify you of any change.

6.2: Liquid Propellant Definitions

Ambient: Condition of surrounding area. Thus ambient temperature or pressure is the prevailing temperature or pressure surrounding the object in question, generally the atmosphere.

Anhydrous: Free of water.

Atmosphere: A unit of pressure equal to 14.7 psi or 760 TORR at sea level.

Auto-Ignition Temperature: The lowest temperature at which a substance in contact with air (or other oxidizer if specified) will ignite spontaneously and continue to support combustion.

Boiling Point: The temperature at which the vapor pressure of a liquid becomes equal to the pressure of the ambient atmosphere. Boiling point varies with the pressure of the liquid.

Catalyst or Catalytic Agent: Any substance which, by virtue of its presence, affects the rate of a chemical reaction and which may be recovered practically unchanged at the end of the reaction.

Compatible: Having no undesirable effect with or upon another material under specified conditions of use.

Corrosive: A material which acts upon another material in such a way as to destroy or damage it permanently. Example: Acid destruction of the interior of a pipe or tubing installment.

Critical Pressure: The existing pressure at the critical temperature.

Critical Temperature: The highest temperature at which a gas can be liquefied without regard to the pressure applied.

Cryogenic Temperature: Very low temperature, typically a material whose upper limit of the critical temperature is -238˚ F (-150˚ C) or colder.

Decomposition: Separation of a propellant or solvent into two or more substances which can cause a rapid rise in system pressure.

Density: Concentration of material either liquid or solid, measured by the weight per unit volume.
Ductile: Able to stand deformation under a load without fracture. Also, pliant or flexible. In rocket testing we are concerned with the ability of certain materials to remain pliant of flexible at test temperatures.

Flammable: Combustible. A material which can be ignited.

Flammable Limits, Upper and Lower: Limits established by the richest and leanest mixtures of flammable gas and air that will support flame propagation upon ignition. They are expressed in terms of percentages of gas or vapor in air by volume (e.g., the flammable limits of gasoline are 6 percent to 1 percent and mixtures beyond these limits are too rich or too lean respectively, to support flame propagation).

Flash Point: The minimum temperature at which the surface of a liquid may be momentarily ignited by an open flame.

Freezing Point: The temperature at which a material changes phase, from a liquid state to a solid state. The freezing point is slightly dependent upon pressure.

Fuel: Any combustible material which can burn with an oxidizer.

Hygroscopic: Capable of absorbing moisture from the air.

Hypergolic: A term applied to describe self-ignition of a fuel and oxidizer upon contact with each other.

Impervious: Impenetrable; pertaining to clothing which may be impenetrable to certain fluids, chemicals, etc.

Inert: Incapable of producing a reaction. A material which will not burn or support combustion.

Inhibit: To check or retard a chemical action.

Liquid Propellant: A chemical in liquid form used as a fuel, oxidizer, or monopropellant to provide the combustion necessary for the production of thrust by a rocket engine.

Liquid to Gas Ratio: A comparison of the volume of the liquid state of a material at its boiling point, to the volume of its gaseous state at standard temperature and pressure (59˚ F and 14.7 psia). Example: 1 cubic foot of liquid oxygen, at its boiling point, will evaporate into 862 cubic feet of gaseous oxygen at 59˚ F and one atmosphere. Therefore, the liquid to gas ratio is 1:862.

Maximum Allowable Concentration: The maximum amount of a toxic gas or vapor that the body can stand for an 8-hour period in one day, for an indefinite number of days, without causing any effect to health. It is expressed in parts per million (ppm), by volume, of the gas or vapor in air. Some rocket propellants are toxic by nature.

Monopropellant: A single material, usually utilized with a catalyst to cause it to react for purposes of powering a rocket engine or some component thereof.

Oxidizer (or Oxidizing Agents): A chemical that will actively support combustion or oxidation of a fuel.

Padding or Blanket Purging: Filling the void or ullage of a closed container with an inert gas (usually nitrogen) to prevent oxidation or contamination of the chemical contained therein, and to avoid the formation of flammable or explosive mixtures by excluding air from the container.

Passivation: The treatment of metals to render them inert to the action of a particular chemical or mixture by the formation of an impervious film on the contact surface.

Psia: Pounds per square inch absolute (14.7 psia = 1 atmosphere at sea level; 0 psia = a complete absence of pressure, constituting vacuum).

Psig: Pounds per square inch gauge (0 psig = 1 atmosphere at sea level).

Pyrophoric: Any fuel or other material which will ignite spontaneously upon contact with air. Example: Triethylaluminum and Triethylborane (TEA/TEB).

Pyrotechnic: A mixture of an oxidizing agent and solid fuel designed to produce light, heat or perform some other non-propulsive function. Usually used as igniters.

Solid Propellant: A solid mixture consisting of a fuel and oxidizer cured in the form of a block or "grain" which is typically cast into the combustion chamber of the rocket for the production of thrust.

Specific Gravity: The ratio of the weight of any volume of a substance to the weight of an equal volume of some substance taken as a standard of unit. Water is usually the standard for solids and liquids, and air for gases

Stability: State of balance. A condition in which opposing forces exactly balance or equal each other. In rocket usage, thermal and shock stability are important. Thermal stability refers to a material's ability to remain stable when a change of temperature occurs, and shock stability refers to a material's ability to remain stable when subjected to shock

Storable: Refers to liquid propellants which may be stored over an extended period of time at or near ambient condition without chemical or physical change (e.g., NTO, MMH, IRFNA, etc.).

Threshold Limit Value (TLV): Concentrations of airborne contaminants to which most workers can be exposed during working hours (that is, 8 hours a day, 5 days a week) for indefinite periods without adversely affecting their health; sometimes referred to as MAC (maximum allowable concentration).

Toxic: Poisonous, or causing poisoning.

Ullage: Unfilled space above the liquid in a container, typically a pressure vessel.

Specific Gravity-Vapor: Is the relative density of a vapor as compared with the density of air, which is taken a 1. Example: Acetone vapor density is 2.00, air density is 1.00. Acetone vapors are twice as heavy as air.

Vapor Pressure: The pressure exerted by the evaporation of a liquid at any given temperature.

6.3: Liquid Propellant, Pressurant, and Solvent Data

Table 6-1. Liquid Propellant, Pressurant, and Solvent Data

	Color		Odor	Topic Threshold Limit Value	Toxic	Irritant	Asphyxiating	Flammable Range	Supports Combustion	Corrosive	Odor Threshold	Comments
	Liquid	Vapor										
MMH	Colorless	Invisible	Ammonia	0-2 PPM	YES	YES	NO	25-98%	NO	NO	0-5 PPM	Toxic at extremely low level
NTO	Brown	Brown	Pungent	5 PPM	YES	YES	NO	Non-Flammable	YES	YES	0-5 PPM	Hypergolic with fuel as MMH
LOX	Blue	Invisible	None	None	NO	NO	NO	Non-Flammable	YES	NO	None	Highly explosive when mixed with fuel. May appear as white cloud, due to condensation of moisture in air. Avoid drawing or walking through it
F_2	Yellow	Brownish	Pungent	1 PPM	YES	YES	NO	Non-Flammable	YES	YES	PPG	The most reactive element
CIF	Greenish	Nearly Colorless	Pungent	0-1 PPM	YES	YES	NO	Non-Flammable	YES	YES	--	Toxic at extremely low level
TEA	Colorless	Invisible	Combustion by Products	None	YES	YES	NO	Pyrophoric	Pyrophoric	NO	--	Ignites spontaneously in air
TEG	Colorless	Invisible	Combustion by Products	None	YES	YES	NO	Pyrophoric	Pyrophoric	NO	--	Ignites spontaneously in air
H_2	Colorless	Invisible	None	None	NO	NO	YES	4-75%	NO	NO	None	Hydrogen fires are almost invisible
N_2	Colorless	Colorless	None	None	NO	NO	YES	Non-Flammable	NO	NO	None	Inert gas
He	Colorless	Invisible	None	None	NO	NO	YES	Non-Flammable	NO	NO	None	Inert gas
Trichloroethylene	Colorless	Invisible	Chloroform	25 PPM	YES	NO	NO	12.5-90%	NO	NO	21 PPM	May form phosgene when heated
Trichloroethane	Colorless	Invisible	Chloroform	350 PPM	YES	NO	NO	Non-Flammable	NO	NO	500 PPM	May form phosgene when heated
Freon	Colorless	Invisible	Strong	1000 PPM	NO	NO	YES	Non-Flammable	NO	NO	--	May form phosgene when heated
Jet Fuels, RP-1, JP-5	Colorless	Invisible	Kerosene	Not established	YES	YES	NO	0.8-6%	NO	NO	--	A mixture of various petroleum products

6.4: Compatible Materials

Table 6-2. Compatible Materials (Sheet 1 of 4)

CRYOGENICS			
SERVICE	METALS	NONMETALS	LUBRICANTS
Liquid Oxygen	Stainless Steel 18-8 Copper Bronze Brass Aluminum Monel	Teflon Kel-F Asbestos Certain Silicon Rubbers	*
Liquid Nitrogen & Liquid Helium	Some Chrome- Nickel Steels (Austenitic-9 % Nickel) ** Stainless Steel 18-8 Copper Brass Bronze Copper-Silicone Alloys Monel Aluminum Shredded Lead	Teflon Kel-F Cotton-free Asbestos Graphite (Selected types)	*
Flourine & FLOX	Monel Aluminum Stainless Steel 304L 347 Copper Brass	None	None
Liquid Hydrogen	Stainless Steel 300 series Austenitic Copper Bronze Brass Monel Aluminum	Dacron Teflon Kel-F Nylon Mylar films Asbestos impregnated with Teflon	*

* For the proper lubricants to be used in this system, check the appropriate process specification and/or specification drawing.

** Nine percent nickel, limited to -320˚F (LN_2)

Table 6-2. Compatible Materials (Sheet 2 of 4)

STORABLE OXIDIZERS			
SERVICE	METALS	NONMETALS	LUBRICANTS
Nitrogen Tetroxide	Carbon Steels Aluminum Stainless Steel Nickel Iconel	Ceramic (acid-resistant) Pyrex glass Teflon Kel-F Asbestos (cotton free)	*
Hydrogen Peroxide	Aluminum 1060, 1260, 1360, 5254, 5652 Stainless Steel 304, 304ELC, 309, 310, 316, 316ELC, 317, 321, 347	Teflon Kel-F	*
Inhibited Red Fuming Nitric Acid	Aluminum 1060, EC, 1100, 3003, 3004, 6061, 5052, 5154 Stainless Steel 347, 19-9DL, 19-9DX, 304ELC, 321, 303, 316	Teflon Kel-F Polyethylene	*
Chlorine Triflouride	Stainless Steel 18-8 Copper Silver-solder Brass Steel Magnesium Aluminum Monel Nickel	Pyrex glass	None

* For the proper lubricants to be used in this system, check appropriate process specification and/or specification drawing.

Table 6-2. Compatible Materials (Sheet 3 of 4)

STORABLE FUELS			
SERVICE	METALS	NONMETALS	LUBRICANTS
Hydrazine	Aluminum 1100 & 3003 Stainless Steel 303, 304, 321, 347 Nickel	Polyethylene Teflon Kel-F (unplasticized)	*
Monomethylhydrazine	Stainless Steel 304, 307 Aluminum 3003, 5052, 5154, 1060, 6061 Durimet 20	Polyethylene Teflon Kel-F (unplasticized)	*
Unsymmetrical Dimethylhydrazine	Low Carbon Steels Aluminum Stainless Steel 347 series	Teflon Kel-F Butyl Rubber JM-76	*
Hydyne	Stainless Steel Nickel Monel Aluminum 1100, 5052-0	Teflon Polyethylene	
RP-1	Most Metals	Neoprene Teflon Kel-F Buna-N Synthetics	*
Ethyl Alcohol	Most Metals	Polyvinyl Chloride Neoprene Rubber Kel-F Teflon Polyethylene Asbestos gasket material	*

* For the proper lubricants to be used in this system, check appropriate process specification and/or specification drawing.

Table 6-2. Compatible Materials (Sheet 4 of 4)

PYROPHORIC FUELS			
SERVICE	METALS	NONMETALS	LUBRICANTS
Pentaborane	Aluminum 5052-S, 6061-T6, 7075-T6, 2024-T3, 3003-H14, 356-T6 Stainless Steel 18-8 Low Carbon Steel K-Monel Monel M-8330-B Nickel Nichrome “V” Magnesium Fed QQ-M44A Fed QQ-M-56-A263 Titanium C-130AM, C-110AM Copper Brass Hastelloy	Kel-F Kel-F-5500 Teflon Flourosilicone rubbers Flouroflex “T” Glass Viton “A” & “B” Dry Asbestos Garlock 230 Carbon	*
Triethylaluminum	Stainless Steel	Glass	*
Triethylboron	0Copper	Teflon	
Triethylaluminum-boron	Iron	Kel-F	

SOLVENTS			
SERVICE	METALS	NONMETALS	LUBRICANTS
Acetone	Stainless Steel 300 series	Teflon	*
Freons	Nickel	Kel-F	*
Trichloroethylene	Steel	Polyethylene	*

* For the proper lubricants to be used in this system, check appropriate process specification and/or specification drawing.

6.5: Safety Clothing Data

Table 6-3. Safety Clothing Data

Propellants and Solvents	SAFETY CLOTHING DATA					
	HEAD Hat or Hood	FACE Shield or Hood	BODY Clothes or Suit	HAND Gloves	FOOT Shoes or Boots	Respiratory Equipment Required
Cryogenics						
LOX	Hard Hat	Face Shield (a)	Work Clothes	Leather	Work	None
LN_2	Hard Hat	Face Shield (a)	Work Clothes	Leather	Work	Yes (b)
LHe	Hard Hat	Face Shield (a)	Work Clothes	Leather	Work	Yes (b)
LF_2	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Neoprene	Neoprene	Yes (c)
FLOX	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Neoprene	Neoprene	Yes (c)
LH_2	Hard Hat	Face Shield (a)	Work Clothes (d)	Leather	Work	Yes (b)
Storable Oxidizers						
NT0	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
H_2O_2	Hard Hat	Face Shield (a)	Vinyl Apron	Vinyl-Coated	Neoprene	Yes (e)
IRFNA	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (d)
CTF	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Neoprene	Neoprene	Yes (d)
Storable Fuels						
HZ	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
MMH	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
UDMH	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
HYDYNE	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
RP-1	Hard Hat	Face Shield (a)	Work Clothes	Neoprene	Work	Yes (c)
Ethyl Alcohol	Hard Hat	Face Shield (a)	Work Clothes	Vinyl-Coated	Work	Yes (c)
Pyrophoric Fuels						
PB	Gra-Lite Hood	Gra-Lite Hood	Gra-Lite Suit	Vinyl-Coated	Neoprene	Yes (c)
TEA	Hard Hat	Face Shield (a)	Apron (f)	Leather	Leather Leggings	Yes (c)
TEB	Hard Hat	Face Shield (a)	Apron (f)	Leather	Leather Leggings	Yes (c)
TEAB	Hard Hat	Face Shield (a)	Apron (f)	Leather	Leather Leggings	Yes (c)
Solvents						
Acetone	Hard Hat	Face Shield (a)	Plastic Apron	Neoprene	Work	Yes (c)
Freons	Hard Hat	Face Shield (a)	Plastic Apron	Neoprene	Work	Yes (c)
Trich	Hard Hat	Face Shield (a)	Plastic Apron	Neoprene	Work	Yes (c)

(a) Safety glasses must be used when face protectors are used.
(b) Required when suffocation hazard is present.
(c) Required when MAC value is exceeded.
(d) Aluminized hood, coveralls, and gloves required for full protection.
(e) Required when excessive vapors are present.
(f) Impregnated asbestos open-back jacket or apron.

6.6: First Aid Treatment

ALL MATERIALS:
CRYOGENS, STORABLE OXIDIZERS, STORABLE FUELS, AND SOLVENTS

SKIN CONTACT:

Seek immediate medical attention or call 911.

INHALATION:

Remove the person from the contaminated area. Seek immediate medical attention or call 911.

INGESTION:

Seek immediate medical attention or call 911.

BREATHING STOPS:

Apply artificial respiration or mouth-to-mouth resuscitation.

In all cases when a person requires First Aid—seek immediate medical attention or call 911.

6.7: Fire Control Methods

Table 6-4. Fire Control Methods

Propellants and Solvents	FIRE CONTROL METHOD					
	WATER COOLING AND DILUTION			SUFFOCATION METHOD		
	Stream	Spray	Fog	CO_2	Dry Chemical	Foam
Cryogenics						
LOX	No	No	Yes	No	No	No
LN_2	Not Flammable	Not Flammable	Not Flammable	Not Flammable	Not Flammable	Not Flammable
LHe	Not Flammable	Not Flammable	Not Flammable	Not Flammable	Not Flammable	Not Flammable
LF_2	No	No	Possibly (a)	No	No	No
FLOX	No	No	Possibly (a)	No	No	No
LH_2	Yes	Yes	Yes	Yes (b)	Yes	No
Storable Oxidizers						
NT0	Yes	Yes	Yes	No	No	No
H_2O_2	Yes (c)	Yes (c)	Yes	No	No	No
IRFNA	Yes (d)	Yes (d)	Yes	No	No	No
CTF	No	No	Possibly (a)	No	No (e)	No
Storable Fuels						
HZ	Yes	Yes	Yes	Yes	Yes	Yes (f)
MMH	Yes	Yes	Yes	No	Yes	Yes (f)
UDMH	Yes	Yes	Yes	Yes	Yes	Yes (f)
HYDYNE	Yes	Yes	Yes	Yes	Yes	Yes (f)
RP-1	No	No	Yes	Yes	Yes	Yes
Ethyl Alcohol	Yes	Yes	Yes	Yes	Yes	No (Dissolves)
Pyrophoric Fuels						
PB	No	No	Possibly (g)	Yes (h)	Yes (h)	Yes (i)
TEA	No	No	Possibly (g)	Yes (h)	Yes (h)	Yes (i)
TEB	No	No	Possibly (g)	Yes (h)	Yes (h)	Yes (i)
TEAB	No	No	Possibly (g)	Yes (h)	Yes (h)	Yes (i)
Solvents						
Acetone	No	No	Yes	Yes	Yes	Yes
Freons	Not Flammable	Not Flam. (j)	Not Flammable	Not Flammable	Not Flammable	Not Flammable
Trich	No	No	Yes	Yes	Yes	Yes

(a) Fluorine FLOX and CTF react with water; therefore, it cannot be used to put out a Fluorine-fed fire, but a controlled fog stream can substantially reduce effluent by controlled reaction.
(b) CO_2 is not as effective as water because of the high temperatures involved.
(c) Large amounts of water can effectively dilute peroxide.
(d) Large amounts of water on IRFNA can cause an increase in vapor pressure in an enclosed area.
(e) Dry chemicals can be used to decontaminate spills.
(f) Foam tends to break down rapidly, due to the high temperature of hydrazine-fed fires. CO_2 is effective in most cases involving small fires, especially for protection of personnel.
(g) Pyrophoric fuels react violently with water; therefore, water cannot be used to put out a fire, but a controlled fog can be used to burn up the fuel faster, while providing cooling for the surrounding area.
(h) CO_2, dry chemical, and foam are effective as long as they cover the fire; once removed, the fire may reignite.
(i) Foam and water deluge are the most effective control.
(j) At the present time, Freon solvents are considered to be non-flammable.

Rigging
Contents

7.1: Introduction

Rigging consists of the ropes, cables, chains, slings, pulleys, winches, and related materials used in moving heavy equipment. Safe rigging operations require observance of correct procedures and knowledge of the materials used. Hoisting equipment is made according to rigid standards of manufacture. It is tested and its limits verified by such national societies as American Society for Testing Materials (ASTM). Thus the user is assured that an individual item is suitable for use within certain load limits. These limits are indicated in various tables in this section. Great personal harm and extensive property damage can result from failure to observe the design limitations of hoisting equipment or from failure to recognize evidence of wear, weakening, or damage.

7.2: Estimation of Safe Loads

It is often necessary to make quick estimations of the load capacity of equipment used in rigging operations. Table 7-1 presents methods for quickly determining the safe load capacity of commonly used rigging.

Table 7-1. Estimation of Safe Loads

Rigging Equipment	**Safe Load in Tons is Equal To:**	**Remarks**
Eye Bolts	$2D^2$	D = diameter (in inches) of bolt stock where it forms the eye. Not accurate when D is greater than 1 inch.
Manila Rope Sisal Rope	D^2 $0.7\ D^2$	D = diameter (in inches) of rope. Not accurate when D is greater than 1 inch.
Plow Steel Wire Rope	$8D^2$	D = diameter (in inches) of wire rope.
Open Eye Hooks	D^2	D = diameter (in inches) at the point where the inside curve starts its arc. (See Figure page 8-9.)
Shackles	$6D^2$	D = diameter (in inches) of the shackle. Do not use pin diameter. (See figure page 8-18.)
Chain	$6D^2$	D = diameter (in inches) of chain stock.

7.3: Estimating Load Weights

Frequently, the rigger has to compute loads in order to make the best use of his equipment and assure safety of personnel and protection of equipment. Both the load limit of the equipment being used and the approximate weight of the material being handled must be known.

Determine the size of the object by visualizing it as being square or rectangular. Deduct any small component parts or offshoots from the object to be lifted, and calculate the volume of the object in cubic inches or feet by multiplying the object's length times its width times its height. Take the component parts or offshoots and do the same thing. Add both answers together to find total volume of objects to be lifted.

Determine what the object is made of and its weight in pounds per cubic inch or foot (See Table7-2). Multiply the weight per cubic foot or inch times the object’s volume. This will give the approximate weight of the object. As an extra margin of safety, overestimate the object's weight a little.

Table 7-2. Weights of Materials

Weights of Materials (Solids)		
Material	**Pounds Per Cubic Inch**	**Pounds Per Cubic Foot**
Wood (Spruce)	.016	27
Water	.036	62.5
Earth	.058	100
Sand	.070	120
Concrete	.083	144
Cast Iron	.24	442
Steel	.28	488
Brass	.31	534
Lead	.44	710
Aluminum	.092	160
Copper	.322	555

Steal plate weighs approximately 10 pounds per square foot for each 1/4-inch of thickness. Aluminum weighs approximately 1/3 as much as steel. The relationship of the weight of steel to the weight of other materials can be seen in the table above.

7.4: Estimating Center of Gravity

The rigger has to determine the approximate locations of the center of gravity of a load he intends to lift. The center of gravity is the point where the entire weight of the object is theoretically concentrated. This point, when the object is freely suspended from a hook, will always hang directly below the hook. Finding the exact center of gravity requires mathematical calculations, but for the average rigging job it can be estimated closely enough. Figure 7-1 below shows some familiar and some irregular-shaped plane figures representing, say, the length or cross section of the object and showing the approximate locations of their centers of gravity. Most centers of gravity are within the object, but some are located outside.

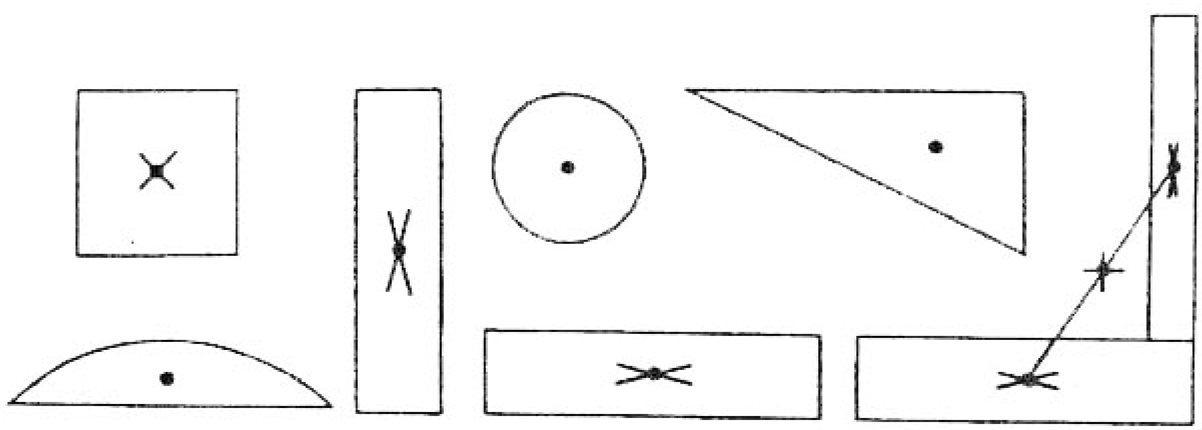


Figure 7-1. Approximating the Location of the Center of Gravity of Plane Figures

A simple but near-exact method of locating the center of gravity of a plane figure of irregular shape is to cut out a similar figure, at any convenient scale, from a piece of cardboard (see Figure 7-2). Punch pinholes near two adjacent corners of the cardboard and suspend it freely from one pinhole by a pin or nail stuck into a wall. Suspend from the nail or pin a small weight attached to a string, and draw a line on the card along the string. Remove the cutout and place the nail in the other hole and draw another line. Where the two pencil lines cross is the center of gravity. See Figure 7-2, "Locating Center of Gravity."

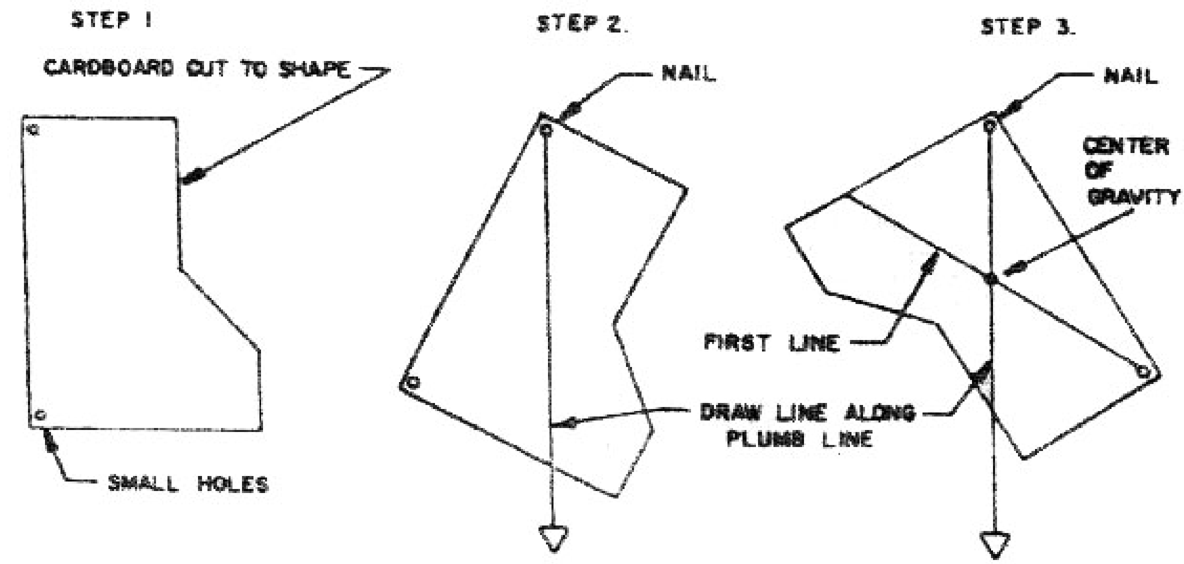


Figure 7-2. Locating Center of Gravity

7.5: Plow Steel Wire Rope

Plow steel rope is more flexible than standard wire rope and is made of wire drawn from specially selected high strength steel to produce a finished rope of great strength and toughness capable of resisting severe abrasion. Plow steel rope is recommended for all types of hoisting (see Figure 7-3) and for all rough uses requiring maximum strength and toughness. See Table 7-3 for safe loads.

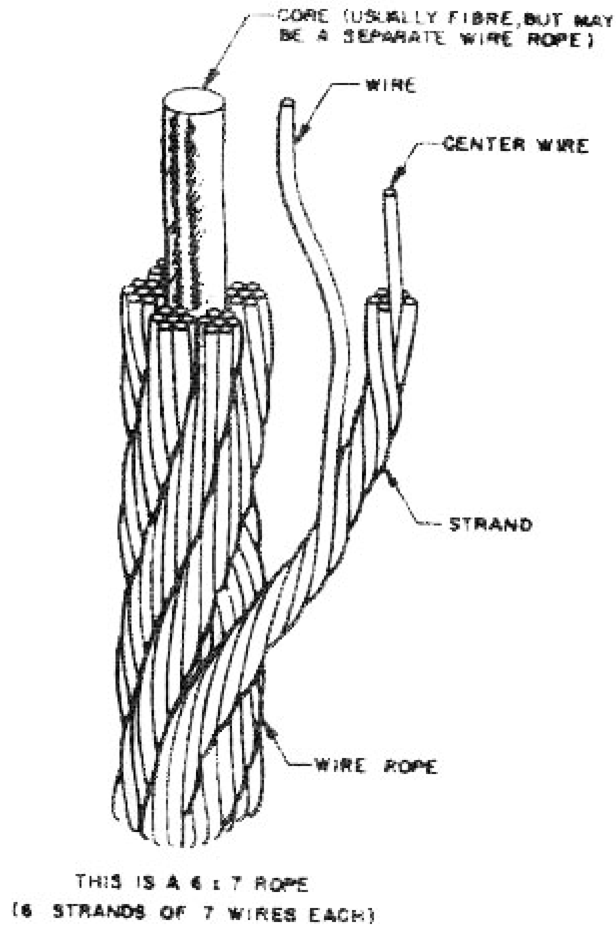


Figure 7-3. Plow Steel Wire Rope

Table 7-3. Safe Load in Pounds for Plow Steel Hoisting Rope
(Six Strands of Nineteen Wires, Hemp Center)

Diameter in Inches	**Safe Load in Pounds**	**Diameter in Inches**	**Safe Load in Pounds**
1/4	1,100	1	16,000
5/16	1,800	1-1/8	21,200
3/8	2,400	1-1/4	26,000
7/16	3,300	1-3/8	31,400
1/2	4,200	1-1/2	37,000
9/16	5,400	1-5/8	43,200
5/8	6,600	1-3/4	49,600
3/4	9,400	1-7/8	56,800
7/8	12,800	2	64,400

NOTE: Slings may be covered only with clear protective coating through which any defects can be readily seen.

Small loops often develop in the slack portion of wire rope during handling (Figure 7-4). If tension is applied to the rope when loops exist in it, sharp kinks (Figure 7-5) will form, resulting in “unlaying" of the rope (Figure 7-6). It is impossible to remove a kink which has been formed in a rope, and serious weakening occurs at the kinked point. Further damage can be inflicted upon a wire rope by rust or abrasion. No wire rope which has been subjected to weakening by kinking, rust, or abrasion should be used where the possibility of damage to personnel or material exists.

Figure 7-4.Small Loop

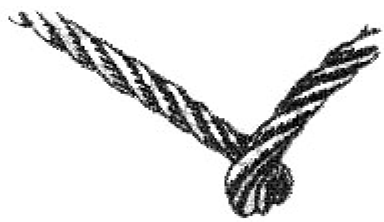


Figure 7-5.Sharp Kink

Figure 7-6. Unlaying

7.5.1: Inspection of Wire Rope

Frequency: Wire rope should be inspected before each use. Frayed, kinked, worn or corroded rope should be replaced.

Procedure: The weak points in the rope, or the points where the greatest stress occurs, should be inspected with extreme care.

1. Worn spots will show up as shiny flattened spots on the wires. Measure some of these shiny spots. If the outer wires have been reduced in diameter by one-fourth, the worn spot is unsafe.

2. Broken wires: When 4 percent of the total number of wires in the rope are found to have breaks within the length of one rope lay, the rope is unsafe.

7.5.2: Common Causes of Rope Failure

1. Allowed to drag over obstacles
2. Overwinding or crosswinding on drums
3. Subjected to moisture, acid fumes, and salty air
4. Improperly attached fittings
5. Permitted to untwist
6. Subjected to excessive heat
7. Kinks
8. Subjected to severe overloads
9. Destroyed by internal wear caused by grit penetrating between strands
10. Used without proper cable clamp
11. Scuffed and damaged when rope slides as the lift or turn is made
12. Crushed when the load is lowered upon them
13. Damaged by putting nails or other sharp objects through the strands
14. Kinked by tying two together to make a longer rope
15. Kinked by not removing small loops formed in a slack rope before applying tension

7.6: Chains

The safe load limits of chain can be obtained from Tables 7-4 and 7-5. These tables suppose a new or like new condition and that the chain has not been overstressed. A chain may also be damaged by abrasion and rust. Careful inspection of a chain should be made periodically regardless of the frequency of its use. If it is stretched, worn or rusted, it should not be used. Stretching can be detected by small checks or cracks in the links, by links binding on each other, and by elongation (Figure 7-7). Useful chain life can be extended by prevention of overloads, protection from rust and by protecting the chain from sharp corners or abrasive applications.

Chain Terminology:

Size of chain — The diameter of chain link stock

Pitch — The distance from the center of one link to the center of the next

Proof Test Two load, expressed in pounds, that a chain will carry, (two times safe working load) without deformation

Breaking Strain The load point at which a chain will break. It is approximated as five times the safe working load

Safe Working Load.....One half of proof test

Table 7-4. Safe Loads for Standard Carbon Steel Chain

Diameter of Link Stock, Inch	Safe Load Pound	Diameter of Link Stock, Inch	Safe Load Pound
1/4	1,000	5/8	6,600
3/8	2,300	3/4	9,500
1/2	4,200		

Table 7-5. Safe Loads in Pounds for Alloy Steel Chains

Size, Inch	Vertical Load	Loads are Given for Each Leg			Choker Hitch Vertical Load	Basket Hitch Vertical Load
		60^o Angle	45^o Angle	30^o Angle		
3/8	3,182	2,757	2,251	1,592	2,387	5,730
1/2	5,733	4,965	4,045	2,867	4,300	10,320
5/8	8,433	7,303	5,963	4,216	6,325	11,580
3/4	11,000	9,526	7,778	5,500	8,250	19,800
7/8	14,700	12,774	10,430	7,375	11,062	26,550
1	19,166	16,950	13,552	9,583	14,375	34,500
1-1/8	25,166	21,795	17,795	12,583	18,875	45,300
1-1/4	32,500	28,146	22,981	16,250	24,375	50,850

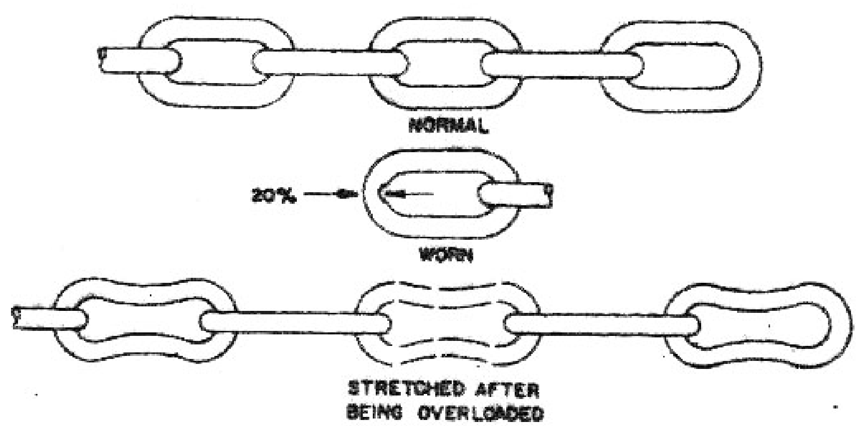


Figure 7-7. Detecting Chain Stretching

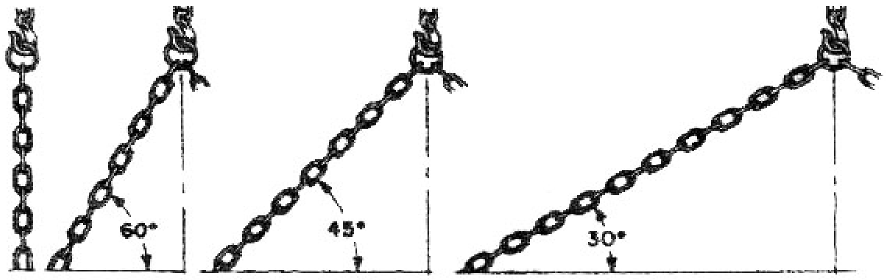


Figure 7-8. Chain Angles

7.7: Manila Rope

7.7.1: General

Manila rope requires caution in its use because of the difficulty encountered in determining its condition and because of its lower resistance to weathering than other hoisting materials. It is subject to abrasion and must be protected from rough surfaces and sharp corners. Moisture affects rope adversely and special care must be observed in handling storage. It should not be stored wet, and, even when dry, it should be stored in loose coils with provision for free circulation of dry air. Damage by aging or moisture may be detected by twisting a rope against the lay to uncover the center of the rope. A dry powdery condition indicates deterioration. A rope in this condition should not be used. Rope should also be examined for frayed strands or fibers or variations in color, which indicate that sections have been subjected to unequal weathering. Examination of used or aged rope against new rope will reveal its condition. Safe loads for the most commonly used manila rope sizes are listed in Table 7-6.

Table7-6. Manila Rope Data (Based on US Spec. T-R—601)

Diameter Inch	Circumference, Inch	Feet per Pound	Weight 100 ft Pound	Breaking Strength Pound	Working Load, Pound
3/16	5/8	66.60	1.5	450	90
1/4	3/4	50.00	2.0	600	120
5/16	1	34.50	2.9	1,000	200
3/8	1-1/8	24.40	4.1	1,350	270
7/16	1-1/4	19.00	5.3	1,750	350
1/2	1-1/2	13.30	7.5	2,650	530
9/16	1-3/4	9.61	10.4	3,450	690
5/8	2	7.50	13.2	4,400	880
3/4	2-1/4	6.00	16.7	5,400	1080
13/16	2-1/2	5.13	19.5	6,500	1300
7/8	2-3/4	4.45	22.5	7,700	1540
1	3	3.71	27.0	9,000	1800
1-1/16	3-1/4	3.20	31.3	10,500	2100
1-1/8	3-1/2	2.78	36.0	12,000	2400
1-1/4	3-3/4	2.40	41.8	13,500	2700
1-5/16	4	2.09	48.0	15,000	3000
1-1/2	4-1/2	1.67	60.0	18,500	3700
1-5/8	5	1.34	74.4	22,500	4500

1-3/4	5-1/2	1.12	89.5	26,500	5300
2	6	.93	108.0	31,000	6200

7.7.2: Knot Strength

A manila rope will separate first at a point where it is subjected to unnatural stress, sharp corners and turns being common points of separation. Figure 7-9 illustrates various knots and their effect upon the strength of lines follows. It should be used in conjunction with the Manila Rope Data, Table 7-6.

(A knot will reduce rope strength to the indicated percentage of its original value.)

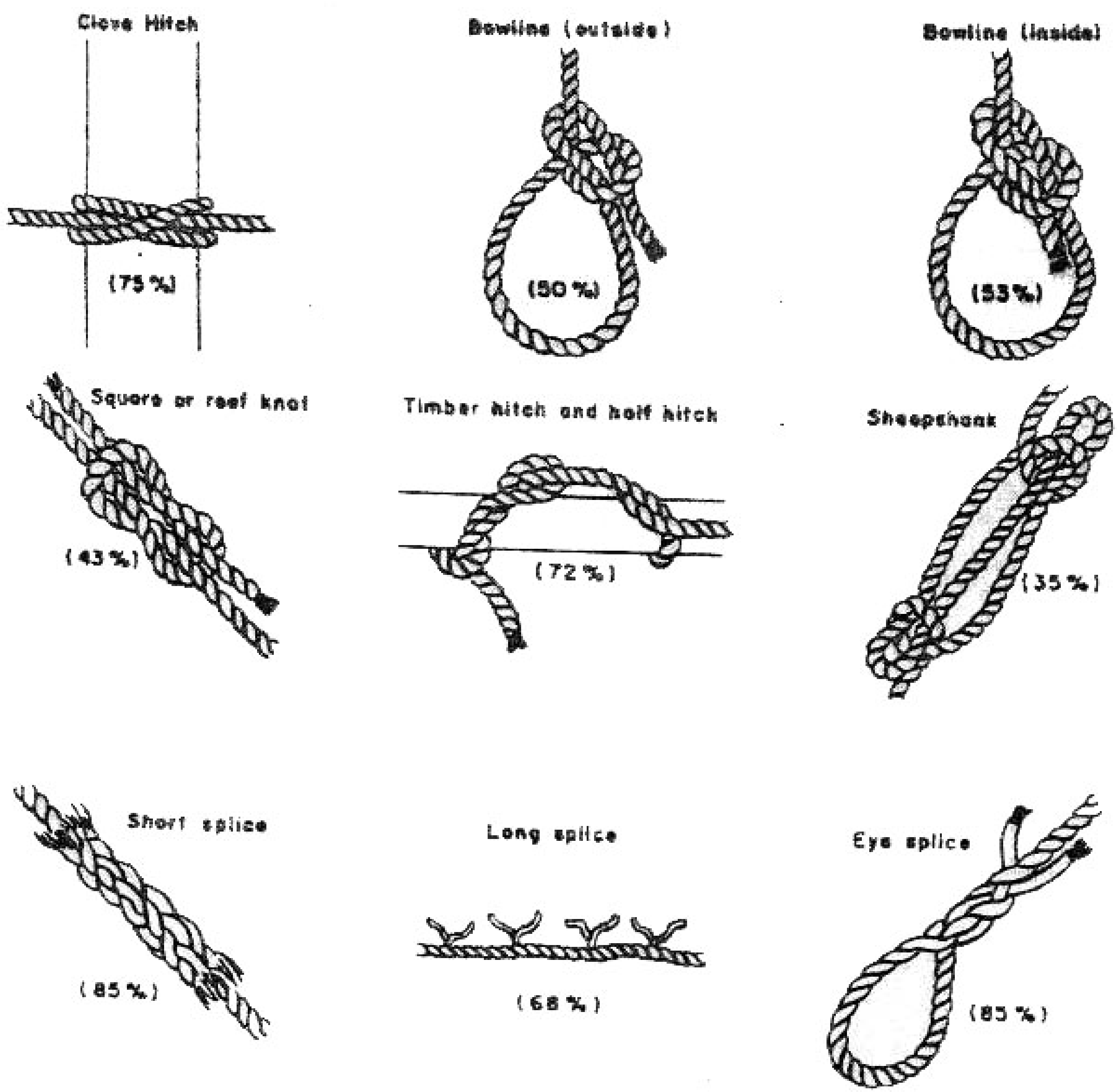


Figure 7-9. Knot Strength of Manila Rope

7.8: Hoisting Hooks

There are two types of hoisting hooks commonly used at the Field Laboratory on hoisting equipment. These are the slip hook with a safety latch, and the grab hook. See Figure 7-10.

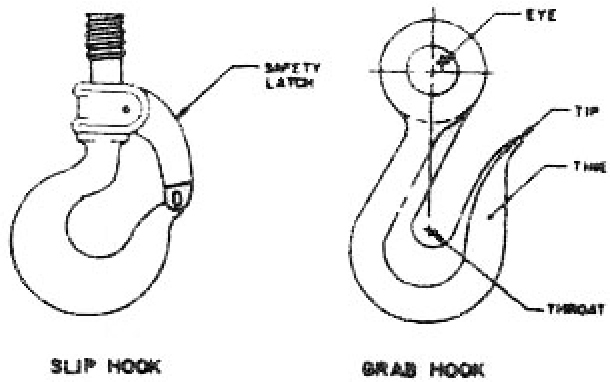


Figure 7-10. Hook Types

The slip hook, with a safety latch, is the most commonly used hook. Slip hooks with their large throat opening permits easy installation of such lifting equipment as slings, shackles, etc. The safety latch is not designed to hold rigging equipment in the hook under load conditions but only when under slack or no-load conditions. While hitching to a part, the slings, shackles, etc., will stay on the hook with the safety latch in the closed position. A wide sling angle will cause the sling to slide up the point of the hook, distorting the safety latch and allowing the sling to slip off the hook. Slip hooks are also used on wire rope and chain slings.

The grab hook has a narrow throat opening and is generally used with alloy chain slings. The small opening allows the hook to be positioned between the links of a chain, making it useful for hitching the sling to any desired length and preventing slippage.

The maximum throat opening (spread) of a hook should not exceed 35 percent beyond the designed opening. See Table 7-7, for the designed opening dimensions for slip hooks.

Hooks are designed for operation within established load limits. These limits can be computed readily by reference to the below formula or Table 7-7.

A hook is designed to fail by straightening before its chain is overloaded. Because of this design feature, a type of weight of hook other than that originally installed should not be used without full knowledge of the load limits of both hook and chain.

The safe working capacity (SWC) of a hook can he approximated in tons by squaring the diameter of the hook in inches at the point where the inside curve starts its arc (dimension A in Figure 8.17). Thus, when A = 1-1/4 inches, SWC = A2 or WC = 1-1/4 x 1-1/4 = 1-9/16 tons. Safe working loads can be computed in this manner or can be determined from Table 7-7.

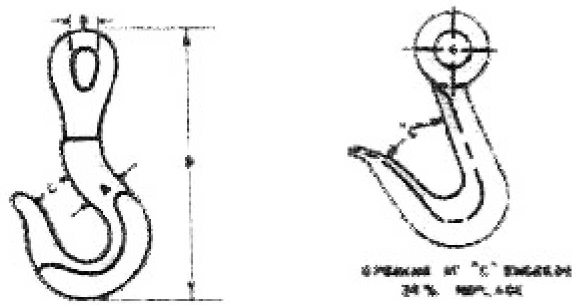


Figure 7-11. Hook Dimensions

Table 7-7. Hoisting Hook Dimensions and Safe Loads

Dimensions, Inch				Safe Load in Pounds
A	B	C	D	
11/16	7/8	1- 1/16	4-15/16	1,200
3/4	1	1- 1/8	5-13/32	1,400
7/8	1- 1/8	1- 1/4	6- 1/4	2,400
1	1- 1/4	1- 3/8	6- 7/8	3,400
1- 1/8	1- 3/8	1- 1/2	7- 5/8	4,200
1- 1/4	1- 1/2	1-11/16	8-19/32	5,000
1- 3/8	1- 5/8	1- 7/8	9- 1/2	6,000
1- 1/2	1- 3/4	2- 1/16	10-11/32	8,000
1- 5/8	2	2- 1/4	11-27/32	9,400
1- 7/8	2- 3/8	2- 1/2	13- 9/32	11,000
2- 1/4	2- 3/4	3	14-13/16	13,600
2- 5/8	3- 1/8	3- 3/8	16- 1/2	17,000
3	3- 1/2	4	19- 3/4	24,000

7.9: Slings

There are many types of slings in use, some of which are illustrated (see Figure 7-12). The choice of sling will depend on the materials being handled, some slings being more secure or less apt to damage the load than others. Slings are made of improved plow steel rope, chain, or web belts. Information as to the strength and care of these materials can be found elsewhere in this section.

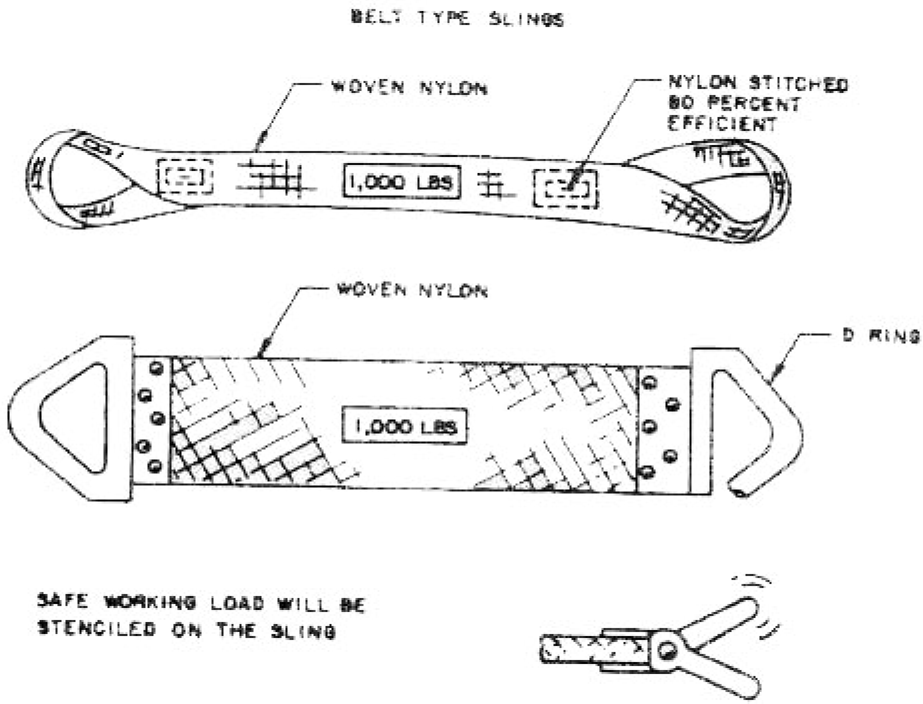


Figure 7-12. Belt Type Slings

Slings must be inspected and tagged for maximum working loads every 6 months. It is the responsibility of the user, however, to use the appropriate equipment in the prescribed manner and make sure that the equipment is in a safe condition.

Woven nylon belt type slings are used to lift objects that are easily crushed or damaged, such as thin-wall vessels or thrust chambers. The belt sling, being wider than a rope or chain, spreads the force that tends to crush the object during lifting over a larger surface area. Thus, there is less concentrated pressure against the object and less chance of crushing or damaging it.

7.9.1: Chain Slings

Chain sling is not used for making heavy lifts for two reasons: (1) flaws are more difficult to detect in chain than in wire rope; and (2) the links in a chain big enough to carry our larger assemblies would be difficult to snake in and around some of the complex shapes that must be handled. Although chain slings have their limitations, they are useful for rigging in particular applications where heat and acids are present. One advantage of a chain which makes it very useful as a sling, is that it may be shortened by merely positioning a new link in the grab hook throat. Never place the point of the hook through the center of the link (see Figure 7-13 for correct attachment).

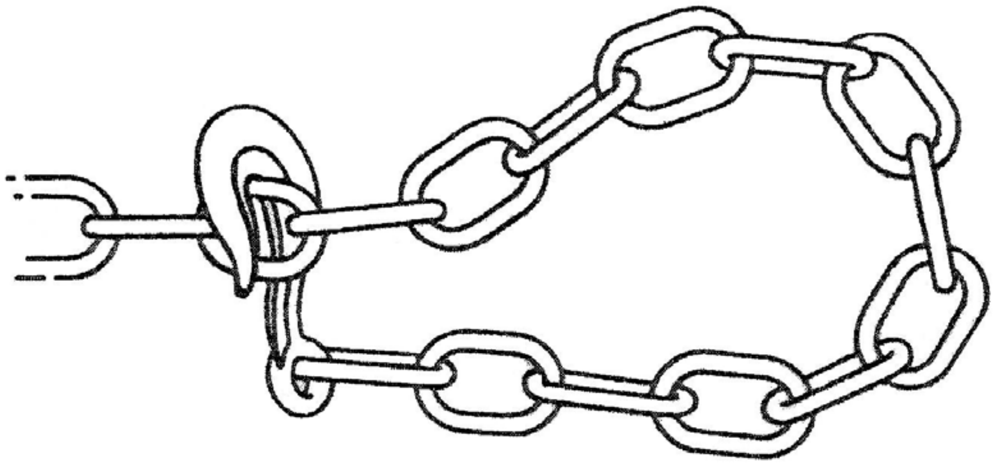


Figure 7-13. Chain Slings

7.9.2: Wire Rope Slings

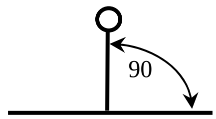
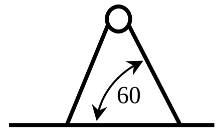
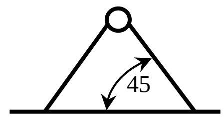
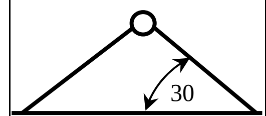
For lifting and turning use, a wire rope must be made into a sling. This is done by forming a loop at each end and splicing the wire rope together, a job for the Maintenance Department. Once the sling is put to use, it is the rigger's responsibility to keep it from being damaged. Most slings are damaged through carelessness; using too small a cable for a lift, using the wrong hitch, setting the work on the sling, not straightening the rope before attaching it to the hook, and frequently, not using a cable guard when wrapping the sling around a sharp corner. Wire rope is used for most of our slings because of the limitations of other materials. Wire rope is strong – much stronger than manila rope and equally as strong as chain; it is flexible so that it can be laid in and around a complex assembly or casting; it has good resistance to abrasion; and wire damage can be readily detected.

7.9.3: Sling Strength

The tension on a sling depends on the load and on the angle of the sling to the load. A vertical sling is the strongest, while a widely spread sling can develop tensions greatly in excess of the actual load being lifted. Sling load angles of less than 45 degrees should be avoided since they result in high sling tensions, which can lead to sling failure or crushing of the material being lifted. Table 7-8 and Figure 7-14 show the relationship of sling load angle to sling tension.

Safe load in pounds for new improved plow steel wire rope slings under different loading conditions (6 strands of 19 wires, hemp center).

Table 7-8. Wire Rope Sling Safe Working Loads

Size Diameter Inch	**Single Wire Rope Sling Vertical Lift**  Load Angle	**Sling or Two Wire Ropes – Used at 60 Degree Angle**  Load Angle	**Sling or Two Wire Ropes – Used at 45 Degree Angle**  Load Angle	**Sling or Two Wire Ropes – Used at 30 Degree Angle**  Load Angle
3/8	2,500	4,300	3,600	2,500
1/2	4,300	7,400	5,800	4,300
5/8	6,600	11,400	9,400	6,600
3/4	9,400	16,200	13,000	9,400
7/8	12,800	22,100	17,400	12,800
1	16,000	27,700	23,200	16,000
1-1/8	21,200	36,700	29,700	21,200
1-1/4	26,000	45,000	36,200	26,000
1-3/8	31,400	54,300	43,500	31,400
1-1/2	37,000	64,000	52,200	37,000

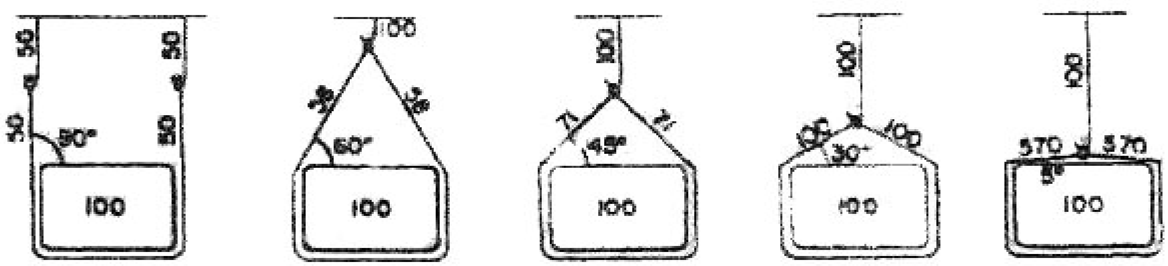


Figure 7-14. Effect of Sling Angle on Sling Tension

7.9.4: Hitches

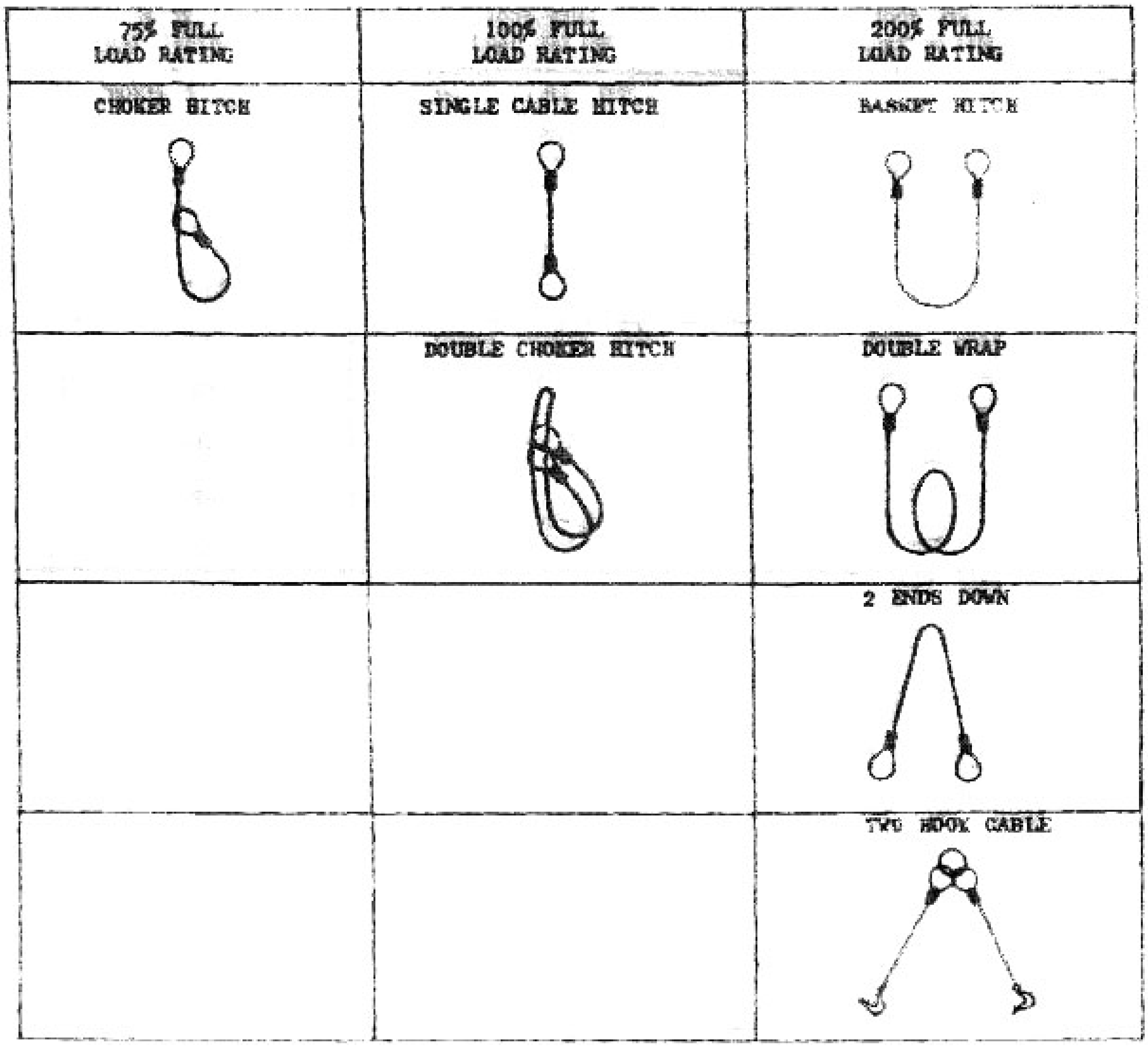


Figure 7-15. Commonly Used Hitches and Approximate Load Carrying Capacity of Hitches

7.10: Lifting Accessories

7.10.1: Wire Rope Clips

Use of Crosby clips is probably the most common method of securing a loop in wire rope. These clips should be spaced at least six rope diameters apart, and all clips must be placed on the rope with the U-bolts bearing upon the short or "dead" end of the rope. A heavy-duty thimble should be provided for every eye. When properly made, a clipped eye develops about 80 percent of the strength of the rope. Do not use malleable iron clips or brass clips.

To install Crosby clips, first bind the rope on itself at the toe of the thimble. Then apply the clip farthest from the thimble, at about 4 inches from the dead end of the rope, and thoroughly tighten it. Next, put on the clip nearest the thimble and screw the nuts on hand tight. Then put on the intermediate clips hand tight. Apply tension to the rope, and while the rope is under tension, thoroughly tighten the rest of the clips. (See Figure 7-16 and Table 7-9 for details.)

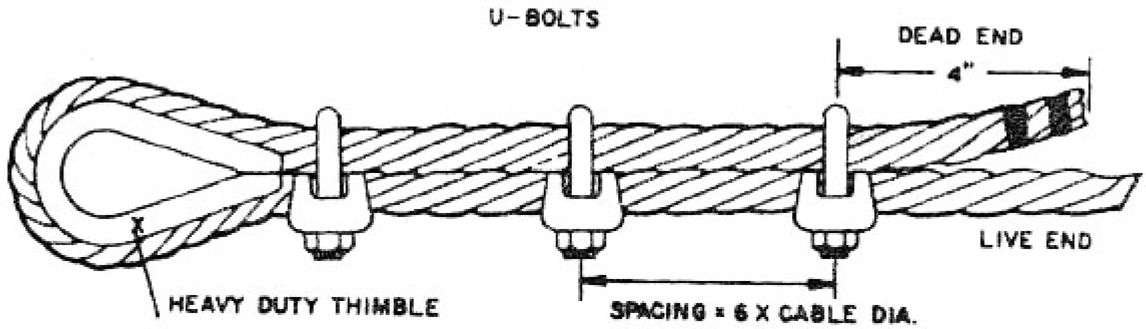


Figure 7-16. Installation of Crosby Clips

Table 7-9. Number of Clips and Distance Between Clips for Safety

Diameter of Rope, Inch	Number of Clips	Distance Between Clips	Efficiency
1/4 to 3/8	3	2 – 1/4”	77% to 82%
7/16 to 5/8	4	3 – 3/4”	
3/4 to 1-1/8	5	6 – 3/4”	
1-1/4 to 1-1/2	6	9”	
1-5/8 to 1-3/4	7	10 – 1/2”	

7.10.2: Eye Bolts

If a casting or housing has threaded holes, eye bolts screwed into the holes can be very useful in the making of lifts. Two precautions concerning eye bolts should be considered: all threads of the eyebolt should be fully engaged, and slings running between eye bolt and hook should be as close to a vertical attitude as possible. In other words, maintain as great a load angle as possible. Manufacturers of eye bolts guarantee the safe working load in pounds for the bolts they manufacture. By referring to the manufacturer's catalog the safe working load for each individual eye bolt may be found. Recommended safe working loads for various points of hitching are shown in Tables 7-10 and 7-11.

Tables 7-10. Ordinary Drop Forged Steel Eye Bolts Recommended Working Load, Pound

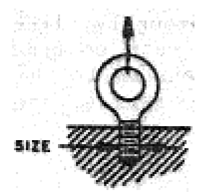
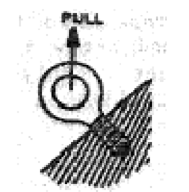
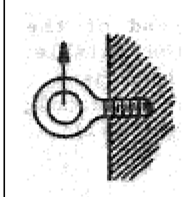
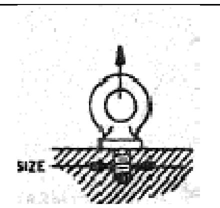
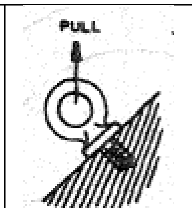
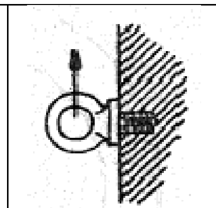
Size, Inch			
1/4	250	40	30
1/2	1,100	50	40
5/8	1,800	90	65
3/4	2,800	135	100
7/8	3,900	210	150
1	5,100	280	210
1-1/4	8,400	500	370
1-1/2	12,200	770	575
1-3/4	16,500	1,080	800
2	21,800	1,440	1,140

Table 7-11. Drop Forged Steel Shoulder-Type Eye Bolts Recommended Working Load, Pound

Size, Inch			
1/4	300	30	40
1/2	1,300	140	150
3/4	3,000	250	300
1	6,000	500	600
1-1/4	9,000	800	900
1-1/2	13,000	1,200	1,300
2	23,000	2,100	2,300
2-1/4	37,000	3,800	4,300

7.10.3: Shackles

Shackles are very useful accessories in rigging operations, and when correctly used can very often make what might have been a poor hitch a very efficient one. For example, shackles can be used to hitch slings to stationary eyelets which provide flexibility to the hitch during a turning operation. If a shackle had not been used, the sling might have been scuffed by the eyelet when a turn was performed. Shackles may also be used to prevent point loading crane hooks by slipping a shackle over the hook and passing the sling through the shackle.

Some Do's and Don'ts concerning shackles are listed below:

1. They should be of the threaded-pin type. The pin should thread into the mating part easily.

2. Shackles are not proof loaded (except as a sling assembly) by the Maintenance Department and one should calculate the approximate safe working load by using the formula ($SWL = D^2 \times 6$) prior to selection and use of the shackle (see Figure 7-17).

3. Do not use pin diameter in calculations.

4. Shackles should be examined carefully for worn spots, cracks, fractures, or being sprung. Discard for any defect listed above.

5. Do not use anything other than the designed pin in a shackle. If pin is missing, replace pin with like type, or replace shackle.

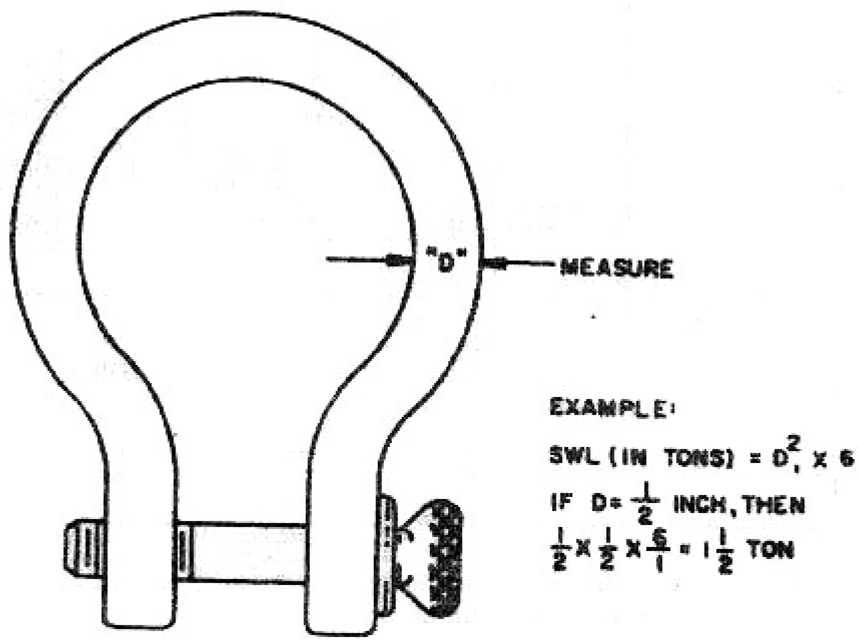


Figure 7-17. Shackle Safe Working Load

7.10.4: Cable Guards

Many months of service can be added to the life of a sling or cable if a few simple rules are followed, one of which is the protection of cables over sharp edges or sharp bends. This can be accomplished by the use of cable guards. Cable guards are designed to fit over the contour of the part. One side of the guard is near match to the contour; the other side is shaped to allow the cable to pass over a curving surface, therefore protecting the cable from the sharp edge. (See Figure 7-18.)

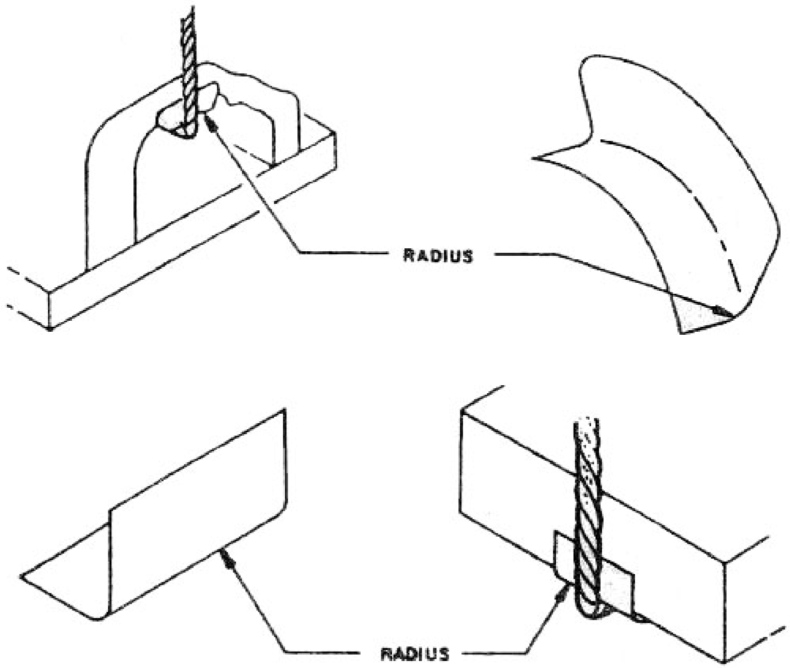


Figure 7-18. Cable Guards

7.11: Pull Lifts

Probably the most widely used piece of hoisting equipment at the Field Laboratory next to the sling, is the pull lift. There are many types, sizes, and capacities. The sizes range anywhere from 3/4 ton to 15 tons. Each size will have the load capacity stamped on the side of the roller housing.

Before making a lift with a pull lift, one must always verify its safe working condition. Pull lifts should be thoroughly inspected.

Examine the chain to see that the links and rollers work freely, and that the chain is not bent or twisted. The chain should also be checked for elongation. Should the pull lift ever get splashed with water or oil, it should be sent to Maintenance personnel.

On chains with unsecured dead ends, a safety ring shall be attached to prevent running the chain through the housing.

Inspect the top and hooks for correct suspension and application of loads. The load must be carried in the center of the hook, not on the tip because hooks are only efficient when the load is carried in the center. If the load is incorrectly applied so that it is carried out at the tip, the hook will open approximately one-half the rated capacity. The maximum opening of the hook, for safety sake, should not exceed 35 percent beyond the normal opening. Make sure the hook nut is tight and riveted or pinned.

Operating instructions: (See Figures 7-19 and 7-20.)

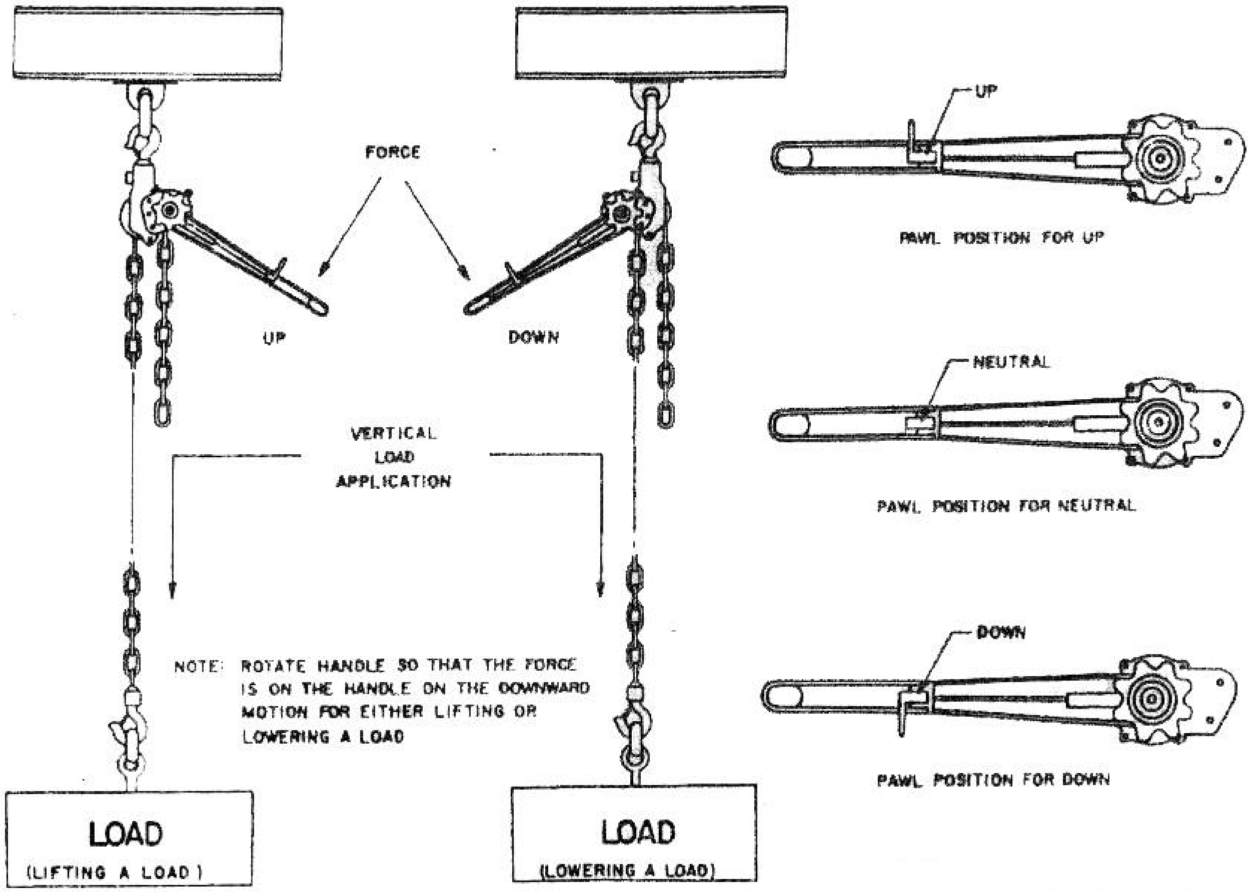


Figure 7-19. Pull Lift Operation

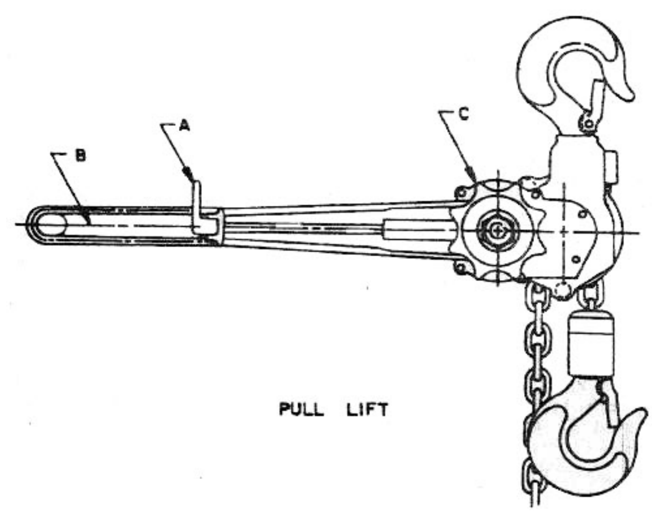


Figure 7-20. Checking Pull Lift Load Brake

7.11.1: Lifting with a Load

To lift a load, turn the pawl lever "A" so that the marking "UP" is visible, and the lever seats in the handle slot. Operate the handle "B" with a pumping action.

To lower the load, turn the pawl rod lever "A" so that the marking "DN" is visible and the lever seats in the handle slot. Operate the handle "B" with a pumping action.

The pumping action in hoisting or lowering should be with the force applied on the downward movement of the handle, and with the upward movement free. The opposite action is obtained by reversing the movement of the handle.

7.11.2: Lifting without a Load

Turn the pawl rod lever "A" to the neutral position. To raise or lower the empty hook to the desired position, turn hand wheel "C."

To pull the chain, hold the two lines of the chain tightly with one hand, turn the hand wheel "C" to free the load brake, and pull the chain hook towards the roller housing. Always use the hand wheel instead of the handle when operating without a load.

Raising the lower hook to a point where it jams against the housing, or excessive overloading of the pull lift, may "freeze" the load brake. If this occurs, the brake can be released by setting the pawl rod lever "A" to the “DN" position, tapping the handle with a hammer, and lowering with the handle.

7.11.3: Checking the Load Brake

To check out the load brake to see if it is operating properly, do the following: Put the pawl rod lever "A" in the neutral position. Hang the upper hook on a convenient beam or eye bolt. Grasp both ends of the chain and pull the chain through the housing. You should be able to pull the chain hook towards the housing but not away from the housing: If the chain hook can be pulled away from the housing the load brake is faulty. Send to maintenance for repair. Usual cause of faulty load brakes is moisture or oil getting on the discs and causing slippage of the load brake.

<u>Never Use a "Cheater" on the Handle</u>

Manufacturer's instructions on the operation of the pull lift state that when the handle gets hard to pull, you have reached the maximum safe working load. The maximum safe load of a pull lift can be exceeded through normal use and without the aid of a "cheater." Unknown loads should be checked before the lift is made.

7.12: Additional Rigging Equipment

7.12.1: Jacks

When jacks are used, blocks should be placed under the load during lifting in case the Jack should fail. No part of one's body should ever be exposed to a situation in which it would be dangerous if the equipment failed.

When a jack is used in a horizontal position, it should be lashed or supported to prevent it from falling should the object unexpectedly move faster than the jack.

7.12.2: Rollers

For moving heavy loads across a floor or ground, hardwood rollers (usually maple) 7-1/2 inches in diameter and 10 feet long are commonly used. Pipe rollers may also be used. Under no circumstances should an oxygen cylinder or any other gas cylinder be used as a roller. Cylinders when full may be pressurized in excess of 2,000 psi, and constitute a high pressure gas hazard if mishandled.

7.12.3: Skids

Skids are commonly used under heavy machinery or other equipment that is being moved. The skids can be used as stationary rails or can be used as a sled.

7.12.4: Hoisting Equipment

Cranes, derricks. hoists, and such auxiliary equipment as chains, wire rope, slings, hooks, and clips are designed for specific jobs and loads and should not be used in other than design services or at greater than design loads.

Tags on hoisting equipment or on supporting structures show the maximum load capacity and the color code tape of the lost proof-load test. Proof-load tests are conducted by Maintenance every 6 months. Hoisting equipment not bearing the current color code tag should not be used, and this condition should be reported to responsible supervision.

7.12.5: Fork Lifts

The use of fork lifts is limited to those who have been granted operator's licenses by the Safety Department. These are granted only after a demonstration of ability to handle the equipment.

7.12.6: Block and Tackle

Tackle is an assembly of ropes and blocks used to multiply force. The rope is reeved, or threaded through blocks which may have one or several sheaves. Simple tackle consists of one or more blocks reeved with a single rope. Compound tackle is comprised of two or more blocks reeved with more than one rope. The pulling force is applied to a single rope leading from the tackle system. The rope called the fall line may be led through a leading block which is an additional block used to change the direction of pull.

7.12.7: Inclined Planes

Inclined planes furnish a simple means of mechanical advantage. The mechanical advantage is equal to the length of the inclined surface divided by the rise. The grade is expressed in percentage of the rise divided by the horizontal length. See Figure 7-21.

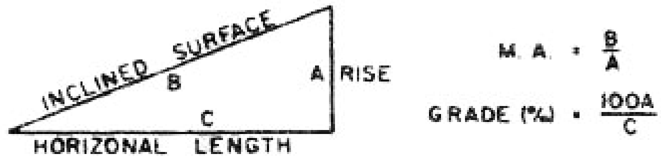


Figure 7-21. Inclined Planes

7.12.8: Chocks

Chocks are used to prevent cylindrical objects from rolling. The effective height of the chock is the highest point of contact with the cylinder. For safe design of chocks, the rule of thumb is: the effective height of the chock in inches should equal the diameter of the cylinder in feet. For a 2-foot tank diameter, the effective height of the chock is 2 inches; for 2 3-foot tank diameter, the effective height of the chock is 3 inches. See Figure 7-22.

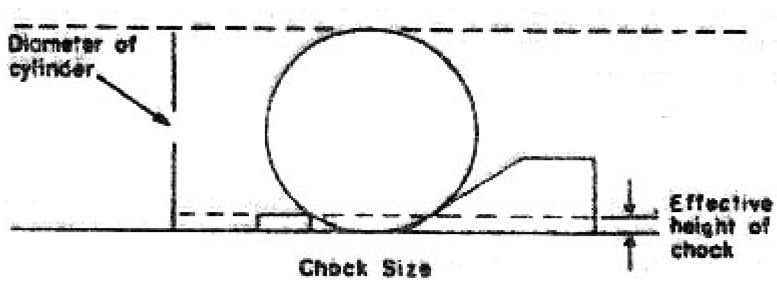


Figure 7-22. Chock Size

7.13: Hand Signals

Hand signals are used in winch and crane operation because of the distances end the noise conditions of operation. Safe operation depends upon clear signaling by the person directing and full understanding by the crane or winch operator. Figures 7-23 and 7-24 illustrate commonly accepted hand signals for crane and winch operation.

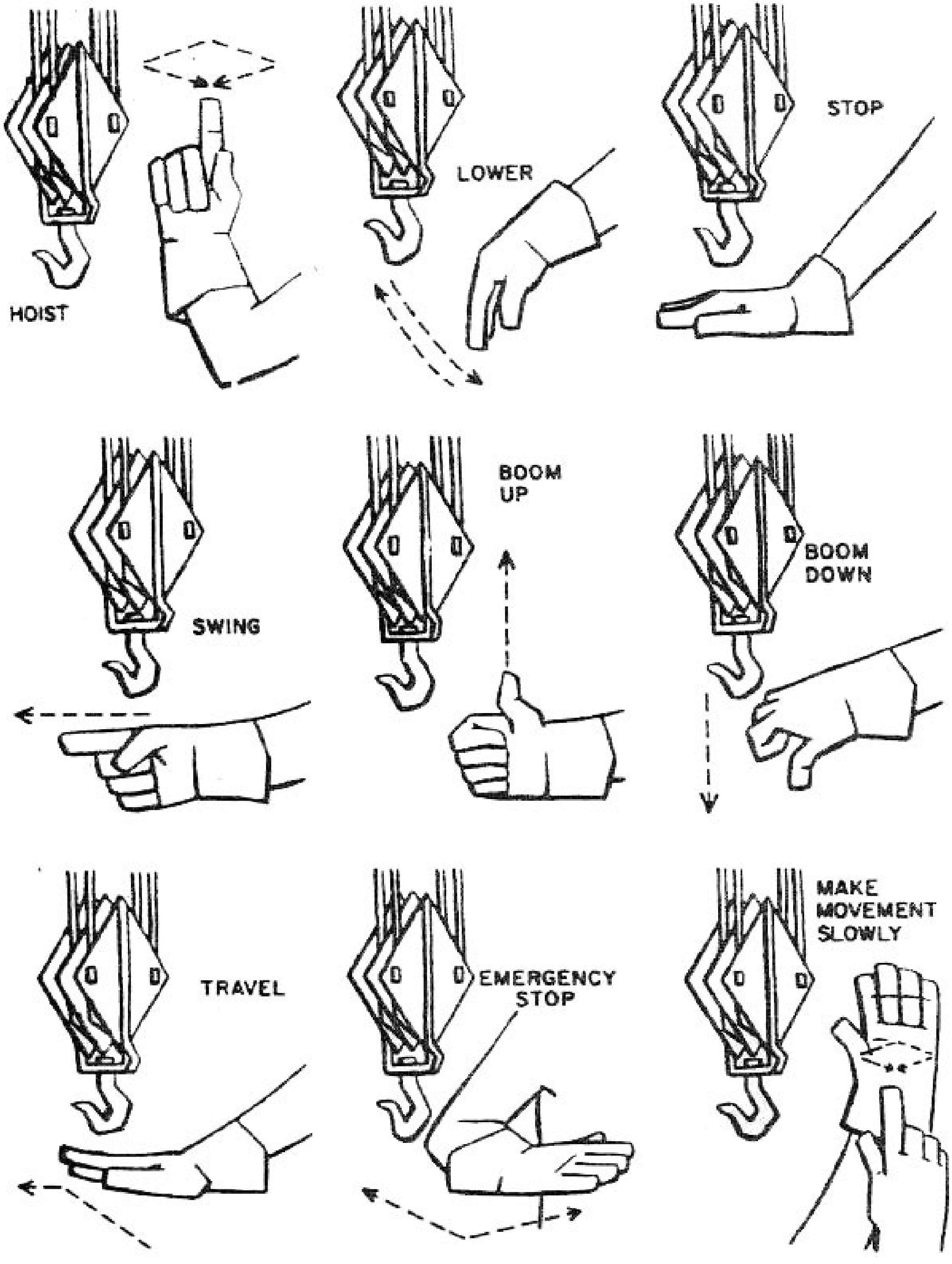
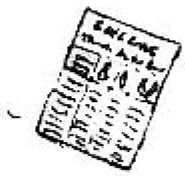


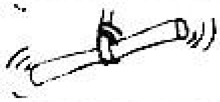
Figure 7-23. Hand Signals for Crane or Swinging Boom Operation

Figure 7-24. Hand Signals for Winch Operation

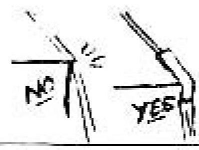
7.14: Basic Rules of Hitching and Rigging



1. RATED CAPACITY - Be sure the sling you intend to use is strong enough for the job. Know the weight of the load. Bear in mind that various hitches have different rated capacities. If in doubt, check it out!



2. CONTROL - Use a hitch that will keep the load under control at all times. A hitch that allows the load to become unbalanced, or to rotate, introduces the possibility of losing control and may cause an accident.

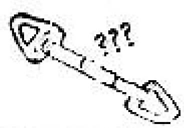


3. PREVENT SLING DAMAGE - It is often said that a rigger is as good as his tools. Take good care of your slings!

Use sliding sleeves or other forms of sling protection when the sling must touch sharp edges. Remember: If the sling isn't protected, can your feet be far behind?

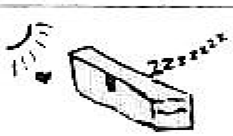
4. LIFT LOADS CAREFULLY - Accelerate lifting devices smoothly. Don't jerk the load off the ground! Jerking can produce terrific shock loads to the sling --- often exceeding the rated capacity of the sling. It could break the sling!

5. KEEP IT BALANCED - Always try to lift the load in a level position, with the crane hook directly over the center of gravity. Careful adjustment of the lengths of the various legs is necessary to do this, but it pays off in excellent control of the load.



6. KNOW THE CONDITION OF YOUR SLINGS - Slings, shackles, hooks and other lifting tools should be examined carefully before each use. Is the sling damaged? If in doubt, throw it out! Remember: Crushed sections, cuts, burns and knots all affect the strength of slings.

7. USE EYEBOLTS CAREFULLY - Many loads are equipped with eyebolts for easy attachment of the sling. Properly designed eyebolts are excellent when the pull is transmitted to them on a straight line with that of the shank of the bolt. Take care not to pull on eyebolts at a sharp angle. They are not designed to withstand side pulls.



8. KEEP RIGGING IN A PROPER PLACE - Lifting devices should have their proper place. Inside, they sould be hung up off the floor. Outside, nylon slings should have a covered box to keep them out of sunlight. Remember: Ultraviolet light damages them without leaving any mark.

Figure 7-25. Basic Rules of Hitching and Rigging

Hand Tools
Contents

8.1: Introduction

Regardless of the task to be done, choose and use the correct tools that are in good condition. Particular care should be taken to maintain them if they are to last and be safe and reliable for use. Improper use of tools can cause personal injury, damage to equipment, or damage to the tools.

8.2: Hacksaws

8.5.1: Frame Types

- Solid
- Adjustable (8 to 16 inches)

8.5.2: Blade Types

1. Hardened and tempered tool steel (Molybdenum steel is best blade).
   A. All hard (Full blade temper)
      Used on large sections of steel and on skilled work where accuracy is needed.
   B. Flexible (Only teeth tempered)
      General purpose blade.

2. Pitch (Number of teeth per inch) (See Figure 8-1.)
   A. 14 – Pitch, for mild soft material.
   B. 18 – Pitch, for tool, high carbon and high speed steels. (General Purpose Blade)
   C. 24 – Pitch, for angle iron, brass, copper, and iron pipe.
   D. 32 – Pitch, for thin sheet metal, and thin wall tubing.

3. Set (Offset of teeth on blade)
   A. Alternate (Most common)
      Teeth lean off to side of blade alternately; one to one side other to other side. General purpose set, used on all materials.
   B. Raker
      Every third tooth is straight up and down. Used on material where clogging of teeth is a problem.
   C. Wave
      Teeth curve from side to side. Used mainly on 32-pitch blades where a precision cut is needed.
      NOTE: The set of a blade is for the blade's clearance in cutting.

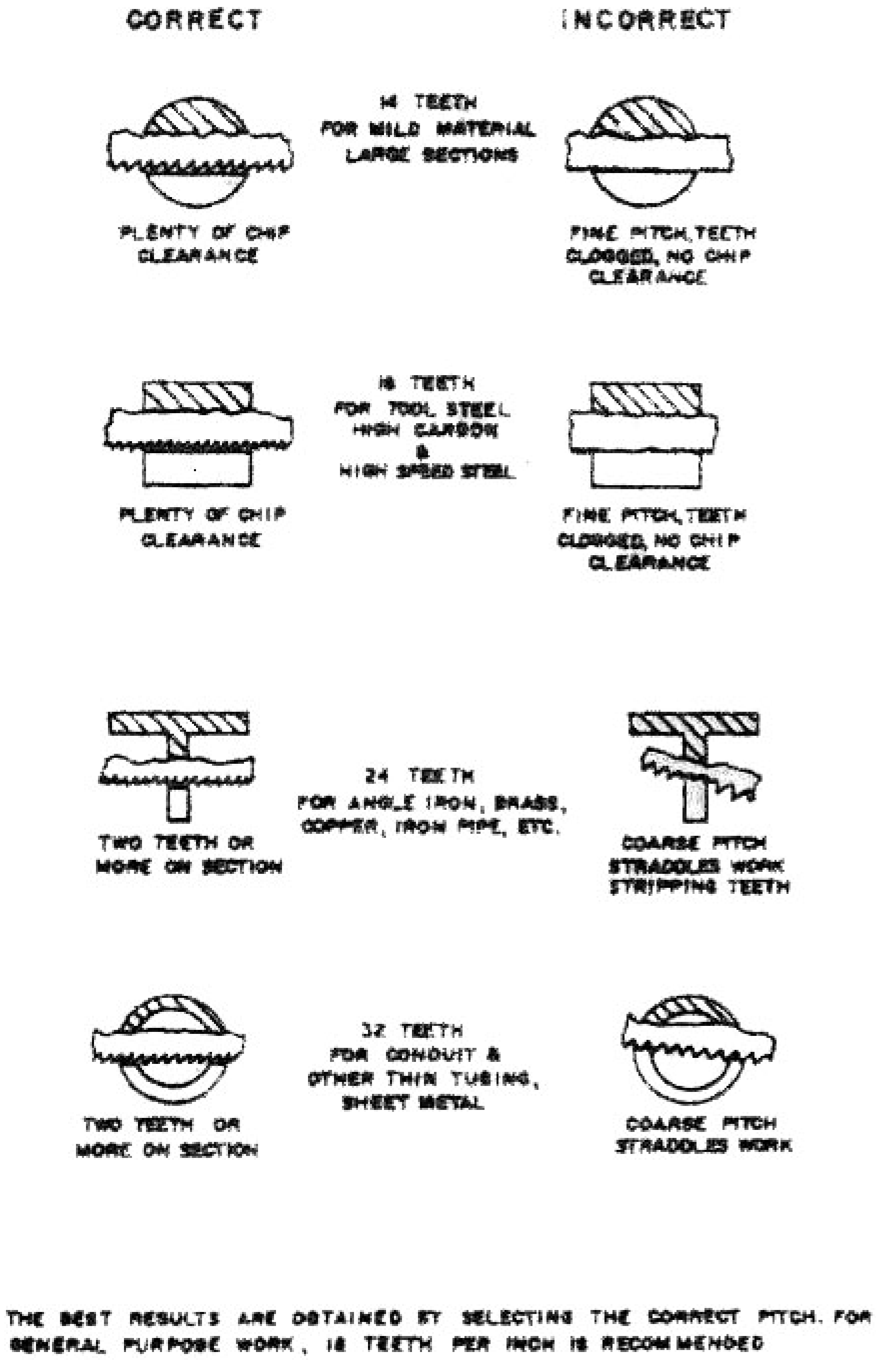


Figure 8-1. Hacksaw Blades

8.5.3: Use of Hacksaw

1. Teeth should face away from handle when blade is in frame. (See Figure 8-2.)

2. Apply light to moderate force on the forward stroke, approximately 32 strokes per minute. The hacksaw only cuts on the forward stroke.

3. For deep cuts use a deep frame hacksaw.

4. Rule of Thumb:
   A. On soft material—use blade with fewer teeth.
   B. On hard material—use blade with more teeth.
   C. On thin material—use blade with many teeth. (No less than 3 teeth on cutting surface.)
   NOTE: Note: Never use hacksaw with a rapid motion heat removes temper from teeth

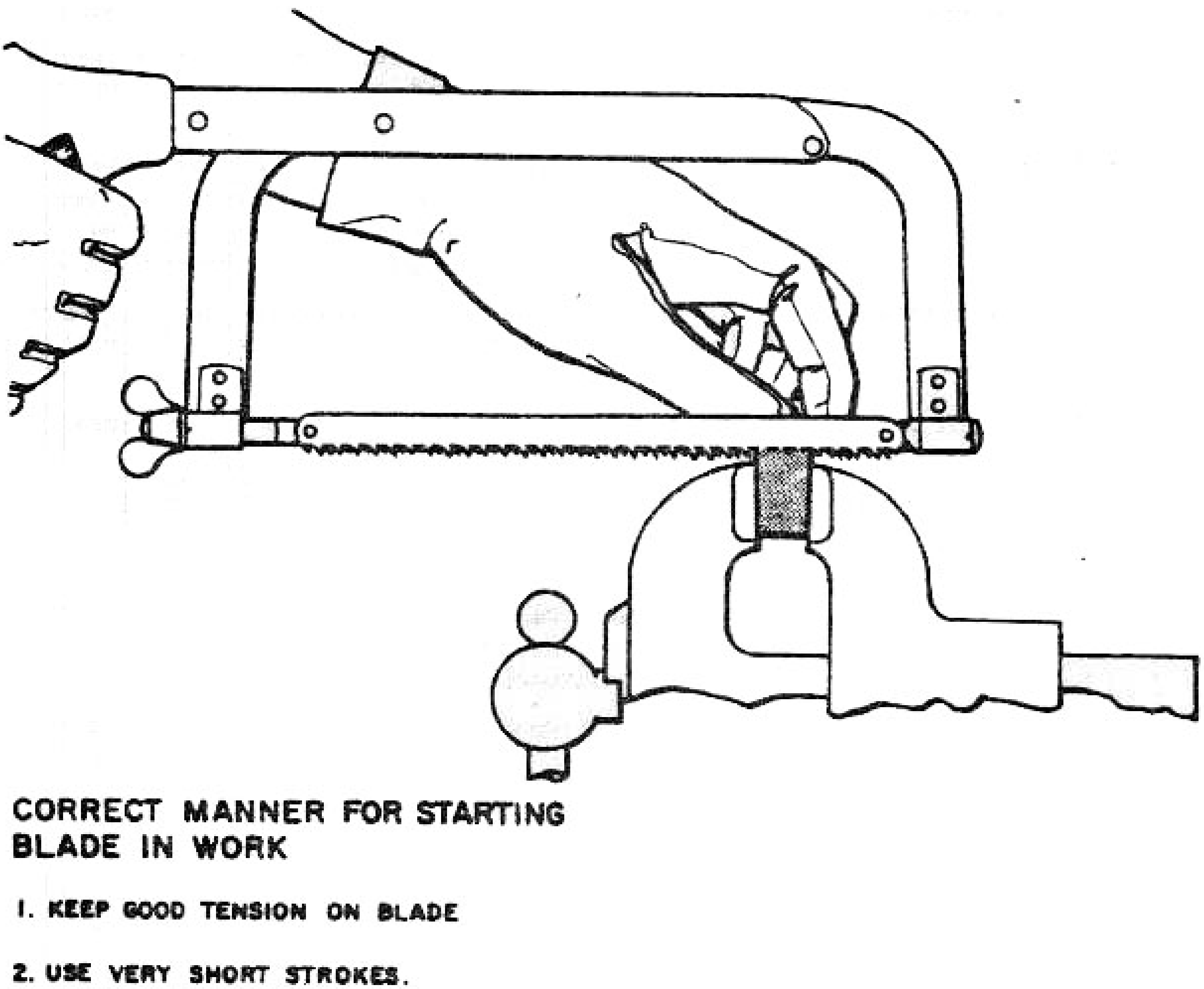


Figure 8-2. Use of Hacksaw

8.3: Files

Files are hardened steel tools used for cutting, removing, smoothing or polishing metal. The tang is the only part of a file not tempered. (See Figure 8-3.)

8.3.1: Terms

- Coarse
- Bastard
- Second cut
- Smooth
- Dead smooth

8.3.2: Classifications

1.	Flat Bastard File	Used for general purpose rough filing.
2.	Mill File (second cut)	Used for removing a small amount of metal and making the filed surface smooth.
3.	Half Round Bastard File	The rounded face of this file is used to file a surface having a large concave radius. The flat face can be used for general purpose rough filing.
4.	Round Bastard File	Used for enlarging holes, also for filing surfaces having a small concave radius.
5.	Smooth Mill File	Used for all work where surfaces are flat or convex.
6.	Half Round Second Cut File	Used same as half round bastard file but on work where there is not so much metal to be removed.
7.	Three-Square or Triangular File	Very useful for filing small notches, square or cornered holes, and for cleaning up burred threads.
8.	Round Smooth File	Used same as round bastard file, but on work where there is not so much metal to be removed.

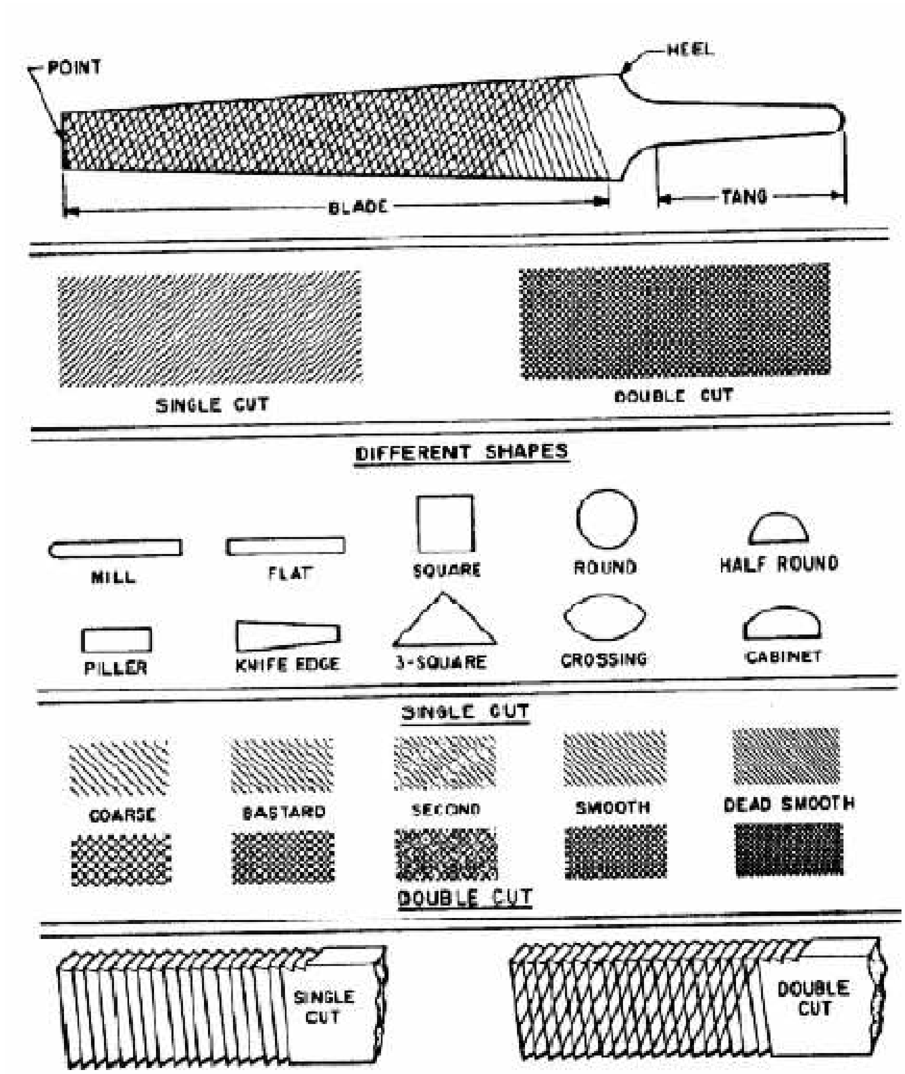


Figure 8-3. Parts of a File

8.3.3: Selecting the Correct File

1. For heavy rough cutting, a large, coarse, double cut file.
2. For finishing cuts, use a second cut or a smooth single cut file.
3. When filing cast iron, start with a bastard cut file and finish with a second cut file.
4. When filing soft steel, start with a second cut file and finish with a smooth cut file.
5. When filing hard steel, start with a smooth cut file and finish with a dead smooth file.
6. When filing brass or bronze, start with a bastard cut file and finish with a second cut file.

7. When filing aluminum, lead or babbit metal, use a bastard file.

8. For small work use a short file; for large work use a file as large as can be controlled conveniently.
   NOTE: Apply pressure on forward stroke only on all files.

8.3.4: The Use and Care of Files

1. Before attempting to use any file, it should be equipped with a tight fitting handle. Using a file without a handle could result in a painful injury from the sharp end of the tang into the hand or other part of the body.

2. To put a handle on a file: First, make sure the handle is the right size, and that the hole is large enough for the tang. Insert the tang into the hole in the handle then tap the back end of the handle on the bench. Make sure the handle is on straight. (See Figure 8-4.)

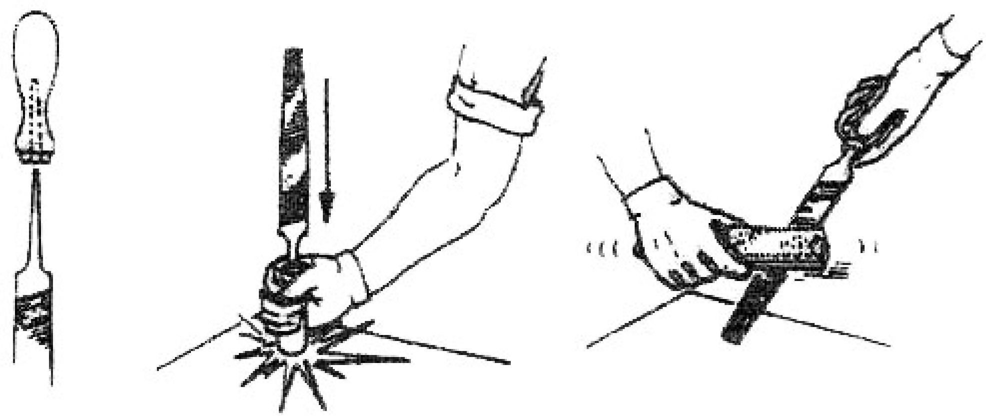


Figure 8-4. Use and Care of Files

3. To remove a file handle: Hold the handle in your right hand, hold the file with your left hand, and give the ferrule end of the handle a sharp rap against the edge of the bench. The ferrule is the metal sleeve on the hole end of the handle.

4. Whenever possible, the part to be filed should be clamped rigidly in a vise. The teeth on a file are so arranged to cut when the file is moving in one direction only. The forward stroke is the cutting stroke, and all file pressure against the work should be relieved on the back stroke.

   The teeth are set at an angle across the face of the file and slanting toward the tip of the file. (See Figure 8-4.) On a single-cut file, the teeth are cut at an angle of 65 to 85 degrees to the centerline. On double-cut files the angle of the first set of teeth usually is 40 to 50 degrees and the crossing teeth 70 to 80 degrees. Proper methods of holding a file are shown in Figure 8-5.

5. Never use a file after the teeth become "choked" with particles of metal. Occasional bumping of the file against the bench will jar loose the filings which stick in the teeth. If the teeth get too loaded, it is should be cleaned with a file card. This is a brush with short, stiff, wire bristles. (See Figure 8-4.)

6. Don't throw files around on a bench or into a drawer with other tools and expect them to stay sharp.

7. Keep files away from moisture and water to prevent rusting.

8. Never use a file for prying. A light bending force will snap it in two.

9. Never hammer with a file. It may shatter and cause injury from flying fragments and shard edges.

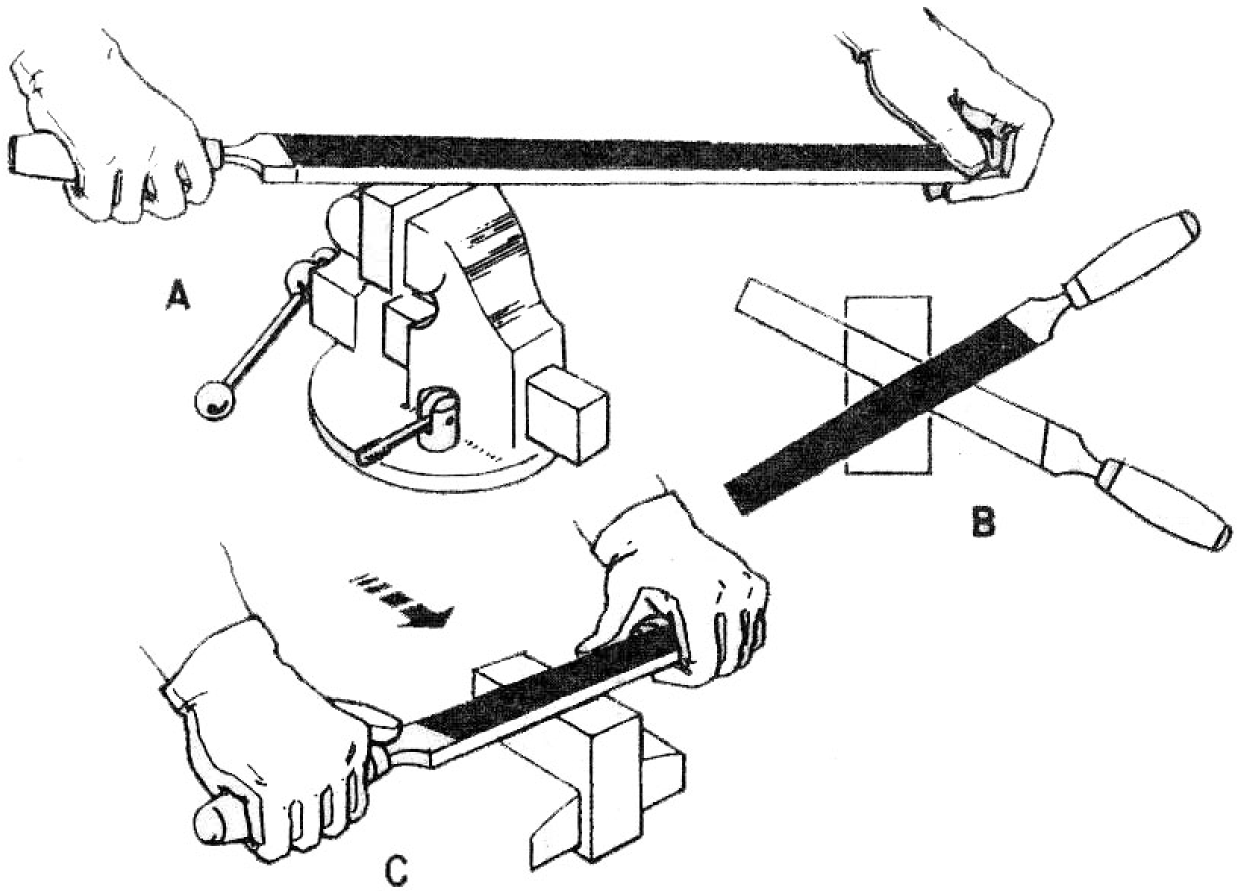


Figure 8-5. Filling Techniques

8.4: Drills

1. Common devices for holding twist drills:
   A. Hand brace (egg beater)..(For holes with no need
   B. Breast drill brace ....for accuracy)
   C. 1/4, 3/8, 1/2 drill (electric or air pressure)
   D. Drill press (machine)

2. Types of twist drills:
   A. Carbon steel
   B. High speed steel

3. Parts of a drill: (See Figure 8-6)
   A. Body (flute or spiral)
   B. Shank (drill size stamped on it)
   C. Point

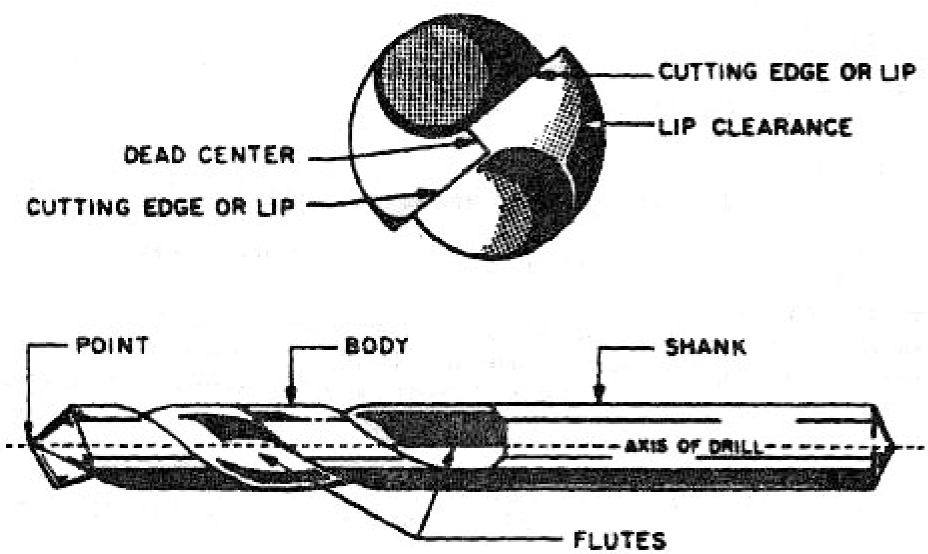


Figure 8-6. Parts of a Drill

4. Drill sizes: (are measured either in fractions, numbers, or letters) (Refer to Table 8-1.)
   A. Number drills:
      1. No. 80 (smallest diameter) .0135-inch diameter
      2. No 1 (largest diameter) .228-inch diameter
   B. Fractional drills
      1. A to Z
      2. A = .234-inch diameter
      3. Z = .413-inch diameter

Table 8-1. Drill Sizes

TAP DRILL SIZES

NC (COARSE THREAD) Screw Size	NC Tap Drill	NF (FINE THREAD) Screw Size	NF Tap Drill
7/16-14	U	7/16-20	25/64
1/2-13	27/64	1/2-20	29/64
9/16-12	31/64	9/16-18	33/64
5/8-11	17/32	5/8-18	37/64
11/16-11	19/32	11/16-16	5/8
3/4-10	21/32	3/4-16	11/16
13/16-10	23/32	7/8-14	13/16
7/8-9	49/64	1-14	15/16
15/16-9	53/64	1-1/8-12	1-3/64
1-8	7/8	1-1/4-12	1-11/64
1-1/8-7	63/64	1-1/2-12	1-27/64
1-1/4-7	1-7/64		
1-1/2-6	1-11/32		

MACHINE SCREW

Screw Size	Drills for Tap	Drills for Clearance
2-56	No 50	No 43
3-48	No 47	No 40
4-40	No 43	No 32
6-32	No 36	No 28
8-32	No 29	No 19
10-24	No 25	No 10
10-32	No 21	No 10
12-24	No 16	7/32
1/4-20	No 7	1/4
1/4-28	No 3	1/4
5/16-18	F	5/16
5/16-24	I	5/16
3/8-16	5/16	3/8
3/8-24	O	3/8

PIPE

Diameter of Tap	Drills for Tap	Drills for Clearance
1/8-27	11/32	7/16
1/4-18	7/16	9/16
3/8-18	37/64	3/4
1/2-14	23/32	7/8
3/4-14	59/64	1-3/16
1-11 1/2	1-5/32	1-7/16
1-1/4-11 1/2	1-1/2	1-3/4
1-1/2-11 1/2	1-47/64	2
2-11 1/2	2-7/32	2-1/2
2-1/2-8	2-5/8	3
3-8	3-1/4	3-3/4
3-1/2-8	3-3/4	4-1/4
4-8	4-1/4	4-3/4

DECIMAL EQUIVALENTS

NUMBER, LETTER AND FRACTIONAL SIZE DRILLS

Size Drill	Decimal	Size Drill	Decimal	Size Drill	Decimal
80	0.0135	1/8	0.1250	21/64	0.3281
79	0.0145	30	0.1285	Q	0.3320
1/64	0.0156	29	0.1360	R	0.3390
78	0.0160	28	0.1405	11/32	0.3437
77	0.0180	9/64	0.1406	S	0.3480
76	0.0200	27	0.1440	T	0.3580
75	0.0210	26	0.1470	23/64	0.3594
74	0.0225	25	0.1495	U	0.3680
73	0.0240	24	0.1520	3/8	0.3750
72	0.0250	23	0.1540	V	0.3770
71	0.0260	5/32	0.1562	W	0.3860
70	0.0280	22	0.1570	25/64	0.3906
69	0.0292	21	0.1590	X	0.3970
68	0.0310	20	0.1610	Y	0.4040
1/32	0.0313	19	0.1660	13/32	0.4062
67	0.0320	18	0.1695	Z	0.4130
66	0.0330	11/64	0.1719	27/64	0.4219
65	0.0350	17	0.1730	7/16	0.4375
64	0.0360	16	0.1770	29/64	0.4531
63	0.0370	15	0.1800	15/32	0.4687
62	0.0380	14	0.1820	31/64	0.4843
61	0.0390	13	0.1850	1/2	0.5000
60	0.0400	3/16	0.1875	33/64	0.5156
59	0.0410	12	0.1890	17/32	0.5312
58	0.0420	11	0.1910	35/64	0.5469
57	0.0430	10	0.1935	9/16	0.5625
56	0.0465	9	0.1960	37/64	0.5781
3/64	0.0469	8	0.1990	19/32	0.5937
55	0.0520	7	0.2010	39/64	0.6094
54	0.0550	13/64	0.2031	5/8	0.6250
53	0.0595	6	0.2040	41/64	0.6406
1/16	0.0625	5	0.2055	21/32	0.6562
52	0.0635	4	0.2090	43/64	0.6719
51	0.0670	3	0.2130	11/16	0.6875
50	0.0700	7/32	0.2187	45/64	0.7031
49	0.0730	2	0.2210	23/32	0.7187
48	0.0760	1	0.2280	47/64	0.7344
5/64	0.0781	A	0.2340	3/4	0.7500
47	0.0785	15/64	0.2344	49/64	0.7656
46	0.0810	B	0.2380	25/32	0.7812
45	0.0820	C	0.2420	51/64	0.7969
44	0.0860	D	0.2460	13/16	0.8125
43	0.0890	1/4	0.2500	53/64	0.8281
42	0.0935	F	0.2570	27/32	0.8437
3/32	0.0937	G	0.2610	55/64	0.8594
41	0.0960	17/64	0.2656	7/8	0.8750
40	0.0980	H	0.2660	57/64	0.8906
39	0.0995	I	0.2720	29/32	0.9062
38	0.1015	J	0.2770	59/64	0.9219
37	0.1040	K	0.2810	15/16	0.9375
36	0.1065	9/32	0.2812	61/64	0.9531
7/64	0.1093	L	0.2900	31/32	0.9687
35	0.1100	M	0.2950	63/64	0.9844
34	0.1110	19/64	0.2968	1	1.000
33	0.1130	N	0.3020		
32	0.1160	5/16	0.3125		
31	0.1200	O	0.3160		
		P	0.3230		

5. Angles: (See Figures 8-7 through 8-9.)
   A. For mild steel: Lip angle is 59 degrees
   B. For hard steel: Lip angle is 65 degrees

Lip clearance: Lip clearance is the relief which is given the cutting edges of the drill to allow them to enter the metal without interference. The heel is ground away from the cutting lip at an angle of 12 to 18 degrees for drills pointed for aluminum and 10 to 14 degrees for drills to be used on stainless steel and titanium. See Figure 8-7.

Figure 8-7. Drill Angles: Lip Clearance

Length and Angle of the Lips: The lips are of equal length and at the same angle with the axis of the drill. See Figure 8-8.

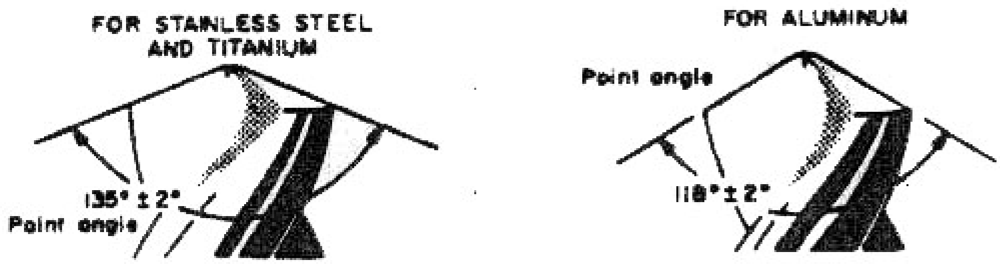


Figure 8-8. Drill Angles: Length and Angle of the Lips

Central Locations of Point and Center of the Drill: If I and 2 have been correctly ground, the point and dead center will be centrally located on the axis of the drill. See Figure 8-9.

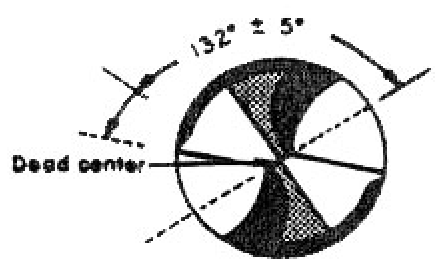


Figure 8-9. Drill Angles: Locations of Point and Center of Drill

6. Common drill troubles and causes. (See Figure 8-10.)

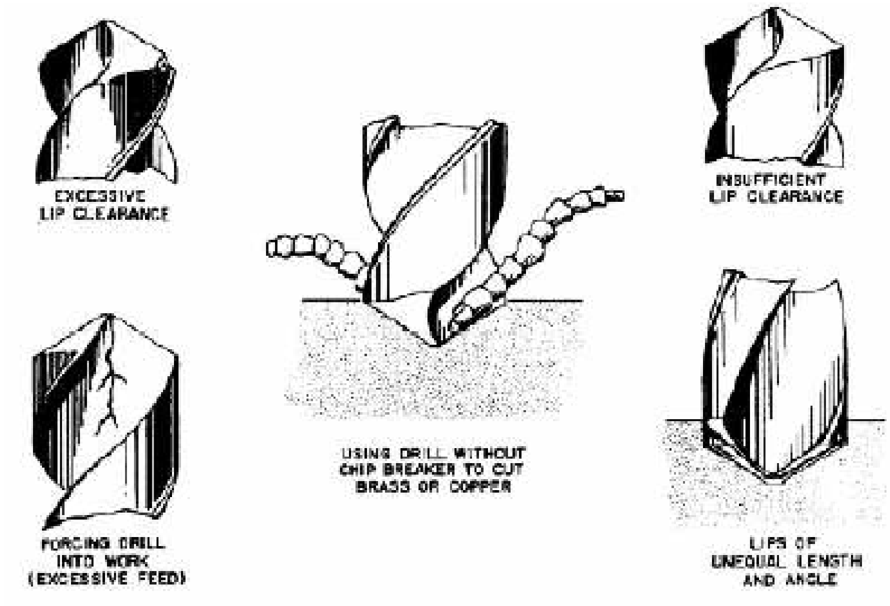


Figure 8-10. Common Drill Troubles and Causes

7. Suggested speeds and feeds for high speed drills. (Refer to Tables 8-2 through 8-7.)

Table 8-2. Suggested Speeds for High Speed Drills

Material	Recommended Speed SFPM
Aluminum and its Alloys	200-300
Bakelite	100-150
Brass, Bronze (soft)	200-300
Bronze (High Tensile)	70-100
Cast Iron (Soft)	100-150
Cast Iron (Hard)	70-100
Magnesium and its Alloys	250-400
Malleable Iron	80-90
Nickel and Monel Metal	40-60
Slate, Marble, Stone	15-25
Steel Forgings	50-60
Steel, Manganese (15% Mn)	15-25
Steel (Soft)	80-110
Stainless Steel	30-40
Tool Steel	50-60
Wrought Iron	50-60
Wood	300-400

NOTE: Carbon steel drills should be run at speeds approximately 40 to 50 % of those recommended for high speed drills.

Table 8-3. Feeds for Drills

Drill Diameter in Inches	Feed per Revolution in Inches
Under 1/8	.001 to .002
1/8 to 1/4	.002 to .004
1/4 to 1/2	.004 to .007
1/2 to 1	.007 to .015
1 Inch and Over	.015 to .025

NOTE: It is best to start with a moderate speed and feed, increasing either one, or both, after observing the action and condition of the drill.

Table 8-4. Operating Speeds – Fractional Sizes (Sheet 1 of 4)

Size		Surface Feet Per Minute										
Fractional	Decimal Equiv.	10	15	20	25	30	40	50	60	70	80	90
		Revolutions Per Minute										
1/64	.015625	2448	3672	4890	6112	7334	9779	12224	14669	17114	19558	22003
1/32	.03125	1222	1834	2445	3056	3667	4890	6112	7334	8557	9779	11002
1/16	.0625	611	917	1222	1528	1834	2445	3056	3667	4278	4890	5501
3/32	.09375	407	611	815	1019	1222	1630	2037	2445	2852	3260	3667
1/8	.125	305	458	611	764	917	1222	1528	1834	2139	2445	2750
5/32	.15625	244	367	489	611	733	978	1222	1467	1711	1956	2200
3/16	.1875	204	306	407	509	611	815	1019	1222	1426	1630	1834
7/32	.21875	175	262	349	437	524	699	873	1048	1222	1397	1572
1/4	.250	153	229	306	382	458	611	764	917	1070	1222	1375
5/16	.3125	122	183	244	306	367	489	611	733	856	978	1100
3/8	.375	102	153	204	255	306	407	509	611	713	815	917
7/16	.4375	87	131	175	218	262	349	431	524	611	699	786
1/2	.500	76	115	153	191	229	306	382	458	535	611	688
9/16	.5625	68	102	136	170	204	272	340	407	475	543	611
5/8	.625	61	92	122	153	183	244	306	367	428	489	550
11/16	.6875	56	83	111	139	167	222	278	333	389	445	500
3/4	.750	51	76	102	127	153	204	255	306	357	407	458
13/16	.8125	47	70	94	118	141	188	235	282	329	376	423
7/8	.875	44	65	87	109	131	175	218	262	306	349	393
15/16	.9375	41	61	81	102	122	163	204	244	285	326	367
1	1.000	38	57	76	96	115	152	191	229	267	305	344

Table 8-5. Operating Speeds – Fractional Sizes (Sheet 2 of 4)

Size		Surface Feet Per Minute									
Fractional	Decimal Equiv.	100	125	150	175	200	250	300	400	600	1000
		Revolutions Per Minute									
1/64	.015625	24448	30528	36672							
1/32	.03125	12224	15364	18336							
1/16	.0625	6112	7632	9168	10688	12024					
3/32	.09375	4075	5088	6112	7125	8149	10187				
1/8	.125	3056	3816	4584	5344	6112	7640	9168	12224		
5/32	.15625	2445	3053	3667	4275	4890	6112	7334	9779	14669	
3/16	.1875	2037	2544	3056	3563	4075	5093	6112	8149	12224	
7/32	.21875	1746	2181	2619	3054	3493	4366	5239	6985	10478	
1/4	.250	1528	1908	2292	2672	3056	3820	4584	6112	9168	15276
5/16	.3125	1222	1526	1834	2138	2445	3056	3667	4890	7334	12221
3/8	.375	1019	1272	1528	1781	2037	2547	3056	4075	6412	10184
7/16	.4375	873	1090	1380	1527	1746	2183	2619	3493	5239	8729
1/2	.500	764	954	1146	1336	1528	1910	2292	3056	4584	7638
9/16	.5625	679	848	1019	1188	1358	1698	2037	2716	4075	6789
5/8	.625	611	763	917	1069	1202	1528	1834	2445	3667	6110
11/16	.6875	556	694	833	972	1111	1389	1667	2223	3334	5555
3/4	.750	509	636	764	891	1019	1273	1528	2037	3056	5092
13/16	.8125	470	587	705	822	940	1175	1410	1881	2821	4700
7/8	.875	437	545	655	763	873	1091	1310	1746	2619	4365
15/16	.9375	407	509	611	713	815	1019	1222	1630	2445	4074
1	1.000	382	477	573	668	764	955	1146	1528	2292	3820

Table 8-6. Operating Speeds –Letter Sizes (Sheet 3 of 4)

Size		Surface Feet Per Minute									
Letter	Decimal Equiv.	15	20	25	30	40	50	60	70	80	90
		Revolutions Per Minute									
A	.234	245	327	409	491	654	818	982	1145	1309	1472
B	.238	241	321	401	482	642	803	963	1124	1284	1445
C	.242	237	315	394	473	631	789	947	1105	1262	1420
D	.246	233	311	389	467	622	778	934	1089	1245	1400
E	.250	229	305	382	458	611	764	917	1070	1222	1375
F	.257	223	297	371	446	594	743	892	1040	1189	1337
G	.261	220	292	365	440	585	732	878	1024	1170	1317
H	.266	215	287	359	430	574	718	862	1005	1149	1292
I	.272	210	281	351	421	562	702	842	983	1123	1264
J	.277	207	276	345	414	552	690	827	965	1103	1241
K	.281	204	272	340	408	544	680	815	951	1087	1223
L	.290	197	263	329	395	527	659	790	922	1054	1185
M	.295	194	259	324	389	518	648	777	907	1036	1166
N	.302	190	253	316	380	506	633	759	886	1012	1139
O	.316	181	242	302	363	484	605	725	846	967	1088
P	.323	177	236	296	355	473	592	710	828	946	1065
Q	.332	172	230	287	345	460	575	690	805	920	1035
R	.339	169	225	282	338	451	564	676	789	902	1014
S	.348	164	219	274	329	439	549	659	769	878	988
T	.358	160	213	266	320	426	533	640	746	853	959
U	.368	155	207	259	311	415	519	623	727	830	934
V	.377	152	202	253	304	405	507	608	709	810	912
W	.386	148	198	247	297	396	495	594	693	792	891
X	.397	144	192	240	289	385	481	576	672	769	865
Y	.404	142	189	236	284	378	473	567	662	756	851
Z	.413	138	185	231	277	370	462	555	647	740	832

Table 8-7. Operating Speeds –Letter Sizes (Sheet 4 of 4)

Size		Surface Feet Per Minute								
Letter	**Decimal Equiv.**	**100**	**110**	**120**	**130**	**140**	**150**	**175**	**200**	**250**
		Revolutions Per Minute								
A	.234	1636	1796	1959	2122	2285	2448	2857	3272	4090
B	.238	1605	1765	1926	2086	2247	2407	2808	3210	4013
C	.242	1578	1736	1894	2052	2210	2368	2762	3156	3945
D	.246	1556	1708	1863	2018	2174	2329	2718	3112	3890
E	.250	1528	1681	1834	1968	2139	2292	2674	3056	3820
F	.257	1486	1635	1784	1932	2081	2229	2600	2972	3715
G	.261	1463	1610	1756	1903	2049	2195	2560	2926	3658
H	.266	1436	1580	1723	1867	2010	2154	2513	2872	3590
I	.272	1404	1545	1685	1827	1966	2106	2457	2808	3510
J	.277	1379	1517	1655	1793	1930	2068	2413	2758	3448
K	.281	1359	1495	1631	1767	1903	2039	2379	2718	3398
L	.290	1317	1449	1581	1712	1844	1976	2305	2634	3293
M	.295	1295	1424	1554	1683	1813	1942	2266	2590	3238
N	.302	1265	1391	1518	1644	1771	1897	2213	2530	3163
O	.316	1209	1330	1450	1571	1692	1813	2115	2418	3023
P	.323	1183	1301	1419	1537	1657	1774	2070	2366	2958
Q	.332	1150	1266	1384	1496	1611	1726	2013	2300	2875
R	.339	1127	1239	1355	1465	1577	1690	1972	2254	2818
S	.348	1098	1207	1317	1427	1537	1646	1920	2196	2745
T	.358	1066	1173	1280	1387	1494	1600	1866	2132	2665
U	.368	1038	1142	1246	1349	1453	1557	1816	2076	2595
V	.377	1013	1114	1219	1317	1418	1520	1773	2026	2533
W	.386	989	1088	1188	1286	1385	1484	1731	1978	2473
X	.397	962	1058	1155	1251	1347	1443	1683	1924	2405
Y	.404	945	1040	1135	1229	1324	1418	1654	1890	2363
Z	.413	925	1017	1110	1202	1295	1387	1618	1850	2312

8. Cutting fluids (Refer to work order or to Table 8-8 where cutting fluids are not prohibited.)

Table 8-8. Recommended Cutting Fluids

METAL	**CUTTING FLUID**
Aluminum and its alloys:	Soluble oil; kerosene and lard oil compounds; light, non-viscous, neutral oil; kerosene and soluble oil mixtures.
Brass:	Dry; soluble oil; kerosene and lard oil compounds; light, non-viscous, neutral oil.
Copper:	Soluble oil; winter-strained lard oil; oleic acid compounds.
Cast Iron:	Dry, or with a jet of compressed air for a cooling medium.
Malleable Iron:	Soluble oil, or non-viscous, neutral oil.
Monel Metal:	Soluble oil, or sulfurized mineral oil.
Steel, Ordinary:	Soluble oil; sulfurized oil; high Extreme Pressure value mineral oil.
Steel, very hard and refractory:	Soluble oil, or sulfurized mineral oil.
Steel, Stainless	Soluble oil, or sulfurized mineral oil.
Wrought Iron:	Soluble oil; sulfurized oil; high animal oil content, mineral oil compound.
Intermittent cooling of hardened steel should be avoided, as it may cause small checks or cracks which will result in tool failure.	

9. Drilling Tips:
   A. Material should always be center punched to aid in accurately starting drill.
   B. To avoid breaking drills ease up on feed pressure as drill starts to break through.
   C. Material to be drilled should always be clamped to drill press table to prevent material from spinning if drill seizes.
   D. Hand held drills 3/8" and larger should always be used with extra side grip to avoid having drill motor wrenched from the hand if the drill seizes.
   E. A drill is not a satisfactory tool for making large holes in sheet metal. Fly cutters, chassis punches or special thin metal hole cutter should be used.
   F. Remember that drilling, especially hand held drills do not produce accurate holes either in regard to location or hole diameter. Accurate diameter holes (to within a thousandth) are usually produced by drilling with a drill 1/64-inch undersize and finishing with a reamer to size.

8.5: Micrometers

The micrometer is the most commonly used precision tool in use. It is used for accurately measuring dimensions. A micrometer divides the inch into 1,000 parts. It has a screw with 40 threads per inch which advances through a nut at .025 of an inch per revolution. (See Figure 8-11 for typical readings.)

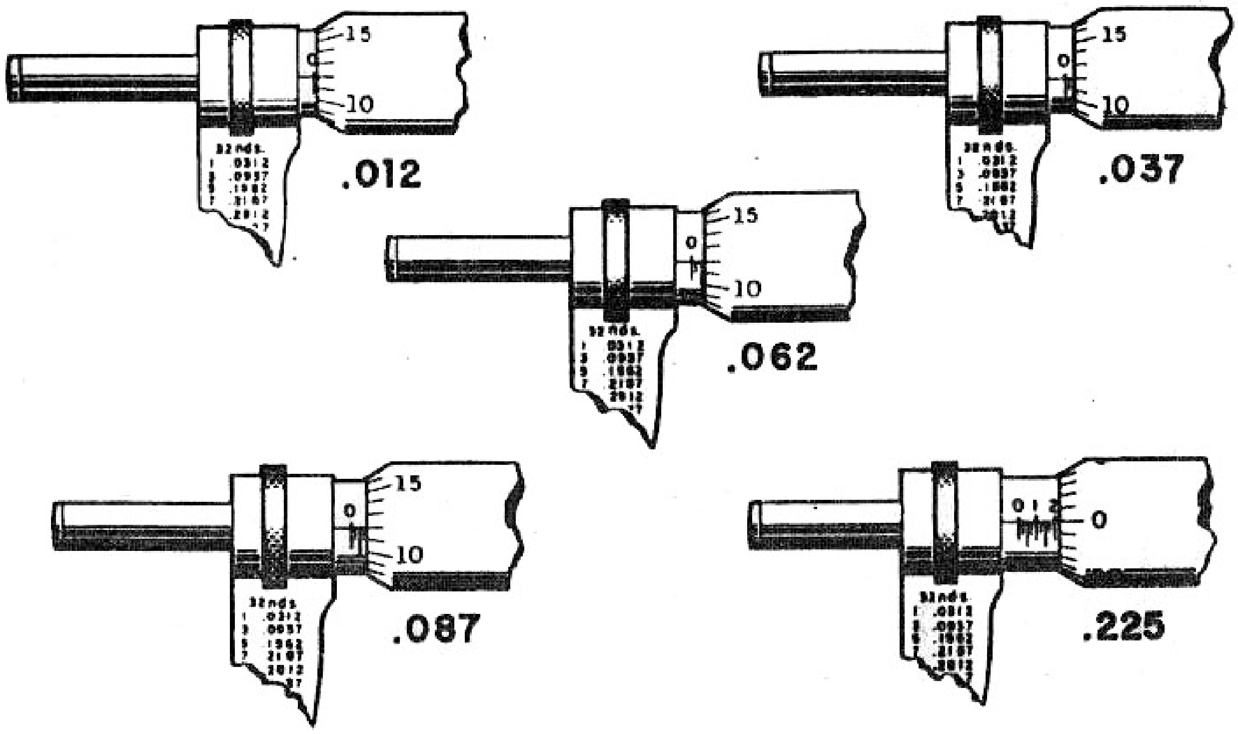


Figure 8-11. Typical Micrometer Readings

8.5.1: Care and Use

Verify calibration before use. Slowly bring the micrometer measuring surfaces together using a light pressure. Avoid placing micrometer where it might be affected by heat. A micrometer is a precision tool; mistreatment by dropping it on the floor or flooding it with coolant containing emery may impair its accuracy. Protect the micrometer when not in use by storing it away from grit and dirt. See Figure 8-12.

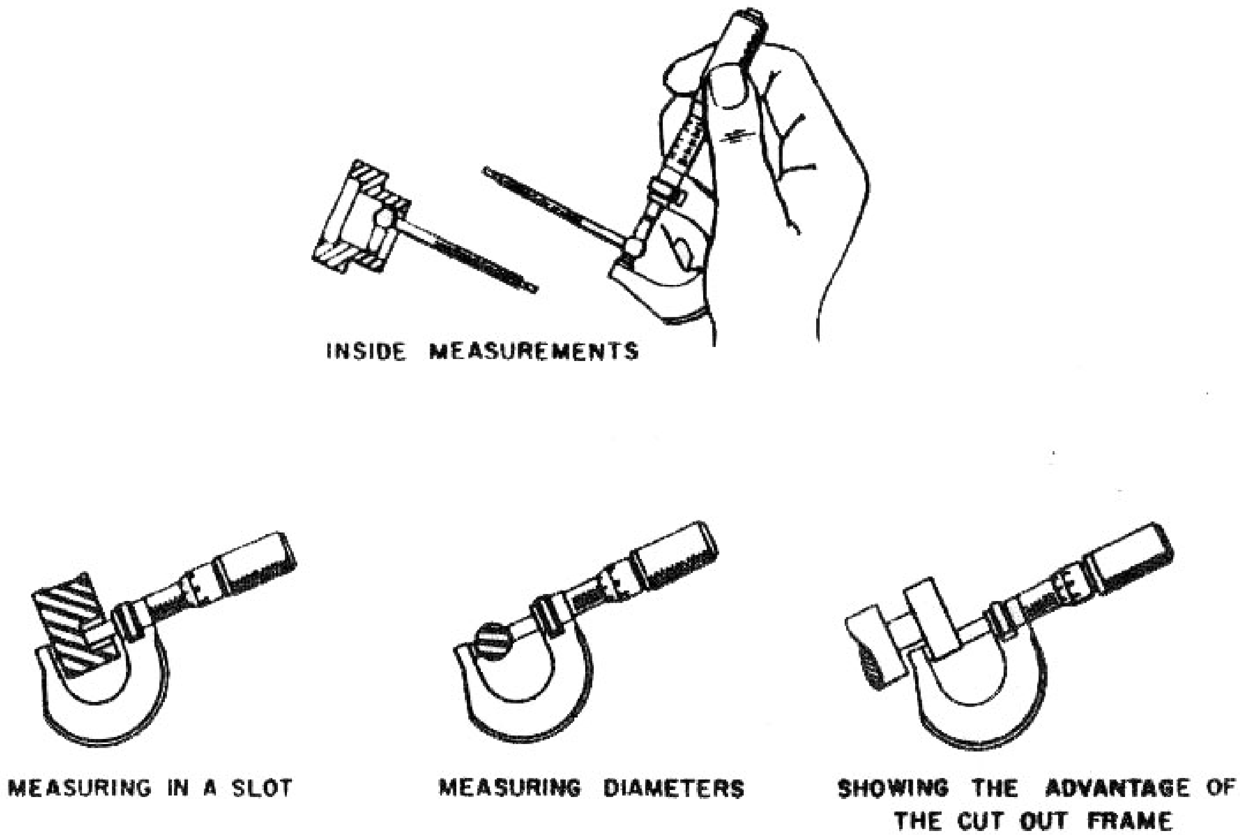


Figure 8-12. Uses for Micrometer Caliper

8.5.2: Ratchet Stop and Clamp Ring

The ratchet stop provides a uniform measuring pressure of approximately 1 pound, 4 ounces. A slight rotation of the outer ring of the clamp ring locks the micrometer spindle at any desired setting.

> ***CAUTION:***
> ***Never tighten clamp ring when spindle is removed. To do so may damage the clamping mechanism.***

8.5.3: Types

- Inside micrometer
- Outside micrometer
- Depth micrometer

8.5.4: Principal Parts of a Micrometer

The principal parts of a micrometer consist of the following (see Figure 8-13):
- Frame
- Anvil
- Spindle
- Barrel
- Thimble

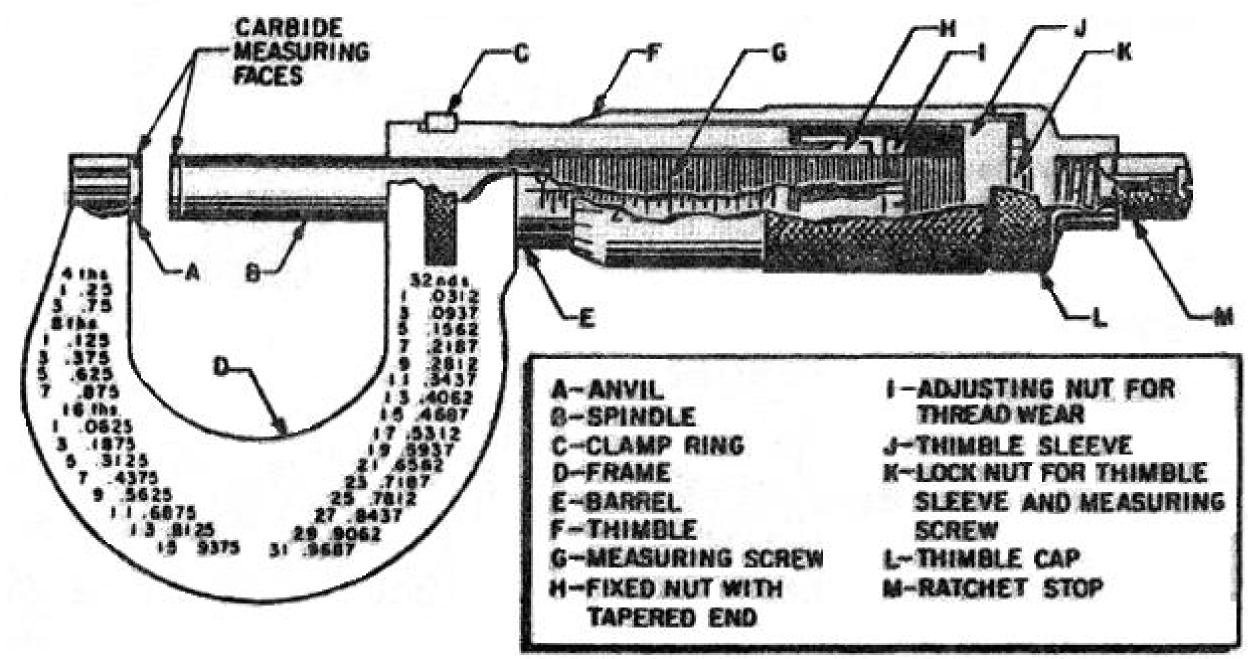


Figure 8-13. Micrometer Caliper Section View

8.5.5: Tools Used in Conjunction with Micrometer

Tools used in conjunction with micrometers include the following:
- Ball gauge (inside diameter 1/2 Inch or less)
- “T” gauge or snap gauge (inside diameter 1/2 inch or more)

8.5.6: Other Gauges

- Radius gauges — Used to find radius of bend on parts you are copying.
- Thread gauges — Used to get thread count on a bolt, in a hole, etc.
- Feeler gauges — Used to check clearance between moving parts.
- Trammel points — Used in direct transfer of dimensions from parts, blueprints, etc.

8.6: Vernier Caliper

Direct readings of both outside and inside measurements can be obtained on Vernier Calipers. The front side is graduated for outside measurements and the reverse side for inside measurements. (See Figure 8-14.)

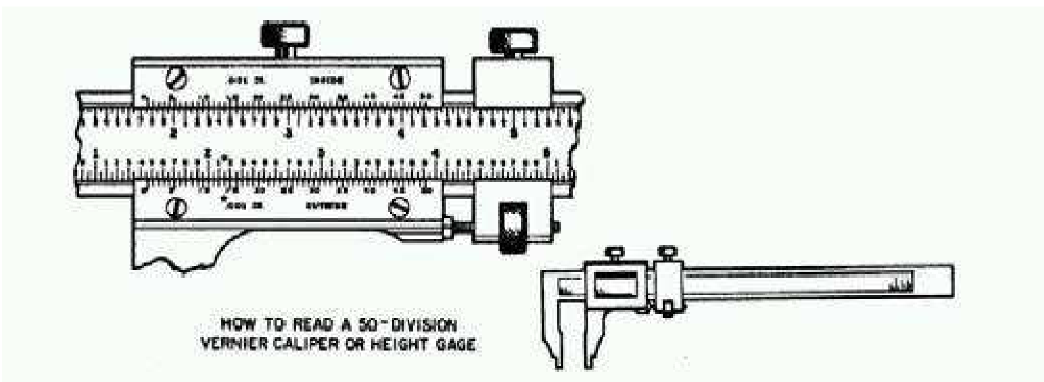


Figure 8-14. Vernier Caliper

The bar of the tool is graduated in twentieths of an inch (.050 inch). Every second division represents a tenth of an inch and is numbered. On the Vernier plate there is a space divided into 50 parts and numbered 0, 5, 10, 15, 20, 25, etc., to 50. The fifty divisions on the Vernier occupy the same space as 49 divisions on the bar.

To read the tool, note how many inches, tenths (or .100) and twentieths (or .050) to 0 mark on the Vernier is from the 0 mark on the bar. Then note the number of division on the Vernier from 0 to a line which exactly coincides with a line on the bar.

Example:
In the figure below the Vernier has been moved to the right one and four hundred fifty thousandths (1.450), as shown on the bar and the fourteenth line on the Vernier coincides with a line, as indicated by the stars, on the bar. Fourteen thousandths of an inch is therefore to be added to the reading on the bar and the total reading in one and four hundred and sixty-four thousandths inches (1.464).

> ***CAUTION:***
> ***It is important for the bar to be wiped before moving the slide so that all dirt or other particles are removed, thereby preventing possible damage to graduations and interference with operation of the tool.***

8.7: Bench Grinders

Bench grinders are used by the mechanic for hand grinding operations, such as sharpening chisels or screw drivers, grinding drills, removing excess metal from work, etc. They are usually fitted with both a medium grain and a fine grain abrasive wheel. In some cases a wire brush wheel is substituted for one of the abrasive wheels. The medium wheel is satisfactory for rough grinding. For grinding to close limits for size, sharpening tools, or when a smooth finish is desired, the fine wheel should be used.

DO'S AND DONT'S

1. Never use soft materials on a grinder.
2. Make sure tool rest is close to grinder wheel (1/8 inch or less) (Figure 8-15).
3. Do not wear gloves or loose clothing when operating grinder.
4. Never grind on the side of a wheel.
5. Never jam the work into the face of the wheel.
6. Never use a wheel that has a chunk out of it or a crack in it.
7. Replace the wheel when it gets too small. (80% of its original diameter or when item 2 above is unattainable.)
8. Make sure eye shield is in place. (Figure 8-15).
9. Always wear safety glasses.
10. If wheel needs dressing use proper tool.
11. Allow grinder wheel to get up to full rpm before using.

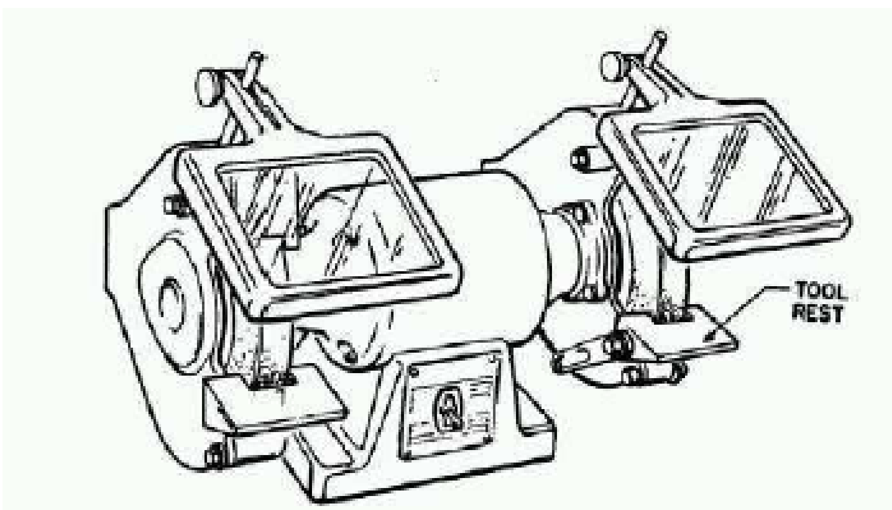


Figure 8-15. Bench Grinder

8.8: Holding Devices

Vises and clamps are tools used for holding work of various kinds on which some operation is being performed.

CLASSIFICATIONS

- Machinist vise
- Utility bench vise (most common)
- Drill press vise (usually has to be clamped to drill press table)
- “C” clamps (come in many sizes)
- Parallel clamps
- Pipe vise

NOTE: 0n bench vises soft jaws are sometimes needed to protect part. (See Figure 8-16.)

8.9: Punches and Punching

Punches are used to locate centers for drawing circles, to start hole for drilling, to punch hole in metal sheets, and to drive out pins or bolts. (See Figure 8-16.)

CLASSIFICATIONS

- Prick punch — Used to mark center
- Center punch — Used to mark drill point center
- Pin punch — Indicates pin diameter, stock diameter
- Starting punch — Used to drive out bolts, pins, etc.
- Scribes — Used to scribe lines on metal, not used on aluminum
- Aligning punch — Used to align flange holes

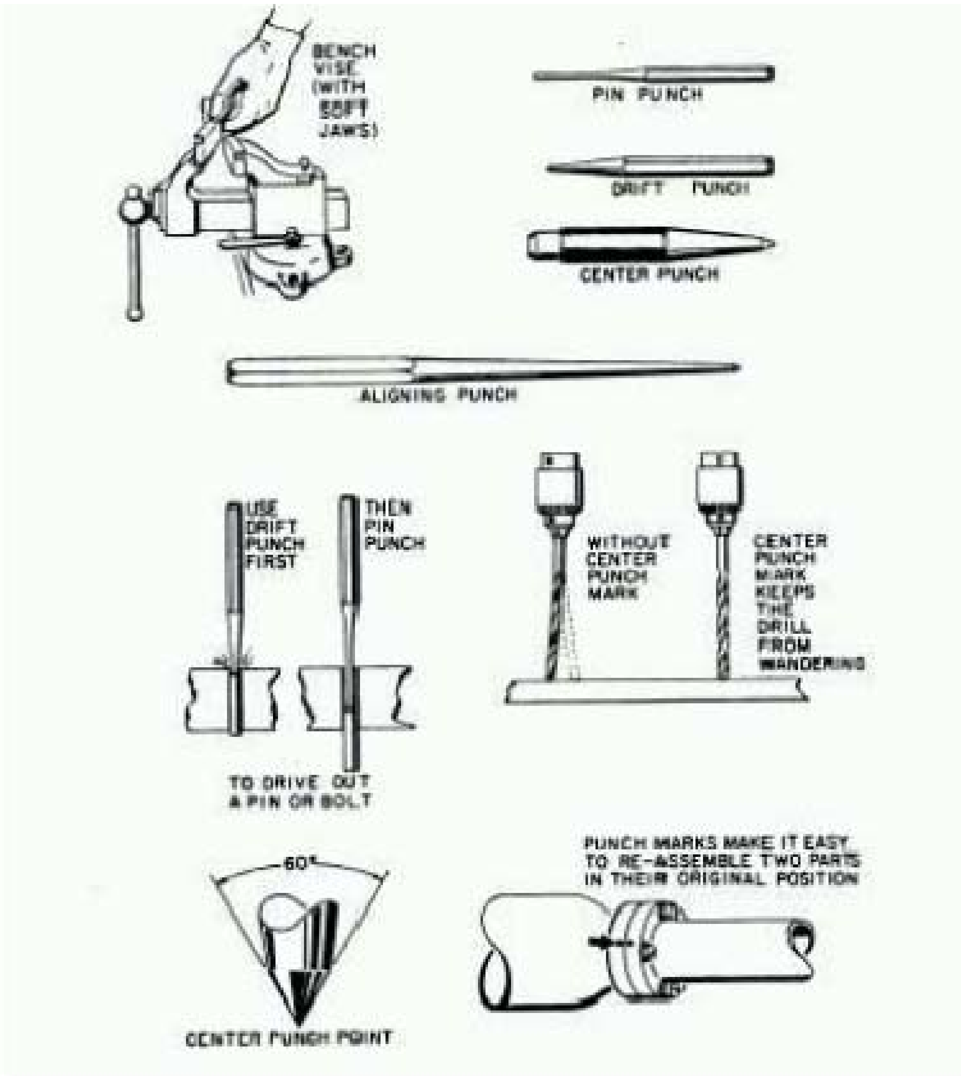


Figure 8-16. Holding Devices and Punches

8.10: Chisels

Chisels are tools used to cut, chip, or remove metal. They are made of good grade tool steel, hardened at the point and sharpened to a cutting edge. They will cut any metal softer than themselves. Never use a chisel with a mushroomed head. See Figure 8-17 for "before" and "after" dressing.

CLASSIFICATIONS

- Flat — Used for cutting sheet metal or for chipping
- Cape — Used for cutting grooves, slots or keyways
- Round nose — Used for cutting round (concave) grooves
- Diamond point — Used for cutting V shaped grooves

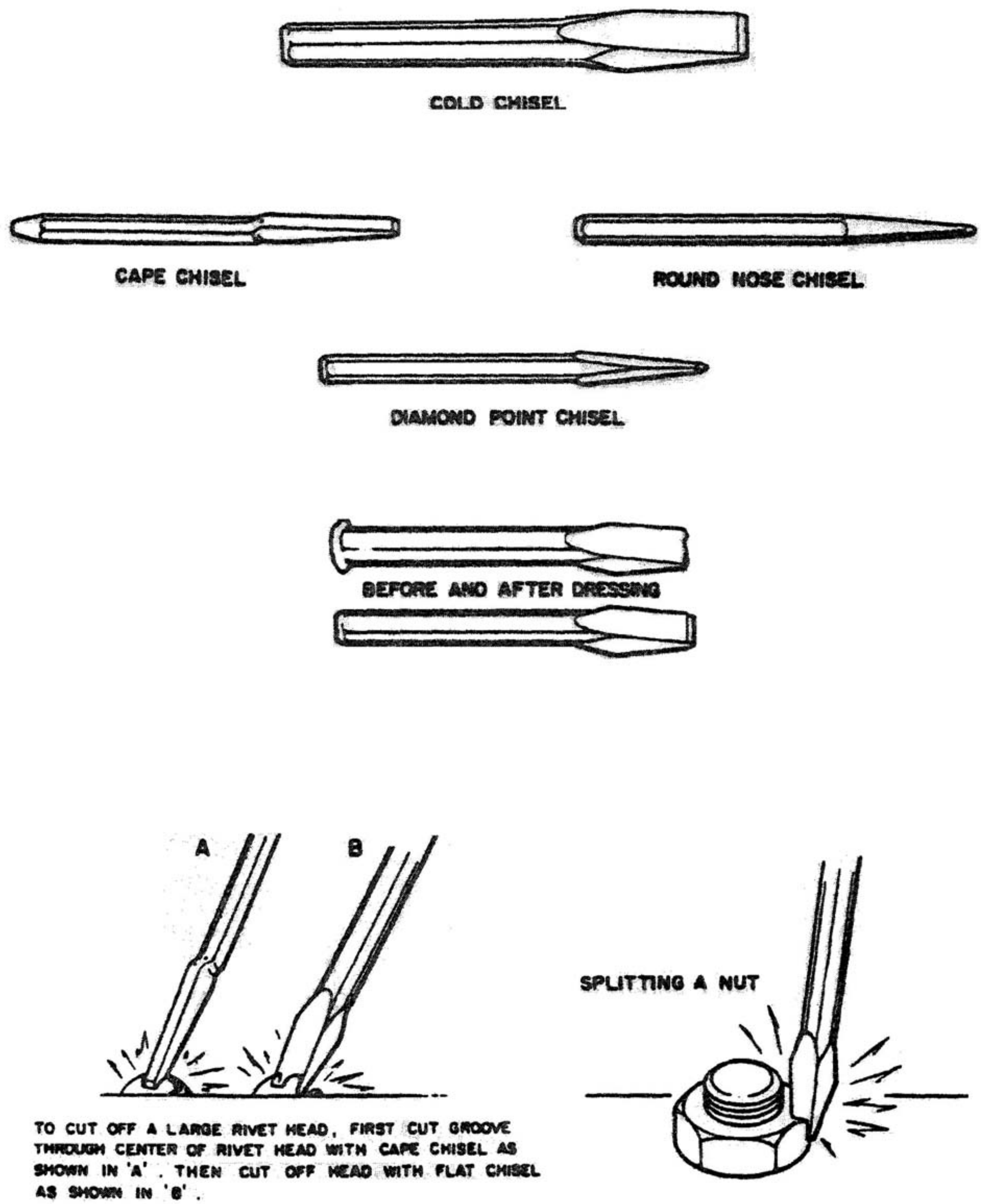


Figure 8-17. Chisels

8.11: Hammers

Hammers are classified as common, soft and sledges. Each has its special use. The following information will aid in selecting the right hammer for the particular work at hand. (See Figure 8-18)

CLASSIFICATIONS

- The <u>common (ball-peen) hammer</u> is used for sheet metal work, driving rivets, general purpose work, and the peen does a good job of cutting out holes for cap screws or studs.
- The <u>soft hammers</u> have heads made of lead, copper and babbit. These hammers are used when force is needed but you do not want to damage the part being struck. Frequent dressing of the head is necessary due to the mushrooming effect from hard usage. Soft hammers are also made out of plastic and rawhide. These should be used on parts where damage to part cannot be tolerated.
- <u>Sledges</u> are used for heavy work, where great force is needed, such as: slug wrench applications, driving stakes or breaking up rock. (See Figure 8-24.)

  NOTE: Hammer handles should always fit head tightly. Do not use the end of the hammer handle for bumping purposes; this will split and ruin the handle. Never use the handle for prying.

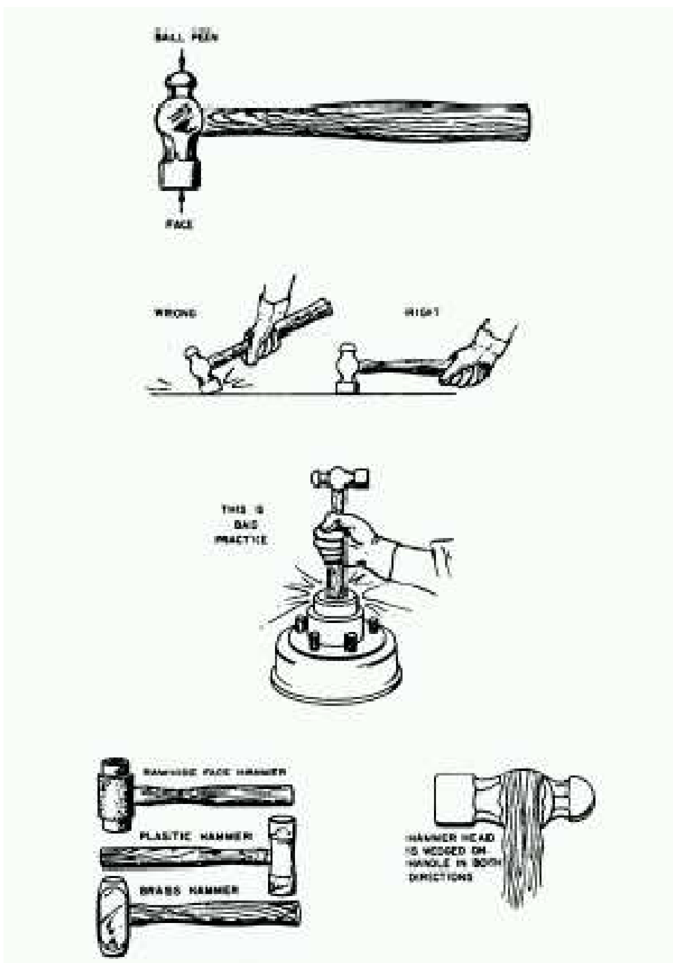


Figure 8-18. Hammers

8.12: Shears and Pliers

Shears, pliers and nippers are tools used to hold, turn, cut, shape or bend light work by hand. (See Figure 8-19 and Table 8-9.)

SHEARS
- Right and left cutting snips
- Tin snips
- Dikes (diagonal cutters)

PLIERS
- Slip joint (5" to 10")
- Duck bill
- Needle nose
- Channel type
- Vise grip

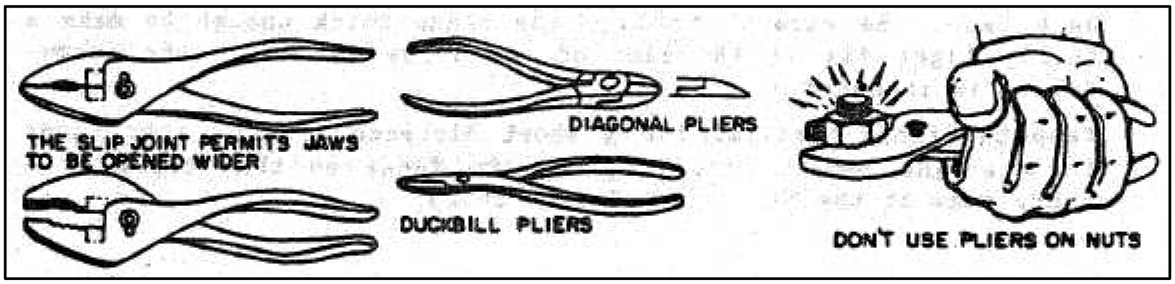


Figure 8-19. Pliers

Table 8-9. Usage of Pliers and Shears

Shears	Pliers
• Used for cutting sheet metal of various materials and thickness • Diagonal cutters are used for cutting off small stock, such as cotter keys and electrical wire	• Used principally for holding or bending thin material, or cutting electrical wire • Long nose pliers often help a mechanic out of a tight spot in recovering a washer or a nut which gets into a hard-to--reach spot, and in safety wiring applications where the wire has to be pushed or pulled through a hole • Pliers like all other tools, should be kept clean **CAUTION**: • Avoid using pliers on a hardened surface as this dulls the teeth and will cause loss of grip • Mechanics sometimes use pliers for loosening or tightening nuts. Always use wrenches on nuts, NEVER PLIERS. In fact, don't use pliers when any other tool will work

8.13: Screwdrivers

8.13.1: Common

Screwdrivers for general purpose are classified by size according to the length of the shank and blade. Various sizes are: 2-1/2, 3. 4, 5, 6, 8, 10, and 12 inches. The blade tip is proportionate to the length of the shank and blade.

1. Select the right size screwdriver for the screw slot. This not only prevents the screw slot free becoming burred and the blade tip from being damaged, but reduces the force required to keep the screwdriver in the slot.

2. Screwdrivers are not designed to he used as a pry or pinch bar, and if much force is applied when so used, it might bend or the blade may break. The tip of the blade is hardened to keep it from wearing, and the harder it is, the easier it will break if a heavy bending strain is applied.

3. Do not hammer on the end of a screwdriver. It is not to be used in place of a cold chisel, a punch, or a drift punch.

4. Do not use pliers on a screwdriver.

5. If a screwdriver blade becomes damaged through misuse, replace it.

8.13.2: Phillips

The tips of these screwdrivers have two points which cross at the center. These points correspond to the slots in the head of the screw. The correct size screwdriver must be used for each different size screw. The sizes most commonly used at the Field Laboratories are No. 1, No. 2, and No. 3.

The advantage of Phillips head screws over screws with standard slots is that the screwdriver can't slide sideways out of the slot and mar a surface. However, more downward pressure must be exerted on the Phillips screwdriver to keep it in the cross-slot. See Figure 8-20.

8.13.3: Reed and Prince

Another type of recessed head screw in common use is the Reed and Prince cross-slot screw. This type of screw should not be confused with the Phillips screw for there is a great difference in the slots. Compare them closely and you will see that each requires a special and different type of screwdriver. The sizes most commonly seen are ¼”, 3/16”, 5/16”, and 3/8”. See Figure 8-20.

8.13.4: Offset

The offset screwdriver has one blade forged in line with the shank or handle and the other blade at right angles to the shank. With such an arrangement, when the swinging space for the screwdriver is limited, the mechanic can change ends after each swing and thus work the screw in or out of the threaded hole. The tips of the blade can be either Common or Phillips or a combination of both. See Figure 8-20.

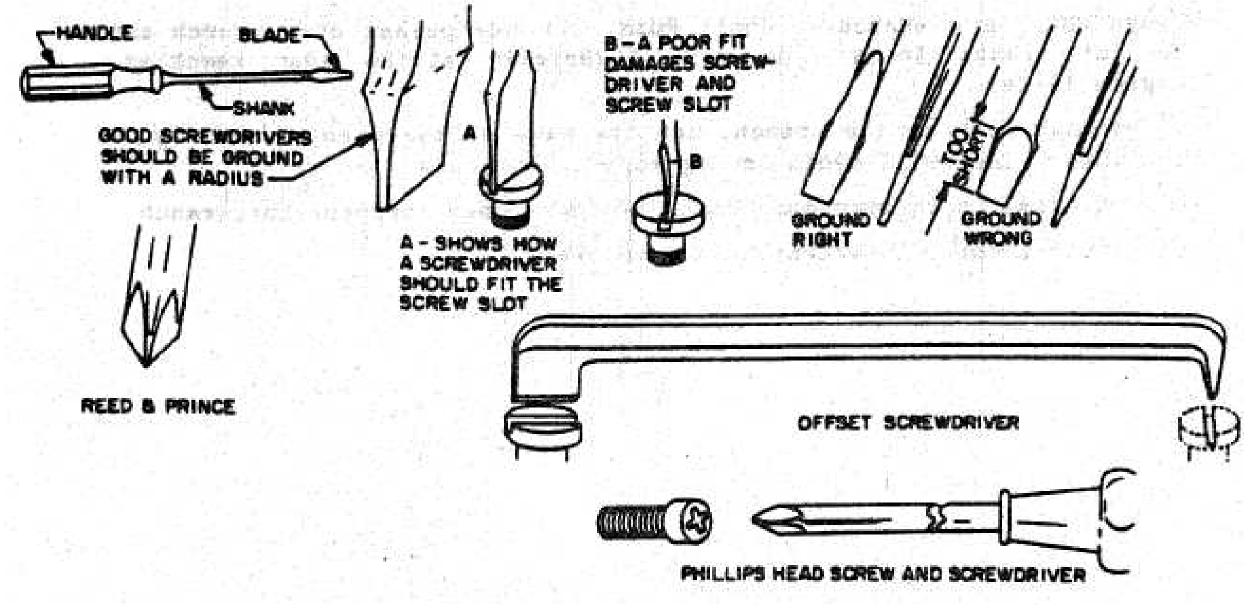


Figure 8-20. Screwdrivers

8.14: Wrenches

8.14.1: Open-End Wrenches

Solid non-adjustable wrenches with openings in each end are called open-end wrenches. The average set in a tool kit numbers about 10 wrenches with openings that range from 5/16” to 1 inch. This combination of sizes will fit most of the nuts, cap-screws, and bolts normally used. See Figure 8-21.

The size of the openings between the jaws determines the size of the wrench. The openings actually measure from five to fifteen thousandths of an inch larger than the nominal sizes marked on the wrenches, so that they can easily be slipped onto the nuts or bolt heads.

The smaller the openings are in the wrench, the shorter its overall length. The larger the opening is, the longer its overall length. This proportions the lever advantage of the wrench to the size of the bolt or nut. This helps reduce the possibility of the mechanic applying too great a force on the bolt or nut.

It takes practice to know whether you are using enough or too much force on a wrench. Experience develops a sense of “feel,” which enables a technician to know whether a nut or cap-screw is tightened the right amount.

There are a few simple rules for the correct use of open-end wrenches:

1. Be sure that the wrench fits the nut or bolt head.
2. When one has to put a bard pull op a wrench, make sure the wrench seats squarely on the sides of the nut.
3. Always PULL on a wrench—don't PUSH. If one pushes on a wrench and the nut breaks loose, you will invariably strike your knuckles. (See Figure 8-21.)

4. If one must push on the wretch, us the base of the palm, and hold your hand open. This will avoid injury to your knuckles.

5. When the jaws on an open-end wrench become spread, replace the wrench.

6. Do not use a cheater (extension) on a wrench.

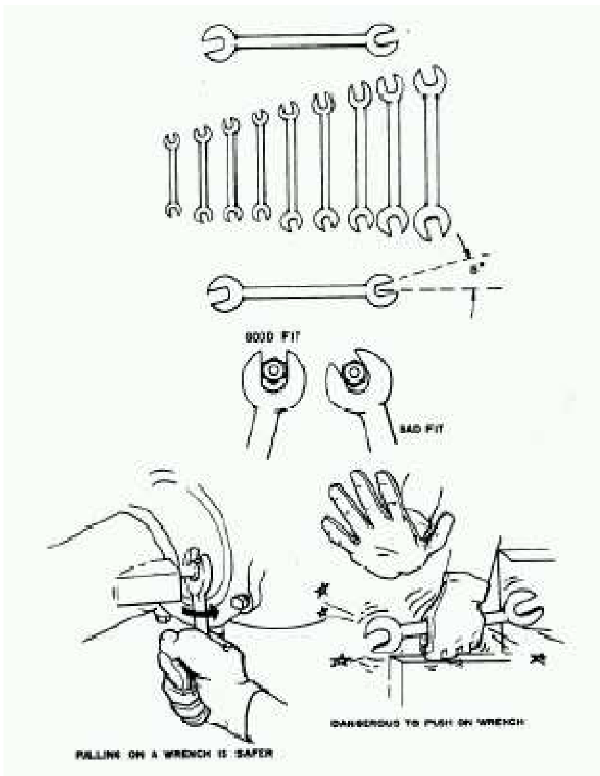


Figure 8-21. Open End Wrenches

8.14.2: Box-End Wrenches

Box-end wrenches are very popular with mechanics. One reason for this is that they can be operated in very close quarters. They are called "box-end" wrenches because they box or completely surround the nut or bolt head. (See Figure 8-22.)

Box end wrenches commonly are either 6-point or 12-point. A 12-point wrench can be used to continuously loosen or tighten a nut with a minimum swing of the handle.

Still another advantage of the box wrench is that there is practically no chance of the wrench slipping off the nut, and it can’t spread on the nut.

The sides of the opening in a box wrench are thin, and it is ideally suited for nuts that are hard to get at with an open-end wrench.

Some box-end wrenches have the heads set at an angle of 15 degrees to the handle. This tips the end of the wrench, which is not on the nut, upward and provides clearance for the mechanic's hand.

The same rules for use shown for open-end wrenches hold true for box-end wrenches.

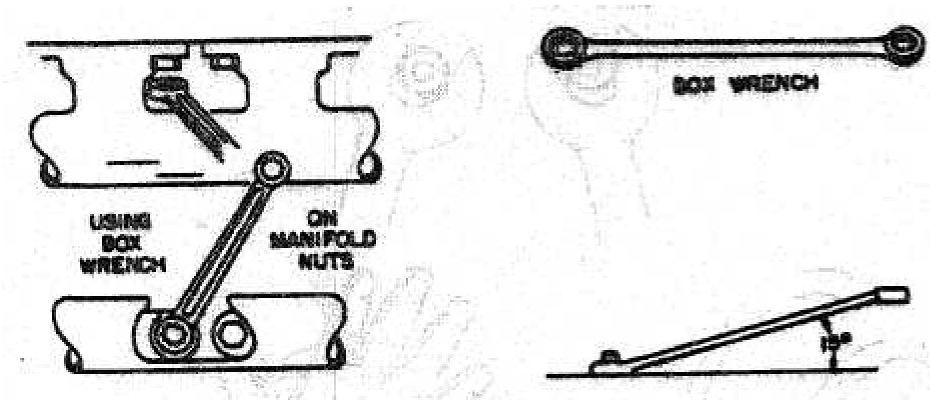


Figure 8-22. Box Wrenches

8.14.3: Combination Box and Open-End Wrenches

Many mechanics prefer combination wrenches that has a box-end wrench on one end and an open-end wrench on the other. They use the box-end and for "breaking-loose" or "snugging down" nuts and the open-end the rest of the time. (See Figure 8-23.)

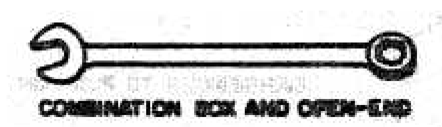


Figure 8-23. Combination Box and Open-End Wrench

8.14.4: Striking Wrench

Never hammer a common wrench. However there is one type of box wrench made for this purpose. These wrenches are heavy and strongly made. The handle is short and has a pad on which the hammer blows are struck. These box wrenches are known as "hammer" or "striking" wrenches. These wrenches are especially useful on large size nuts. See Figure 8-24.

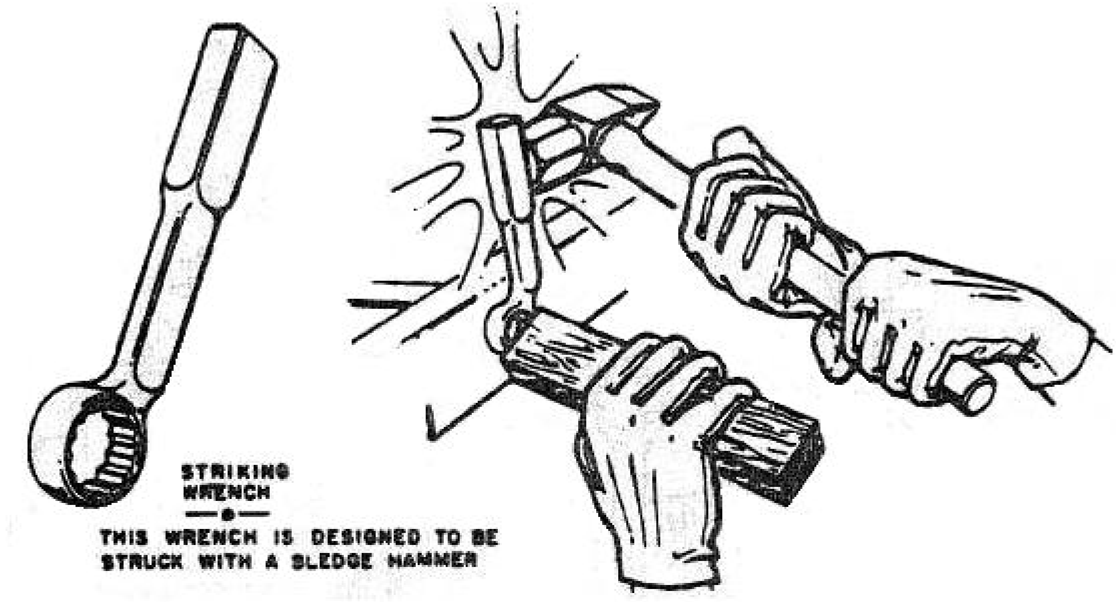


Figure 8-24. Sledging Wrench

8.14.5: Set Screw Wrenches

The trade name for this type is an Allen wrench. All of them are L-shaped bars of tool steel. The most common type is hexagonal to fit the hexagon socket in the set screw. See Figure 8-25.

These set screw wrenches vary in size according to the size of the socket in the set screw. These wrenches usually come in a set when they are purchased. The correct size must be used or the screw socket will be rounded out and next to impossible to remove.

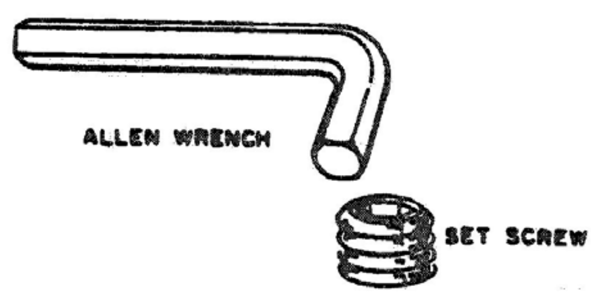


Figure 8-25. Set-Screw Wrench

8.14.6: Socket Wrenches

The wrench type which has done most to make the technician's work easier and save time is the socket wrench.

The socket is detachable and may be attached to several different types of handles for many different applications. (See Figure 8-26 through 8-30.)

The handle most commonly used is the ratchet. (Figure 8-26)

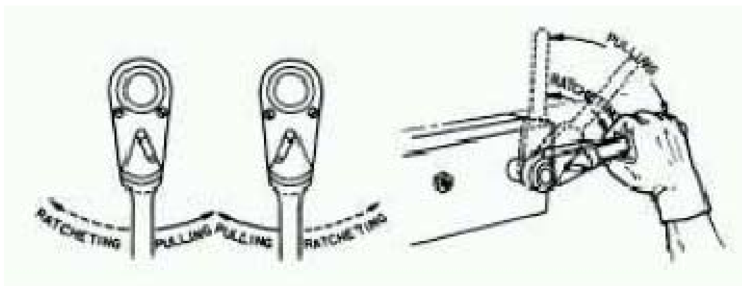


Figure 8-26. Ratchet Handle

Socket wrench sets also contain extra deep sockets for use on nuts which are a long way down on the bolt, or for bolts that are in recessed holes. (Figure 8-27)

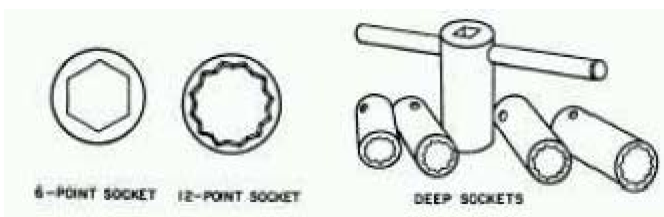


Figure 8-27. Ratchet Handle and Deep Sockets

HINGED OFFSET HANDLE

The hinged offset handle is very convenient. To loosen a tight nut the handle can be swung so as to be at a right angle to the socket and thus provide the greatest possible leverage. Then, after the nut is loosened to the point where it turns easily, the handle can be hinged into the vertical position and twisted by the fingers to completely remove the nut from the bolt or stud. (Figure 8-28)

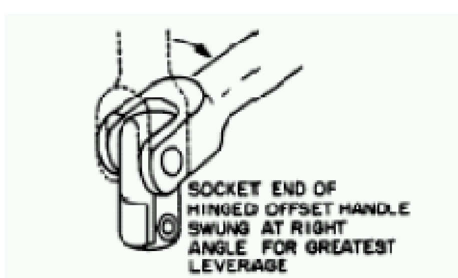


Figure 8-28. Hinged Offset Handle

SLIDING OFFSET HANDLE

The head can be positioned at the end or at the center of the handle. The sliding offset and an extension bar can be made up as a "T" handle. (Figure 8-29)

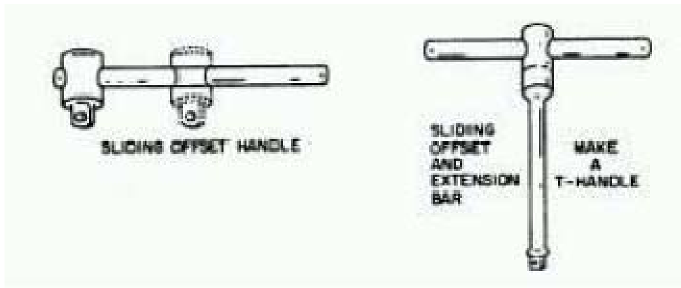


Figure 8-29. Sliding Offset Handle

8.14.7: Speed Handle

Speed handles sometimes called "speeders" or "spinners" are convenient for many jobs. The speed handle is worked like a brace which the woodworker uses with a bit to bore holes. A speed wrench will help you get nuts off in a hurry after they are first broken loose. (Figure 8-30)

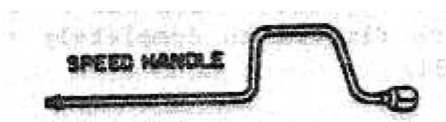


Figure 8-30. Speed Handle

8.14.8: Adjustable Wrenches

Adjustable or crescent type wrenches are shaped somewhat similar to open-end wrenches but have one jaw adjustable. (Figure 8-31)

The angle of the opening to the handle on an adjustable wrench is 22-1/2 degrees.

Although adjustable wrenches are convenient they are not intended to take the place of standard open-end wrenches, box wrenches, or socket wrenches.

DO'S AND DON'T'S

1. Adjustable wrenches aren't intended for hard service; treat them gently.

2. There are two important rules to remember:
   A. Always place the wrench on the nut so that the pulling force is applied to the stationary jaw side of the handle. (Figure 8-31)
   B. After placing the wrench on the nut, tighten the adjusting knurl so that the wrench fits the nut snugly. (Figure 8-31)

3. Adjustable wrenches, like all other tools, should be kept clean. Give them a bath in cleaning solvent and apply a little light oil to the knurl and the sides of the adjustable jaw where it slides in the body.

4. Inspect them for cracked knurls or jaws, which may result in failures.

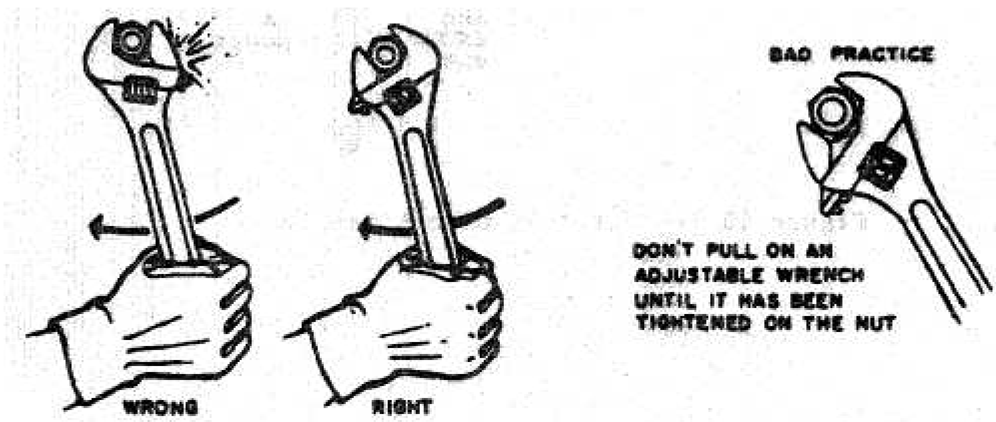


Figure 8-31. Adjustable Wrench

8.14.9: Pipe Wrenches

There is need on occasions for using a pipe wrench, but only on round objects, never on hexagon or square nuts. The teeth on the jaws of the pipe wrench always leave their mark on the work. No instructions are necessary on which way to pull on this wrench because it works only in one direction. However, the wrench works best when the "bite" is taken at about the center of the jaws. (Figure 8-32)

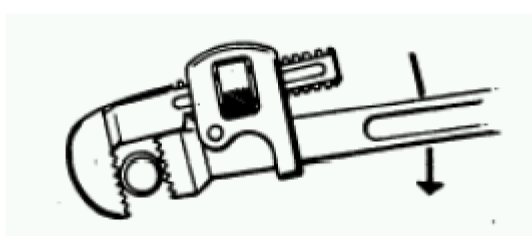


Figure 8-32. Pipe Wrench

8.15: Threads, Taps, and Dies

8.15.1: General Information

In assembly and disassembly operations in test areas, threaded parts such as nuts, bolts and screws are handled so frequently that every mechanic should be thoroughly familiar with the various types and their uses, and should understand the common methods of cutting or renewing threads.

Two types of threads commonly used are, National Coarse (NC) and National Fine (NF). NC threads range from 6 to 64 threads per inch, NF from 12 to 80 per inch.

In cutting threads two measurements must be known—the diameter and pitch. Machine screws have their diameter indicated by a number, No. 0 being smallest and No. 12 the largest. To this number is always added the number of threads per inch as No. 10-24. Larger sized screws or bolts have their diameters indicated by actual measurement as 5/16-24.

8.15.2: Use of Taps

1. Taps are tools used for cutting inside or female threads in holes in metal, fiber or other material. The tap should always be cleaned before use.

2. There are three forms of taps:
   A. Taper tap—(always used first)
   The taper tape is used to start all threads and may be used to finish the operation when it can be run entirely through the work.
   B. Plug tap—(2nd one used)
   The plug tap is used when one end of the hole is closed.
   C. Bottoming tap—(last one used)
   The bottoming tap is used when it is necessary to cut a full thread to the bottom of a closed hole. Plug taps or bottoming taps should never be used to start a thread.
   Note: Start all taps perpendicular to the hole.

8.15.3: Use of Dies

Dies are used for cutting male or external threads.

1. Clean die before use.

2. Die adjustment screw started loosely and then adjusted tighter, in steps while making threads.

3. Die inserted in handle (stock) with tapered thread side down or towards the work.

4. Set screw in handle inserted in recess hold in die and securely tightened.

5. Die started perpendicular to center line of part.

6. Use proper cutting fluid.

7. Back off die after every 1/2 to 1 turn to remove chips.

8.16: Combination Square

A combination square combines in handy form the equivalent of several tools; inside try square, outside try square, miter square, plumb, level, depth gage, marking gage, straight edge, etc.

Blade is usually 12 inches long. The handle can be moved to any position on the blade. The handle is usually fitted with one or two level glasses, and a scratch awl screwed into handle.

Graduations on the blade are 8ths, 16ths, and 32nds. Handle can be locked to the blade at any position by a knurled knob.

Common uses for the combination square are shown in Figure 8-33.

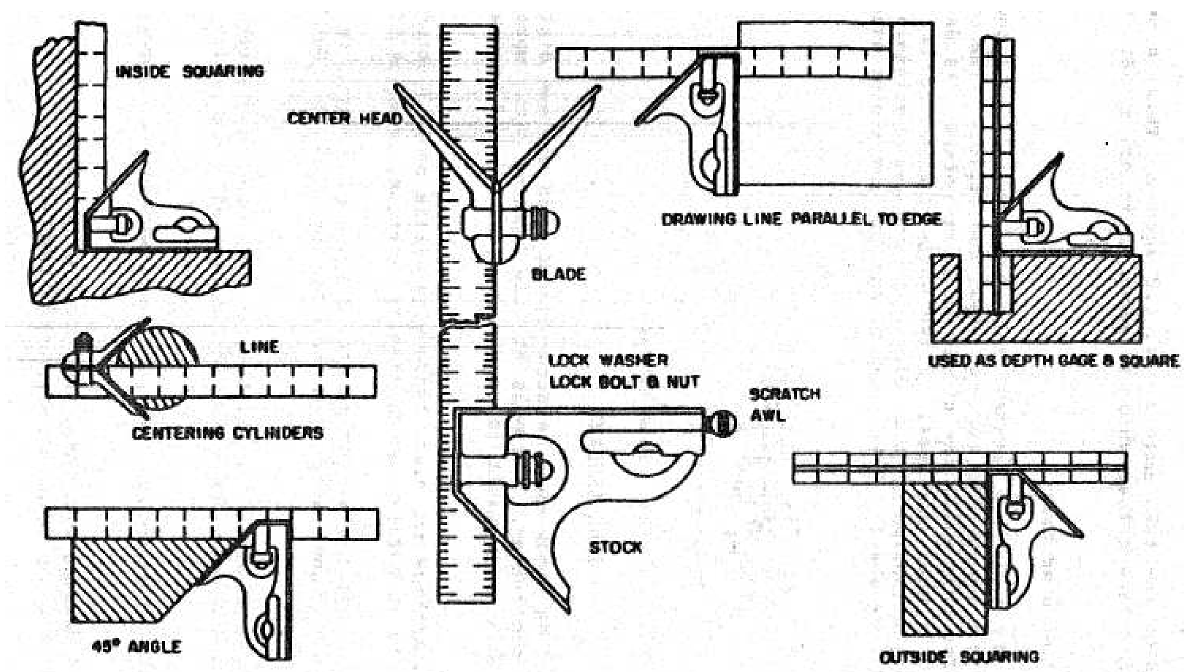


Figure 8-33. Uses for Combination Square

8.17: Protractor

Common uses for the protractor are shown in Figure 8-34.

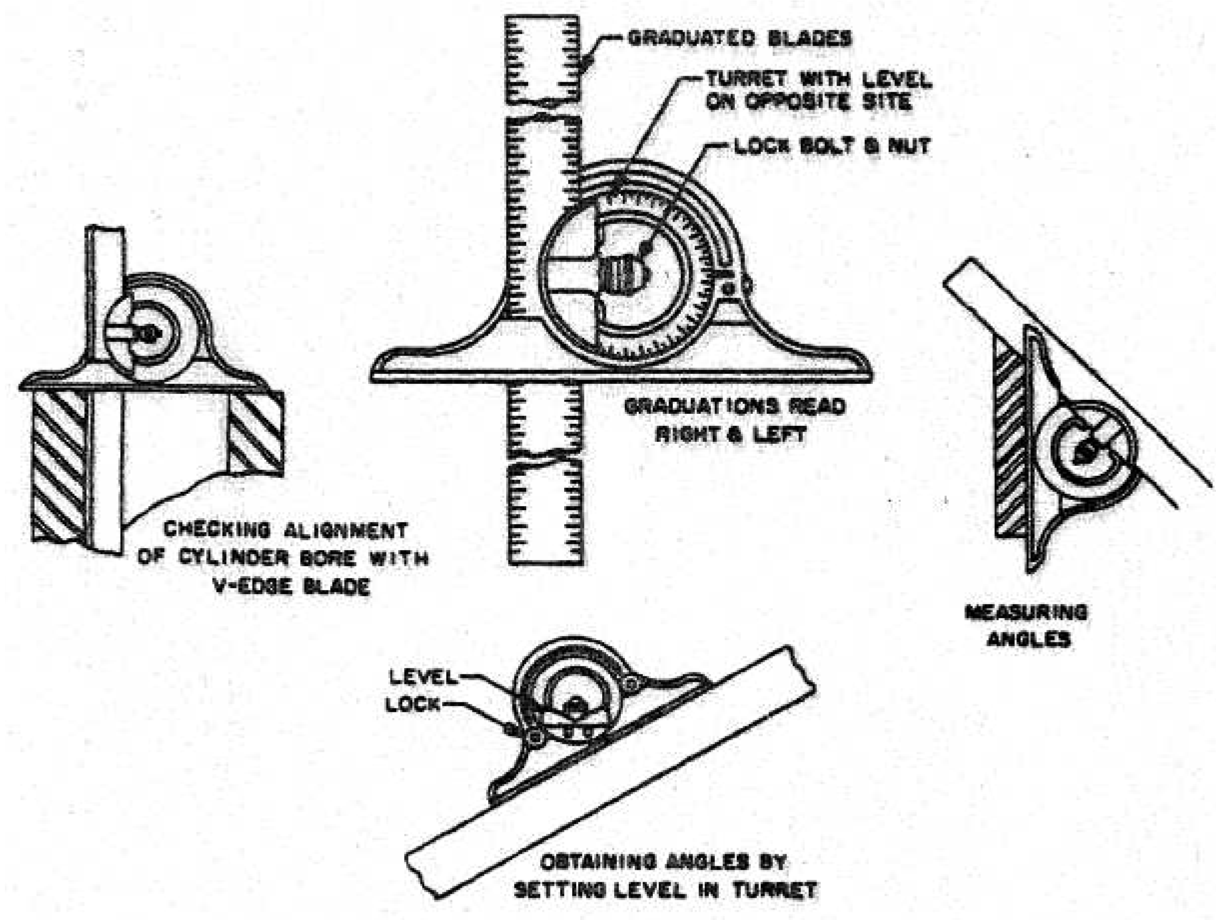


Figure 8-34. Uses for Protractor

8.18: Tube Cutters

To provide a good tube joint the tube must be cut off square. This is best accomplished by the use of a tube cutter which is shown in Figure 8-35. Cut tubing as follows:

1. Clamp standard tube cutter over tube.

2. Rotate cutter towards its open side, gradually feeding cutting wheel downward by turning adjustable screw. Do not feed wheel too rapidly. The cutting wheel should be fed only while the cutter is being rotated, as dents will be caused in tubing when the wheel is fed while the cutter is not moving. Moderate or light tension on the adjustable screw will maintain an even tension on the cutting wheel. This prevents bending and avoids excessive burrs on soft tubing.

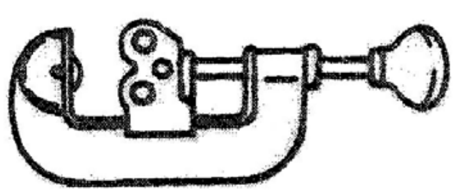


Figure 8-35. Tube Cutter

8.19: Tube Benders

Tubing installations requiring bends must be accomplished with minimum distortion and constriction of the tubing. Attempts at tube bending with improper tools or by incorrect methods will result in constricted sections of bend with a reduction of fluid flow.

When correct equipment and methods are used, bends with little or no flattening are produced. Common defects in bending are flattening, kinking, or wrinkling.

Flattened bends result from not having the mandrel far enough forward in the tube, by bending thin-walled tubes without a mandrel, or when too short a radius is attempted.

A kinked and flattened bend is caused by slipping of the tube in the bender. Tubes must be firmly clamped by the clamp block to prevent slippage during the bending process.

Wrinkled bends result when thin-walled tube is bent without a supporting mandrel.

When hard tubing is bent, breakage will sometimes occur when the mandrel is too far forward in the tube or when too short a radius is attempted.

A typical hand tube bender is shown in Figure 8-36. See Operating Instructions for the Hand Tube Bender starting in the next section. A bench installed tube bender is shown in Figure 8-37.

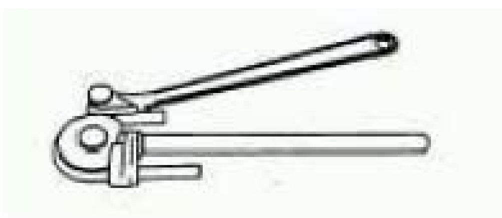


Figure 8-36. Hand Tube Grinder

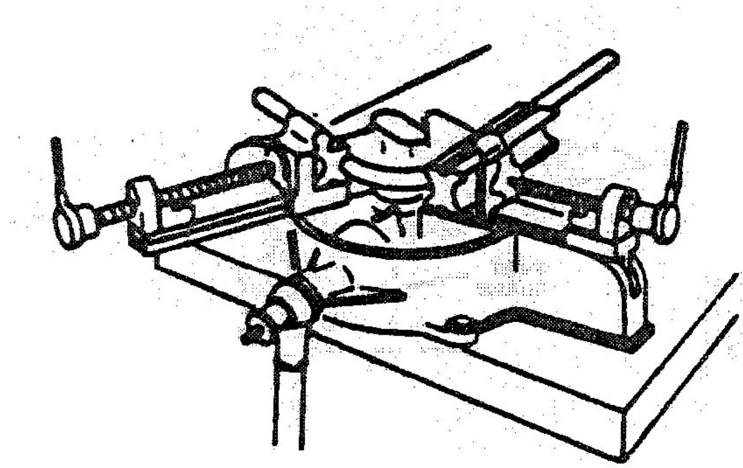


Figure 8-37. Bench Tube Grinder

8.19.1: Instructions for Operating Lever-Type Tube Benders

This bender can be used for bending steel, stainless steel, copper, aluminum and other metal tubing of bending temper. Extremely thin walled and/or hard temper tubing should be avoided.

BENDER SETUP

1. Raise form handle. (Figure 8-38)

Figure 8-38. Raise Form Handle

2. Position tubing in groove as shown. Also be sure that the tube is engaged with the tube clamp.

3. Lower the form handle to position shown. (Figure 8-39)

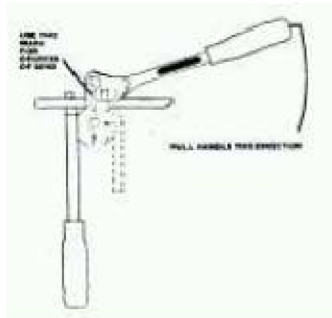


Figure 8-39. Lowering the Form Handle

4. Then pull lever handle in direction of arrow until the desired bend angle is obtained.

5. Degree of bend is indicated by mark on form handle and shown in Figure 8-39. Bends up to 180 degrees can be made in one sweep of the handle.

90 Degree Bends

1. Measure from end of tube (first bend) and place mark on tubing.

2. Position tube in bender as shown in Figure 8-40. If the end from which you measured is left of the tube clamp, the measured mark should be directly over graduation "L" located on the right side of the form lever and shown in Figure 8-40.

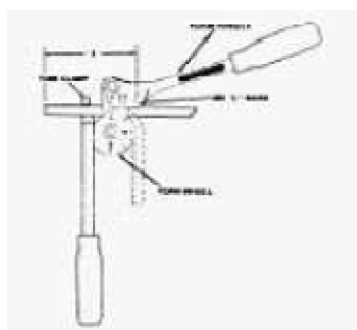


Figure 8-40. Using the “L” Mark

3. If the end from which you measured is placed to the right of the tube clamp, set the mark on the tube directly over graduation “R” located on the form lever and shown in Figure 8-41. With a steady motion, pull form lever handle around until the "0" mark on form handle is directly opposite the 90 degree mark on form wheel.

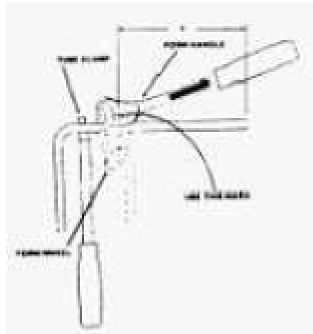


Figure 8-41. Using the “R” Mark

4. If more than one bend is required (Figure 8-42), measure from the center line of the first bend leg and mark per drawing dimension. Proceed with bend as described in Step 2.

Figure 8-42. Measuring for More Than One Bend

Single 45 Degree Bends

A single 45 degree bond may be made by measuring from end of tube to where bend is to be located and placing a mark at this point. Place tube in bender so that the mark tube is located directly in line with the "45" graduation on form handle shown in Figure 8-43.

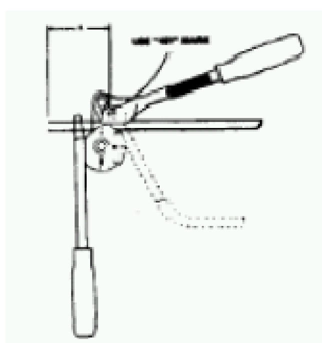


Figure 8-43. Using the “45” Gradation

Double 45 Degree or 30 Degree Offset Bends

When forming a tube offset, it is necessary to make two bends. It is important to mark the tube at both bend locations before proceeding. After marking the tube proceed as explained under “45 Degree Bends".

STEPS FOR FIGURING OFFSET BENDS

1. Determine the total amount of offset required (dimension "Y" in diagram) and angle of offset. Wherever possible use 45 degree offset bends. This will enable you to figure the total amount of tubing required for a given app1ication as explained in section on How to Figure Length of Tubing Required for 45 Degree Offset Applications.

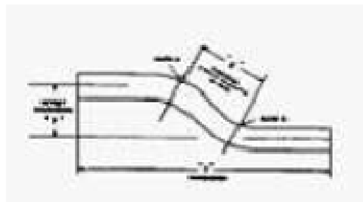


Figure 8-44. Determining Total Offset Required

2. Figure the length of tube which is needed to meet your offset requirements (X in dimension diagram of Figure 8-45) from the following table. For example: Say the amount of offset you require ("Y" dimension, Step 1) is 2-1/2" and the offset angle is 45 degrees. Check the 45 degree column and find 2-1/2". The figure next to this is the amount of tubing required for the offset bend you want ("X" dimension). In this case it's 3-17/32".

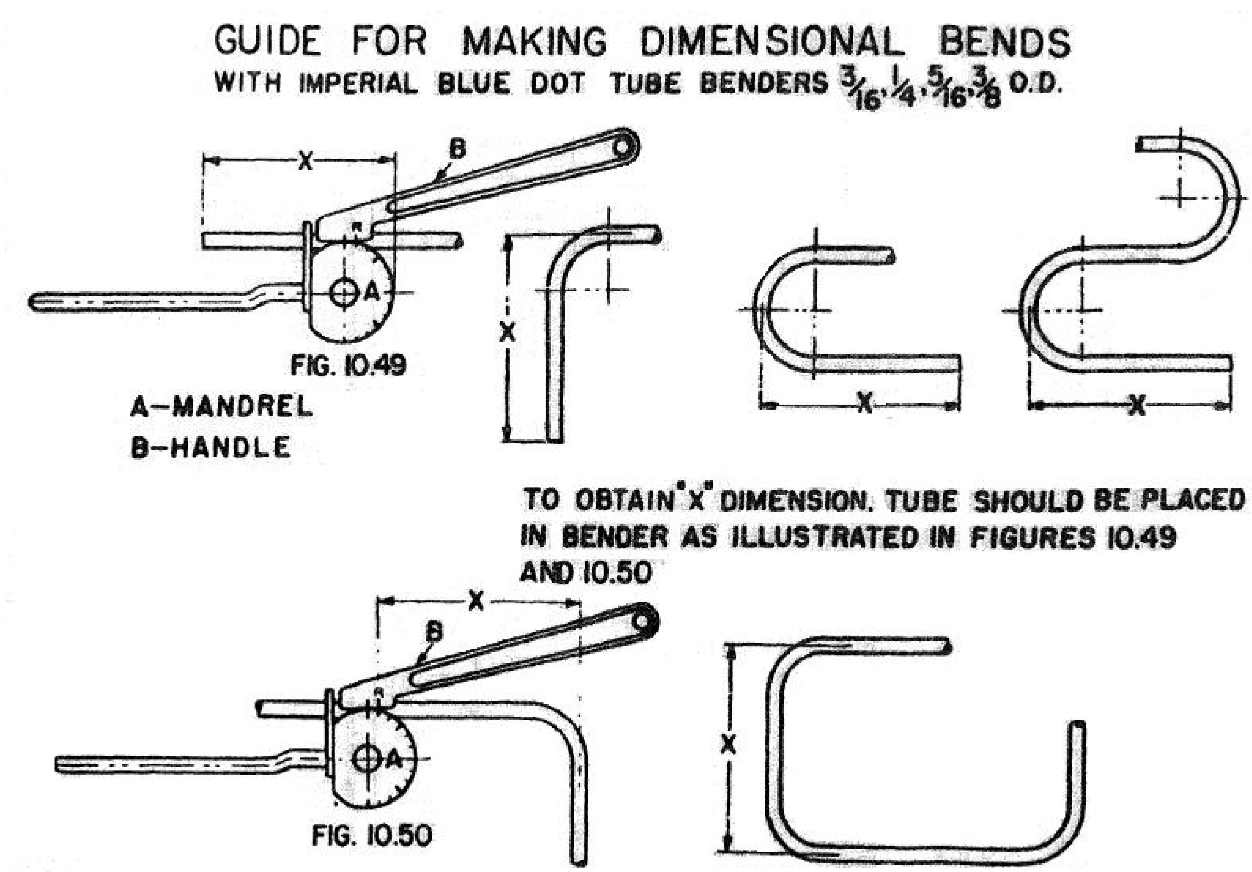


Figure 8-45. Guide for Making Dimensional Bends

3. Determine where you want the center of the offset bend on the tube and make a reference mark (A). Now measure off the "X" dimension (determined in Step 2, example 3-17/32") starting from the reference mark and make a second mark (B). You are now ready to make the bends.

4. Align mark (A) with reference mark 45 degrees on bender and proceed with first bend. Then align (B) with 45 degree mark and make second bend in proper direction.

   NOTE: When the amount of offset exceeds what is listed on the table, choose an offset from the table which is a multiple of the offset you need. Look this up on the table and multiply the "X" dimension by the multiple you used. Example: For an offset of 20" for a 45 degree bend. Look up 5" offset in Table 8-10 in the 45 degree column and multiply "X" dimension (7-1/16") by 4. The resulting "X" dimension you would use is 28-1/4".

Table 8-10. Offset Bend Calculator

ANGLE OF OFFSET 30° AMOUNT OF OFFSET		ANGLE OF OFFSET 45° AMOUNT OF OFFSET	
(Y Dimension)	(X Dimension)	(Y Dimension)	(X Dimension)
1	2	1	1-13/32
-1/8	2-1/4	-1/8	1-19/32
-1/4	2-1/2	-1/4	1-25/32
-3/8	2-3/4	-3/8	1-15/16
-1/2	3	-1/2	2-1/8
-5/8	3-1/4	-5/8	2-5/16
-3/4	3-1/2	-3/4	2-15/32
-7/8	3-3/4	-7/8	2-21/32
2	4	2	2-13/16
-1/8	4-1/4	-1/8	3
-1/4	4-1/2	-1/4	3-3/16
-3/8	4-3/4	-3/8	3-11/32
-1/2	5	-1/2	3-17/32
-5/8	5-1/4	-5/8	3-23/32
-3/4	5-1/2	-3/4	3-7/8
-7/8	5-3/4	-7/8	4-1/16
3	6	2	4-1/4
-1/8	6-1/4	-1/8	4-13/32
-1/4	6-1/2	-1/4	4-19/32
-3/8	6-3/4	-3/8	4-25/32
-1/2	7	-1/2	4-15/16
3-5/8	7-1/4	3-5/8	5-1/8
-3/4	7-1/2	-3/4	5-1/16
-7/8	7-3/4	-7/8	5-15/32
4	8	4	5-21/32
-1/8	8-1/4	-1/8	5-27/32
-1/4	8-1/2	-1/4	6
-3/8	8-3/4	-3/8	6-3/16
-1/2	9	-1/2	6-3/8
-5/8	9-1/4	-5/8	6-17/32
-3/4	9-1/2	-3/4	6-23/32
-7/8	9-3/4	-7/8	6-29/32
5	10	5	7-1/16
-1/8	10-1/4	-1/8	7-1/4
-1/4	10-1/2	-1/4	7-7/16

-3/8	10-3/4	-3/8	7-19/32
-1/2	11	-1/2	7-25/32
-5/8	9-1/4	-5/8	7-31/32
-3/4	9-1/2	-3/4	8-1/8
-7/8	9-3/4	-7/8	8-5/16
6	12	6	8-15/16

NOTE: Keep bender and form handle grooves lubricated. Keep oil away from form wheel grooves.

8.19.2: Flaring Machine

The flaring machine is designed for efficient production flaring of pressure tubing. It consists of an electric driven motor which drives a spindle inserted with a 37-degree flaring center tool or squaring and burring tool; the rpm of this spindle is regulated by the variable speed control rotor handle, and the horizontal movement of the spindle is manually operated by a hand lever. The moving jaws which contain the flaring dies will clamp and secure the tubing. The jaws are operated by a compressed air actuator and controlled by a foot pedal air valve. It is necessary to depress the foot pedal air valve and move the operating lever to the right (approximately one inch) in order to close the movable jaw. (See Figure 8-52)

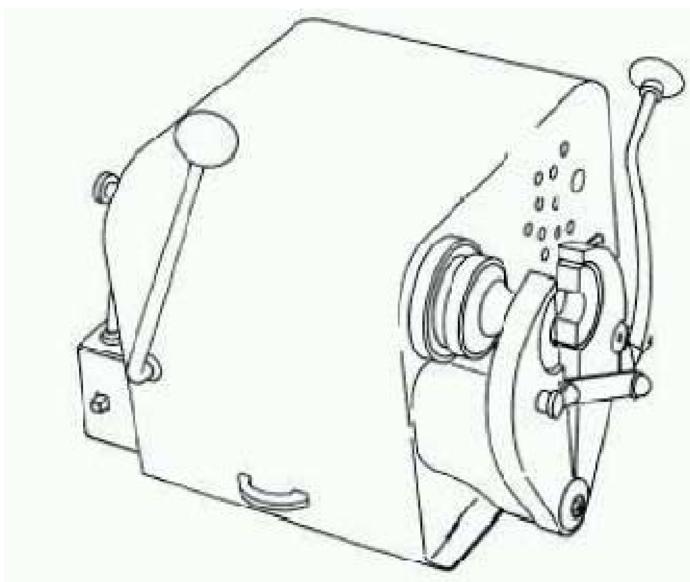


Figure 8-52. Flaring Machine

Procedures for flaring tubing are as follows:

1. Install 37-degree flaring center into small tool adapter spindle.

2. Adjust calibrated ring on spindle for number which is tube OD, to with marked groove, by use of an Allen-type screwdriver.

3. The die adapter is installed in the movable jaws and the matched flaring dies of the correct tube OD size are placed in these adapters. All foreign matter in the grooves of the jaws, adapter, and dies will be removed prior to assembly of these parts.

4. The tube stop finger on the fired jaw should be allowed to drop to dead center of the flaring die by means of the two-stage stops. The finger adjusting screw should be turned to adjust the amount of tube length which sticks through the die to determine the correct flare diameter.

5. Slowly operate hand lever of horizontal spindle toward flaring die; then adjust and lock positive spindle positive stopscrew, located on top of machine casting, to keep flaring center from coining tube and yet bringing tube flaring to correct diameter.

6. Start electric motor by pushing switch to ON.

7. Position tube into rear flare die and against finger stop.

8. Depress and hold foot pedal air valve and move operating lever slowly until movable jaws close and clamp tube.

9. Continue to use manual operating lever to flare tube until completed; release it and remove flared tube.

8.19.3: Superpressure Fitting Installation

Supplier-furnished tools shall be used to prepare the tube end for fitting into the various size valves and fittings (1/4 - 9/l6-inch size). Preparation of tubing consists of coning and threading operations.

CONING SUPERPRESSURE TUBING

Care should be taken to avoid nicking or scratching the tubing during coning and threading operations. The pressure rating of the tubing may be greatly affected if tubing is nicked or scratched.

1. Clamp tubing in a smooth-jaw machinist's vise, with soft material or wood over jaws.

2. Unscrew clamping ring of forming tool to rear position.

3. Slide forming tool over tubing until tubing end butts against cutting edge.

4. Tighten setscrew to hold forming tool firmly on tubing. See Figure 8-47.

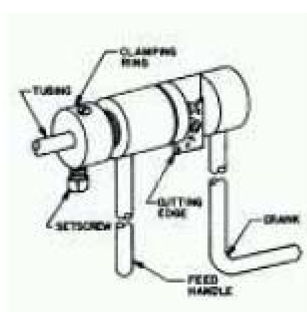


Figure 8-47. Forming Tool for Superpressure Tubing

5. Lubricate tubing-cutting edge junction.

   NOTE: Cutting edge should be lubricated freely and frequently with an approved sulphur base cutting oil during coning operation.

6. Rotate crank at approximately one turn per second while rotating feed handle clockwise until tubing has attained the required cone tip diameter (Table 8-11).

   NOTE: Cutting edge will last longer when a uniform, light feed, just heavy enough to keep the cutting edge cutting continuously, is employed. If too light a cut is taken, surface will work-harden and make a smooth cut difficult; too heavy a cut may break the cutting edge.

Table 8-11. Supressure Tubing Threads

OD and ID of Tubing (Inch)	**Left-Hand Thread**	**Length of Thread (Tip of Cone to End of Thread) (Inch)**	**Diameter of Cone Tip (Inch)**
1/4 x 1/16	1/4 – 28	9/16	1/8
1/4 x 3/32	1/4 – 28	9/16	1/8
3/8 x 1/8	3/8 – 24	3/4	7/32
9/16 x 3/16	9/16 – 18	15/16	9/32
9/16 x 5/16	9/16 - 18	15/16	11/32

7. Hold feed handle still at end of cut and make several turns with crank to ensure smooth finish on cone.

8. Loosen setscrew and remove forming tool from tubing.

ASSEMBLY OF THREADING TOOL

1. Assemble threading tool (Figure 8-48) as follows:

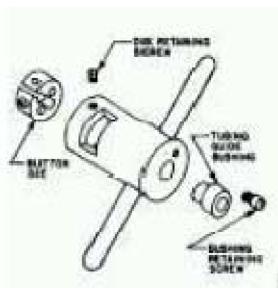


Figure 8-48. Threading Tool for Superpressure Tubing

2. Select proper size tubing guide bushing for tubing, to be threaded, and insert it into threading tool, aligning curved slot with retaining screw hole.

3. Secure tubing guide bushing with bushing retaining screw.

4. Partially unscrew three die retaining screws, and insert appropriate button die, adjusted for two-thirds of required thread depth.

   NOTE: The surface on which the thread size is marked shall face the guide bushing end of the threading tool.

5. Align button die until two conical recesses and slot of die line up with three die retaining screws.

6. Tighten die retaining screws.

THREADING SUPERPRESSURE TUBING

1. Slide threading tool (guide bushing end first) over rigidly held coned tubing.

2. Lubricate tubing and die freely with an approved sulphur-base cutting oil.

3. Rotate threading tool counterclockwise approximately 1-1/2 to 2 revolutions; back off 30 degrees, and lubricate freely. Continue this procedure until required length of thread (Table 8-11) is attained.

4. Rotate threading tool clockwise until die disengages from tubing, and remove tool from tubing.

5. Remove button die from threading tool and adjust for full thread depth, or replace with different die set for full thread depth.

6. Install button die in threading tool and repeat steps 1 through 4.

Compressed Gas Bottles
Contents

9.1: Introduction

Compressed gas bottles or cylinders are used to transport and store such gases as nitrogen, helium oxygen, acetylene, argon, hydrogen, carbon dioxide, fluorine, and refrigerants at pressures up to 3,000 psi. Careful handling of these containers is essential to prevent serious accidents from the high pressures or dangerous gases involved. The following rules should be observed.

9.2: Storage

1. Store in compatible areas. Store fuel and oxidizers in separate areas.
2. Store upright and chained in position to prevent falling.
3. Store at temperatures of less than 125˚ F, and preferably out of the direct sunlight. In freezing weather keep valves dry.
4. Store containers marked “MT” or "full" separately.

9.3: Transport

1. Protective cap must be in place prior to movement.
2. Handle carefully. Do not drop or bang together.
3. Secure containers by chocks and chains or place on an approved rack.
4. Keep acetylene bottles upright. (They contain liquid acetone in a porous filler. The liquid may cause a fire if it gets into the regulator.)

9.4: Use

1. Open valves slowly and observe systems for leaks. If containers or cylinder valves leak, do not attempt repair. Return the cylinder to the vendor, clearly marking it as defective.
2. Regulators and pressure gages provided for use with a particular gas must not be used with other gases.
3. Do not use a wrench to close valves equipped with hand wheels.
4. Release the adjusting screw of the regulator before opening a cylinder valve; close the cylinder valve and release the pressure from the regulator before removing it.
5. Never lubricate bottle fittings. Lubricants can cause explosions upon contact with oxidizers.
6. Left-hand threads are indicated by a groove around the circumference of the nuts.
7. Leave at least 25 psi in empty bottles to prevent contamination.

8. Acetylene regulators must be set below 15 psi to avoid possible explosion.

9. Compressed gas bottles require an I.C.C. inspection every 5 years. This date is stamped on the neck of each bottle.

COMPRESSED GAS BOTTLES ARE POTENTIALLY DANGEROUS - TREAT THEM WITH RESPECT.

General Information for the Electrical Chapters
Contents

Page

10.1 Introduction and Scope

10.2 Electrical Measurements

10.2.1 Digital Multimeter

The modern hand-held digital multimeter has simplified most electrical measurements. Measurement functions generally found on a multimeter are:

- AC/DC voltage (V)
- AC/DC current (mA)
- Resistance (Ω) or conductance (nS)

Additional functions of the digital multimeter are:

- Peak detection for positive DC or AC RMS level
- Diode junction testing

10.2.1.1 Voltage Measurement

A voltmeter is used to measure the electromotive force (voltage) applied to a circuit or it may be used to measure the drop in voltage caused by a circuit component. The connection of the meter is made in parallel with the measured device. When the voltage value read on the meter is positive, the current is flowing in the direction from the positive lead to the negative lead. When the value is negative, current direction is negative to positive.

10.2.1.2 Current Measurement

An ammeter is used to measure current flowing through a circuit. It is connected in series with the line delivering the current, by disconnecting the line and inserting the meter.

CAUTION:
Be aware of the ammeter current rating. Measuring a current greater than the rated value will blow the internal fuse or damage the meter.

10.2.1.3 Resistance Measurement

An ohmmeter is used to measure the resistance of a circuit or a component and the meter is connected in parallel, like the voltmeter.

CAUTION:
The circuit must not have any voltages present when using the ohmmeter. Be sure to have all power turned off.

10.2.1.4 Conductance Measurement

As the ohmmeter is the measure of resistivity of a circuit, the conductance meter is, conversely, the measure of the conductivity of a circuit. They are inversely proportional to each other, so the conversion of resistance units (ohms, Ω) to conductance units (Siemens, S) is: 1/Ω= S. The connection for measuring conductance is the same as the ohmmeter.

10.2.1.5 Peak Hold Operation

The peak hold function provides short term memory of the most positive DC or AC RMS level. One would want to know these peaks to see if they fall within the limits of the current rating or fuse rating of a circuit. The peak hold function is intended to be used for voltage and current measurements.

10.2.1.6 Diode Junction Testing

An ohmmeter can be used to check semiconductor junctions in most transistors and diodes. The only requirement is that the voltage output at the ohmmeter leads exceed 0.7 VDC. Some meters have special ohm ranges used for diode measurements. Care must be exercised when using older meters, such as the Triplett, since on high resistance ranges the meter may output sufficient voltage to destroy most semiconductor devices. A diode or transistor is checked by measuring the forward and reverse bias junction resistances. For a good diode the two resistance ratios should exceed 1000 to 1. Some semiconductor devices, such as Light Emitting Diodes (LED's) cannot be checked with an ohmmeter.

The ranges of 200k Ω, 20k Ω, and 200 Ω generate an internal voltage too small to overcome the diode cut-in voltage. The ranges of 20M Ω, 200k Ω, and 2k Ω, however, do register a voltage which turn on the PM junction of a diode. Measuring the resistance across the diode using the three latter ranges, can be used to test correct forward and reverse bias conditions of a diode. Forward bias will yield a reading of about .900 and reverse bias will show the over-range display. Some devices, such as Light Emitting Diodes (LED's), may not show proper readings due to their high cut-in voltage.

10.2.2 Oscilloscope

The oscilloscope monitors a voltage signal as a function of time. It helps in displaying periodic wave signals and transient behavior of high frequency responses, both of which cannot be picked up by ordinary multimeters. Measurements that can be made with an oscilloscope include:

- Peak to peak voltages
- Wave periods or frequencies
- Transient slopes and overshoots
- High frequency noise
- Voltage ripple
- Transient noise spikes

The oscilloscope can present both DC and AC levels which are important in analyzing voltage signals.

10.2.2.1 Oscilloscope Operation

1. Power up the oscilloscope.
2. Connect external voltage source to input connector of display channel.
3. Depress the correct channel display button to allow the input signal to be seen on the screen. *For example, to see any signal entering the Channel A input connector, the display Channel A button must be depressed.*
4. Set the volts/division and time/division to values corresponding to the magnitude and frequency of the input signal.
5. Turn the main trigger level knob until a clear and stable signal appears on the display.

10.2.2.2 Basic Features of the Oscilloscope

1. **BEAM FIND** - Pressing this button increases the intensity and compresses the display within the viewing area. This button helps locate the signal when not in the immediate display area.
2. **BEAM INTENSITY** - Controls the brightness of the CRT display.
3. **FOCUS** - Adjusts the writing beam for the sharpest trace. Always keep this display focused to prevent damaging the CRT internally.
4. **CHANNEL A (CHA)** - Displays the Channel A input signal.
5. **CHANNEL B (CHB)** - Displays the Channel B input signal.
6. **A&B** - This feature displays the algebraic sum of the Channel A and Channel B input signals.
7. **ALTERNATE (ALT)** - Channel A and B signals (if the oscilloscope has a dual-channel feature) are displayed alternately on consecutive sweeps.
8. **CHOP** - Channels A and B signals are displayed simultaneously by switching between channels at a given rate.
9. **TRIGGER A** - Selects a sample of the Channel A signal as a trigger signal.
10. **TRIGGER B** - Selects a sample of the Channel B signal as a trigger signal.
11. **AC** - In the AC position, the dc component of the input signal is blocked. This helps with efforts concentrated solely on the high frequency part of a signal; for example, noise, spikes, ripple, etc.
12. **GRD** - The input signal is disconnected from the amplifier and the amplifier input is grounded. This is used before switching to DC to set beam position on the screen.
13. **DC** - All elements of the input signal (ac and dc) are passed to the vertical amplifier.
14. **VOLTS/DIVISION** - Selects the vertical deflection factor in an organized sequence, usually from 0.005V/div to 2OV/div.
15. **TIME/DIVISION** - This feature controls the main-sweep rate.
16. **INPUT** - The external input signal is connected here. Usually a BNC connector is used to apply external signals to the Channel A or Channel B.
17. **TRIGGER LEVEL** - Selects the voltage level on the input trigger signal where the sweep is triggered.
18. **EXTERNAL TRIGGER** - This is the connection for an external trigger input. This button is normally not used.

10.3 Electrical Components

10.3.1 Resistors and Capacitors

The color of the bands or dots on a resistor or capacitor are codings, which reveal resistance in ohms (Ω) or capacitance in microfarads (µF). The voltage rating of a resistor or capacitor can be determined only by referring by part number to manufacturer's specifications. The colors of the first two bands (or dots) represent the first and second digits of the resistance or capacitance. The following RETMA color code (Table 10-1) shows the values of the different colors. Thus a green band (5) and a red band (2) represent the number 52. The color of the third band (or dot) represents the value of the multiplier used with the first and second digits. If a green band (5) and a red band (2) were followed by a third yellow band (10K), the value represented would be 52 x 10K or 520,000. The fourth color band indicates the tolerance. The absence of the fourth band indicates a tolerance of 20%. Fifth and sixth color bands are employed on capacitors only. They give the voltage in hundreds of volts. Thus, if the colors of these bands were red and orange, they would represent the digits 2 and 3. As these colors represent voltage in hundreds of volts, red and orange represent 2300 volts.

Additional bands, represented by the letters G, H, I, and J in Figure 10.1 are manufacturer's codings. They indicate classes and temperature coefficients. These values are not shown on the Table and must not be considered when the color bands of ceramic radial lead, axial lead, and standoff capacitors are being interpreted.

Table 10-1. RETMA Color Code for Resistors and Capacitors

Color	Digit	Resistors		Molded Paper Capacitors		Molded Mica Capacitors		Ceramic Capacitors	
		Multiplier	Tolerance	Multiplier	Tolerance	Multiplier	Tolerance	Multiplier	Tolerance
Black	0	1		1	±20%	1	±20%	1	±20% (or 2.0 µµfd*)
Brown	1	10		10		10		10	±1%
Red	2	100		100		100	±20%	100	±2%
Orange	3	1K		1K		1K	±3%	1K	±2.5%
Yellow	4	10K		10K	±5%	10K		10K	
Green	5	100K					±5%		±5% (or 0.5 µµfd*)
Blue	6	1000K							
Violet	7	10,000K							
Gray	8	100,000K						0.01	±0.25 µµfd*
White	9	1,000,000K			±10%			0.1	±10% (or 1.0 µµfd*)
Gold		0.1	±5%	0.1	±5%	0.1	±5%		
Silver		0.01	±10%		±10%	0.01	±10%		
None			±20%		±20%				

Resulting values are in ohms for resistors, and in µµfd for capacitors. “K” indicates thousand. Capacitance less than 10 µµfd.

10.3.2 Soldering Electrical Connectors

Soldered joints are often used in electrical and electronic circuits and if properly made, make more reliable connections than most mechanical devices. An acceptable soldered joint, however, requires proper techniques and correct materials. Surfaces to be soldered or tinned must be free of oxides, scale, oil, and other foreign matter. This cleaning should be performed just before flux is applied. Rosin is the only flux acceptable for use in instrumentation work. It may be either a liquid rosin flux or a rosin core solder. Eventual corrosion of circuit components will occur if acid fluxes are used because of the difficulty of removing all traces of flux from the finished joint. Whenever possible, surfaces to be connected by solder should be tinned before being joined. Tinning makes surfaces easier to join and results in more positive connections. Before acceptable tinning can be achieved, the iron itself must be properly tinned. First one side of the hot iron is cleaned, exposing the metal. Rosin core solder is applied immediately. The process is repeated for the other soldering faces, excess solder being wiped off with a clean rag. The iron should also be wiped frequently during soldering operations. Solder is always applied to the work, not to the soldering iron. Before the soldering operation is attempted, the iron should be clean, properly tinned, and heated to the proper working temperature. The iron should be held against the parts to be joined until the solder flows smoothly and envelops the work. Movement of the parts before the solder has solidified will result in a "cold joint," which has a white appearance rather than the normal shiny silver. Cold joints tend to be of high resistance and may have a bad effect on the circuit. See Figure 10-1 for proper application of solder to contact pins.

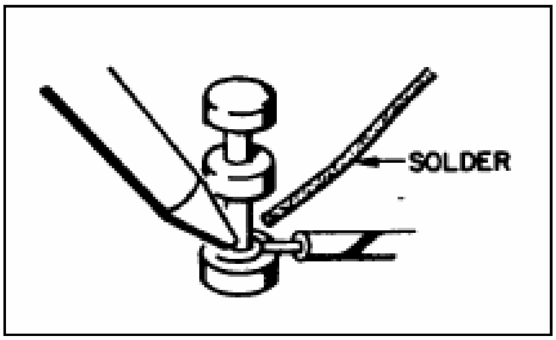


Figure 10-1. Method of Applying Solder to Contact Pins

10.3.2.1 Wire Preparation

The correct preparation and tinning of wire prior to soldering it to a component is one of the basic steps in securing a good soldered connection. Wire strippers must be adjusted so that none of the strands of wire are cut or damaged in any way. If the wire is damaged, it might ultimately be the cause of a unit failure in the finished installation.

When stranded conductors are stripped, the strands have a tendency to unwind. If this condition occurs, the strands should be twisted back into their former position prior to tinning. After wire has been stripped and all frayed strands twisted back into place, it is ready for tinning. A small amount of solder should be applied to the tip of the iron. The wire is then placed on top of this solder and allowed to heat. When the wire has reached the temperature of the iron, solder will flow into its strands. At this time a small amount of solder is applied to the wire, not the iron. Solder is then allowed to flow until the wire has absorbed enough to tin every strand only enough to accomplish this purpose must be used. Too much solder will increase the diameter of the wire and will prevent it from passing through the hole in the lug. Too much solder will also make it hard to form around the lug. Too little solder will allow the strands to fray and will result in a poor connection. To prevent the wire from separating from the terminal under vibration and shock conditions, the following precautions should be observed:

1. The wire lead must be protected from damage during installation. Sharp bends should be avoided.
2. The lead must be wrapped sufficiently around the terminal. The lead wrap should be at least three quarters turn but not in excess of one complete turn.
3. The lead must allow a small degree of flexibility. Typical methods of wrapping are shown in Figure 10-2.

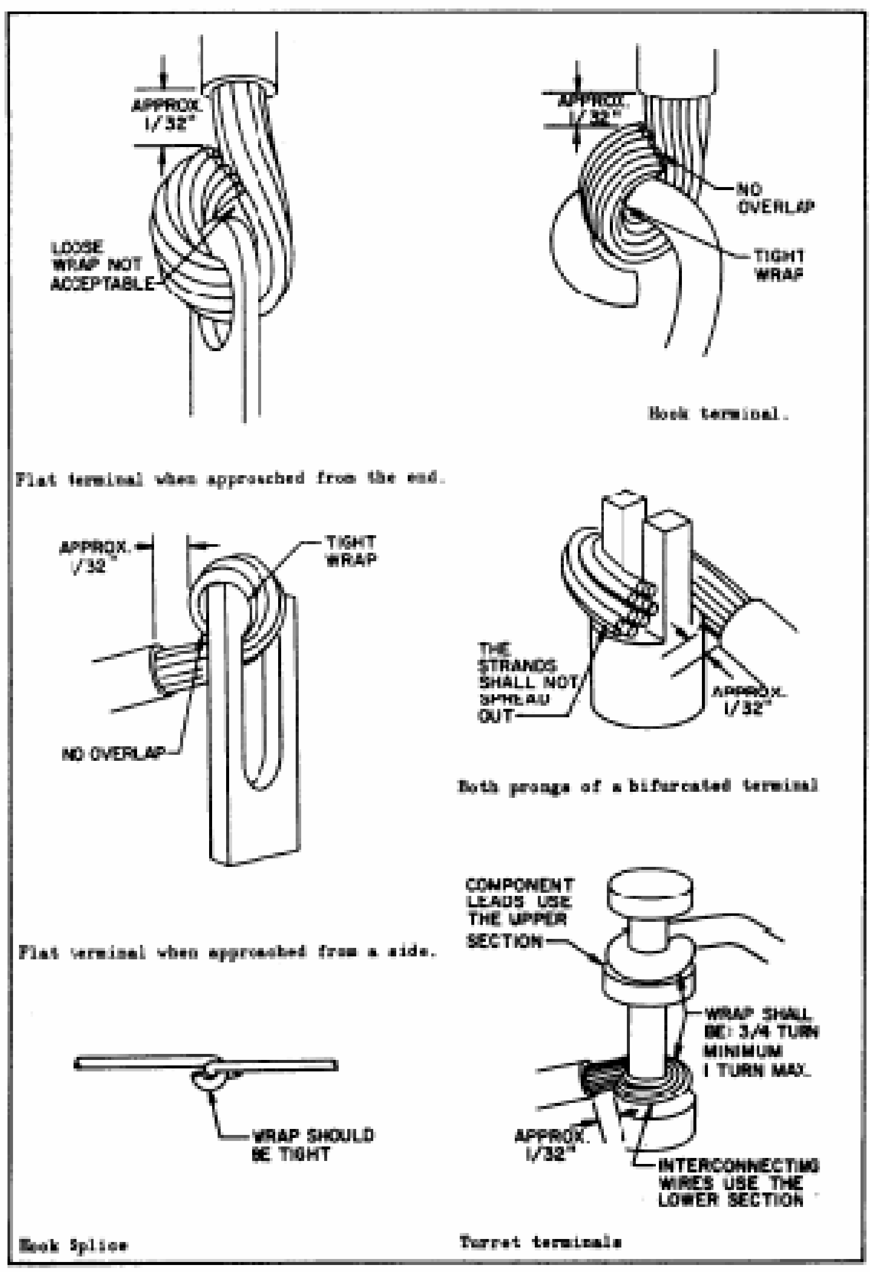


Figure 10-2. Methods of Wrapping Wire Around Terminals or Splices

10.3.2.2 Shielded Wire Preparation

Shielded wire is often used in instrumentation circuits and requires special preparation, i.e., one end of the shield of this type of wire being grounded by pig-tailing, while the other end is terminated by insulating it from possible grounding.

In the pig-tailing operation, the outer covering of the shielded wire is carefully removed, care being taken not to damage the shield. The shield is then pushed back from the conductor or conductors and the strands of the shield carefully separated with a scribe. The inner conductor is then worked through the shield at the point where the strands are most separated, and the shield is bent to one side. The shield is next cut approximately 3/8 in. Using a heat shunt, the shield is then soldered to the ground wire.

As shown in Figure 10.3, a piece of Temflex is inserted over the conductor or conductors and tied. A larger piece of Temflex is installed over the entire connection and tied.

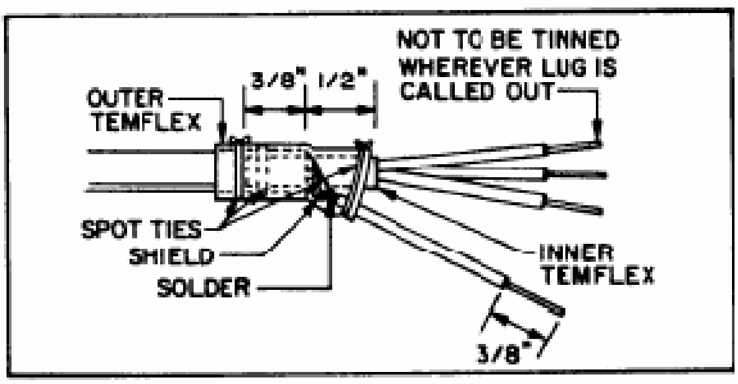


Figure 10-3. Shielded Wire Preparation

One method of so terminating an ungrounded shield is shown in Figure 10.4 and consists of the following steps:
(1) The outer nylon jacket is cut back about 7/8 in. from the end of the wire.
(2) The metal shield is cut back as shown, care being taken not to damage the inner nylon jacket.
(3) The desired length of inner nylon jacket is then removed, using the correct wire stripper.

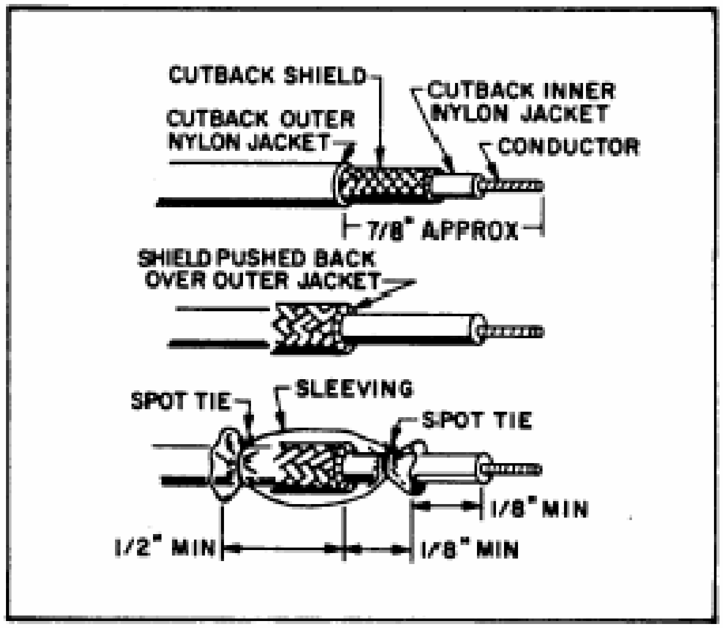


Figure 10-4. Method of Terminating Ungrounded Shield

10.3.2.3 Connector Preparation

The major cause of failure in connectors is poorly soldered wires. Special care should be taken to fill the solder pots of connectors and to prevent the rosin flux from sinking to the bottom and taking up space that should be filled with solder. A poorly filled solder pot is subject to cracking under vibration. The wire may come loose, resulting in a poor electrical connection which might ultimately result in the failure of a whole unit. To obtain a correctly filled solder pot, solder must be fed slowly. See Figure 10-5 for correct method of preparing connector for soldering.

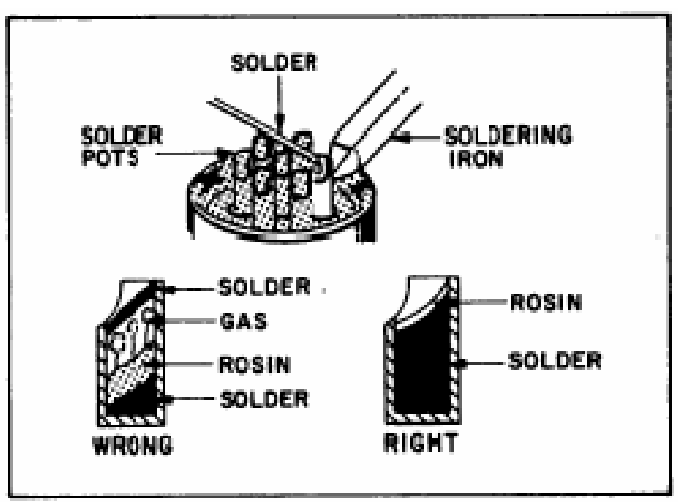


Figure 10-5. Preparation for Soldering on Connectors

To properly solder a cable to a connector, the following procedure is recommended:

1. Strip the wire and insert it in the pot – when bottomed, approximately 1/32" of the wire should be exposed above the pot (see Figure 10-6). Cut wire to fit.
2. Install insulation tubing above the exposed end of the wire.
3. Tin the entire length of the stripped wire that is to be inserted in the pot of the connector. The insulation must not be discolored or curled by this operation.
4. Insert a small piece of solder in the pot of the connector.
5. Place the iron tip on the back of the pot. When the solder melts and bubbles; insert the conductor into the pot until it is bottomed. If necessary, apply a small amount of solder to the joint (see Figure 10-5).
6. Remove the iron and hold the conductor steady until the solder cools and hardens. The contour of the individual strands of wire should be easily seen when the solder has cooled.
7. Clean the joint using an acid brush dipped in Isopropyl Alcohol to remove flux residues.
8. Slip the insulation tubing over the soldered connection.

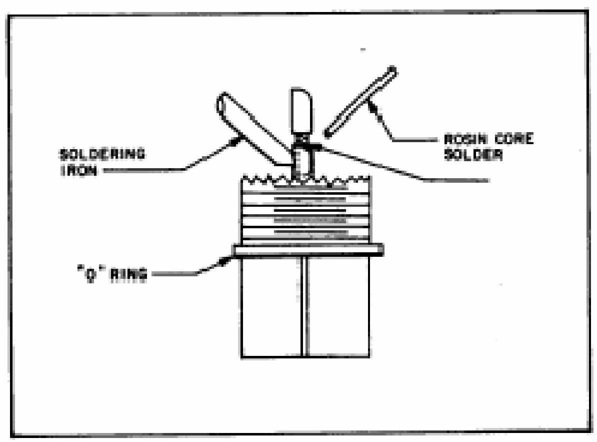


Figure 10-6. Joining Cables to Connectors

10.4 Electrical Industrial Standards and Practices

10.4.1 Purpose

The purpose of this section is to provide general information on the requirements of the National Electric Code for Wiring and Protection, Wiring Methods and Materials, General Electrical Equipment, Electrical Hazardous Area Classifications, and General Electrical Documentation.

10.4.2 Wiring Protection

10.4.2.1 Feeders

The minimum feeder-circuit conductor size, before the application of any adjustment or correction factors, shall have an allowable ampacity not less than the non-continuous load plus 125 percent of the continuous load. Exception No. 1: Where the assembly, including the Overcurrent devices protecting the feeder(s), is listed for operation at 100 percent of its rating, the allowable ampacity of the feeder conductors shall be permitted to be not less than the sum of the continuous load plus the non-continuous load. Exception No. 2: Grounded conductors that are not connected to an over-current device shall be permitted to be sized at 100 percent of the continuous and non-continuous load.

10.4.2.2 Overcurrent Protection

Where a feeder supplies continuous loads or any combination of continuous and non-continuous loads, the rating of the over-current device shall not be less than the non-continuous load plus 125 percent of the continuous load. Exception No. 1: Where the assembly, including the Overcurrent devices protecting the feeder(s), is listed for operation at 100 percent of its rating, the ampere rating of the over-current device shall be permitted to be not less than the sum of the continuous load plus the non-continuous load.

Unless specifically permitted in the National Electric Code Section 240.4(E) or (G), the over-current protection shall not exceed after any correction factors for ambient temperature and the number of conductors have been applied.

(1) 18 AWG Copper - 7 amperes, provided the continuous loads do not exceed 5.6 amperes
(2) 16 AWG Copper - 10 amperes, provided the continuous loads do not exceed 8 amperes
(3) 14 AWG Copper - 15 amperes
(4) 12 AWG Aluminum and Copper-Clad Aluminum - 15 amperes
(5) 12 AWG Copper - 20 amperes
(6) 10 AWG Aluminum and Copper-Clad Aluminum - 25 amperes
(7) 10 AWG Copper - 30 amperes

10.4.2.3 Grounding

The following general requirements identify what grounding and bonding of electrical systems are required to accomplish. The prescriptive methods contained in Article 250 of the National Electric Code shall be followed to comply with the performance requirements of this section.

<u>(A) Grounded Systems</u>
(1) Electrical System Grounding. Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.
An important consideration for limiting the imposed voltage is the routing of bonding and grounding conductors so that they are not any longer than necessary to complete the connection without disturbing the permanent parts of the installation and so that unnecessary bends and loops are avoided.

(2) Grounding of Electrical Equipment. Normally non– current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials.

(3) Bonding of Electrical Equipment. Normally non– current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

(4) Bonding of Electrically Conductive Materials and Other Equipment. Normally non–current-carrying electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

(5) Effective Ground-Fault Current Path. Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a low-impedance circuit facilitating the operation of the over-current device or ground detector for high-impedance grounded systems. It shall be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source. The earth shall not be considered as an effective ground-fault current path.

(B) Ungrounded Systems

(1) Grounding Electrical Equipment. Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth in a manner that will limit the voltage imposed by lightning or unintentional contact with higher-voltage lines and limit the voltage to ground on these materials.

(2) Bonding of Electrical Equipment. Non–current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the supply system grounded equipment in a manner that creates a low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

(3) Bonding of Electrically Conductive Materials and Other Equipment. Electrically conductive materials that are likely to become energized shall be connected together and to the supply system grounded equipment in a manner that creates a low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

(4) Path for Fault Current. Electrical equipment, wiring, and other electrically conductive material likely to become energized shall be installed in a manner that creates a low impedance circuit from any point on the wiring system to the electrical supply source to facilitate the operation of over-current devices should a second ground fault from a different phase occur on the wiring system. The earth shall not be considered as an effective fault-current path.

10.4.3 Wiring Methods and Materials

Conductors of AC and DC circuits, rated 600 volts, nominal, or less, shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. All conductors shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway. Otherwise, AC and DC circuits must be separated in different enclosures, cables, or raceways.

10.4.3.1 Cable Tray

Cable Tray System. A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten or support cables and raceways.

Uses Permitted. Cable tray shall be permitted to be used as a support system for service conductors, feeders, branch circuits, communications circuits, control circuits, and signaling circuits. Cable tray installations shall not be limited to industrial establishments. Where exposed to direct rays of the sun, insulated conductors and jacketed cables shall be identified as being sunlight resistant. Cable trays and their associated fittings shall be identified for the intended use.

Multi-conductor Cables Rated 600 Volts or Less. Multi-conductor cables rated 600 volts or less shall be permitted to be installed in the same cable tray.

Number of Multi-conductor Cables, Rated 2000 Volts or Less, in Cable Trays. The number of multi-conductor cables, rated 2000 volts or less, permitted in a single cable tray shall not exceed the requirements of this section. The conductor sizes herein apply to both aluminum and copper conductors.

Any Mixture of Cables. Where ladder or ventilated trough cable trays contain multi-conductor power or lighting cables, or any mixture of multi-conductor power, lighting, control, and signal cables, the maximum number of cables shall conform to the following:

(1) Where all of the cables are 4/0 AWG or larger, the sum of the diameters of all cables shall not exceed the cable tray width, and the cables shall be installed in a single layer. Where the cable ampacity is determined according to 392.11(A)(3), the cable tray width shall not be less than the sum of the diameters of the cables and the sum of the required spacing widths between the cables.
(2) Where all of the cables are smaller than 4/0 AWG, the sum of the cross-sectional areas of all cables shall not exceed the maximum allowable cable fill area in Column 1 of Table 392.9 for the appropriate cable tray width.
(3) Where 4/0 AWG or larger cables are installed in the same cable tray with cables smaller than 4/0 AWG, the sum of the cross-sectional areas of all cables smaller than 4/0 AWG shall not exceed the maximum allowable fill area resulting from the calculation in Column 2 of Table 392.9 for the appropriate cable tray width. The 4/0 AWG and larger cables shall be installed in a single layer, and no other cables shall be placed on them.

Multi-conductor Control and/or Signal Cables Only. Where a ladder or ventilated trough cable tray having a usable inside depth of 150 mm (6 in.) or less contains multi-conductor control and/or signal cables only, the sum of the cross-sectional areas of all cables at any cross section shall not exceed 50 percent of the interior cross-sectional area of the cable tray. A depth of 150 mm (6 in.) shall be used to calculate the allowable interior cross-sectional area of any cable tray that has a usable inside depth of more than 150 mm (6 in.).

10.4.3.2 Wireways

Sheet metal troughs with hinged or removable covers for housing and protecting electrical wires, and cable, and in which conductors are laid in place after the wireway has been installed as a complete system.

Uses Permitted. The use of metal wireways shall be permitted in the following:

(1) For exposed work
(2) In concealed spaces as permitted in NEC Section 376.10(4)
(3) In hazardous (classified) locations as permitted by NEC Section 501.10(B) for Class I, Division 2 locations; 502.10(B) for Class II, Division 2 locations; and 504.20 for intrinsically safe wiring. Where installed in wet locations, wireways shall be listed for the purpose.
(4) As extensions to pass transversely through walls if the length passing through the wall is unbroken. Access to the conductors shall be maintained on both sides of the wall.

Uses Not Permitted. Metal wireways shall not be used in the following:
(1) Where subject to severe physical damage
(2) Where subject to severe corrosive environments

Size of Conductors. No conductor larger than that for which the wireway is designed shall be installed in any wireway.

Number of Conductors and Ampacity. The number of conductors and their ampacity shall comply with NEC Section 376.22(A) and (B).
(A) Cross-Sectional Areas of Wireway. The sum of the cross-sectional areas of all contained conductors at any cross section of a wireway shall not exceed 20 percent of the interior cross-sectional area of the wireway.

(A) Horizontal Support. Wireways shall be supported where run horizontally at each end and at intervals not to exceed 1.5 m (5 ft) or for individual lengths longer than 1.5 m (5 ft) at each end or joint, unless listed for other support intervals. The distance between supports shall not exceed 3 m (10 ft).
(B) Vertical Support. Vertical runs of wireways shall be securely supported at intervals not exceeding 4.5 m (15 ft) and shall not have more than one joint between supports. Adjoining wireway sections shall be securely fastened together to provide a rigid joint.

10.4.3.3 Conduit

Rigid Metal Conduit (RMC): A threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated coupling and appropriate fittings. RMC is generally made of steel (ferrous) with protective coatings or aluminum (nonferrous). Special use types are red brass and stainless steel.

Uses Permitted: Galvanized steel, and stainless steel RMC shall be permitted under all atmospheric conditions and occupancies.

RMC shall be securely fastened within 900 mm (3 ft) of each outlet box, junction box, device box, cabinet, conduit body, or other conduit termination. Fastening shall be permitted to be increased to a distance of 1.5 m (5 ft) where structural members do not permit fastening within 900 mm (3 ft). Where approved, conduit shall not be required to be securely fastened within 900 mm (3 ft) of the service head for above the roof termination of a mast.

RMC shall be supported in accordance with one of the following:
(1) Conduit shall be supported at intervals not exceeding 3 m (10 ft).
(2) The distance between supports for straight runs of conduit shall be permitted in accordance with NEC Table 344.30(B)(2), provided the conduit is made up with threaded couplings and such supports prevent transmission of stresses to termination where conduit is deflected between supports.
(3) Exposed vertical risers from industrial machinery or fixed equipment shall be permitted to be supported at intervals not exceeding 6 m (20 ft) if the conduit is made up with threaded couplings, the conduit is supported and securely fastened at the top and bottom of the riser, and no other means of intermediate support is readily available.
(4) Horizontal runs of RMC supported by openings through framing members at intervals not exceeding 3 m (10 ft) and securely fastened within 900 mm (3 ft) of termination points shall be permitted.

Liquidtight Flexible Metal Conduit (LFMC): A raceway of circular cross section having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core with associated couplings, connectors, and fittings for the installation of electric conductors.

Uses Permitted. LFMC shall be permitted to be used in exposed or concealed locations as follows:
(1) Where conditions of installation, operation, or maintenance require flexibility or protection from liquids, vapors, or solids
(2) As permitted by NEC Sections 501.10(B), 502.10, 503.10, and 504.20 and in other hazardous (classified) locations where specifically approved, and by NEC Section 553.7(B)
(3) For direct burial where listed and marked for the purpose.

Uses Not Permitted: LFMC shall not be used as follows:
(1) Where subject to physical damage
(2) Where any combination of ambient and conductor temperature produces an operating temperature in excess of that for which the material is approved

LFMC shall be securely fastened in place by an approved means within 300 mm (12 in.) of each box, cabinet, conduit body, or other conduit termination and shall be supported and secured at intervals not to exceed 1.4 m (41⁄2 ft).

<u>*Exception No. 1:*</u> *Where LFMC is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical.*
<u>*Exception No. 2:*</u> *Where flexibility is necessary after installation, lengths shall not exceed the following:*
(1) 900 mm (3 ft) for metric designators 16 through 35 (trade sizes 1⁄2 through 11⁄4)
(2) 1200 mm (4 ft) for metric designators 41 through 53 (trade sizes 11⁄2 through 2)
(3) 1500 mm (5 ft) for metric designators 63 (trade size 21⁄2) and larger

Horizontal runs of LFMC supported by openings through framing members at intervals not greater than 1.4 m (41⁄2 ft) and securely fastened within 300 mm (12 in.) of termination points shall be permitted.

10.4.3.4 Enclosures

The purpose of this section is to provide general information on the definitions of NEMA Enclosure Types to architects, engineers, installers, inspectors and other interested parties. [For more detailed and complete information, NEMA Standards Publication 250-2003, "*Enclosures for Electrical Equipment (1000 Volts Maximum)*" should be consulted. This Standards Publication as well as all other NEMA publications are available from IHS @ 800 854-7179 or http://www.global.ihs.com].

<u>**Definitions**</u>
[*from NEMA 250-2003*]

In <u>Non-Hazardous Locations</u>, the specific enclosure Types, their applications, and the environmental conditions they are designed to protect against, **when completely and properly installed**, are as follows:

Type 1 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts and to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt).

Type 2 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 3 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.

Type 3R Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.

Type 3S Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and for which the external mechanism(s) remain operable when ice laden.

Type 3X Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an additional level of protection against corrosion and that will be undamaged by the external formation of ice on the enclosure.

Type 3RX Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that will be undamaged by the external formation of ice on the enclosure that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.

Type 3SX Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an additional level of protection against corrosion; and for which the external mechanism(s) remain operable when ice laden.

Type 4 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose directed water); and that will be undamaged by the external formation of ice on the enclosure.

Type 4X Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose directed water); that provides an additional level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.

Type 5 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and settling airborne dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 6 Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose directed water and the entry of water during occasional temporary submersion at a limited depth); and that will be undamaged by the external formation of ice on the enclosure.

Type 6P Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose directed water and the entry of water during prolonged submersion at a limited depth); that provides an additional level of protection against corrosion and that will be undamaged by the external formation of ice on the enclosure.

Type 12 Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 12K Enclosures constructed (with knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 13 Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against the spraying, splashing, and seepage of oil and non-corrosive coolants.

Table 10-2. Comparison of Specific Applications of Enclosures
for Indoor Nonhazardous Locations *[From NEMA 250-2003]*

Provides a Degree of Protection Against the Following Conditions	**Type of Enclosure**									
	1 *	**2 ***	**4**	**4X**	**5**	**6**	**6P**	**12**	**12K**	**13**
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (falling dirt)	X	X	X	X	X	X	X	X	X	X
Ingress of water (Dripping and light splashing)	...	X	X	X	X	X	X	X	X	X
Ingress of solid foreign objects (Circulating dust, lint, fibers, and flyings **)	...	...	X	X	...	X	X	X	X	X
Ingress of solid foreign objects (Settling airborne dust, lint, fibers, and flyings **)	...	...	X	X	X	X	X	X	X	X

Ingress of water (Hosedown and splashing water)	...	...	X	X	...	X	X	...	...	...
Oil and coolant seepage	...	...	...	..	...	...	...	X	X	X
Oil or coolant spraying and splashing	...	...	...	...	...	...	...	...	...	X
Corrosive agents	...	...	...	X	...	...	X	...	...	...
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	X	X	...	...	...
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	X	...	...	...

* These enclosures may be ventilated.

** These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.

Table 10-3. Comparison of Specific Applications of Enclosures for Outdoor Nonhazardous Locations *[From NEMA 250-2003]*

Provides a Degree of Protection Against the Following Conditions	Type of Enclosure									
	3	3X	3R*	3RX*	3S	3SX	4	4X	6	6P
Access to hazardous parts	X	X	X	X	X	X	X	X	X	X
Ingress of water (Rain, snow, and sleet **)	X	X	X	X	X	X	X	X	X	X
Sleet ***	...	...	...	...	X	X	...	...	...	...
Ingress of solid foreign objects (Windblown dust, lint, fibers, and flyings)	X	X	...	...	X	X	X	X	X	X
Ingress of water (Hosedown)	...	...	...	...	...	...	X	X	X	X
Corrosive agents	...	X	...	X	...	X	...	X	...	X
Ingress of water (Occasional temporary submersion)	...	...	...	...	...	...	...	...	X	X
Ingress of water (Occasional prolonged submersion)	...	...	...	...	...	...	...	...	...	X

* These enclosures may be ventilated.
** External operating mechanisms are not required to be operable when the enclosure is ice covered.
*** External operating mechanisms are operable when the enclosure is ice covered.

In Hazardous Locations**, when completely and properly installed and maintained**, Type 7 and 10 enclosures are designed to contain an internal explosion without causing an external hazard. Type 8 enclosures are designed to prevent combustion through the use of oil-immersed equipment. Type 9 enclosures are designed to prevent the ignition of combustible dust.

Type 7 Enclosures constructed for indoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, or D as defined in NFPA 70.

Type 8 Enclosures constructed for either indoor or outdoor use in hazardous (classified) locations classified as Class I, Division 1, Groups A, B, C, and D as defined in NFPA 70.

Type 9 Enclosures constructed for indoor use in hazardous (classified) locations classified as Class II, Division 1, Groups E, F, or G as defined in NFPA 70.

Type 10 Enclosures constructed to meet the requirements of the Mine Safety and Health Administration, 30 CFR, Part 18.

Table 10-4. Comparison of Specific Applications of Enclosuresfor Indoor Hazardous Locations
(If the installation is outdoors and/or additional protection is required by
Table 10-2 and Table 10-3, a combination-type enclosure is required.) [From NEMA 250-2003]

Provides a Degree of Protection Against Atmospheres Typically Containing (See NFPA 497M for Complete Listing)	Class	Enclosure Types 7 and 8, Class I Groups **				Enclosure Type 9, Class II Groups			
		A	B	C	D	E	F	G	10
Acetylene	I	X	...	...	...	...	...	...	...
Hydrogen, manufactured gas	I	...	X	...	...	...	...	...	...
Diethyl ether, ethylene, cyclopropane	I	...	...	X	...	...	...	...	...
Gasoline, hexane, butane, naphtha, propane, acetone, toluene, isoprene	I	...	...	...	X	...	...	...	...
Metal dust	II	...	...	...	...	X	...	...	...
Carbon black, coal dust, coke dust	II	...	...	...	...	...	X	...	...
Flour, starch, grain dust	II	...	...	...	...	...	...	X	...
Fibers, flyings *	III	...	...	...	...	...	...	X	...
Methane with or without coal dust	MSHA	...	...	...	...	...	...	...	X

* For Class III type ignitable fibers or combustible flyings see the National Electrical Code, Article 500.
** Due to the characteristics of the gas, vapor, or dust, a product suitable for one Class or Group may not be suitable for another Class or Group unless marked on the product.

10.5 Electrical Equipment for General Use

10.5.1 Lighting and Receptacles

TBD

10.5.2 Heating

TBD

10.5.3 Motors

TBD

10.5.4 Industrial Machinery

TBD

10.6 Electrical Area Classifications

10.6.1 Class I Locations

Classifications of Locations. Locations shall be classified depending on the properties of the flammable gas, flammable liquid-produced vapor, combustible-liquid produced vapors, combustible dusts, or fibers/flyings that may be present, and the likelihood that a flammable or combustible concentration or quantity is present. Where pyrophoric materials are the only materials used or handled, these locations shall not be classified. Each room, section, or area shall be considered individually in determining its classification.

Note: Through the exercise of ingenuity in the layout of electrical installations for hazardous (classified) locations, it is frequently possible to locate much of the equipment in a reduced level of classification or in an unclassified location and, thus, to reduce the amount of special equipment required. Rooms and areas containing ammonia refrigeration systems that are equipped with adequate mechanical ventilation may be classified as “unclassified” locations.

Class I Locations. Class I locations are those in which flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

Class I, Division 1. A Class I, Division 1 location is a location

(1) In which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors can exist under normal operating conditions, or
(2) In which ignitible concentrations of such flammable gases, flammable liquid–produced vapors, or combustible liquids above their flash points may exist frequently because of repair or maintenance operations or because of leakage, or
(3) In which breakdown or faulty operation of equipment or processes might release ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors and might also cause simultaneous failure of electrical equipment in such a way as to directly cause the electrical equipment to become a source of ignition.

Note 1: This classification usually includes the following locations:

(1) Where volatile flammable liquids or liquefied flammable gases are transferred from one container to another
(2) Interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used
(3) Locations containing open tanks or vats of volatile flammable liquids
(4) Drying rooms or compartments for the evaporation of flammable solvents
(5) Locations containing fat- and oil-extraction equipment using volatile flammable solvents
(6) Portions of cleaning and dyeing plants where flammable liquids are used
(7) Gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape
(8) Inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids
(9) The interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers
(10) All other locations where ignitible concentrations of flammable vapors or gases are likely to occur in the course of normal operations

Note 2: In some Division 1 locations, ignitible concentrations of flammable gases or vapors may be present continuously or for long periods of time. Examples include the following:

(1) The inside of inadequately vented enclosures containing instruments normally venting flammable gases or vapors to the interior of the enclosure
(2) The inside of vented tanks containing volatile flammable liquids
(3) The area between the inner and outer roof sections of a floating roof tank containing volatile flammable fluids
(4) Inadequately ventilated areas within spraying or coating operations using volatile flammable fluids
(5) The interior of an exhaust duct that is used to vent ignitible concentrations of gases or vapors Experience has demonstrated the prudence of avoiding the installation of instrumentation or other electrical equipment in these particular areas altogether or where it cannot be avoided because it is essential to the process and other locations are not feasible [see 500.5(A), FPN] using electrical equipment or instrumentation approved for the specific application or consisting of intrinsically safe systems as described in Article 504.

Class I, Division 2. A Class I, Division 2 location is a location

(1) In which volatile flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems or in case of abnormal operation of equipment, or
(2) In which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors are normally prevented by positive mechanical ventilation and which might become hazardous through failure or abnormal operation of the ventilating equipment, or
(3) That is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of flammable gases, flammable liquid–produced vapors, or combustible liquid–produced vapors above their flash points might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided.

Note 1: This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used but that, in the judgment of the authority having jurisdiction, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.

Note 2: Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Depending on factors such as the quantity and size of the containers and ventilation, locations used for the storage of flammable liquids or liquefied or compressed gases in sealed containers may be considered either hazardous (classified) or unclassified locations. See NFPA 30-2008, *Flammable and Combustible Liquids Code*, and NFPA 58-2008, *Liquefied Petroleum Gas Code*.

10.6.2 Intrinsically Safe Systems

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Controls Engineering
Contents

11.1. Electrical Control Systems

11.1.1: Programmable Logic Controllers (Analog and Discrete Systems)

11.1.1.1: General Information

A medium sized PLC is designed for up to 2048 points of I/O. This PLC shall offer enhanced processing and communication options and shall be a chassis mounted modular system. The PLC shall accommodate replacement of cards while powered and operating. The cards that can be replaced include all non-intrinsically safe I/O modules, redundant power supplies, stand-alone power supplies, and the Central Processing Unit. The system shall be configured using either: Local, Extension, or Remote I/O as detailed below.

a. Local I/O modules shall be located in the same rack as the CPU.
b. Extension I/O will be used for I/O that cannot be accommodated by the local rack and located within 100 meters of the local rack. Extension I/O will be capable of interfacing to the CPU without the need of remote communication modules or remote processor.
c. Remote I/O shall interface through the processor or a communication card located in the local rack. Remote I/O racks shall consist of a network adapter and an I/O base with removable terminal blocks, or removable I/O cards that will permit exchange of a module without disturbing the field wiring of other modules.

<u>Processor Features</u>
Pick one, or more, of the following processors depending on project conditions. Other processors exist that are not listed. See manufacturers' literature for more information. When a project requires multiple PLCs of a specific type, be sure to indicate which processor is intended for each machine/process. Remove unwanted processors from the list.

The PLC shall have a variety of processors available. Each processor will be capable of being programmed via serial communications with a PC. Modbus shall be available through a PCMCIA module. The system shall be designed to execute all languages without a significant decrease in processing speed in a single processor. Multiple processors will only be allowed in a redundant system. The processor will have a display block with colored indicator lamps for RUN (Green), ERR (Red), I/O (Red), and TER (Yellow). Processors with an integrated Ethernet port shall have colored indicator lamps for RUN (Green), ERR (Red), COL (Red), STS (Yellow), TX (Yellow), and RX (Yellow). The processor shall be programmable through the USB port of a personal computer using a direct cable scheme. The acceptable processors are detailed below:

- 96KB of base program and data memory (96KB data, and 224KB program after expansion), and up to 512 channels of I/O with 24 channels of analog I/O. Also includes an integrated 10BASE-T/100BASE-TX RJ45 Ethernet Port.
- 96KB of base program and data memory (96KB data, and 224KB program after expansion), and up to 512 channels of I/O with 24 channels of analog I/O.
- 160KB of base program and data memory (160KB data, and 768KB program after expansion), and up to 1024 channels of I/O with 80 channels of analog I/O. Also includes an integrated 10BASE-T/100BASE-TX RJ45 Ethernet Port.
- 160KB of base program and data memory (160KB data, and 768KB program after expansion), and up to 1024 channels of I/O with 80 channels of analog I/O. Processor

Specify the processor in the following paragraph if using the smaller memory redundancy system.

- 192KB of base program and data memory (192KB data, and 768KB program after expansion), and up to 1024 channels of I/O with 80 channels of analog I/O. Also includes an integrated RJ45 Port. This port shall be dedicated for Hot Standby processor synchronization.
- 192KB of base program and data memory (192KB data, and 1.75MB program after expansion), and up to 1024 channels of I/O with 128 channels of analog I/O. Also includes an integrated 10BASE-T/100BASE-TX RJ45 Ethernet Port.
- 192KB of base program and data memory (192KB data, and 1.75MB program after expansion), and up to 1024 channels of I/O with 128 channels of analog I/O.
- 320KB of base program and data memory (440KB data, and 2MB program after expansion), and up to 2048 channels of I/O with 256 channels of analog I/O. Also includes an integrated 10BASE-T/100BASE-TX RJ45 Ethernet Port.
- 320KB of base program and data memory (440KB data, and 2MB program after expansion), and up to 2048 channels of I/O with 256 channels of analog I/O.

Specify the processor in the following paragraph if using the larger memory redundancy system.

- 440KB of base program and data memory (440KB data, and 2.048MB program after expansion), and up to 2048 channels of I/O with 256 channels of analog I/O. Also includes an integrated RJ45 Port. This port shall be dedicated for Hot Standby processor synchronization.
- 640KB of base program and data memory (896KB data, and 7168KB program after expansion), and up to 2048 channels of I/O with 512 channels of analog I/O. Also includes an integrated 10BASE-T/100BASE-TX RJ45 Ethernet Port.
- 640KB of base program and data memory (896KB data, and 7168KB program after expansion), and up to 2048 channels of I/O with 512 channels of analog I/O. The PLC shall use a lithium battery to back up the PLC RAM. The battery shall be able to sustain memory for approximately 365 days assuming the PLC is at 25°C and the backup period started with a fully charged battery. A BAT light shall indicate when it is time to replace the battery. The PLC shall have on board status lights to indicate the following various functions:
    - Green RUN lamp that will illuminate while the program is executing
    - Red ERR lamp that will illuminate when a fault occurs in the processor
    - Red I/O Lamp that will illuminate upon an I/O failure or configuration fault.
    - Yellow TER lamp will illuminate when activity is present on the TER or
    - AUX Terminal Port
    - Red FIP lamp will illuminate to indicate activity on the FIPIO bus.

<u>Power Supplies</u>

The PLC shall have chassis mounted power supplies to power the chassis backplane, and provide power for the processor and applicable modules. There shall be a single power supply per chassis. The power supplies will have a visible LED to indicate that the incoming power is acceptable, and that output voltage is present. The power supplies will be sized to accommodate the anticipated load, plus an additional 30% capacity. Each power supply shall have independent line fuses or circuit breakers that comply with the manufacturers recommendations. The power supplies shall allow for brown outs of at least ½ of a cycle, a harmonic rate of 10%, and will sustain continuous operation through momentary interruptions of AC line voltage of 10ms or less. The power supplies shall be available in both 24-48VDC and 100-240VAC models. The available power ratings will be from 26 to 50W.

<u>Chassis</u>

The PLC shall have chassis to mount processors, power supplies, and other applicable cards. The chassis shall come in 4, 6, and 12 position configurations. The chassis will be designed to mount individual enclosed cards. The chassis shall not have top, bottom, or side walls. The cards will be secured to the chassis via a screw connection.

11.1.1.2: I/O Cards

I/O Cards: The I/O cards listed are the most widely used. Other cards, such as combination cards, are available. See manufactures' literature for more detail. Furthermore, to save room and provide a cleaner specification, remove the I/O cards that will not be required.

The PLC shall have a series of general I/O cards. I/O modules shall be plugged into a backplane that restricts installation in only one direction and prohibits upside down insertion of the modules as well. The modules and connectors shall be keyed to safeguard against the insertion of a module into the wrong backplane slot. All modules shall be enclosed in rugged plastic housings. All field wiring shall be to a removable terminal strip that will permit pre-wiring of the module, or removal and replacement of a module without disturbing the field wiring or any other I/O modules. They will be as follows:

1. **Analog Inputs:** All analog input cards will offer isolation between channels, between bus and channels, and between channels and ground.
   - Eight (8) channel differential +/- 10V, 0-25mA input card.
   - Eight (8) channel Type B, E, J, K, R, S, T thermocouple input card
   - Eight (8) channel RTD (2-,3-,or 4-wire), Pt, Ni input card
   - Sixteen (16) channel differential or single ended +/- 10V, 0-20mA input card.

2. **Analog Outputs:** All analog output cards will offer isolation between channels.
   - Four (4) channel +/- 10V output card
   - Four (4) channel 4-20mA output card
   - Eight (8) channel 0-25mA output card

3. **Digital Inputs:**
   - Sixteen (16) channel 10-60VDC Sink input card
   - Sixteen (16) channel 115VAC input card
   - Thirty two (32) channel 10-64VDC Sink input card
   - Thirty two (32) channel 24VDC Source input card
   - Thirty two (32) channel 115VAC input card
   - Ninety Six (96) channel 24VDC Sink input card

4. **Digital Outputs:**
   - Eight (8) channel 150VDC/250VAC (5A/channel) NO/NC relay output card
   - Twelve (12) channel 24-125VDC source (0.75A/channel) output card
   - Sixteen (16) channel 10-60VDC source (2A/channel) output card
   - Sixteen (16) channel 150VDC/250VAC (2A/channel) NO relay output card
   - Sixteen (16) channel 24-48VAC (4A/channel) output card
   - Sixteen (16) channel 24-230VAC (4A@20-132VAC/channel or 3A@170-253VAC/channel) output card
   - Thirty-two (32) channel 5VDC/TTL sink (75mA/channel) output card
   - Thirty two (32) channel 24VDC source (0.5A/channel) output card
   - Thirty two (32) channel 24VDC sink (0.5A/channel) output card

- Thirty two (32) channel 24-230VAC (1A/channel) output card
- Thirty-two (32) channel 10-30VDC source (0.5A/channel) verified output card
- Ninety-Six (96) channel 19.2-30VDC (0.5A/channel) output card

5. **Specialized I/O Cards:** The PLC shall have a series of application specific I/O cards.
   - **Counter Modules:** A four (4) channel 40 KHz counter module will be available. Each channel will have three (3) 24VDC enable, preset and read inputs; 1 24VDC line check, or incremental encoder power supply input; and 2 24VDC reflex outputs per channel.
   - **High Speed Counter Module:** A two (2) channel 500 KHz counter module will be available. Each channel will have two (2) 24VDC preset and read inputs, one (1) point configurable as an enable input or 24VDC output, two (2) 24VDC reflex outputs, one (1) 24VDC programmable output, and one (1) encoder power supply input for 5VDC or 24VDC.

11.1.1.3: Communications

The PLC will be capable of the following communication protocols without third party modules:

1. 10BASE-T/100BASE-TX Modbus TCP Ethernet communication
2. AS-Interface (V1 and V2)
3. Modbus (RTU and ASCII)
4. Profibus DP for up to 126 slaves
5. Ethernet: 10BASET and 100BASE-TX communication.

At least one of the following two paragraphs must be specified if redundancy is required. Otherwise delete them.

1. PLC will have an Ethernet card capable of scanning I/O for up to 64 stations. They will also have global data capabilities, and an integrated FDR server for automatic reconfiguration (BootP/DHCP)
2. PLC will have an Ethernet card capable of scanning I/O for up to 64 stations. They will also have global data capabilities, and an integrated FDR server for automatic reconfiguration (BootP/DHCP). Additionally the card will have an alarm display, a graphic data editor, and the capability to handle custom web pages (8MB max memory).

<u>Web page based HMI services</u>
The PLC will be capable of handling an alarm display, a graphic data editor, and the capability to handle custom web pages (8MB max memory). The PLC will also be capable of email, interpreted math and logic functions, and connection to relational databases.

11.1.1.4: Data Acquisition

11.1.2: Human-Machine Interface (HMI)

11.1.2.1: General Information

TBD

11.1.2.2: Console Switch and Annunciator Layout

TBD

11.1.2.3: Graphical Schematic Representation

TBD

11.1.2.4: Ethernet Communications

TBD

11.1.3: Discrete Event Recorders (DER)

11.1.3.1: General Information

Power Supply

- Input power: 90 - 250Vac, 50/60Hz 90-350Vdc 48Vdc 24Vdc.
- Field contact power supply: 250Vdc 125Vdc 48Vdc 24Vdc (internally supplied). Customer supplied external field contact power supply input option (ranges as per internal selection).

Performance:

- Maximum point capability: Single chassis - 512 points total in increments of 64 (eight 64 point cards) Multiple chassis - (maximum of sixty four chassis) up to a point count of 4096 (in multiples of 64 point cards).
- Maximum separation distance: Between chassis - 1 mile (1.6km).
- Sequential memory capability: >4500 event messages per 64 points.
- Historical memory capability: Circular buffer with 6000 point event storage.
- Auxiliary relay outputs: 8 available rated at 0.5A at 120Vac or 2A at 30Vdc.
- Clock synchronization: 50/60 Hz External sync pulse, once per hour IRIG-B.
- Scan time: 10µs or less.
- Resolution: 1ms.
- Clock accuracy: Standard 25ppm. Optional 0.1ppm.

Communication Ports

- EIA-232 ports 3 standard, 3 optional: One port fixed for configuration, including use of Remote Configuration workstation software. One port fixed for clock synchronization: Satellite clock synchronization IRIG B clock synchronization. All other ports are user selectable for supporting EIA-232 equipment compatibility.
- EIA-232 equipment compatibility: Compatible equipment: Color CRT display Configuration terminals, including Remote Configuration workstation software Printers, including 80 column printer (available in two colors). Various modems (long/short haul) Computers Serial input window annunciators Distributed control systems Programmable controllers GPS receivers (time sync).

Configuration

- Software adjustable parameters: Via keyboard initiated commands: N.O./N.C. field contacts Alarm input time delay Return-to-normal time delay Point enable/disable 60 character legends with editing EIA-232 output

ports, fully configurable for device type, baud rate, and parity Point assignments to EIA-232 ports Eight configurable relay outputs Time set/correction and date input Oscillatory inputs defined.
- Operator initiated reports: Point configuration report System configuration report Output port assignment report Full historical buffer report Historical buffer update report Point delete report Alarm summary report Functional test report List legend report.

Immunity
- Input isolation: Point input protected by a 1500V rated optical coupler input to output.
- SWC: Surge withstand capability to ANSI C37 90a, IEEE 472 and IEC 225-4.

Environmental
- Operating temperature: O° to 50°C (32° to 122°F).
- Humidity: O to 95% non-condensing.
- Compatibility: Meets current RFI/EMI standard.

Mechanical
- Enclosure: 8U, 19” rack mountable chassis. Meets EIA-310-B requirements.
- Dimensions: Width: 482.6mm (19”). Depth: 406.4mm (16”). Height: 352.4mm (13.87”).
- Weight: Approx. 13.6kg (30lbs).
- Terminals: Field inputs via 37 pin D-shell connectors. Can be cabled to supplied input terminals, optional 64-point terminal panels or terminal rail assemblies.
- Cabinets/cubicles: Standard and customer specific cabinet/cubicle enclosures available.

11.1.3.2: Discrete Event Emulator (DEE)

11.1.4: Analog Chart Recorders

11.1.4.1: General Information

TBD

11.1.4.2: Analog Inputs

TBD

11.1.4.3: Channel Setup

TBD

11.1.5: Hardwired Shutdown Systems (HWS)

TBD

11.1.6: Electro-Hydraulic Controllers

TBD

11.1.6.1: Servovalve Output

TBD

11.1.6.2: Linear Variable Differential Transformer (LVDT) Input

TBD

11.1.6.3: Analog Inputs

TBD

11.1.6.4: Analog Outputs

TBD

11.1.6.5: Digital Inputs

TBD

11.1.6.6: Digital Outputs

TBD

11.1.6.7: Controller Setup

1. Measure resistance of each servo coil.

2. Setup (2) decade boxes to match coil resistance, and connect to EHV Controller with a J2 Valve Test Cable.
   a. Decade Box (1) connected to Black and White
   b. Decade Box (2) connected to Red and Green

3. Use Extender Card on the Servo Module

4. Select the valve's normal position when in Stand-By
   a. Set SW503 = DOWN to select **Stand-By** and **Closed**
   b. Set SW503 = UP to select **Stand-By** and **Open**

5. Setup Total Current

a. Set SW501 = CW Position for 15mA Total Current for a 200Ω Servo Coil
b. Set SW501 = Center Position for 25mA Total Current
c. Set SW501 = CCW Position for 50mA Total Current for a 80Ω Servo Coil
d. Measure DC Voltage on the Servo Module (Current Test Point) and the Display Module (Common), and adjust the Current Potentiometer on the Servo Module to 1.5VDC.

6. Setup Pedestal Current
   a. Set SW502 = CW Position to set the Pedestal Current
   b. Place the EHV Controller in **Operate**
   c. Measure DC Voltage on the Servo Module (Current Test Point) and the Display Module (Common), and adjust the Pedestal Potentiometer on the Servo Module to 0.15VDC.
   d. Return the EHV Controller to **Stand-By**
   e. Return SW502 = Center Position for normal operation.

7. Setup the Dither Current
   a. Measure the AC Voltage and the Frequency at TP515.
   b. Adjust Potentiometer R558 to obtain a Voltage Measurement of 0.75VAC.
   c. Adjust Potentiometer R556 to obtain a Frequency Measurement of 228 Hz.

8. Verify the Command DC Voltage from the Display Module and the Target DC Voltage from the Servo Module. Adjust the Null Potentiometer until both values match.

9. From the Manual / Position Module, adjust the following LVDT parameters (LVDT Measurement are taken from the Feedback Test Point on the Manual / Position Module and the Common Test Point on the Display Module):
   a. With the EHV Controller in the Operate Mode and 0% Command, adjust the ZERO Potentiometer to 2% Stroke. (**Note: Verify no change in LVDT reading)**
   b. With the EHV Controller in the Operate Mode and 100% Command, adjust the SPAN Potentiometer to match 100% Stroke.

10. From the Servo Module, adjust the following SERVO parameters:
    a. With the EHV Controller in the Operate Mode and 0% Command, adjust the Seat Coarse Potentiometer to ensure the EHV is closed, and to ensure the valve begins to open at < 5% Command.
    b. With the EHV Controller in the Operate Mode and 100% Command, adjust the Signal Gain Potentiometer to ensure the EHV is 100% Open, and to ensure the valve begins to close at >98% Command.
    c. With the EHV Controller in the Standby Mode and 50% Command, verify with a chart recorder the valve response when placed in Operate. Adjust the ERROR GAIN Potentiometer (CW) to minimize opening time while avoiding valve position overshoot.

11. Verify no change in LVDT Reading when changing the EHV Controller to the following positions.
    a. (Standby and Closed) to (Operate / 0% Command) to (Operate / Override Close)
    b. (Operate / 100% Command) to (Operate / Override Open)

Notes:

1. LVDT Spans can be from –10vdc @ 0% OPEN to +10vdc @ 100% OPEN.
   a. 50K LOX S/O LVDT measurements are –4.33vdc @ 0% OPEN and 3.66vdc @ 100% OPEN.
   b. 50K Fuel S/O LVDT measurements are –4.07vdc @ 0% OPEN and 3.28vdc @ 100% OPEN.

11.1.7: Electrical Ignition Systems

11.1.7.1: NASA Standard Initiator (NSI)

The contents of this section have been removed due to export control considerations. Interested parties may contact the Rocket Propulsion Test Program Office to request access to this information.

11.1.7.2: Exploding Bridgewire (EBW)

The contents of this section have been removed due to export control considerations. Interested parties may contact the Rocket Propulsion Test Program Office to request access to this information.

11.1.7.3: Spark Igniter

TBD

11.1.7.4: Instability Bombs

TBD

11.2. Electrical Control Devices

11.2.1: Purpose

TBD

11.2.2: Electro-Hydraulic Valves (EHV)

TBD

11.2.2.1: General Information

TBD

11.2.2.2: Servovalve

NOZZLE FLAPPER TORQUE MOTOR DESCRIPTION

An electrical command signal (flow rate set point) is applied to the torque motor coils and creates a magnetic force which acts on the ends of the pilot stage armature. This causes a deflection of armature/flapper assembly within the flexure tube. Deflection of the flapper restricts fluid flow through one nozzle which is carried through to one spool end, displacing the spool. [Spool actuation relative to valve operation is detailed on page 17] Movement of the spool opens the supply pressure port (P) to one control port while simultaneously opening the tank port (T) to the other control port. The spool motion also applies a force to the cantilever spring, creating a restoring torque on the armature/flapper assembly. Once the restoring torque becomes equal to the torque from the magnetic forces, the armature/flapper assembly moves back to the neutral position, and the spool is held open in a state of equilibrium until the command signal changes to a new level. In summary, the spool position is proportional to the input current and, with constant pressure drop across the valve, flow to the load is proportional to the spool position.

POSITION SERVO SYSTEM

A load positioning servo system is comprised of a Servo, ServoJet® or Direct Drive Valve, actuator, position feedback transducer, position command generator, and a Servoamplifier. A typical linear position servo system using a double-ended piston is shown to the right (a rotary position servo system can be created by substituting the appropriate rotary components). The valve's two output control ports are connected across the load cylinder. In the Servoamplifier, the command input is compared to the present position output of the position transducer. If a difference between the two exists, it is amplified and fed to the valve as an error signal. The signal shifts the valve spool position, adjusting flow to the actuator until the position output agrees with the command input.

NOZZLE FLAPPER SERVOVALVE OPERATION

<u>HYDRAULIC AMPLIFIER</u>

- Armature and flapper rigidly joined and supported by thin-wall flexure sleeve.
- Fluid continuously flows from pressure PS, through both inlet orifices, past nozzles into flapper chamber, through drain orifice to tank T.
- Rotary motion of armature/flapper throttles flow through one nozzle or the other.
- This diverts flow to one end of the spool.

<u>VALVE SPOOL</u>

- Spool slides in bushing (sleeve) or directly in body bore.
- Bushing contains rectangular holes (slots) or annular grooves that connect to supply pressure PS and tank T.
- At "null" spool is centered in bushing; spool lobes (lands) just cover PS and T openings.
- Spool motion to either side of null allows fluid to flow from PS to one control port and from other control port to T.

<u>OPERATION</u>

1. Electrical current in torque motor coils creates magnetic forces on ends of armature.
2. Armature and flapper assembly rotates about flexure sleeve support.
3. Flapper closes off one nozzle and diverts flow to that end of spool.
4. Spool moves and opens PS to one control port; opens other control port to T.
5. Spool pushes ball end of feedback spring creating a restoring torque on the armature/flapper.
6. As feedback torque becomes equal to torque from magnetic forces, armature/flapper moves back to centered position.
7. Spool stops at a position where feedback spring torque equals torque due to input current.
8. Therefore, spool position is proportional to input current.
9. With constant pressures, flow to load is proportional to spool position.

<u>ELECTRICAL</u>

Input Current – The electrical current to the valve which commands control flow, expressed in milliamperes (mA).

Rated Current – The specified input of either polarity to produce rated flow, expressed in milliamperes (mA). Rated current is specified for a particular coil configuration (differential, series, individual or parallel coils) and does not include null bias current.

Coil Impedance – The complex ratio of coil voltage to current. Coil impedance will vary with signal frequency, amplitude, and other operating conditions, but can be approximated by the DC coil resistance R, expressed in ohms (½) and the apparent coil inductance L, expressed in henrys (H), measured at a specific signal frequency.

Dither – An AC signal sometimes superimposed on the valve input to improve system resolution. Dither is expressed by the dither frequency hertz (Hz) and the peak-to-peak dither current, expressed in milliamperes (mA).

<u>MECHANICAL FEEDBACK VALVE ELECTRICAL CHARACTERISTICS</u>

Rated Current and Coil Resistance: The specified input of either polarity to produce rated flow, expressed in milliamperes (mA). Rated current is specified for a particular coil configuration (differential, series, individual or parallel coils) and does not include null basis current.

Mechanical Feedback Standard Electrical Configuration: Standard electrical connections and electrical polarity for flow out of left control port when viewing valve from pressure side area are:

Single coil:	A+, B-; or C+, D
Series coil:	tie B to C; A+, D
Parallel coils:	tie A to C and B to D; [A & C]+, [B & D]-

Coil Connections: A four pin electrical connector that mates with a MS3106R14S-2S or equivalent is standard. All four coil leads are available at the connector, allowing external connections for signal, series, or parallel coil operation. Servoamplifier: A Servovalve responds to input current. Therefore, in order to reduce the effects of coil resistance variations, a Servoamplifier with high internal impedance (as obtained with current feedback) should be used.

Dither: Small amplitude, high frequency sinusoidal signal may be used to reduce friction and hysteresis effects within the valve, improving system performance. If used, the peak-to-peak amplitude should be less than 10% of rated signal. Since the desired frequency is dependent on the valve style, consult factory for recommended frequency.

Coil Impedance: The two coils in each Servovalve are wound for equal turns with a normal production tolerance on coil resistance of ±12%. Copper magnet wire is used, resulting in a coil resistance that will vary significantly with temperature. The effects of coil resistance changes can be essentially eliminated through the use of a current feedback Servoamplifier having high output impedance. Inductance is determined under pressurized operating conditions and varies greatly with signal frequencies above 100 Hz.

Intrinsically Safe: Optional intrinsically safe designs are available for most standard valve models. These designs have been granted both entity and loop approval by Factory Mutual (FM). Please consult factory for the latest CSA information on hazardous location approvals.

Electrical Connections: Connector MS3106R14S-2S

11.2.2.3: Linear Variable Differential Transformer (LVDT)

An LVDT Displacement Transducer comprises 3 coils; a primary and two secondaries.

The transfer of current between the primary and the secondaries of the LVDT displacement transducer is controlled by the position of a magnetic core called an armature.

On our position measurement LVDT's, the two transducer secondaries are connected in opposition.

At the centre of the position measurement stroke, the two secondary voltages of the displacement transducer are equal but because they are connected in opposition the resulting output from the sensor is zero.

As the LVDT's armature moves away from center, the result is an increase in one of the position sensor secondaries and a decrease in the other. This results in an output from the measurement sensor.

With LVDT's, the phase of the output (compared with the excitation phase) enables the electronics to know which half of the coil the armature is in.

The strength of the LVDT sensor's principle is that there is no electrical contact across the transducer position sensing element which for the user of the sensor means clean data, infinite resolution and a very long life.

Our range of signal conditioning electronics for LVDT's handles all of the above so that you get an output of voltage, current or serial data proportional to the measurement position of the displacement transducer.

Principle of LVDT Operation

The principal of operation is essentially two small transformers sharing the same magnetic core. As the core moves the output of one increases while the other decreases. The 'out of balance' current is a measure of the core position with the best linearity occurring at the mid way point when the transformers are almost in balance.

The LVDT is sensitive, reliable and repeatable.

The accepted mode of operation is to measure a perfect sample (a setting master) and to then measure the unknown sample. Thus the accuracy is derived from the setting master and the LVDT is used as a comparative tool. The master is measured once a day, or whenever the temperature changes to effectively calibrate out all other variables relating to support fixtures etc.

An LVDT returns to its original output following a power shutdown. LVDT's work on AC energization and support electronics available include modulators / demodulators, amplifiers and zero / gain controls.

When an AC excitation signal is applied to the Primary Coil (P), voltages are induced in the two Secondary Coils (S). The MAGNETIC CORE inside the COIL WINDING ASSEMBLY provides the magnetic flux path linking the Primary and secondary Coils. Since the two voltages are of opposite polarity, the Secondary Coils are connected series opposing in the center, or Null Position. The output voltages are equal and opposite in polarity and, therefore, the output voltage is zero. The Null Position of an LVDT is extremely stable and repeatable.

When the MAGNETIC CORE is displaced from the Null Position, an electromagnetic imbalance occurs. This imbalance generates a differential AC output voltage across the Secondary Coils which is linearly proportional to the direction and magnitude of the displacement

As shown in Figure 11-5, when the MAGNETIC CORE is moved from the Null Position, the induced voltage in the Secondary Coil, toward which the Core is moved, increases while the induced voltage in the opposite Secondary Coil decreases.

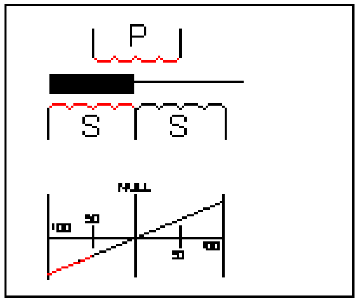


Figure 11-5. LVDT Induction of a Secondary Coil

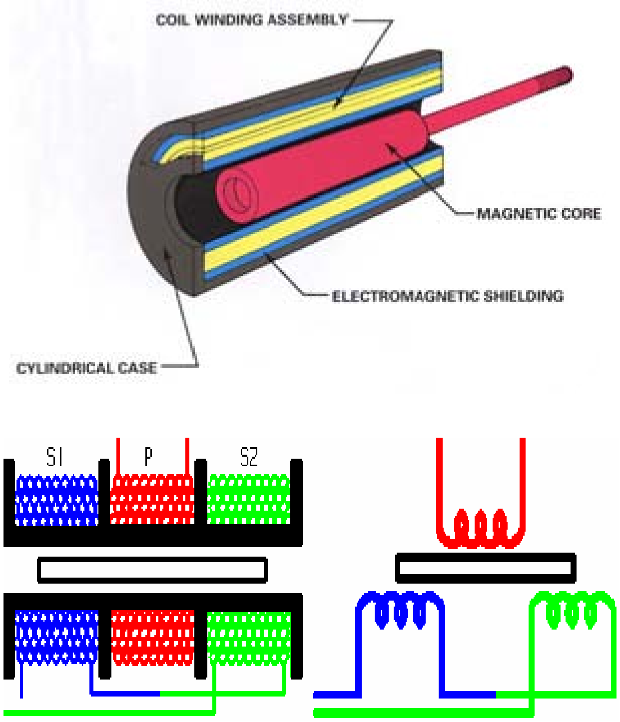
LVDT's possess the inherent ruggedness and durability of a transformer and truly provide infinite resolution in all types of environments. As a result of the superior reliability and accuracy of LVDT's, they are the ideal choice for linear motion control

Multi-Layer Insulation

G.L. Collins manufactures all LVDT's with the stringent quality standards required for spacecraft, missiles, supersonic aircraft and high grade commercial and industrial control systems. We adhere to superior material standards and utilize manufacturing techniques not ordinarily considered in commercial LVDT production.

Special winding techniques must be used to ensure superior stability, linearity and repeatability in the most hostile environments. It is standard practice at G. L. Collins to layer-wind the LVDT coils, as opposed to random winding often found on low-grade transducers. Precision layer winding incorporates insulation between each layer of wire and constant control of the tension and spacing of the wire. This technique provides added protection from dielectric breakdown, stability under the effects of vibration, acceleration, mechanical and thermal shock, and insures unit-to-unit consistency.

Experience has proven that the cost of these techniques is easily offset by the resultant consistency, reliability and long life so vital to modern control systems.



The LVDT (Linear Variable Differential Transformer) is an electromagnetic device that produces an electrical voltage proportional to the displacement of a movable Magnetic Core. The LVDT is composed of these basic components:

- A COIL WINDING ASSEMBLY consisting of a Primary Coil and two Secondary Coils symmetrically spaced on a tubular center.
- A CYLINDRICAL CASE which encloses and protects the Coil Winding Assembly.
- A rod shaped MAGNETIC CORE which is free to move axially within the Coil Winding Assembly.
- A separate shield is used for ELECTROMAGNETIC SHIELDING

Figure 11-6. Cutaway of an LVDT

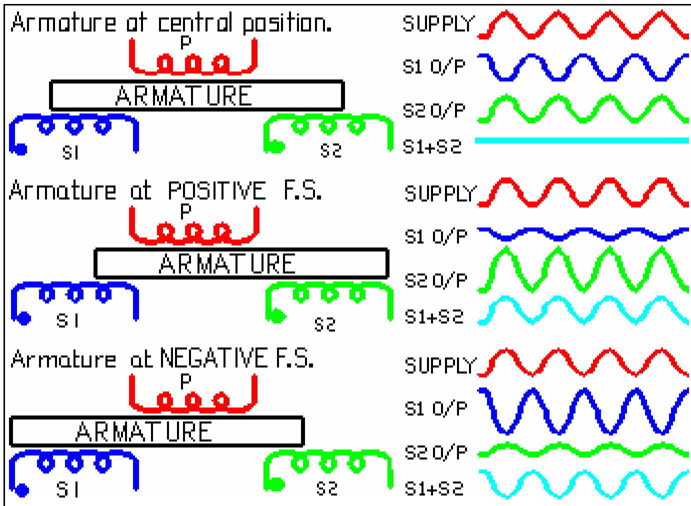
<u>LVDT Operating Principles</u>

The main advantage of LVDT transducers over other types of displacement measurement sensors is their high degree of robustness. This is derived from their very principle in which there is no physical contact across the sensing element and so there is zero wear in the sensing element. This also means that LVDT's can be made waterproof and in a format suitable for the most arduous applications.

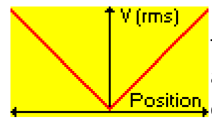
The measurement principle is based on magnetic transfer which also means that the resolution of LVDT transducers is infinite. The smallest fraction of movement can be detected by suitable signal conditioning electronics.

The combination of these two factors plus other factors such as accuracy and repeatability has ensured that this technology is still at the forefront of displacement measurement after over 90 years.

An LVDT comprises a coil former or bobbin onto which three coils are wound. The first coil, the primary is excited with an a.c. current, normally in the region of 1 to 10kHz at 0.5 to 10V rms. The other two coils, the secondaries are wound such that when a ferritic core is in the central linear position, an equal voltage is induced into each coil. However, the secondaries are connected in opposition so that in the central position the outputs of the two secondaries cancel each other out.



With the armature in the central position the in-phase and out-of-phase voltages sum to zero (except for a small residual).



In the positive half of the coil, the in -phase voltage is higher and when it is added to the out-of-phase voltage (due to their electrical connection) the result is an in-phase output.

Figure 11-7. LVDT Armature Position and Output Voltage

The reverse is true when the armature is in the negative half of the coil. The change in output is completely stepless.

The output of an LVDT is an AC. waveform and so it does not actually have a polarity as such. The magnitude of the output of an LVDT rises, regardless of the direction of movement from the electrical zero position.

In order to know in which half of the coil the centre of the armature is located, one must consider the phase of the output as well as the magnitude. The output phase is compared with the excitation phase and it can be either in or out of phase with the excitation, depending upon which half of the coil the centre of the armature is in.

The electronics therefore, must combine information on the phase of the output with information on the magnitude of the output. This will then allow the user to know exactly where the armature is rather than how far from the electrical zero position it is.

11.2.3: Pneumatic Remote Operated Valves (ROV)

TBD

11.2.3.1: General Information

TBD

11.2.3.2: Solenoid Valves (SOV)

TBD

11.2.3.3: Limit Switches

TBD

Instrumentation
Contents

12.1: Measurements

12.1.1: Pressure Transducers

Pressure Gauges and Switches

Mechanical methods of measuring pressure have been known for centuries. U-tube manometers were among the first pressure indicators. Originally, these tubes were made of glass, and scales were added to them as needed. But manometers are large, cumbersome, and not well suited for integration into automatic control loops. Therefore, manometers are usually found in the laboratory or used as local indicators. Depending on the reference pressure used, they could indicate absolute, gauge, and differential pressure.

Differential pressure transducers often are used in flow measurement where they can measure the pressure differential across a venturi, orifice, or other type of primary element. The detected pressure differential is related to flowing velocity and therefore to volumetric flow. Many features of modern pressure transmitters have come from the differential pressure transducer. In fact, one might consider the differential pressure transmitter the model for all pressure transducers.

"Gauge" pressure is defined relative to atmospheric conditions. In those parts of the world that continue to use English units, gauge pressure is indicated by adding a "g" to the units descriptor. Therefore, the pressure unit "pounds per square inch gauge" is abbreviated psig. When using SI units, it is proper to add "gauge" to the units used, such as "Pa gauge." When pressure is to be measured in absolute units, the reference is full vacuum and the abbreviation for "pounds per square inch absolute" is psia.

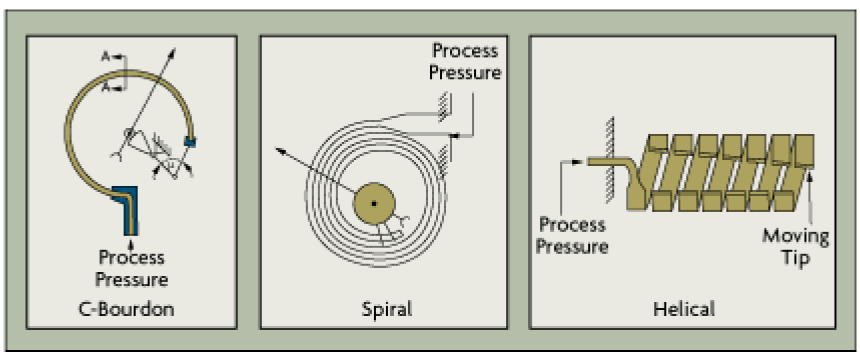


Figure 12-1: Bourdon Tube Designs

Often, the terms pressure gauge, sensor, transducer, and transmitter are used interchangeably. The term pressure gauge usually refers to a self-contained indicator that converts the detected process pressure into the mechanical motion of a pointer. A pressure transducer might combine the sensor element of a gauge with a mechanical-to-electrical or mechanical-to-pneumatic converter and a power supply. A pressure transmitter is a standardized pressure measurement package consisting of three basic components: a pressure transducer, its power supply, and a signal conditioner/retransmitter that converts the transducer signal into a standardized output.

Pressure transmitters can send the process pressure of interest using an analog pneumatic (3-15 psig), analog electronic (4-20 mA dc), or digital electronic signal. When transducers are directly interfaced with digital data acquisition systems and are located at some distance from the data acquisition hardware, high output voltage signals are preferred. These signals must be protected against both electromagnetic and radio frequency interference (EMI/RFI) when traveling longer distances.

Pressure transducer performance-related terms also require definition. Transducer accuracy refers to the degree of conformity of the measured value to an accepted standard. It is usually expressed as a percentage of either the full scale or of the actual reading of the instrument. In case of percent-full-scale devices, error increases as the absolute value of the measurement drops. Repeatability refers to the closeness of agreement among a number of consecutive measurements of the same variable. Linearity is a measure of how well the transducer output increases linearly with increasing pressure. Hysteresis error describes the phenomenon whereby the same process pressure results in different output signals depending upon whether the pressure is approached from a lower or higher pressure.

From Mechanical to Electronic

The first pressure gauges used flexible elements as sensors. As pressure changed, the flexible element moved, and this motion was used to rotate a pointer in front of a dial. In these mechanical pressure sensors, a Bourdon tube, a diaphragm, or a bellows element detected the process pressure and caused a corresponding movement.

A Bourdon tube is C-shaped and has an oval cross-section with one end of the tube connected to the process pressure (Figure 12-1). The other end is sealed and connected to the pointer or transmitter mechanism. To increase their sensitivity, Bourdon tube elements can be extended into spirals or helical coils (Figures 12-2). This increases their effective angular length and therefore increases the movement at their tip, which in turn increases the resolution of the transducer.

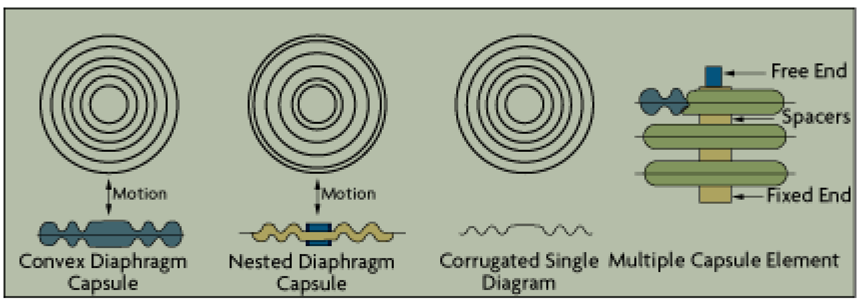


Figure 12-2: Pressure Sensor Diaphragm Designs

The family of flexible pressure sensor elements also includes the bellows and the diaphragms. Diaphragms are popular because they require less space and because the motion (or force) they produce is sufficient for operating electronic transducers. They also are available in a wide range of materials for corrosive service applications.

After the 1920s, automatic control systems evolved, and by the 1950s pressure transmitters and centralized control rooms were commonplace. Therefore, the free end of a Bourdon tube (bellows or diaphragm) no longer had to be connected to a local pointer, but served to convert a process pressure into a transmitted (electrical or pneumatic) signal. At first, the mechanical linkage was connected to a pneumatic pressure transmitter, which usually generated a 3-15 psig output signal for transmission over distances of several hundred feet, or even farther with booster repeaters. Later, as solid state electronics matured and transmission distances increased, pressure transmitters became electronic. The early designs generated dc voltage outputs (10-50 mV; 1-5 V; 0-100 mV), but later were standardized as 4-20 mA dc current output signals.

Because of the inherent limitations of mechanical motion-balance devices, first the force-balance and later the solid state pressure transducer were introduced. The first unbonded-wire strain gages were introduced in the late 1930s. In this device, the wire filament is attached to a structure under strain, and the resistance in the strained wire is measured. This design was inherently unstable and could not maintain calibration. There also were problems with degradation of the bond between the wire filament and the diaphragm, and with hysteresis caused by thermoelastic strain in the wire.

The search for improved pressure and strain sensors first resulted in the introduction of bonded thin-film and finally diffused semiconductor strain gages. These were first developed for the automotive industry, but shortly thereafter moved into the general field of pressure measurement and transmission in all industrial and scientific applications. Semiconductor pressure sensors are sensitive, inexpensive, accurate and repeatable.

Many pneumatic pressure transmitters are still in operation, particularly in the petrochemical industry. But as control systems continue to become more centralized and computerized, these devices have been replaced by analog electronic and, more recently, digital electronic transmitters.

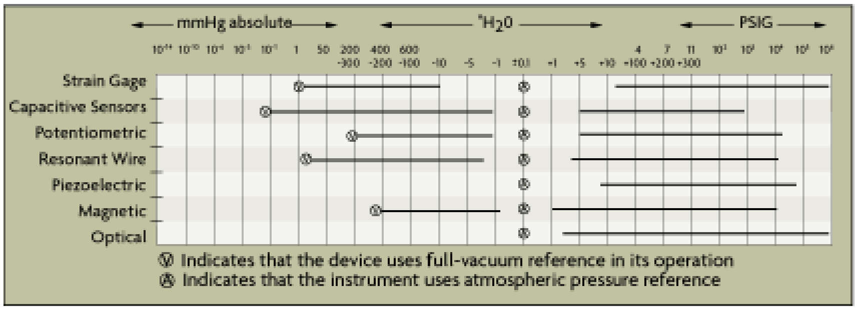


Figure 12-3: Electronic Pressure Sensor Ranges

Transducer Types

Figure 12-4 provides an overall orientation to the scientist or engineer who might be faced with the task of selecting a pressure detector from among the many designs available. The above table shows the ranges of pressures and vacuums that various sensor types are capable of detecting and the types of internal references (vacuum or atmospheric pressure) used, if any.

Because electronic pressure transducers are of greatest utility for industrial and laboratory data acquisition and control applications, the operating principles and pros and cons of each of these is further elaborated in this section.

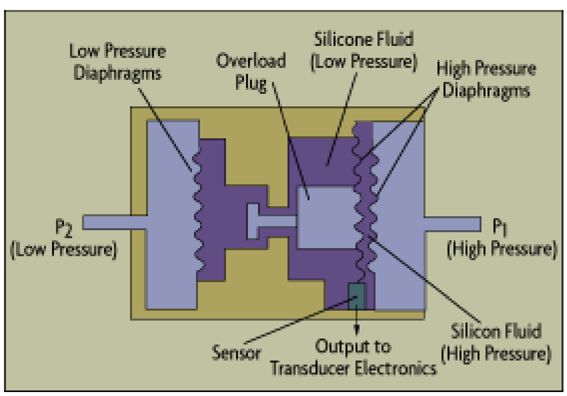


Figure 12-4: Strain-Gage Based Pressure Cell

Strain Gage

When a strain gage, is used to measure the deflection of an elastic diaphragm or Bourdon tube, it becomes a component in a pressure transducer. Strain gage-type pressure transducers are widely used.

Strain-gage transducers are used for narrow-span pressure and for differential pressure measurements. Essentially, the strain gage is used to measure the displacement of an elastic diaphragm due to a difference in pressure across the diaphragm. These devices can detect gauge pressure if the low pressure port is left open to the atmosphere or differential pressure if connected to two process pressures. If the low pressure side is a sealed vacuum reference, the transmitter will act as an absolute pressure transmitter.

Figure 12-5: Differential pressure tranducers in a variety of ranges and outputs.

Strain gage transducers are available for pressure ranges as low as 3 inches of water to as high as 200,000 psig (1400 MPa). Inaccuracy ranges from 0.1% of span to 0.25% of full scale. Additional error sources can be a 0.25% of full scale drift over six months and a 0.25% full scale temperature effect per 1000˚ F.

Capacitance

Capacitance pressure transducers were originally developed for use in low vacuum research. This capacitance change results from the movement of a diaphragm element (Figure 12-6). The diaphragm is usually metal or metal-coated quartz and is exposed to the process pressure on one side and to the reference pressure on the other. Depending on the type of pressure, the capacitive transducer can be either an absolute, gauge, or differential pressure transducer.

Stainless steel is the most common diaphragm material used, but for corrosive service, high-nickel steel alloys, such as Inconel or Hastelloy, give better performance. Tantalum also is used for highly corrosive, high temperature applications. As a special case, silver diaphragms can be used to measure the pressure of chlorine, fluorine, and other halogens in their elemental state.

In a capacitance-type pressure sensor, a high-frequency, high-voltage oscillator is used to charge the sensing electrode elements. In a two-plate capacitor sensor design, the movement of the diaphragm between the plates is detected as an indication of the changes in process pressure.

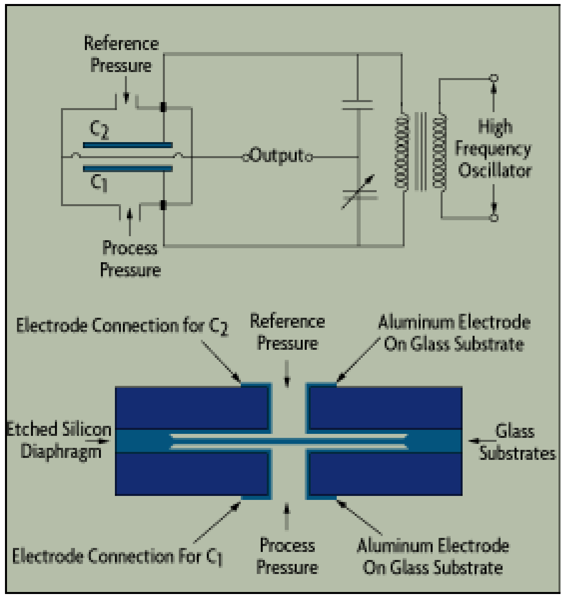


Figure 12-6: Capacitance-Based Pressure Cell

As shown in Figure 12-6, the deflection of the diaphragm causes a change in capacitance that is detected by a bridge circuit. This circuit can be operated in either a balanced or unbalanced mode. In balanced mode, the output voltage is fed to a null detector and the capacitor arms are varied to maintain the bridge at null. Therefore, in the balanced mode, the null setting itself is a measure of process pressure. When operated in unbalanced mode, the process pressure measurement is related to the ratio between the output voltage and the excitation voltage.

Single-plate capacitor designs are also common. In this design, the plate is located on the back side of the diaphragm and the variable capacitance is a function of deflection of the diaphragm. Therefore, the detected capacitance is an indication of the process pressure. The capacitance is converted into either a direct current or a voltage signal that can be read directly by panel meters or microprocessor-based input/output boards.

Capacitance pressure transducers are widespread in part because of their wide rangeability, from high vacuums in the micron range to 10,000 psig (70 MPa). Differential pressures as low as 0.01 inches of water can readily be measured. And, compared with strain gage transducers, they do not drift much. Better designs are available that are accurate to within 0.1% of reading or 0.01% of full scale. A typical temperature effect is 0.25% of full scale per 1000¡ F.

Capacitance-type sensors are often used as secondary standards, especially in low-differential and low-absolute pressure applications. They also are quite responsive, because the distance the diaphragm must physically travel is only a few microns. Newer capacitance pressure transducers are more resistant to corrosion and are less sensitive to stray capacitance and vibration effects that used to cause "reading jitters" in older designs.

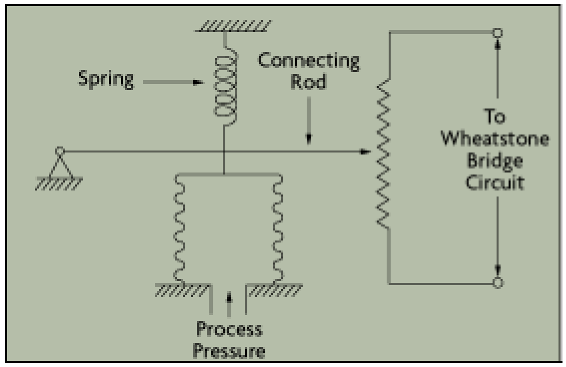


Figure 12-7: Potentiometric Pressure Transducer

Potentiometric

The potentiometric pressure sensor provides a simple method for obtaining an electronic output from a mechanical pressure gauge. The device consists of a precision potentiometer, whose wiper arm is mechanically linked to a Bourdon or bellows element. The movement of the wiper arm across the potentiometer converts the mechanically detected sensor deflection into a resistance measurement, using a Wheatstone bridge circuit (Figure 12-7).

The mechanical nature of the linkages connecting the wiper arm to the Bourdon tube, bellows, or diaphragm element introduces unavoidable errors into this type of measurement. Temperature effects cause additional errors because of the differences in thermal expansion coefficients of the metallic components of the system. Errors also will develop due to mechanical wear of the components and of the contacts.

Potentiometric transducers can be made extremely small and installed in very tight quarters, such as inside the housing of a 4.5-in. dial pressure gauge. They also provide a strong output that can be read without additional amplification. This permits them to be used in low power applications. They are also inexpensive. Potentiometric transducers can detect pressures between 5 and 10,000 psig (35 KPa to 70 MPa). Their accuracy is between 0.5% and 1% of full scale, not including drift and the effects of temperature.

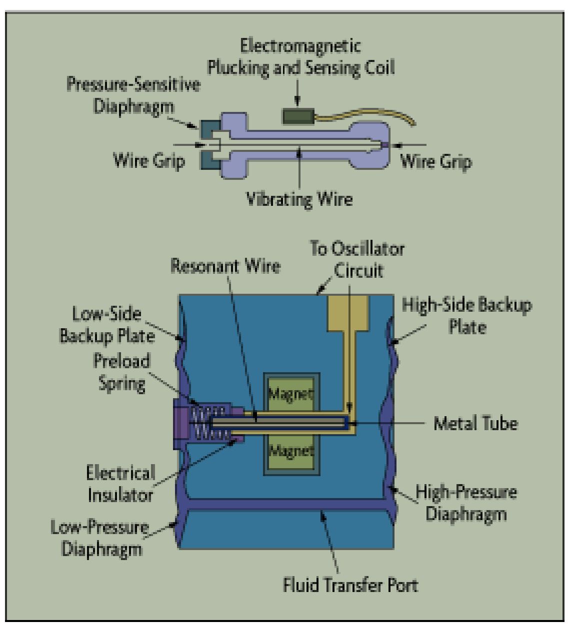


Figure 12-8: Resonant-Wire Pressure Transducer

Resonant Wire

The resonant-wire pressure transducer was introduced in the late 1970s. In this design (Figure 12-8), a wire is gripped by a static member at one end, and by the sensing diaphragm at the other. An oscillator circuit causes the wire to oscillate at its resonant frequency. A change in process pressure changes the wire tension, which in turn changes the resonant frequency of the wire. A digital counter circuit detects the shift. Because this change in frequency can be detected quite precisely, this type of transducer can be used for low differential pressure applications as well as to detect absolute and gauge pressures.

The most significant advantage of the resonant wire pressure transducer is that it generates an inherently digital signal, and therefore can be sent directly to a stable crystal clock in a microprocessor. Limitations include sensitivity to temperature variation, a nonlinear output signal, and some sensitivity to shock and vibration. These limitations typically are minimized by using a microprocessor to compensate for nonlinearities as well as ambient and process temperature variations.

Resonant wire transducers can detect absolute pressures from 10 mm Hg, differential pressures up to 750 in. water, and gauge pressures up to 6,000 psig (42 MPa). Typical accuracy is 0.1% of calibrated span, with six-month drift of 0.1% and a temperature effect of 0.2% per 1000˚ F.

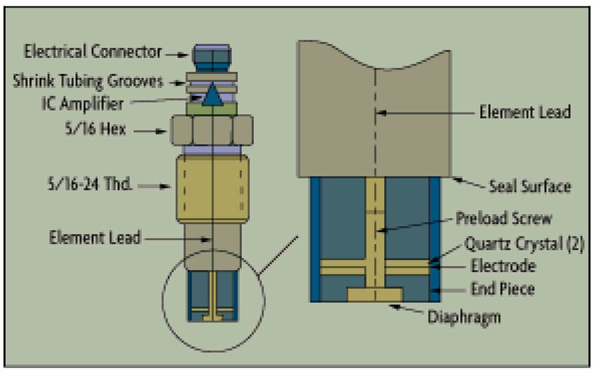


Figure 12-9: Typical Piezoelectric Pressure Sensor

Piezoelectric

When pressure, force or acceleration is applied to a quartz crystal, a charge is developed across the crystal that is proportional to the force applied (Figure 12-9). The fundamental difference between these crystal sensors and static-force devices such as strain gages is that the electric signal generated by the crystal decays rapidly. This characteristic makes these sensors unsuitable for the measurement of static forces or pressures but useful for dynamic measurements. (This phenomenon also is discussed in later chapters devoted to the measurement of dynamic force, impact, and acceleration.)

Piezoelectric devices can further be classified according to whether the crystal's electrostatic charge, its resistivity, or its resonant frequency electrostatic charge is measured. Depending on which phenomenon is used, the crystal sensor can be called electrostatic, piezoresistive, or resonant.

When pressure is applied to a crystal, it is elastically deformed. This deformation results in a flow of electric charge (which lasts for a period of a few seconds). The resulting electric signal can be measured as an indication of the pressure which was applied to the crystal. These sensors cannot detect static pressures, but are used to measure rapidly changing pressures resulting from blasts, explosions, pressure pulsations (in rocket motors, engines, compressors) or other sources of shock or vibration. Some of these rugged sensors can detect pressure events having "rise times" on the order of a millionth of a second, and are described in more detail later in this chapter.

Figure 12-10: Analog pressure transmitter with adjustable zero and span.

The output of such dynamic pressure sensors is often expressed in "relative" pressure units (such as psir instead of psig), thereby referencing the measurement to the initial condition of the crystal. The maximum range of such sensors is 5,000 or 10,000 psir. The desirable features of piezoelectric sensors include their rugged construction, small size, high speed, and self-generated signal. On the other hand, they are sensitive to temperature variations and require special cabling and amplification.

They also require special care during installation: One such consideration is that their mounting torque should duplicate the torque at which they were calibrated (usually 30 in.-lbs). Another factor that can harm their performance by slowing response speed is the depth of the empty cavity below the cavity. The larger the cavity, the slower the response. Therefore, it is recommended that the depth of the cavity be minimized and not be deeper than the diameter of the probe (usually about 0.25-in.).

Electrostatic pressure transducers are small and rugged. Force to the crystal can be applied longitudinally or in the transverse direction, and in either case will cause a high voltage output proportional to the force applied. The crystal's self-generated voltage signal is useful where providing power to the sensor is impractical or impossible. These sensors also provide high speed responses (30 kHz with peaks to 100 kHz), which makes them ideal for measuring transient phenomena.

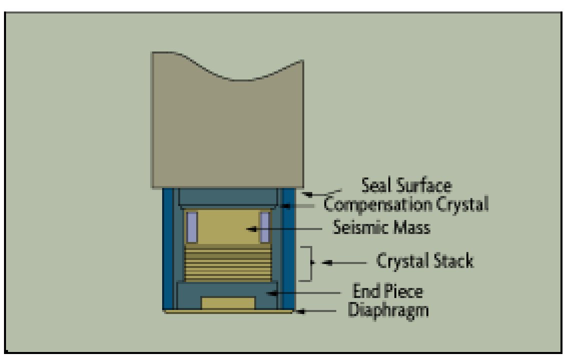


Figure 12-11: Acceleration-Compensated Piezoelectric Sensor

Figure 12-11 illustrates an acceleration-compensated pressure sensor. In this design, the compensation is provided by the addition of a seismic mass and a separate "compensation crystal" of reverse polarity. These components are scaled to exactly cancel the inertial effect of the masses (the end piece and diaphragm) which act upon the pressure-sensing crystal stack when accelerated.

Because quartz is a common and naturally occurring mineral, these transducers are generally inexpensive. Tourmaline, a naturally occurring semi-precious form of quartz, has sub-microsecond responsiveness and is useful in the measurement of very rapid transients. By selecting the crystal properly, the designer can ensure both good linearity and reduced temperature sensitivity.

Although piezoelectric transducers are not capable of measuring static pressures, they are widely used to evaluate dynamic pressure phenomena associated with explosions, pulsations, or dynamic pressure conditions in motors, rocket engines, compressors, and other pressurized devices that experience rapid changes. They can detect pressures between 0.1 and 10,000 psig (0.7 KPa to 70 MPa). Typical accuracy is 1% full scale with an additional 1% full scale per 1000˚ temperature effect.

Piezoresistive pressure sensors operate based on the resistivity dependence of silicon under stress. Similar to a strain gage, a piezoresistive sensor consists of a diaphragm onto which four pairs of silicon resistors are bonded. Unlike the construction of a strain gage sensor, here the diaphragm itself is made of silicon and the resistors are diffused into the silicon during the manufacturing process. The diaphragm is completed by bonding the diaphragm to an unprocessed wafer of silicon.

If the sensor is to be used to measure absolute pressure, the bonding process is performed under vacuum. If the sensor is to be referenced, the cavity behind the diaphragm is ported either to the atmosphere or to the reference pressure source. When used in a process sensor, the silicon diaphragm is shielded from direct contact with the process materials by a fluid-filled protective diaphragm made of stainless steel or some other alloy that meets the corrosion requirements of the service.

Piezoresistive pressure sensors are sensitive to changes in temperature and must be temperature compensated. Piezoresistive pressure sensors can be used from about 3 psi to a maximum of about 14,000 psi (21 KPa to 100 MPa).

Resonant piezoelectric pressure sensors measure the variation in resonant frequency of quartz crystals under an applied force. The sensor can consist of a suspended beam that oscillates while isolated from all other forces. The beam is maintained in oscillation at its resonant frequency. Changes in the applied force result in resonant frequency changes. Figure 12-12 shows the relationship between the applied pressure P and the oscillation frequency, where TO is the period of oscillation when the applied pressure is zero, T is the period of oscillation when the applied pressure is P, and A and B are calibration constants for the transducer.

$$P = A(1-T_O/T) - B(1-T_O/T^2)$$

Figure 12-12. Formula for Applied Pressure, Using Calibration Constants

These transducers can be used for absolute pressure measurements with spans from 0-15 psia to 0-900 psia (0-100 kPa to 0-6 MPa) or for differential pressure measurements with spans from 0-6 psid to 0-40 psid (0-40 kPa to 0-275 kPa).

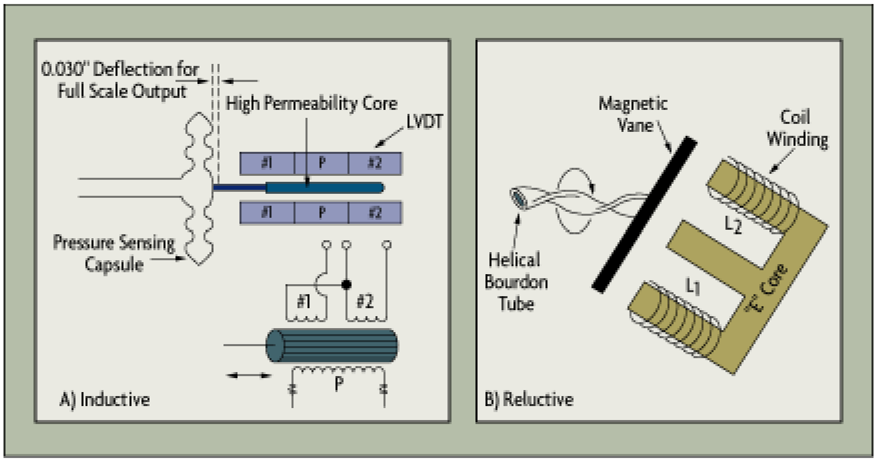


Figure 12-13: Magnetic Pressure Transducer Designs

Inductive/Reluctive
A number of early pressure transducer designs were based on magnetic phenomena. These included the use of inductance, reluctance, and eddy currents. Inductance is that property of an electric circuit that expresses the amount of electromotive force (emf) induced by a given rate of change of current flow in the circuit. Reluctance is resistance to magnetic flow, the opposition offered by a magnetic substance to magnetic flux. In these sensors, a change in pressure produces a movement, which in turn changes the inductance or reluctance of an electric circuit.

Figure 12-14: Flush-mount pressure sensor fits
1/4-in. NPT threads.

A linear variable differential transformer (LVDT) acts as the working element of a pressure transmitter. The LVDT operates on the inductance ratio principle. In this design, three coils are wired onto an insulating tube containing an iron core, which is positioned within the tube by the pressure sensor.

Alternating current is applied to the primary coil in the center, and if the core also is centered, equal voltages will be induced in the secondary coils (#1 and #2). Because the coils are wired in series, this condition will result in a zero output. As the process pressure changes and the core moves, the differential in the voltages induced in the secondary coils is proportional to the pressure causing the movement.

LVDT-type pressure transducers are available with 0.5% full scale accuracy and with ranges from 0-30 psig (0-210 kPa) to 0-10,000 psig (0-70 MPa). They can detect absolute, gauge, or differential pressures. Their main limitations are susceptibility to mechanical wear and sensitivity to vibration and magnetic interference.

Reluctance is the equivalent of resistance in a magnetic circuit. If a change in pressure changes the gaps in the magnetic flux paths of the two cores, the ratio of inductances L1/L2 will be related to the change in process pressure. Reluctance-based pressure transducers have a very high output signal (on the order of 40 mV/volt of excitation), but must be excited by ac voltage. They are susceptible to stray magnetic fields and to temperature effects of about 2% per 1000¡ F. Because of their very high output signals, they are often used in applications where high resolution over a relatively small range is desired. They can cover pressure ranges from 1 in. water to 10,000 psig (250 Pa to 70 MPa). Typical accuracy is 0.5% full scale.

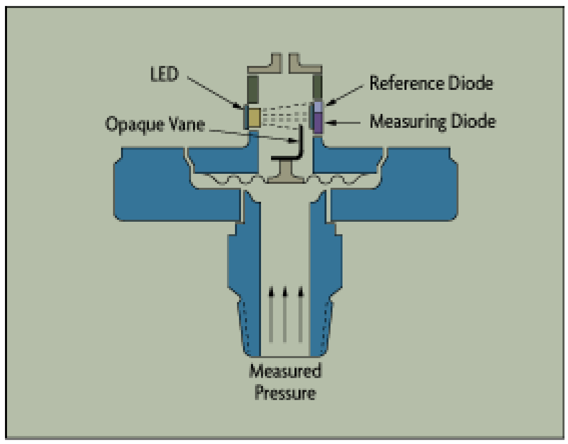


Figure 12-15: Optical Pressure Transducer

Optical

Optical pressure transducers detect the effects of minute motions due to changes in process pressure and generate a corresponding electronic output signal (Figure 12-15). A light emitting diode (LED) is used as the light source, and a vane blocks some of the light as it is moved by the diaphragm. As the process pressure moves the vane between the source diode and the measuring diode, the amount of infrared light received changes.

The optical transducer must compensate for aging of the LED light source by means of a reference diode, which is never blocked by the vane. This reference diode also compensates the signal for build-up of dirt or other coating materials on the optical surfaces. The optical pressure transducer is immune to temperature effects, because the source, measurement and reference diodes are affected equally by changes in temperature. Moreover, because the amount of movement required to make the measurement is very small (under 0.5 mm), hysteresis and repeatability errors are nearly zero.

Optical pressure transducers do not require much maintenance. They have excellent stability and are designed for long-duration measurements. They are available with ranges from 5 psig to 60,000 psig (35 kPa to 413 MPa) and with 0.1% full scale accuracy.

Practical Considerations

In industrial applications, good repeatability often is more important than absolute accuracy. If process pressures vary over a wide range, transducers with good linearity and low hysteresis are the preferred choice.

Ambient and process temperature variations also cause errors in pressure measurements, particularly in detecting low pressures and small differential pressures. In such applications, temperature compensators must be used.

Figure 12-16: Thick-film silicon pressure sensor is available in ranges from 10 to 30,000 psia.

Power supply variations also lower the performance of pressure transducers. The sensitivity (S) of a transducer determines the amount of change that occurs in the output voltage (VO) when the supply voltage (VS) changes, with the measured pressure (Pm) and the rated pressure of the transducer (Pr) remaining constant:

$$V_O = (S)V_S(Pm/Pr)$$

Figure 12-17. Formula for Output Voltage, Affected by Transducer Sensitivity and Supply Voltage

In a pressure measurement system, the total error can be calculated using the root-sum-square method: the total error is equal to the square root of the sums of all the individual errors squared.

Selection Criteria

Pressure transducers usually generate output signals in the millivolt range (spans of 100 mV to 250 mV). When used in transmitters, these are often amplified to the voltage level (1 to 5 V) and converted to current loops, usually 4-20 mA dc.

The transducer housing should be selected to meet both the electrical area classification and the corrosion requirements of the particular installation. Corrosion protection must take into account both splashing of corrosive liquids or exposure to corrosive gases on the outside of the housing, as well as exposure of the sensing element to corrosive process materials. The corrosion requirements of the installation are met by selecting corrosion-resistant materials, coatings, and by the use of chemical seals, which are discussed later in this chapter.

If the installation is in an area where explosive vapors may be present, the transducer or transmitter and its power supply must be suitable for these environments. This is usually achieved either by placing them inside purged or explosion-proof housings, or by using intrinsically safe designs.

Probably the single most important decision in selecting a pressure transducer is the range. One must keep in mind two conflicting considerations: the instrument's accuracy and its protection from overpressure. From an accuracy point of view, the range of a transmitter should be low (normal operating pressure at around the middle of the range), so that error, usually a percentage of full scale, is minimized. On the other hand, one must always consider the consequences of overpressure damage due to operating errors, faulty design (waterhammer), or failure to isolate the instrument during pressure-testing and start-up. Therefore, it is important to specify not only the required range, but also the amount of overpressure protection needed.

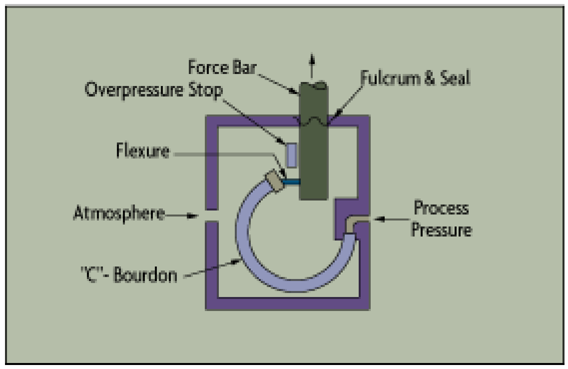


Figure 12-18: Bourdon Tube Overpressure Protection

Most pressure instruments are provided with overpressure protection of 50% to 200% of range (Figure 12-18). These protectors satisfy the majority of applications. Where higher overpressures are expected and their nature is temporary (pressure spikes of short duration--seconds or less), snubbers can be installed. These filter out spikes, but cause the measurement to be less responsive. If excessive overpressure is expected to be of longer duration, one can protect the sensor by installing a pressure relief valve. However, this will result in a loss of measurement when the relief valve is open.

If the transmitter is to operate under high ambient temperatures, the housing can be cooled electrically (Peltier effect) or by water, or it can be relocated in an air-conditioned area. When freezing temperatures are expected, resistance heating or steam tracing should be used in combination with thermal insulation.

When high process temperatures are present, one can consider the use of various methods of isolating the pressure instrument from the process. These include loop seals, siphons, chemical seals with capillary tubing for remote mounting, and purging.

Maintenance
Without exception, pressure sensors require scheduled, periodic maintenance and/or recalibration. It is necessary to periodically remove the transducer from the process and to make sure that this procedure does not require shutting down the process and does not cause injury or damage. Because the process fluid may be toxic, corrosive, or otherwise noxious to personnel or the environment, it is necessary to protect against the release of such fluids during maintenance.

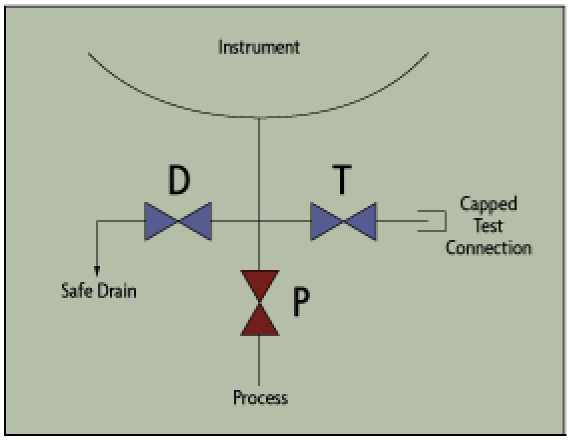


Figure 12-19: Three-Valve Manifold for Instrument Isolation

A three-way manifold (Figure 12-19) can provide such protection. In the illustration, valve P is used to isolate the process and valve D serves to discharge the trapped process fluid from the instrument into some safe containment. The purpose of valve T is to allow the application of a known calibration or test pressure to the instrument. As all the components of the manifold are pre-assembled into a compact package, space and field assembly time are saved and chances for leaks are reduced.

Calibration

Pressure transducers can be recalibrated on-line or in a calibration laboratory. Laboratory recalibration typically is preferred, but often is not possible or necessary. In the laboratory, there usually are two types of calibration devices: deadweight testers that provide primary, base-line standards, and "laboratory" or "field" standard calibration devices that are periodically recalibrated against the primary. Of course, these secondary standards are less accurate than the primary, but they provide a more convenient means of testing other instruments.

A deadweight tester consists of a pumping piston with a screw that presses it into the reservoir, a primary piston that carries the dead weight, and the gauge or transducer to be tested (Figure 12-20). It works by loading the primary piston (of cross sectional area A), with the amount of weight (W) that corresponds to the desired calibration pressure ($P = W/A$). The pumping piston then pressurizes the whole system by pressing more fluid into the reservoir cylinder, until the dead weight lifts off its support.

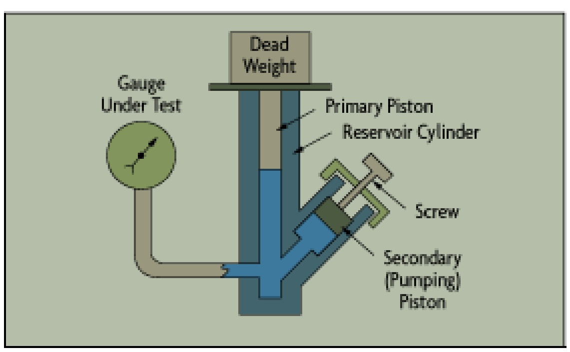


Figure 12-20: Dead-Weight Tester Schematic

Today's deadweight testers are more accurate and more complex than the instrument in Figure 12-20, but the essential operating principles are the same. Sophisticated features include temperature compensation and the means to rotate the piston in its cylinder to negate the effects of friction.

In the United States, the National Institute of Standards & Technology (NIST) provides certified weights and calibrates laboratory piston gauges by measuring the diameter of the piston. Deadweight testers can be used to calibrate at pressure levels as low as 5 psig (35 kPa) and as high as 100,000 psig (690 MPa). Tilting type, air-lubricated designs can detect pressures in the mm Hg range. NIST calibrated deadweight testers can be accurate to 5 parts in 100,000 at pressures below 40,000 psig (280 MPa). For an industrial quality deadweight tester, error is typically 0.1% of span.

A typical secondary standard used for calibrating industrial pressure transducers contains a precision power supply, an accurate digital readout, and a high-accuracy resonant (quartz) pressure sensor. It is precise enough to be used to calibrate most industrial pressure transducers, but must be NIST-traceable to be used as an official calibration standard. The best accuracy claimed by the manufacturers is typically 0.05% full scale.

Installation & Accessories

When possible, pressure instrumentation should be installed in visible, readily accessible locations. Readouts should be located at eye elevation. Headroom should be provided for instrument removal, as well as any space for tools and test equipment that might be needed.

In some applications, it is desirable to prevent the process fluid from coming in contact with the sensing element. The process may be noxious, poisonous, corrosive, abrasive, have the tendency to gel, freeze or decompose at ambient temperatures, or be hotter or colder than the sensor can tolerate. Other reasons for inserting accessories between the process and the pressure instrument are to filter out potentially plugging solids or to remove potentially damaging pressure spikes or vibrations.

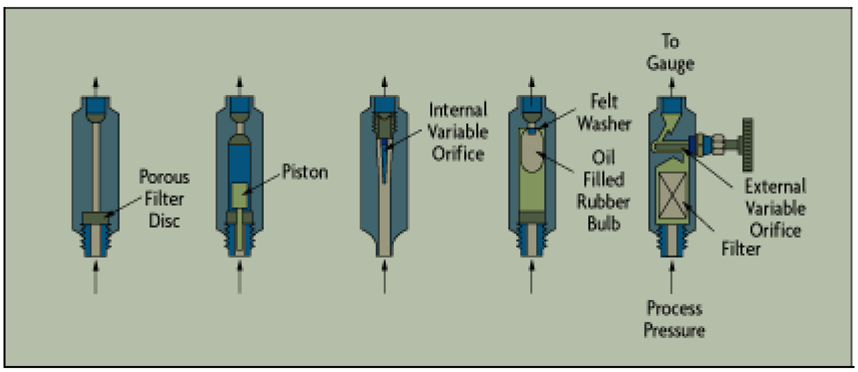


Figure 12-21: Pulsation Damper & Snubber Designs

Snubbers & Pulsation Dampers

An unprotected pressure sensor on the discharge of a positive displacement pump or compressor would never come to rest, and its pointer would cycle continuously. To filter out pressure spikes, or to average out pressure pulses, snubbers and pulsation dampers are installed between the process and the instrument (Figure 12-21).

The first design shown in the illustration uses a corrosion-resistant porous metal filter to delay the pressure reading by about 10 seconds. Other designs provide shorter delays via fixed or variable pistons or restrictions. The advantage of an adjustable restriction is that if, for example, a pressure gauge is placed on the discharge of a compressor, one can see when the pointer cycling has stopped. Naturally, when one is interested in the measurement of fast, transient pressures (such as to initiate safety interlocks on rising pressures), snubbers must not be used, as they delay the response of the safety system.

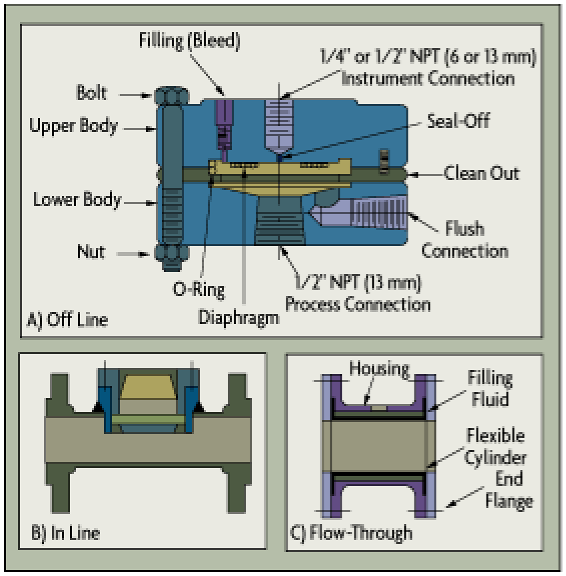


Figure 12-22: Chemical Seal Alternatives

Chemical Seals

The chemical seal is also known as a "diaphragm protector." Its main components (the upper and lower body and the clean-out ring) are shown in Figure 12-22. The pressure instrument is screwed into the upper body, which can be made of standard materials because it contacts only the non-corrosive filling fluid, usually a silicone oil. The top section with the filled diaphragm capsule can be removed with the pressure instrument while the operator cleans out the material accumulated in the bottom housing. This lower body is made of "pipe specification" (process compatible) materials and can be continuously or periodically cleaned by purging.

The seal shown in Figure 12-22A is an off-line design; an in-line design is shown in Figure 12-22B. In-line devices are less likely to plug, but the process has to be shut down if maintenance is required. The ultimate in self-cleaning designs is shown in Figure 12-22C, in which all sharp edges and dead-ended cavities (where solids could accumulate) have been eliminated. The flexible cylinder can be made of a variety of plastics, including PFA, and is available in spool and wafer configurations.

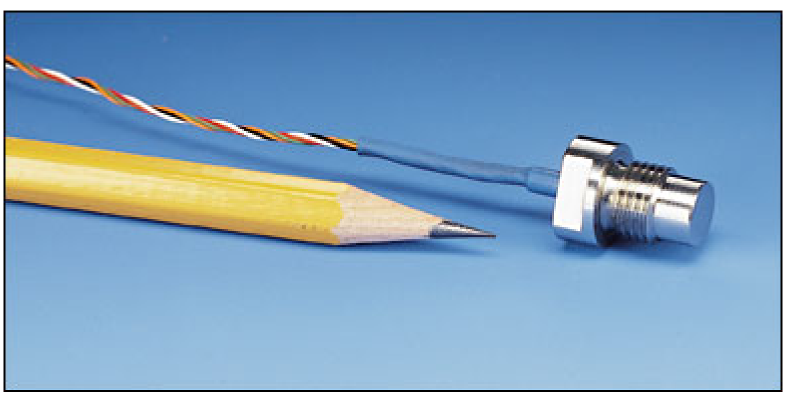


Figure 12-23: Miniature pressure sensor fits in tight spots.

As the process pressure changes, the amount of liquid displaced by the sealing diaphragm is small, and is sometimes insufficient to fill and operate bellows-type sensors. In that case, larger displacement "rolling" diaphragms are used. Volumetric seal elements (Figure 12-24) also can eliminate cavities and sharp edges where material might accumulate. They also are well suited for high pressure and high viscosity applications such as extruders.

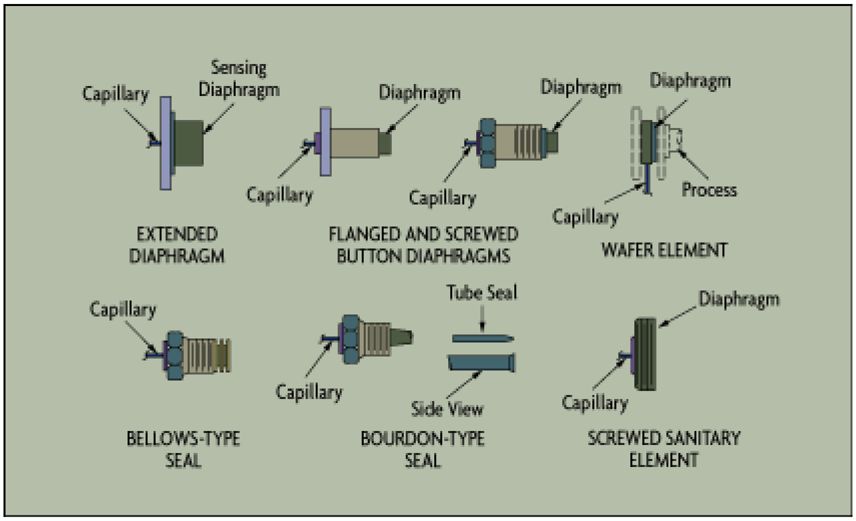


Figure 12-24: Volumetric Seal Element Designs

Adding seals to a press measurement device can cause the following problems:

- Long or large bore capillaries increase the volume of the filling fluid, increasing the temperature error.
- Smaller diameter diaphragms are stiff and increase error, particularly at low temperatures.
- Filling fluid viscosity, acceptable at normal ambient temperatures, may be unacceptably high at low temperatures.
- Long capillary lengths or smaller bores can cause slow response.
- Uneven heating/cooling of seals and capillaries can cause errors.
- Some fill fluids expand excessively with temperature and damage the instrument by overextending the diaphragm.
- High temperature and/or high vacuum may vaporize the fill fluid and damage the instrument.
- Fluid may contract excessively at low temperatures, bottoming the diaphragm and preventing operation.
- Frozen fill fluid also will prevent operation.

For a successful seal installation, the following must also be considered:

- Process and ambient temperature range.
- Relative elevation of the seals and the instrument and the hydrostatic head of the fill fluid. Instrument should be rezeroed after installation to correct for elevation.
- Temperature, pressure, and physical damage potentials during cleaning and emptying.
- Possible consequences of diaphragm rupture in terms of hazard and contamination.
- Identical seals and capillary lengths for both sides of a differential pressure device.
- Seal and instrument performance at maximum temperature/minimum pressure and minimum pressure/temperature combinations.

Wet Legs & Seal Pot

When one or both impulse lines to a differential pressure device are filled with a stable, process compatible fluid, the installation is called a "wet-leg" installation. The net effect of the legs' height above the instrument and specific gravity of the fluid must be considered in the calibration. Wet leg design must also allow for the filling and draining of the leg(s).

Seal pots are used with wet legs when the instrument displaces a large volume of liquid as the measurement changes. A seal pot is a small pressure vessel about one quart in volume that is mounted at the top of the wet leg line. If two wet legs are used in a differential application, the pots must be mounted at the same elevation. Each pot acts as a reservoir in the impulse line where large volume changes will result in minimal elevation change so that seal liquid is not dumped into the process line and elevation shifts of the wet leg liquid do not cause measurement errors.

12.1.1.1: Bonded Strain Gage Pressure Transducer

- Entirely welded stainless steel pressure media cavity
- DC isolation from signal output to excitation
- 20-36 Vdc unregulated excitation
- Output short circuit protected
- Rigid-edge-supported diaphragm sensing element with four active foil strain gages thermal-epoxy- bonded to controlled stress zones
- Ultra-low hysteresis and non-repeatability errors are primary features of design
- Pressure fitting per MS33656-4, AE F250-C® or Cajon 4 VCR® internal or external thread

Figure 12-25. Pressure Transducer

Options:

- Internal shunt
- Compensation available from -65°F to +250°F (-54°C to +121°C)
- Alternate pressure media cavity materials
- EMI input/output filtering
- Special electrical receptacles

Pressure Ranges:

PSIA or PSIS	BAR	PSIA or PSIS	BAR
0-50	0-3.45	0-2000	0-138
0-100	0-6.89	0-2500	0-172
0-150	0-10.3	0-3000	0-207
0-200	0-13.8	0-3500	0-241
0-250	0-17.2	0-4000	0-276
0-300	0-20.7	0-5000	0-345
0-500	0-34.5	0-7500	0-517
0-750	0-51.7	0-10,000	0-689
0-1000	0-68.9	0-15,000	0-1033
0-1500	0-103	0-20,000	0-1378

(PSIS has 14.7 PSIA Ref.)

Specifications:

Table 12-1. Pressure Transducer Specifications

Description	Value
Measured Fluids	All fluids compatible with 17-4 PH stainless steel
Full Scale Output	5.000 ±0.050 volts dc for a 50k ohm load or greater
Zero Balance	0.000 ±0.050 Vdc at +70°F (+21°C)
End Point Linearity	• Within ±0.25% FSO for 0-50 thru 0-500 PSI ranges • Within ±0.15% FSO for 0-750 thru 0-20,000 PSI ranges
Hysteresis	Within 0.10% FSO
Repeatability	Within 0.10% FSO
Resolution:	Infinite
Proof Pressure Rating	• 0-50 thru 0-300 PSI ranges: 4.0 times range • 0-500 thru 0-20k PSI ranges: 2.0 times • Application of proof pressure will not cause any change in performance characteristics
Burst Pressure Rating	• 0-50 thru 0-300 PSI ranges: 6.0 times range • 0-500 thru 0-20k PSI ranges: 3.0 times range
Compensated Temperature Range	-30°F to + 170°F (-34°C to +77°C)
Operating Temperature Range	-65°F to +250°F (-54°C to + 121°C)
Triaxial Mechanical Shock	30 G's applied for 11 millisecond will not change performance characteristics
Excitation	20 to 36 volts dc unregulated. Reverse polarity protected. ±100 volt 10 microsecond spikes will not cause permanent damage
Current Drain	35 mADC typical
Output Impedance	25 ohms typical
Output Noise	Less than 15 millivolts peak to peak at less than 300 kHz
Insulation Resistance	Greater than 1000 megohms at 50 Vdc between all terminals in parallel and case at +70°F (+21°C)
DC Isolation	Greater than 1000 megohms at 50 Vdc from excitation to signal output terminals at +70°F (+21°C)
Pressure Connection	• 0-50 thru 0-10,000 PSI ranges….7/16-20 internal thread per MS33649-4 pressure fitting • 0-15,000 thru 0-20,000 PSI ranges AE F250-C®, 9/16-18 UNF thread. Options available
Electrical Receptacle	Stainless steel hermetic receptacle to mate with MS3116-10-6S. Standard wiring: Excitation +A, -D; Signal +B, -C; No Connection E, F. Options available
Enclosure	Entirely welded and hermetically sealed stainless steel
Weight	Approximately 10.25 ounces (287 g)

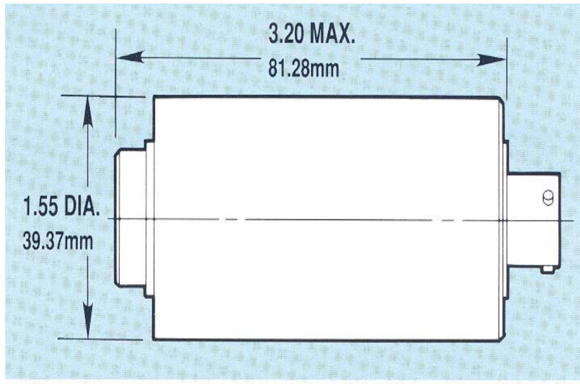


Figure 12-26. Dimension of a Pressure Transducer

12.1.1.2: High Frequency Pressure Transducer

[Source: http://www.pcb.com/spec_sheet.asp?model=101A04&item_id=8947 (1 of 3)2/26/2009 10:14:24 AM Model 101A04 Spec Sheet]

General purpose ICP® pressure sensor, 1000 psi, 5 mV/psi, 3/8-24 mtg thd, ground isolated

Figure 12-27. High Frequency Pressure Transducer

Specifications:

Table 12-2. High Frequency Pressure Transducer Specifications

Description	Value
PERFORMANCE	
Measurement Range(for ±5V output)	1 kpsi
Useful Overrange (for ± 10V output)	2 kpsi
Sensitivity(± 0.5 mV/psi)	5.0 mV/psi
Maximum Pressure(static)	10 kpsi
Resolution	20 mpsi
Resonant Frequency	≥ 400 kHz
Rise Time(Reflected)	≤ 1.5 μ sec
Low Frequency Response (-5 %)	0.005 Hz
Non-Linearity	≤ 2.0 % FS
ENVIRONMENTAL	
Acceleration Sensitivity	≤ 0.002 psi/g
Temperature Range (Operating)	-100 to +275 °F
Temperature Coefficient of Sensitivity	≤ 0.03 %/°F
Maximum Flash Temperature	3000 °F
Maximum Shock	20,000 g pk
ELECTRICAL	
Output Polarity(Positive Pressure)	Positive
Discharge Time Constant (at room temp)	≥ 100 sec
Excitation Voltage	20 to 30 VDC
Constant Current Excitation	2 to 20 mA
Output Impedance	≤ 100 ohm
Output Bias Voltage	8 to 14 VDC
Electrical Isolation	10^8 ohm
PHYSICAL	
Sensing Geometry	Compression
Sensing Element	Quartz
Housing Material	Stainless Steel
Diaphragm	Invar
Sealing	Welded Hermetic
Electrical Connector	10-32 Coaxial Jack
Weight	0.44 oz
SUPPLIED ACCESSORIES	Model 065A03 Seal ring 0.435" OD x 0.377" ID x 0.030" thk brass (3)
OPTIONAL VERSIONS	
H – Hermetic Seal	Welded Hermetic
M – Metric Mount	Supplied Accessory: Model 065A40 Seal ring 0.435" OD x 0.397" ID x 0.030" thk brass (3) replaces Model 084C11
N – Negative Output Polarity	
S – Stainless Steel Diaphragm	316L Stainless Steel
W – Water Resistant Cable	

CE [3]

All specifications are at room temperature unless otherwise specified.

NOTES:

[1] For +10 volt output, minimum 24 VDC supply voltage required. Negative 10 volt output may be limited by output bias.

[2] Zero-based, least-squares, straight line method.

[3] See PCB Declaration of Conformance PS023 for details.

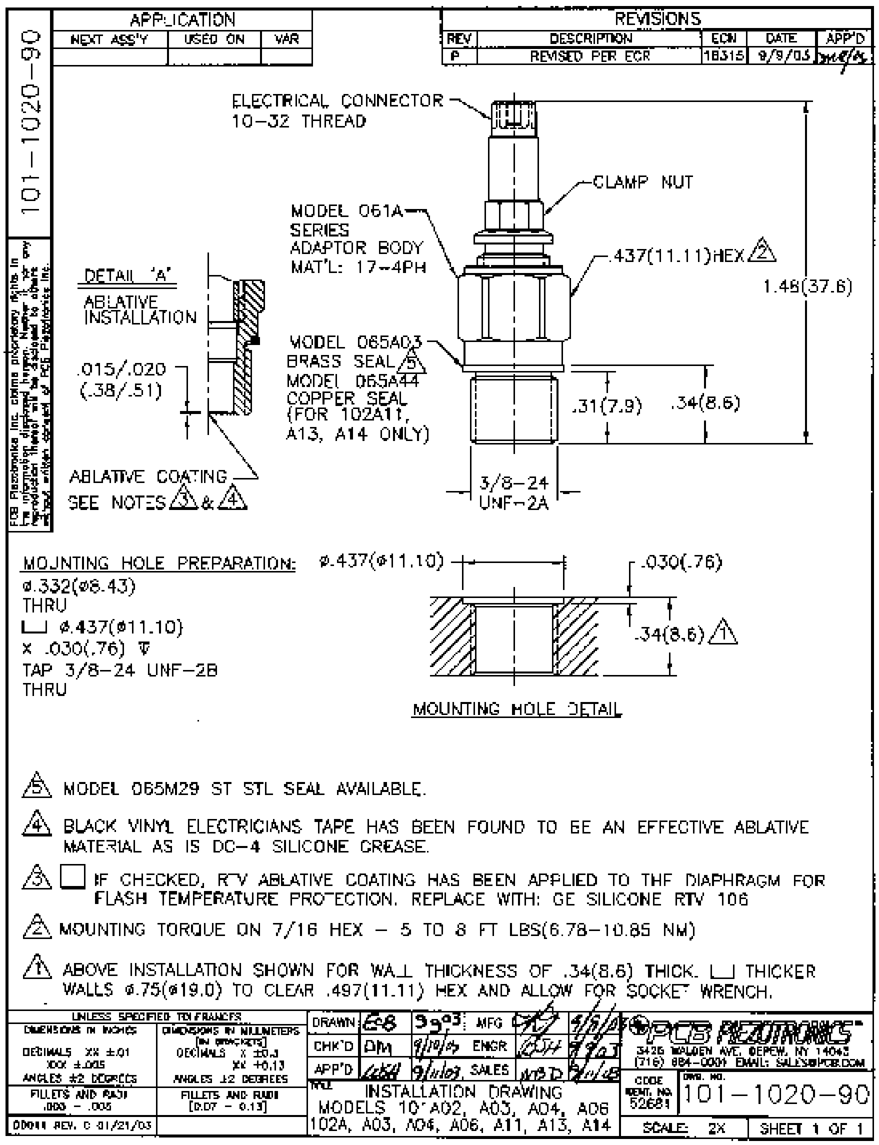


Figure 12-28. Schematic of a High Frequency Pressure Transducer

12.1.1.3: Pressure Transducer Installation and Setup

1. Using a 6-conducter cable install a 8-pin pressure connector on transducer side of cable and a 10-pin SIU connector on the data input side.
2. 8-pin pressure transducer connector should be soldered using the instrumentation color code.
   A – black wire
   B – white wire
   C – red wire
   D – green wire
   G – orange wire
   H – blue wire
   No shield is used on the transducer end
3. 10-pin SIU connector will be installed using crimp on pins and inserted into connector by using a insertion tool. Color code for SIU end is as follows:
   A – black wire
   B – white wire
   C – red wire
   D – green wire
   G – orange wire
   H – blue wire
   J – shield wire
4. After connectors are installed on both ends of cable, use a ohm meter and verify correct pin out.
5. If pin out is good, use 3M potting compound and pot the back shell of the pressure transducer connector for weather proofing purposes. Potting compound cures in 24 hrs.
6. After cable is installed to the transducer and data system, have the DSU operator to put a step on the SIU and adjust the excitation voltage on the SIU mode card to the value that the instrumentation engineer has specified for each transducer.
7. After excitation voltage is set, have DSU operator to remove the step from the SIU and request that DSU operator perform a shunt calibration on the transducer.
8. After shunt calibration is performed, take a pressure transducer shunt box out to the transducer and remove cable from transducer and hook up the shunt box up in line with the transducer and drag-on cable.
9. Transducer is now ready to FAP.
10. A FAP will verify that the info in the DSU database is correct and that the transducer is operational and within tolerance of the specified calibration. You will verify this by shunting the transducer to 25%, 50%, 75% and 100% of its operating range.
11. DSU will verify that all shunt values were ok. Disconnect shunt box from transducer and drag-on cable. Re-install drag-on cable to transducer. That completes the FAP.

12.1.1.4: Strain Gage Installations with M-Bond Adhesives

STRAIN GAGE INSTALLATIONS WITH M-BOND 43-B, 600, AND 610 ADHESIVE SYSTEMS

Introduction

Micro-Measurements M-Bond 43-B, 600, and 610 adhesives are high-performance epoxy resins, formulated specifically for bonding strain gages and special-purpose sensors. When properly cured, these adhesives are useful for temperatures ranging from deep cryogenic -452˚ to +350˚ F (-269˚ to +175˚ C) with M-Bond 43-B, and to +700˚ F (+370˚ C) for short periods with M-Bond 600 and 610. In common with other organic materials, their lives are limited by oxidation and sublimation effects at elevated temperatures. M-Bond 43-B is particularly recommended for transducer applications up to +250˚ F (+120˚ C), and M-Bond 610 for transducers up to +450˚ F (+230˚ C).

Mixing Instructions

Since M-Bond 43-B is a solvent-thinned, precatalyzed epoxy mixture, it is applied at room temperature directed as received. The M-Bond 600 and 610, on the other hand, are two-component systems. These must be mixed as follows:

1. Resin and curing agent bottles *must* be at *room temperature* before opening.

2. Using the disposable plastic funnel, empty contents of bottle labeled “Curing Agent” into bottle of resin labeled “Adhesive”. Discard funnel.

3. After tightening the brush cap (included separately), thoroughly mix contents of this “Adhesive” bottle by vigorously shaking it for 10 seconds.

4. Mark bottle with date mixed in space provided on the label.

Allow this freshly mixed adhesive to stand for at least one hour before using.

Surface Preparation

The extensive subject of surface preparation techniques is covered in *Instruction Bulletin B-129*. Metal surface cleaning procedures usually involve solvent degreasing with either CSM-1 Degreaser or FTF-1 Mild Degreaser, abrading, and cleaning with M-Prep Conditioner A, followed by application of M-Prep Neutralizer 5. When practical, these preparation procedures should be applied to an area significantly larger than that occupied by the gage. Surfaces should be free from pits and irregularities. Porous surfaces may be precoated with a filled epoxy, such as M-Bond GA-61, and this then cured and abraded.

Shelf Life and Pot Life

At room temperature, M-Bond 600 has a useful storage life of approximately three months, while M-Bond 43-B and M-Bond 610 will last about nine months.

Once opened and mixed, M-Bond 600 and 610 have room-temperature pot lives of two weeks and six weeks, respectively. Since M-Bond 43-B is supplied already mixed, its pot life is about the same as its shelf life when kept in a tightly closed container.

These periods of adhesive usefulness can often be doubled by refrigeration at +30˚ to +40˚ F (0˚ to 5˚ C). **Never open a refrigerated bottle until it has reached room temperature.**

HANDLING PRECAUTIONS:
Epoxy resins and hardeners may cause dermatitis or other allergic reactions, particularly in sensitive persons. The user is cautioned to: *(1) avoid contact with either the resin or hardener; (2) avoid prolonged or repeated breathing of the vapors; and (3) use these materials only in well-ventilated areas.* If skin contamination occurs, thoroughly was the contaminated area with soap and water immediately. In case of eye contact, flush immediately and secure medical attention. Rubber gloves and aprons are recommended, and care should be taken not to contaminate working surfaces, tools, container handles, etc. Spills should be cleaned up immediately. For additional health and safety information, consult the Material Safety Data Sheet, which is available upon request.

<u>Gage Installation</u>

The basic steps for bonding of gages using M-Bond 43-B, 600, and 610 adhesives are given in the following pages. These are followed by various cure recommendations.

Step 1

Thoroughly degrease the gaging area with a solvent, such as CSM-1 Degreaser or FTF-1 Mild Degreaser (Fig. 1). The former is preferred, but there are some materials (e.g., titanium and many plastics) which may react with chlorinated solvents. In these cases, FTF-1 Mild Degreaser is an excellent substitute. All degreasing should be done with uncontaminated solvents – thus, the use of one-way containers, such as aerosol cans, is highly advisable.

Figure 12-29. M-Bond 43, 600, and 610 Adhesive Step 1

Step 2

Preliminary dry abrading with 220- or 320-grit silicon-carbide paper (Figure 12-30a) is generally required if there is any surface scale or oxide. Final abrading is done by using 320- or 400-grit silicon-carbide paper on surfaces thoroughly wetted with M-Prep Conditioner A; this is followed by wiping dry with a gauze sponge, as in Figure 12-30b.

With a 4H pencil (on aluminum) or a ballpoint pen (on steel), burnish *(do not scribe)* whatever alignment marks are needed on the specimen. Repeatedly apply M-Prep Conditioner A, and scrub with cotton-tipped applicators until a clean tip is no longer discolored. Remove all residue and Conditioner by slowly wiping through with a clean gauze sponge. Never allow any solution to dry on the surface, because this invariably leaves a contaminating film, and reduces chances of a good bond.

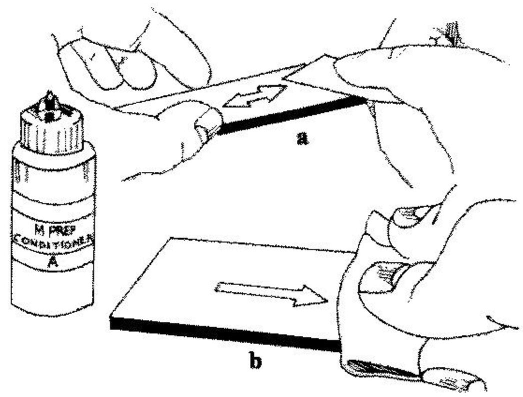


Figure 12-30. M-Bond 43, 600, and 610 Adhesive Step 2

Step 3

Apply a liberal amount of M-Prep Neutralizer 5 and scrub with a cotton-tipped applicator (Figure 12-31). With a single, slow wiping motion, use a gauze sponge to carefully dry this surface. Do not wipe back and forth, as this may allow contaminants to be redeposited on the cleaned surface.

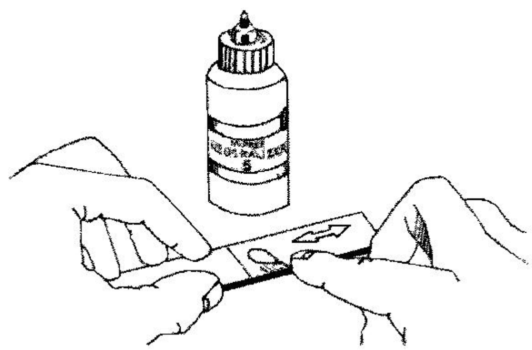


Figure 12-31. M-Bond 43, 600, and 610 Adhesive Step 3

Step 4

Remove a gage from its acetate envelope with tweezers, making certain not to touch any exposed foil. Place the gage, bonding side down, onto a chemically clean glass plate or empty gage box. If a solder terminal is to be incorporated, position it next to the gage. While holding the gage in position with an acetate envelope, place a short length of M-M Part No. MJG-2 mylar tape down over about half of the gage tabs and entire terminals (Figure 12-32).

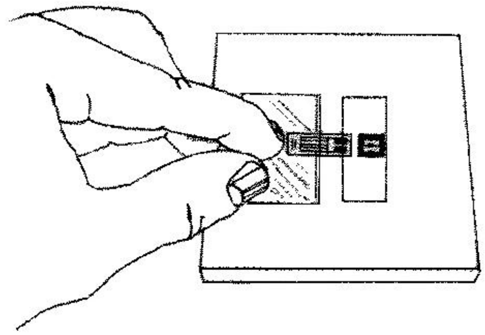


Figure 12-32. M-Bond 43, 600, and 610 Adhesive Step 4

Step 5

Remove the gage/tape/terminal assembly by peeling tape at a shallow angle (about 30˚) and transferring it onto the specimen. Make sure gage alignment marks coincide with specimen layout lines. If misalignment does occur, lift end of tape at a shallow angle until assembly is free. Realign and replace (Figure 12-33). Using a pair of tweezers often facilitates this handling. ***Note: A "hot-tack" method of positioning can be used, which eliminates the need for taping. This method is explained after Step 9.***

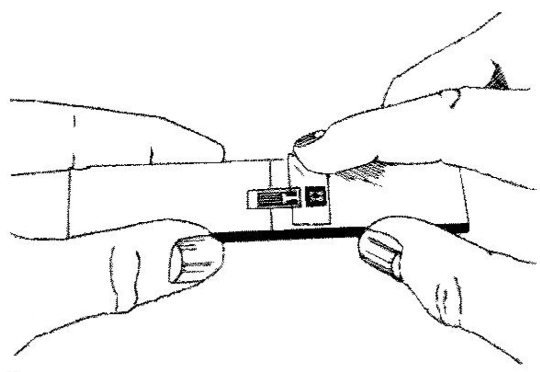


Figure 12-33. M-Bond 43, 600, and 610 Adhesive Step 5

Step 6

Now, by lifting at a shallow angle, peel back one end of the taped assembly so as to raise both gage and terminal. By curing this mylar tape back upon itself, it will remain in position, ready to be accurately relaid after application of adhesive, as in Fig. 12-34.

Coat the gage backing, terminal, and specimen surface with a thin layer of adhesive. Also coat the foil side of open-faced gages. Do not allow the adhesive applicator to touch the tape mastic. Permit adhesive to air-dry, by solvent evaporation, for 5 to 30 minutes at +75˚ F (+24˚ C) and 50% relative humidity. Longer air-drying times are required at lower temperatures and/or higher humidities. ***Note: An additional drying step with 43-B is beneficial for large gages. Place the unclamped installation in an oven for 30 minutes at +175˚ F (+85˚ C), following the air-dry step above.***

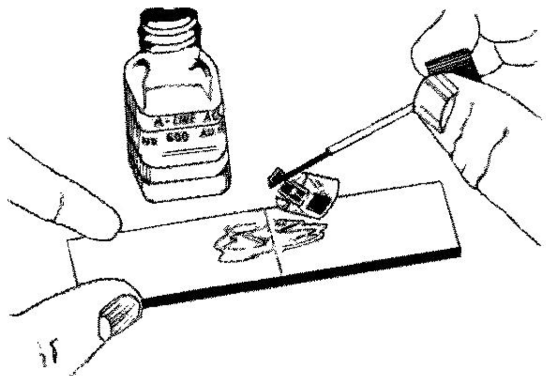


Figure 12-34. M-Bond 43, 600, and 610 Adhesive Step 6

Step 7

Return gage/terminal assembly to its original position over layout marks. Use only enough pressure to allow assembly to be tacked down. Overlay gage/terminal area with a piece of thin Teflon® sheet. If necessary, anchor Teflon in position with a piece of mylar tape across one end.

Cut a 3/32-in (2.5-mm) think silicone gum pad and a metal backup plate to a size slightly larger than the gage/terminal areas, and carefully center these as shown in Figure 12-35. Larger pads may restrict proper spreading adhesive, and entrap residual solvents during cure process. ***Note: Steps 6, 7, and 8 must be completed within 30 minutes with M-Bond 600, 4 hours with M-Bond 610, and 24 hours with M-Bond 43-B.***

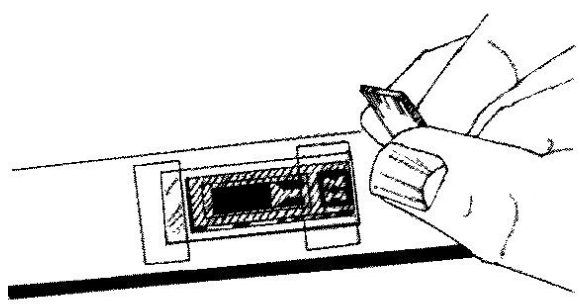


Figure 12-35. M-Bond 43, 600, and 610 Adhesive Step 7

Step 8

Either spring clamps, as in Figure 12-36, or deadweights can be used to apply pressure during the curing cycle. From 40 to 50 psi (275 to 350 kN/m^2) is recommended for transducers and 10 to 70 psi (70 to 480 kN/m^2) for general work. Place clamped gage/specimen into a cool oven and raise temperature to the desired curing level at a rate of 5˚ to 20˚ F (3˚ to 11˚ C) per minute. Air bubbles trapped in the adhesive, uneven gluelines, and high adhesive film stresses often result from starting with a hot oven. Time-versus-temperature recommendations for curing each adhesive are given after Step 9.

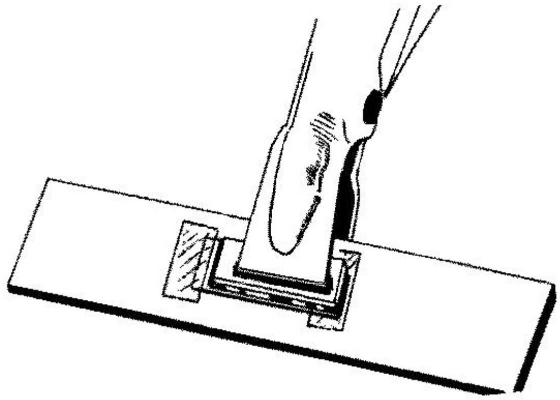


Figure 12-36. M-Bond 43-B, 600, and 610 Adhesive Step 8

Step 9

Upon completion of the curing cycle, allow oven temperature to drop at least 100˚ F (55˚ C) before removing specimen. Remove clamping pieces and mylar tape. It is advisable to wash off the entire gage area with either M-LINE Rosin Solvent or toluene. This should remove all residual mastic and other contamination. Wipe dry with a gauze sponge.

"Hot-Tack" Method of Gage Installation

This procedure eliminates all need for taping to prevent movement of gage during mounting and is especially suited to M-Bond 43-B and M-Bond 600.

1. After completing Steps 1, 2, and 3 preceding, remove a gage from its acetate envelope using a clean pair of tweezers.

2. Coat bonding side of gage and gaging area of specimen with adhesive, and set each aside to air-dry for at least 15 minutes. M-Bond 43-B may dry for up to 24 hours.

3. Using tweezers, position gage onto the specimen. A properly cleaned dental probe may help.

4. To anchor gage, use a 15- to 25-watt soldering iron with a new conical tip. This is usually done by hot-tack-setting the adhesive at two spots; e.g., at opposite gage alignment marks, while temporarily holding down the gage with an acetate envelope. A little experimentation may be required to learn the correct iron temperature and hot tip contact time. These depend upon type of adhesive used and thermal conductivity of the base material.

5. If gage is open-faced, apply a thin coating of adhesive to its face and allow to dry for at least five minutes before overlaying with Teflon sheet (as in Step 7). Proceed with Steps 8 and 9 preceding.

Recommended Cure Schedule

It should be noted that the following curves represent a range of time-versus-temperature; however, the upper limits of both time and temperature should be employed whenever possible, while keeping in mind the possible effect on the heat treat condition of the substrate material.

M-Bond 43-B: 2 hours at +375˚ F (+190˚ C)
M-Bond 600: Cure at temperature for time period specified by the graph below.

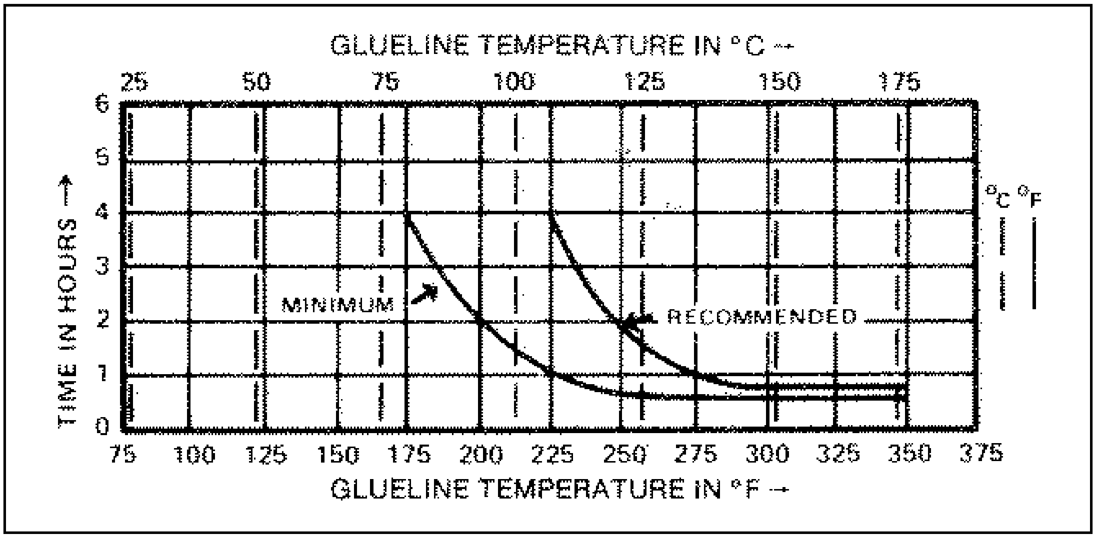


Figure 12-37. Glueline Temperature vs. Hours for M-Bond 43-B and M-Bond 600

M-Bond 610: Cure at temperature for time period specified by graph below.

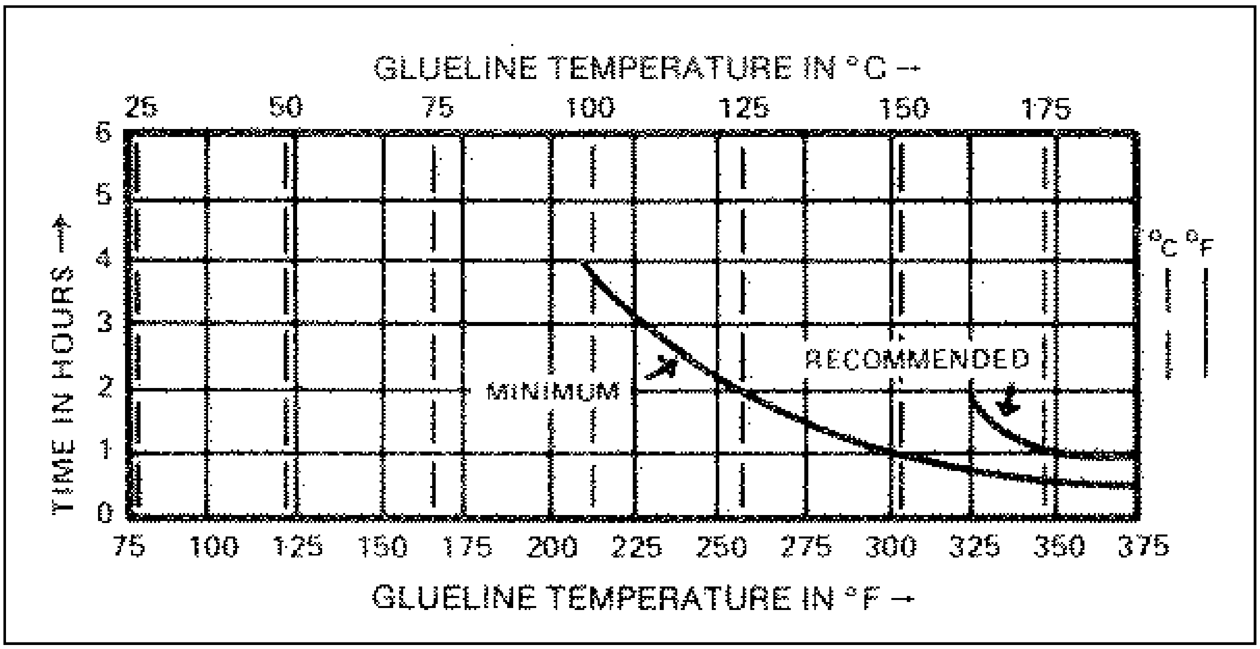


Figure 12-38. Glueline Temperature vs. Hours for M-Bond 610

Postcuring

Postcures with the clamping fixture removed, are usually required for stable transducer applications. Postcuring can be done following Step 9 above, or after wiring the transducer (subject to temperature limits of solder and wire insulation).

M-Bond 43-B: 2 hours at +400˚ F (+205˚ C)

M-Bond 600: 1 to 2 hours at +50˚ F (+30˚ C) above maximum operating or curing temperature, whichever is greater.

M-Bond 610: 2 hours at +75˚ F (+40˚ C) above maximum operating or curing temperature, whichever is greater.

Final Installation Procedure

1.

STRAIN GAGE INSTALLATIONS WITH M-BOND 200 ADHESIVE SYSTEMS

Introduction

Micro-Measurements Certified M-Bond 200 is an excellent general-purpose laboratory adhesive because of its fast room-temperature cure and ease of application. When properly handled, M-Bond 200 can be used for high-elongation tests in excess of +30,000 microstrain, for fatigue studies, for one-cycle proof tests to over +200˚ F (+95˚ C) or to below -300˚ F (-185˚ C). The normal operating range is -25˚ to +150˚ F (-30˚ to +65˚ C). M-Bond 200 is compatible with all Micro-Measurements strain gages and most common structural materials. For best reliability, it should be applied to surfaces between the temperatures of +70˚ and +85˚ F (+20˚ to +30˚ C), and in a relative humidity environment of 30% to 65%. M-Bond catalyst has been specially formulated to control the reactivity rate of this adhesive. The catalyst should be used sparingly for best results. Excessive catalyst can contribute many problems; e.g., poor bond strength, age-embrittlement of the adhesive, poor glueline thickness control, extended solvent evaporation time requirements, etc.

Since M-Bond 200 bonds are weakened by exposure to high humidity, adequate protective coatings are essential. This adhesive will gradually become harder and more brittle with time, particularly if exposed to elevated temperatures. For these reasons, M-Bond 200 is not generally recommended for installations exceeding one or two years.

Shelf and Storage Life

M-Bond 200 adhesive has a shelf life of nine months when stored under normal laboratory conditions. Life can be extended if upon receipt, the *unopened* material is refrigerated [+40˚ F (+5˚ C)]. Due to possible condensation problems which will degrade adhesive performance, care should be taken to insure that the M-Bond 200 has returned to room temperature equilibrium before opening. Refrigeration after opening is not recommended.

HANDLING PRECAUTIONS:
M-Bond 200 is a modified methy-2-cyanoacrylate compound. *Immediate bonding of eye, skin or mouth may result upon contact. Causes irritation*. The user is cautioned to: *(1) avoid contact with skin; (2) avoid prolonged or repeated breathing of the vapors;* and *(3) use with adequate ventilation.* For additional health and safety information, consult the Material Safety Data Sheet, which is available upon request.

Gage Application Techniques

The installation procedure presented on the following pages is somewhat abbreviated and is intended only as a guide in achieving proper gage installation with M-Bond 200. *Micro-Measurements Instruction Bulletin B-129* presents recommended procedures for surface preparation, and lists specific considerations which are helpful when working with most common structural materials.

Step 1

Thoroughly degrease the gaging area with a solvent, such as CSM-1 Degreaser or FTF-1 Mild Degreaser (Figure 12-39). The former is preferred, but there are some materials (e.g., titanium and many plastics) which may react with chlorinated solvents. In these cases, FTF-1 Mild Degreaser is an excellent substitute. All degreasing should be done with uncontaminated solvents – thus, the use of “one-way” containers, such as aerosol cans, is highly advisable.

Figure 12-39. M-Bond 200 Adhesive Step 1

Step 2

Preliminary dry abrading with 220- or 320-grit silicon-carbide paper (Figure 12-40a) is generally required if there is any surface scale or oxide. Final abrading is done by using 320- or 400-grit silicon-carbide paper on surfaces thoroughly wetted with M-Prep Conditioner A; this is followed by wiping dry with a gauze sponge, as in Figure 12-40b.

With a 4H pencil (on aluminum) or a ballpoint pen (on steel), burnish *(do not scribe)* whatever alignment marks are needed on the specimen. Repeatedly apply M-Prep Conditioner A, and scrub with cotton-tipped applicators until a clean tip is no longer discolored. Remove all residue and Conditioner by slowly wiping through with a clean gauze sponge. Never allow any solution to dry on the surface, because this invariably leaves a contaminating film, and reduces chances of a good bond.

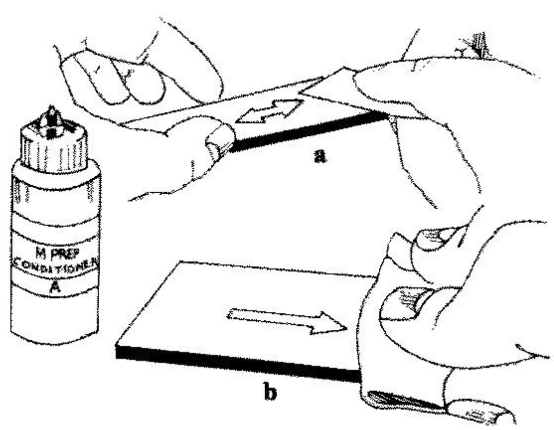


Figure 12-40. M-Bond 200 Adhesive Step 2

Step 3

Now apply a liberal amount of M-Prep Neutralizer 5 and scrub with a cotton-tipped applicator (Figure 12-41). With a single, slow wiping motion, use a gauze sponge to carefully dry this surface. Do not wipe back and forth, as this may allow contaminants to be redeposited on the cleaned surface.

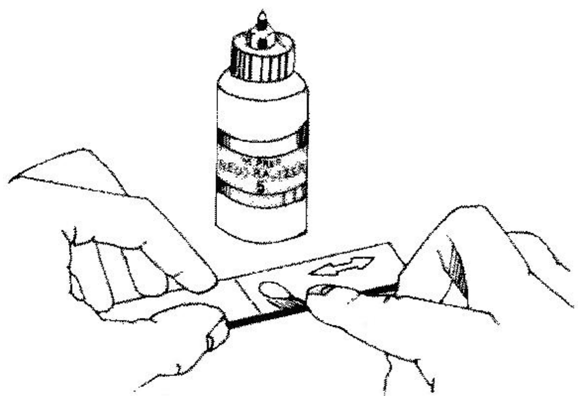


Figure 12-41. M-Bond 200 Adhesive Step 3

Step 4

Using tweezers to remove the gage from the acetate envelope, place the gage (bond side down) on a chemically clean glass plate or gage box surface. If a solder terminal is to be incorporated, position it on the plate adjacent to the gage as shown. A space of approximately 1/16 in (1.6 mm) should be left between the gage backing and terminal. Place a 4- to 6-in (100- to 150-mm) piece of Micro-Measurements No. PCT-2A cellophane tape over the gage and terminal. Take care to center the gage on the tape. Carefully lift the tape at a shallow angle (about 45 degrees to specimen surface), bringing the gage up with the tape as illustrated in Figure 12-42.

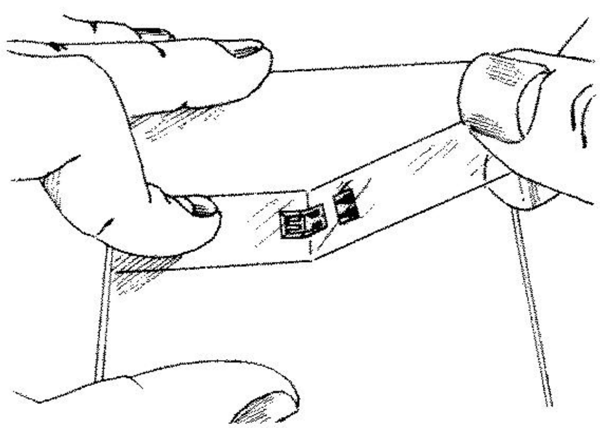


Figure 12-42. M-Bond 200 Adhesive Step 4

Step 5

Position the gage/tape assembly so that the triangle alignment marks on the gage are over the layout lines on the specimen (Figure 12-43). If the assembly appears to be misaligned, lift one end of the tape at a shallow angle until the assembly is free of the specimen. Realign properly, and firmly anchor down at least one end of the tape to the specimen. This realignment can be done without fear of contamination by the tape mastic if Micro-Measurements No. PCT-2A cellophane tape is used. This tape will retain its mastic when removed.

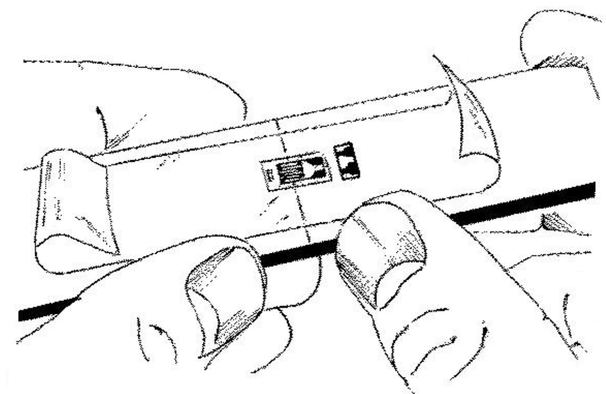


Figure 12-43. M-Bond 200 Adhesive Step 5

Step 6

Lift the gage end of the tape assembly at a shallow angle to the specimen surface (about 45 degrees) until the gage and terminal are free of the specimen surface (Figure 12-44a). Continue lifting the tape until it is free from the specimen approximately 1/2 in (10 mm) beyond the terminal. Tuck the loose end of the tape under and press to the specimen surface (Figure 12-44b) so that the gage and terminal lie flat, with the bonding surface exposed.

Note: Micro-Measurements gages have been treated for optimum bonding conditions and require no pre-cleaning before use unless contaminated during handling. If contaminated, the back of any gage can be cleaned with a cotton applicator slightly moistened with M-Prep Neutralizer 5.

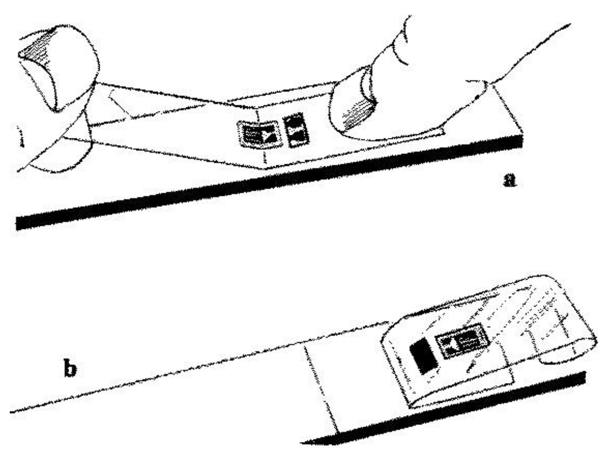


Figure 12-44. M-Bond 200 Adhesive Step 6

Step 7

M-Bond 200 catalyst can now be applied to the bond surface of the gage and terminal. M-Bond 200 adhesive will harden without the catalyst, but less quickly and reliably. Very little catalyst is needed and should be applied in a thin, uniform coat. Lift the brush-cap out of the catalyst bottle and wipe the brush approximately 10 strokes against the lip of the bottle to wring out most of the catalyst. Set the brush down on the gage and swab the gage backing (Figure 12-45). Do not stroke the brush painting style, but slide the brush over the entire gage surface and then the terminal. Move the brush to the adjacent tape area prior to lifting from the surface. Allow the catalyst to dry at least one minute under normal ambient conditions of +75˚ F (+24˚ C) and 30% to 65% relative humidity before proceeding.

Note: The next three steps must be completed in the sequence shown, and within 3 to 5 seconds. Read Steps 8, 9, and 10 before proceeding.

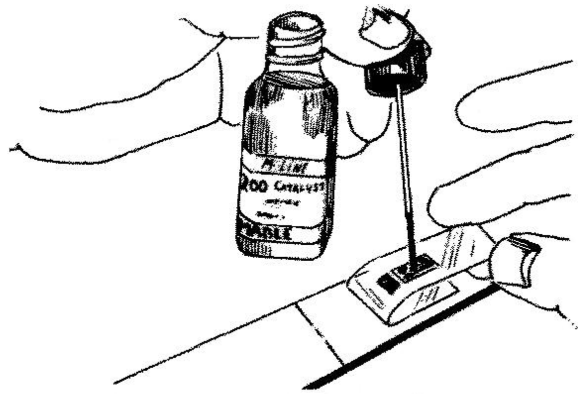


Figure 12-45. M-Bond 200 Adhesive Step 7

Step 8

Lift the tucked-under tape end of the assembly, and, holding in the same position, apply one or two drops of M-Bond 200 adhesive at the fold formed by the junction of the tape and specimen surface (Figure 12-46). This adhesive application should be approximately 1/2 in (13mm) outside the actual gage installation area. This will insure that the local polymerization, taking place when the adhesive comes in contact with the specimen surface, will not cause unevenness in the gage glueline.

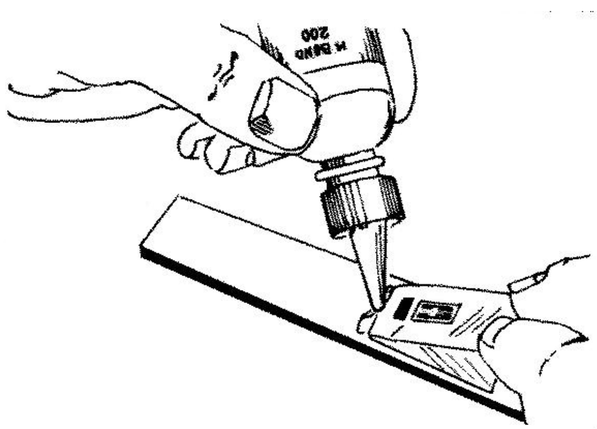


Figure 12-46. M-Bond 200 Adhesive Step 8

Step 9

Immediately rotate the tape to approximately a 30-degree angle so that the gage is bridged over the installation area. While holding the tape slightly taut, slowly and *firmly* make a single wiping stroke over the gage/tape assembly with a piece of gauze (Figure 12-47) bringing the gage back down over the alignment marks on the specimen. Use a firm pressure with your fingers when wiping over the gage. A very thin, uniform layer of adhesive is desired for optimum bond performance.

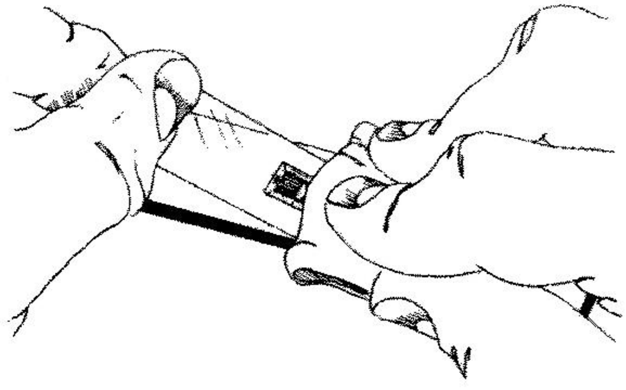


Figure 12-47. M-Bond 200 Adhesive Step 9

Step 10

*Immediately u*pon completion of the wipe-out of the adhesive, firm thumb pressure must be applied to the gage and terminal area (Figure 12-48). This pressure should be held for at least one minute. In low humidity conditions (below 30%) or if the ambient temperature is below +70˚ F (+22˚ C), this pressure application time may have to be extended to several minutes. Where large gages are involved, or where curved surfaces such as fillets are encountered, it may be advantageous to use preformed pressure padding during the operation. Pressure application time should again be extended due to the lack of “thumb heat” which helps to speed adhesive polymerization. Wait two minutes before removing tape.

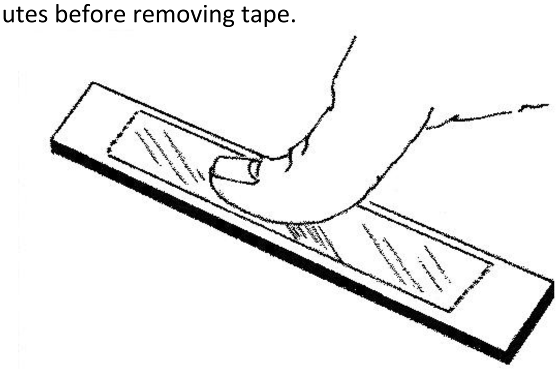


Figure 12-48. M-Bond 200 Adhesive Step 10

Step 11

The gage and terminal strip are now solidly bonded in place. To remove the tape, pull it back directly over itself, *peeling* it slowly and steadily off the surfaces (Figure 12-49). This technique will prevent possible lifting of the foil on open-faced gages or otherwise damaging the installation. The tape will offer mechanical protection for the grid surface and may be left in place until it is removed for gage wiring.

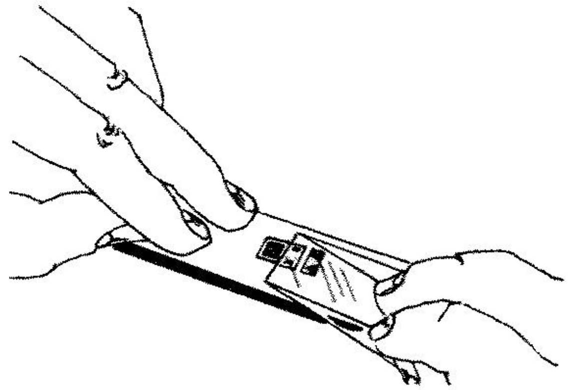


Figure 12-49. M-Bond 200 Adhesive Step 11

12.1.2: Temperature Sensors

12.1.2.1 General Information and Selection

Table 12-3. RTD vs. Thermocouple Comparison Chart

Attributes of the Temperature Sensor		
Parameter/Criteria	**Thermocouple**	**RTD**
Typical Measurement Range	-450 ºF (-267 ºC) to +4200 ºF (2316 ºC)	-400 ºF (-240 ºC) to +1200 ºF (649 ºC)
Interchangeability	Good	Excellent
Long-term Stability	Poor to Fair	Excellent
Accuracy	Medium	High
Repeatability	Poor to Fair	Excellent
Sensitivity (output)	Low	Good
Response	Medium to Fast	Good
Linearity	Fair	Good
Self Heating	No	Low
Tip (end) Sensitivity	Excellent	Fair
Lead Effect	High	Medium
Size/Packaging	Small to Large	Medium to Small

Advantages and Disadvantages		
Sensor	**Advantages**	**Disadvantages**
Thermocouple	• Inexpensive • No resistance leadwire problems • Fastest response • Simple and rugged • High temperature operation • Tip (end) temperature sensing	• Least sensitive • Non-linear • Low voltage • Least stable, repeatable
RTD	• Good stability • Excellent accuracy • Contamination resistant • Good linearity • Area temperature sensing • Very repeatable temperature measurement	• Marginally higher cost • Current source required • Self-heating • Slower response time • Medium sensitivity to small temperature changes

12.1.2.2 Thermocouples (T/C)

A thermocouple consists of two dissimilar metals, joined together at one end. When the junction of the two metals is cooled or heated a voltage is produced that can be correlated back to the temperature. Most thermocouple alloys are commonly available as wire.

Thermocouples are manufactured in different combinations of metals and/or calibrations. The calibrations most regularly specified by Weed Instrument customers are J, K, T and E. High temperature calibrations include R, S, C and GB. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple. While the thermocouple calibration defines the temperature range, the maximum range will also be a factor the diameter of the thermocouple wire. Therefore, a very thin thermocouple may not reach the full temperature range.

Since thermocouples measure wide temperature ranges and are relatively rugged, they are very often used industrial and process applications where accuracy may be a less important factor. In selecting a thermocouple, the following criteria are key considerations:

- Temperature range
- Chemical resistance of the thermocouple or sheath material
- Abrasion and vibration resistance
- Installation requirements (may need to be compatible with existing equipment; existing holes may determine probe diameter)

Thermocouples are temperature sensors suitable for use with any make of instrument designed or programmed for use with the same type of thermocouple. Thermocouples are based on the principle that when two dissimilar metals are joined a predictable voltage will be generated that relates to the difference in temperature between the measuring junction and the reference junction (connection to the measuring device). The selection of the optimum thermocouple type (metals used in their construction) is based on application temperature, atmosphere, required length of service, accuracy and cost. When a replacement thermocouple is required, it is of the utmost importance that the type of thermocouple type used in the replacement matches that of the measuring instrument. Different thermocouple types have very different voltage output curves. It is also required that thermocouple or thermocouple extension wire, of the proper type, be used all the way from the sensing element to the measuring element. Large errors can develop if this practice is not followed.

Thermocouple Probe

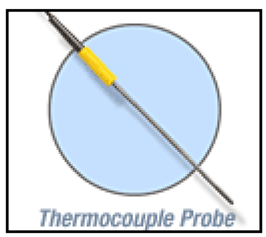


Figure 12-50. Thermocouple Probe

A thermocouple probe consists of thermocouple wire housed inside a metallic tube. The wall of the tube is referred to as the sheath of the probe. Common sheath materials include stainless steel and Inconel. Inconel supports higher temperature ranges than stainless steel; however, stainless steel is often preferred because of its broad chemical compatibility. For very high temperatures, other exotic sheath materials are also available.

The tip of the thermocouple probe is available in three different styles. Grounded, ungrounded and exposed. See Figure 12-51. With a grounded tip the thermocouple is in contact with the sheath wall. A grounded junction provides a fast response time but it is most susceptible to electrical ground loops. In ungrounded junctions, the thermocouple is separated from the sheath wall by a layer of insulation. The tip of the thermocouple protrudes outside the sheath wall with an exposed junction. Exposed junction thermocouples are best suited for air measurement.

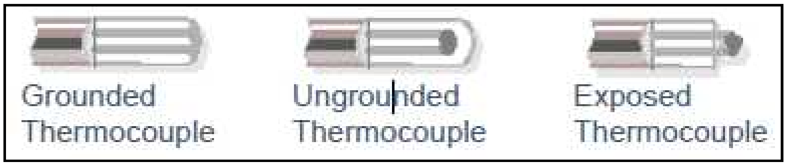


Figure 12-51. Thermocouple Tip Styles

Wire Size of Thermocouple: Selecting the wire size used in the thermocouple sensor depends upon the application. Generally, when longer life is required for the higher temperatures, the larger size wires should be chosen. When sensitivity is the prime concern, the smaller sizes should be used.

Length of Thermocouple Probe**:** Since the effect of conduction of heat from the hot end of the thermocouple must be minimized, the thermocouple probe must have sufficient length. Unless there is sufficient immersion, readings will be low. It is suggested the thermocouple be immersed for a minimum distance equivalent to four times the outside diameter of a protection tube or well.

Location of Thermocouple: Thermocouples should always be in a position to have a definite temperature relationship to the work load. Usually, the thermocouple should be located between the work load and the heat source and be located approximately 1/3 the distance from the work load to the heat source.

Table 12-4. Thermocouple Table

Thermocouple Type	Names of Materials	Useful Application Range
B	Platinum30% Rhodium (+) Platinum 6% Rhodium (-)	2500 - 3100F 1370 - 1700C
C	W5Re Tungsten 5% Rhenium (+) W26Re Tungsten 26% Rhenium (-)	3000 - 4200F 1650 - 2315C
E	Chromel (+) Constantan (-)	200 - 1650F 95 - 900C
J	Iron (+) Constantan (-)	200 - 1400F 95 - 760C
K	Chromel (+) Alumel (-)	200 - 2300F 95 - 1260C
N	Nicrosil (+) Nisil (-)	1200 - 2300F 650 - 1260C
R	Platinum 13% Rhodium (+) Platinum (-)	1600 - 2640F 870 - 1450C
S	Platinum 10% Rhodium (+) Platinum (-)	1800 - 2640F 980 - 1450C
T	Copper (+) Constantan (-)	-330 - 660F -200 - 350C

GLOSSARY OF TERMS FOR THERMOCOUPLES

Cold Junction or Reference Junction - The junction generally at the measuring device that is held at a relatively constant temperature.

Cold Junction Compensation - Measures the ambient temperature at the connection of the thermocouple wire to the measuring device. This allows for accurate computation of the temperature at the hot junction by the measuring device.

Dual Element - Two thermocouple elements housed within one thermocouple hardware assembly.

Extension Wire - Wires which connect the thermocouple itself to a reference junction, i.e. controller, receiver, recorder, etc. Extension wire must be of the same type as the thermocouple. Special plugs and jacks made of the same alloys as the thermocouple should be used if a quick disconnect is required for the application.

Grounded Junction - The internal conductors of this thermocouple are welded directly to the surrounding sheath material, forming a completely sealed integral junction.

Ungrounded Junction - Although the internal thermocouple conductors are welded together they are electrically insulated from the external sheath material and are not connected to the sheath in any way. Ungrounded junction thermocouples are ideal for use in conductive solutions or wherever circuit isolation is required. Ungrounded junctions are required where the measuring instrumentation does not provide channel to channel isolation.

Exposed Junction - The thermocouple junction or measuring point is exposed without any protection assembly or tube. Exposed junction thermocouples due to their design, offer the user the fastest response time.

Hot Junction - The measuring junction.

Immersion Length - The portion of the thermocouple which is subject to the temperature which is being measured.

Measuring Junction - The junction in a thermocouple which actually measures the temperature of the object. Often referred to as the Hot Junction.

Protection Tube - A tube like assembly in which the thermocouple is installed in order to protect the element from harsh environments.

RTD - Abbreviation for Resistance Temperature Detector. It is a sensor which operates on the principle that the resistance increases with an increase in temperature at a specific rate. Commonly manufactured using a platinum resistance element. More accurate and more linear than most thermocouples and generally much more costly and slower responding.

Thermocouple - A temperature sensor based on the principle that a voltage is produced when two dissimilar metals. The junction produces a voltage in proportion to the difference in temperature between the measuring junction and the reference junction.

Thermowell - A threaded or flanged closed end tube which is mounted directly to the process or vessel, designed to protect the thermocouple from the process surroundings.

THERMOCOUPLE COLOR CODES

Thermocouple wiring is color coded by thermocouple types. Different countries utilize different color coding. Jacket coloring is sometimes a colored stripe instead of a solid color as shown.

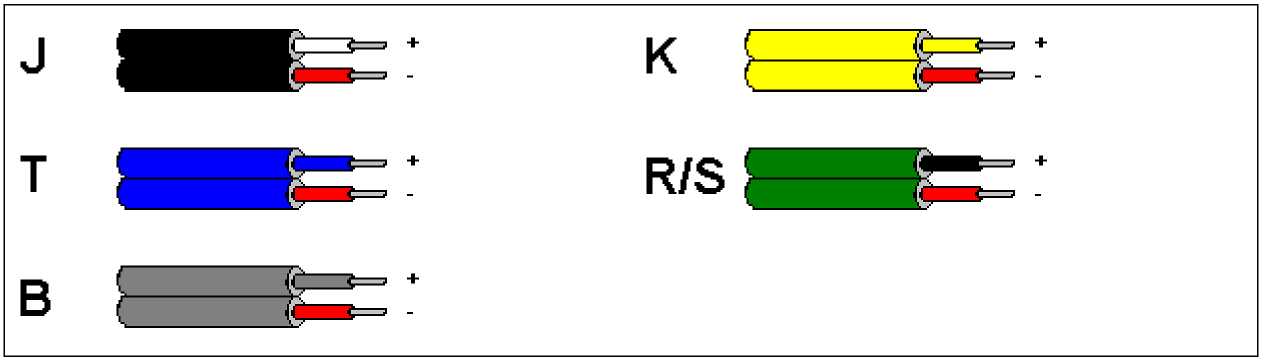


Figure 12-52. United States ASTM

12.1.2.3 Resistance Temperature Devices (RTD)

Resistance Temperature Detectors (RTDs) are sensors that measure temperature by correlating the resistance of the RTD element with temperature. Most RTD elements consist of a length of fine coiled wire wrapped around a ceramic or glass core. The element is typically relatively fragile, so it is generally installed inside a sheath to protect it. The RTD element is constructed from a pure material, the resistance of which, at various temperatures, has been documented by various international standards institutes. The material has a predictable change in resistance as the temperature varies; it is this change that is used to determine temperature.

RTDs are generally considered to be among the most accurate temperature sensors available. In addition to offering very good accuracy, they provide excellent stability and repeatability. RTDs also feature high immunity to electrical noise and are, therefore, well suited for applications in process and industrial automation environments, especially around motors, generators and other high voltage equipment.

[Source for the following: Rosemount Aerospace Model 134 MB Spec Sheet]

Rosemount Aerospace Model 134 MB Resistance Temperature Device (RTD)

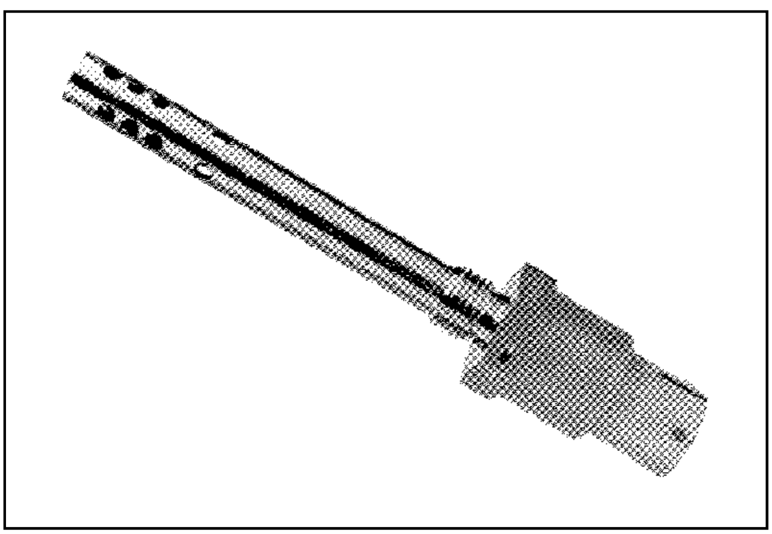


Figure 12-53. Rosemount Aerospace Model 134MB Resistance Temperature Device

General Description

Rosemount Aerospace Model 134MB is a platinum resistance temperature sensor designed to operate in the range -260˚C to +260˚C. The sensing element changes resistance predictably and repeatedly with changes in temperature. The accuracy is assured by the strain free design of the sensing element and the purity (99.999%) of the platinum element wire.

Model 134MB is intended to satisfy applications where accuracy, fast response and ruggedness are important. Model 134MB is recommended for use in nonconductive media such as hydraulic or lubricating oils, gaseous or liquid air, nitrogen, oxygen, or hydrogen.

Performance Specifications

Temperature Range – -260˚C to +260˚C. The connector is rated to +200˚C.

Resistance-Temperature Relationship – Each model 134MB meets the resistance-temperature relationship shown in the table to the tolerance indicated. For models with other ice point resistances, multiply resistance values by ice point ratios. Tolerance in ˚C does not change.

Calibration – Each sensor is calibrated at 0˚C accurate to 0.016˚C. Additional calibration at -268.95˚C, -195.87˚C, -187.97˚C, 100˚C, and 260˚C is available. Calibration is traceable to NIST.

Insulation Resistance – At room temperature, with dry external surfaces, each sensor is given an insulation resistance test. The insulation resistance between any pin and the sensor housing shall exceed 100 MΩ with 100 volts DC applied.

Pressure – Each sensor withstands a pressure of 10,000 psig, using helium gas as the pressurizing medium.

Repeatability – The sensor resistance will repeat at any point within 0.03% of the temperature range over which the unit is cycled, or to 0.10˚C, whichever is greater.

Current Overload – A continuous applied current of 10 milliamperes will not damage the sensor.

Time Constant – Time required for a 63.2 percent response of the sensor to a step change in temperature from room temperature air to water flowing transverse to the sensor at 3 fps and at 76 ±4˚C is less than 0.12 seconds. When tested in #200 Dow Corning 1.5 CTSK oil at the same conditions, the time constant is less than 0.50 seconds.

Self-Heating – The sensor is capable of dissipating an I^2R power of 1000 milliwatts with a temperature rise of less than 1.0˚C when submerged in room temperature water flowing transverse to the sensor at 3 fps. When tested in #200 Dow Corning 1.5 CTSK oil at the same conditions, and I^2R power of 300 milliwatts shall cause a temperature rise of less than 1.0˚C.

Vibration – For immersion lengths of 3 inches or less, the model 134MB design meets the vibration requirements of MIL-STD-810C, Method 514.2, Procedure V, Levels U and AP. This test requires the following vibration curves be followed:

1) *Sine Vibration.* Thirty minutes of sweeping the range of 5 to 2000 Hz in each of three perpendicular axes at the following levels:

5 to 10 Hz	0.2 D.A.
10 to 18 Hz	1 g peak
18 to 128 Hz	.06 D.A.
128 to 2000 Hz	50 g peak

2) *Random Vibration.* Thirty minutes of vibration in each of three perpendicular axes at the following levels:

20 to 100 Hz	+6 db/octave
100 to 1000 Hz	1.50 g2/Hz
1000 to 2000 Hz	-6db/octave
(46.4 grms)	

Mechanical Shock – For immersion lengths of 3 inches or less, the model 134MB design meets the shock requirements of MIL-STD-810B, Method 516.2, Procedure IV. This test specifies the following shocks be applied in each direction along each of three perpendicular axes:

1) Sawtooth pulse, 100 g peak and 6 ms duration.
2) Half sine pulse, 100 g peak and 6 ms duration.

Compatibility –Model 134MB is suitable for use in any gas or liquid compatible with platinum, platinum-rhodium, a metal oxide ceramic, 304L stainless steel, gold, and silver braze.

Identification – The following information is electroetched on the housing:

Model 134MB _________
Serial No. _____________
Rosemount Aerospace Inc.

12.1.3 Flowmeters

12.1.3.1 Liquid Flowmeters

[Source: FTI Flow Technology FT Series Turbine Flowmeter Spec Sheet for liquid flowmeters]

Figure 12-54. FT Series Liquid Turbine Flowmeters

Description

Flow Technology's FT Series turbine flowmeters utilize a proven flow measurement technology to provide exceptionally reliable digital outputs. Because of their versatility, these flowmeters are the solution for a wide variety of liquid flow sensing applications. FT Series turbine flowmeters, which range in size from 3/8 inch to 4 inches, offer a high turndown capability, repeatability of ±0.05% of reading, and excellent speed of response. The precision, axial-mounted rotor design of the standard turbine flowmeter allows it to operate effectively in flow rates from 0.03 to 1,500 GPM, with the linearity rated at ±0.5% of reading over the normal 10:1 turn-down range. All turbine flowmeters can achieve ±0.1% linearity over the full operating range with linearizing electronics. Typical operating pressures for the standard meters are 5,000 PSIG with custom configurations capable of 30,000 PSIG. A choice of construction materials can be specified for the turbine flowmeter's housing, rotor, bearings and shaft, including standard stainless steel, and exotic materials for specialized applications.

Features

- Linearity < 0.10% with linearizing electronics
- High turn-down capability, up to 100:1.
- Excellent repeatability, less than +/- 0.05%.
- Typical response time 3-4mS
- Extensive primary standard NIST traceable calibration capability, offering a wide range of fluids, viscosities and flow rates. Accuracy less than +/-0.05% typical
- Standard materials of construction are 316 SS housing and 430F SS rotor. Additional materials are available.
- Robust, compact design capably of compliance to severe shock and vibration requirements.
- Standard pressure capabilities up to 5,000 PSIG.
- Extreme operating pressures available in custom packages.
- High shock designs available for applications with large hydraulic water hammer effects.
- Custom designs to meet the specific application are routine, not the exception.

Specifications

Table 12-5. Liquid Flowmeter Specifications

Description	Value
Calibration accuracy	±0.05% of reading, traceable to NIST
Repeatability	±0.05% of reading
Linearity	±0.10% with linearizing electronics
Response time	3-4mS typical
Housing material	316 stainless steel, standard
Rotor material	430F stainless steel, standard
Temperature range	-450 to 750°F, dependent on bearing and pick-off
Operating pressure	Up to 30,000PSIG, dependent on fitting
Ball bearing material	440C stainless steel
Journal bearing material	Ceramic, tungsten carbide, graphite
Pick-off's	Modulated carrier and magnetic
Straight Run	10D upstream and 5D downstream minimum
Recommended filtration	Ball bearings: 10 to 100 microns (less filtration with larger sizes) Journal bearings: 75 to 100 microns

12.1.3.2 Liquid Turbine Flowmeter Model Number Selection and Sizing Guidelines

[Source: FTI Flow Technology FT Series Turbine Flowmeter Spec Sheet for liquid flowmeters]

General

There are 4 major steps in defining a turbine flow meter; these are:

- Choosing the flow meter size
- Bearing selection
- Pick-off selection
- Calibration requirements

These components are interrelated and should be considered as a system to obtain optimum meter performance. Additional options need to be selected that are related more to personal preference. These are end fitting type, materials of construction, and units of measure.

<u>Step 1: Meter size and flow range selection</u>
Detailed below are the considerations that should be taken into account when sizing a flow meter.

- Due to the laws of physics, for optimum results any flow meter (including turbine flow meters) should be operated as high up in their turndown range as possible.
- Clearly, there is a tradeoff between your allowable pressure drop and the size of meter that you can install into your process. In other words, at a given flow rate, a smaller meter will operate higher up in its flow rate range, but will generate a higher pressure drop.
- When selecting the size and flow range of the meter, bearing and pick-off selection must be considered. Ball bearings and RF pick-offs have the least amount of drag, thus provide the widest capable flow range. Journal bearings and magnetic pick-offs create more drag, therefore reducing the turndown capability of the flow meter. Where ever possible an RF pickoff is the ideal choice.
- Ideally, it is beneficial to stay within a 10:1 turndown range. However, the phenomenal repeatability and primary calibration accuracy's enable the Flow Technology turbine to provide outstanding performance over a 100:1 turndown.
- See Figure 12-55 for available flow ranges.

<u>Step 2: Pickoff Selection</u>
Reasons to choose a RF pickoff

- Use on FT-24 and smaller meters.
- Use when extended flow range is required.
- Use when real time temperature correction (UVC calibration) is required.
- Flow meter does not require recalibration when pick-off is changed.
- Must be used in conjunction with an amplifier to produce a square wave frequency output.
- Cannot be used above an FT-40 size flow meter.

Reasons to choose a Magnetic pickoff

- Use on FT-32 and larger meters.
- Use on cryogenic temperature applications.
- Use when a direct millivolt output is required.
- Flow meter should be recalibrated when pick-off is changed.
- Can be used on smaller flow meters with reduced flow range.

Pick-off Options

- Standard pick-offs have upper operating temperature of 350°F.
- High temperature pick-offs with a 750°F maximum are available.
- Most electronics are available in hazardous area rated enclosures. If system certification is required, pick-offs are available with various ratings.
- Pick-offs are available with built in RTD's when real time temperature correction is required and a UVC calibration is performed on the flow meter. These pick-offs are normally used in conjunction with the Linear Link TCI electronics.
- Amplified pick-offs are available that house circuitry in the pick-off body to provide a high level 0 – 5 volt square wave pulse output. DC power is required.
- See Figure 12-55 for pick-off selection options.

  <u>Pick-off Mounting Configuration</u>
  MS connector
  - Pick-offs have two, three or four pin MS connectors.

- Connection to the pick-off is via a mating MS connector with soldered connections and loose wire.
- Typical installation is on test stands or on board applications.
- A junction box or conduit cannot be attached to this pick-off style.
- This pick-off is used on flow meters that do not have 1" MNPT nipples welded to the meter body surrounding the pick-off. Flow meters with threaded end connections typically do not have the 1" nipple.

Flying leads with threaded connection

- Pick-offs have flying leads extending from the potted pick-off body.
- Mechanical connection to the pick-off is via a ½" MNPT thread integral to the top of the pick-off body or the 1" MNPT thread of the flow meter nipple.
- This pick-of style is required when a junction box and rigid or flexible conduit is to be mounted directly to the pick-off body.
- Typical installation is a more industrial environment.
- This threaded body pick-off is used on flow meters that **do not** have 1" MNPT nipples welded to the meter body surrounding the pick-off. A flying lead pick-off with smooth body are used on flow meters that **do** have the 1" MNPT nipple. Flow meters with threaded end connections typically do not have the 1" nipple. Flow meters with flanged end connections typically do have the 1" nipple.

<u>Step 3: Bearing Selection</u>

- Bearings are available in two styles, Ball and Journal Sleeve.
- Ball bearings are manufactured from 440C SS and is the typical choice for lubricating applications.
- Journal Sleeve bearings are available in three different material selections. (Note: The Journal Ceramic bearing is the typical bearing of choice for non-lubricating applications.)
- See Figure 12-56 for bearing selection options.

Ball bearings (model # code "A")

- Bearing option to measure lubricating fluids.
- Low frictional drag provides the widest possible flow range.
- Ball bearing set can be replaced in the field.
- 10 to 50 micron filtration required, dependent on meter size.
- Operating temperature range of -450° to 300° F.
- 440C stainless steel materials of construction.
- Provides exceptional life and rugged construction in clean lubricating applications.

Journal Carbide bearings (model # code "D")

- Bearing option to measure low or non-lubricating fluids.
- Hard bearing material provides long life and rugged construction.
- Less turn down capability than the ball bearing. (valid for all journal bearing options)
- Field replacement of bearing not recommended. (valid for all journal bearing options)
- 75 to 100 micron filtration required. (valid for all journal bearing options)
- Operating temperature range of -100° to 1200° F.
- Tungsten Carbide materials of construction.
- Hard bearing material provides long life and rugged construction.

Journal Graphite bearings (model # code "E")

- Bearing option for corrosive applications.
- Operating temperature range of -100° to 550° F.
- Bearing option to measure low or non-lubricating fluids.
- Materials of construction are epoxy impregnated Carbon Graphite bearing with 316 SS shaft.
- Lubricating property of the graphite allows this bearing to run smoother than the other two journal options, however life of the bearing will be slightly reduced.
- Not recommended for use above FT-32 meter size.

Journal Ceramic bearings (model # code "G")

- Typical bearing option to measure low or non-lubricating fluids.
- Operating temperature range of -100° to 800° F.
- Typical bearing option for more corrosive applications.
- AL2O3 (99.5%) Ceramic materials of construction.

- Ceramic material is impervious to most fluids, resists film build up on bearing surface, long life, not as robust as tungsten carbide material.
- Not recommended for use in water above 180° F.

Step 4: Calibration Selection

- Flow Technology has one of the world's largest liquid and gas primary calibration facilities.
- The ability to accurately calibrate a flow meter with traceability to international standards is one of the fundamental requirements in any flow metering application.
- Flow Technology offers a range of water, solvent, oil, and oil blend calibrations.
- A 10 data point calibration is offered as standard, 20 and 30 point calibrations are offered as options. A higher number of data points will define the calibration curve in more detail. If linearizing electronics will be used a minimum of a 20 point calibration is recommended.
- Viscosity does shift the flow meter calibration curve and should be compensated for.

Application will be at relatively constant temperature and viscosity

- For optimum performance your flow meter should be calibrated close to its operating viscosity. Water at 1 cst and solvent at 1.2 cst viscosity is standard, a specific calibration to simulate the operating viscosity can be specified as an option.

Application will cover a range of operating temperature and viscosity

- If the fluid viscosity or density is changing due to temperature variation, a Universal Viscosity Calibration (UVC) should be used to perform real time temperature correction.
- The viscosity range for the calibration is determined by the minimum fluid viscosity at the maximum operating temperature and the maximum fluid viscosity at the minimum operating temperature.
- See Figure 12-56 for calibration options.

FT Meter Sizing and End Fittings

Series / Order Code	End Fitting Nominal Inches	ID	10:1 Standard Range		Extended Flow Range: Ball Bearing / RF Pickoff	Extended Flow Range: Ball Bearing Mag Pickoff	Extended Flow Range: Journal Bearing / RF Pickoff	Extended Flow Range: Journal Bearing / Mag Pickoff	Max	K Factor	Maximum Frequency Approx.
			Min GPM	Max GPM	Min GPM	Min GPM	Min GPM	Min GPM	GPM	P/G	Frequ.
FT 4-6	3/8	0.30	0.25	2.5	0.03	0.10	0.10	0.12	3	48000	2000
FT 4-8	1/2	0.30	0.25	2.5	0.03	0.10	0.10	0.12	3	48000	2000
FT 6-8	1/2	0.37	0.50	5.0	0.05	0.12	0.15	0.20	5	25000	2100
FT 8-8	1/2	0.40	0.75	7.5	0.08	0.16	0.20	0.25	8	16000	2000
FT -08	1/2	0.44	1.00	10.0	0.10	0.20	0.25	0.30	10	12000	2000
FT-10	* 3/4	0.50	1.25	12.5	0.15	0.30	0.30	0.40	15	9600	2000
FT-12	3/4	0.56	2.0	20	0.25	0.50	0.50	0.50	25	6000	2000
FT-16	1	0.86	5.0	50	0.60	1.0	1.0	1.0	60	2400	2000
FT-20	11/4	1.00	9.0	90	1.0	1.5	1.0	1.5	100	1300	1950
FT-24	11/2	1.32	15.0	150	1.6	2.5	1.6	2.5	160	600	1500
FT-32	2	1.75	22.0	225	2.5	3.5	2.5	3.5	250	350	1300
FT-40	21/2	2.22	40.0	400	4.5	5.0	4.5	5.0	450	180	1200
FT-48	3	2.87	65.0	650	N/A	7.5	N/A	7.5	750	75	812
FT-64	4	3.87	125.0	1250	N/A	15	N/A	15	1500	30	625

* AE fitting = 5/8"

Order Code	End Fittings
AE	AN (or MS) external straight threads - 3/8" to 2 1/2 nominal size - 37° flare
NE	NPT external threads - 1/2" to 4 nominal size
HB	Hose Barb - 13 to 51 mm/ 1/2" to 2
WF	Wafer type - serrated surface - 13 to 76 mm/1/2" to 3 nominal size
C1	150# Raised Face Flange
C2	300# Raised Face Flange
C3	600# Raised Face Flange
C4	900# Raised Face Flange
C5	1500# Raised Face Flange
C6	2500# Raised Face Flange
J2	300# Ring Joint Flange
J3	600# Ring Joint Flange
J4	900# Ring Joint Flange
J5	1500# Ring Joint Flange
J6	2500# Ring Joint Flange
T1	Tri-Clamp 1/2" to 3/4
T2	Tri-Clamp 1" to 1 1/2

Part Number Structure

F	T	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X	X
Meter Size					End Fittings		Calibration				Material	Bearing	Pickoff		Optional Designators		

Figure 12-55. FT Meter Sizing and End Fittings Chart, Liquid

Calibration

Order Code	# Points	Flow Range	Fluid
NW	10 point	normal 10:1 range	in water
NS	10 point	normal 10:1 range	in solvent
NB	10 point	normal 10:1 range	in oil blend
XW	10 point	extended range	in water
XS	10 point	extended range	in solvent
XB	10 point	extended range	in oil blend
TW	20 point	normal 10:1 range	in water
TS	20 point	normal 10:1 range	in solvent
TB	20 point	normal 10:1 range	in oil blend
YW	20 point	extended range	in water
YS	20 point	extended range	in solvent
YB	20 point	extended range	in oil blend
GW	30 point	extended range	in water
GS	30 point	extended range	in solvent
GB	30 point	extended range	in oil blend

Order Code	# Points	Cal Style	# Viscosities
U2	10 points each viscosity	Universal Viscosity Curve	2 Viscosities (specify minimum viscosity & maximumviscosity).
U3	10 points each viscosity	Universal Viscosity Curve	3 Viscosities (specify minimum viscosity & maximum viscosity).

Order Code	# Points	# Pickoffs	Cal Style	Fluid
BW	10 points each direction	1 pickoff	Bi-directional	water
BS	10 points each direction	1 pickoff	Bi-directional	solvent
BB	10 points each direction	1 pickoff	Bi-directional	oil blend

Note: W = Water. S = Solvent. B = Oil blend. The fluid viscosity must be provided with oil blend calibrations

Material & Bearing Selection

Order Code	Housing	Rotor	Bearing Code
E	316 SST	430F SST	A - D - E - G - H
G	316 SST	316 SST	D - E - G
H	316 SST	17-4 PH SST	A - D - E - G - H
N	HAST C	HAST C	E - G

Note: Please contact factory for material codes "G" and "N".

3rd Digit of Calibration

Code	The third digit of the calibration designator is normally not used and occupied by a dash (-). When required , the following codes are used.
U	To signify required units of measure other than GPM
R	To signify special calibration flow range other than normal 10:1 or extended range
B	To signify both changes in units and special flow range.

Bearing Selection

Order Code	Bearing selections will affect flow range. Refer to sizing specification table to the left for correct flow ranges.
A	Ball Bearings (440 C)
D	Carbide Journal (Carbide Shaft & Sleeve)
E	Graphite Journal (Graphite Sleeve, 316 SST Shaft)
G	Ceramic Journal (Ceramic Shaft & Sleeve)

Part Number Structure

F	T	x	x	x	x	x	x	x	-	L	x	x	x	x	x	x	x
Meter Size					End Fittings		Calibration				Material	Bearing	Pickoff		Optional Designators		

Figure 12-56. FT Meter Calibration and Bearing Selection Chart, Liquid

Magnetic and RF Pickoff Selection Selection

Order Code	RF (Modulated Carrier)
-1	MS connector
-5	Flying leads/threaded connection
-L	MS connector, 400° C/750° F max.
-M	Flying leads/threaded connection 400° C/750° F max.
-8	MS connector, 330 µH coil
-9	MS connector, 5/8"–18 thread, 1 mH coil
-Y	CSA X-Proof
T1	RTD, MS connector
T5	RTD, flying leads/threaded connection
-X	I.S. approved, MS connector
SS	I.S. approved, flying leads/smooth body
XX	I.S. approved, flying leads/threaded body

Order Code	Magnetic
-2	MS connector
-3	Flying leads/threaded connection
-6	MS connector, 400° C/750° F max.
-7	Flying leads/threaded connection 400° C/750° F max.
-Z	CSA X-Proof
T2	RTD, MS connector
T3	RTD, flying leads/threaded connection
-U	I.S. approved, MS connector
PP	I.S. approved, flying leads/smooth body
TT	I.S. approved, flying leads/threaded body

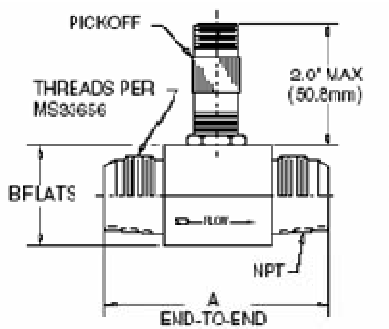
Notes: 1. Maximum temperature rating of pick-offs are 350° F unless otherwise noted.
2. See Amplified Link literature for amplified pick-off codes.

Part Number Structure

F	T	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X	X
Meter Size					End Fittings		Calibration				Material	Bearing	Pickoff		Optional Designators		

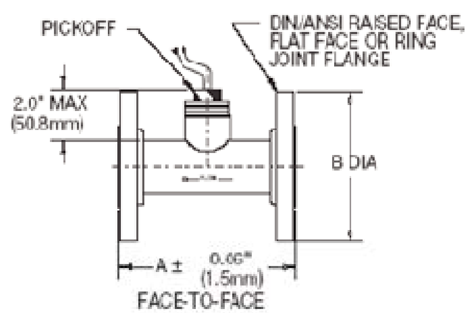
Dimensional Drawings

MS / NPT Fitting



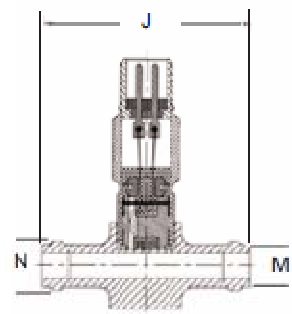
Series	A	B
	in.	in.
FT4-6	2.45	1
FT--8	2.45	1
FT-10	2.72	1.38
FT-12	3.25	1.38
FT-16	3.50	1.63
FT-20	4.06	1.88
FT-24	4.50	2.25
FT-32	6.06	2.75
FT-40	6.9	3.5
FT-48	N/A	N/A
FT-64	N/A	N/A

Flange Fittings



Series	150#		300#		600#		900#	
	A	B	A	B	A	B	A	B
FT-_8	5	3.5	5	3.75	5	3.75	7	4.75
FT-10	5.5	3.88	5.5	4.63	5.5	4.63	5.5	5.13
FT-12	5.5	3.88	5.5	4.63	5.5	4.63	7	5.13
FT-16	5.5	4.25	5.5	4.88	5.5	4.88	8	5.88
FT-20	6	4.63	6	5.25	6	5.25	8	6.25
FT-24	6	5	6	6.13	6	6.13	9	7
FT-32	6.5	6	6.5	6.5	6.5	6.5	9	8.5
FT-40	7	7	7	7.5	9	7.5	9	9.5
FT-48	10	7.5	10	8.25	10	8.25	10	9.5
FT-64	12	9	12	10	12	10.75	12	11.5

Hose Barb Fitting



Series	J	M	N
	in.	in.	in.
FT4-6	2.45	0.50	0.58
FT-8	2.45	0.50	0.58
FT-10	2.72	0.63	0.70
FT-12	3.25	0.75	0.83
FT-16	3.56	1.00	1.12
FT-20	4.06	1.25	1.37
FT-24	4.59	1.50	1.64
FT-32	6.06	2.00	2.16
FT-40	6.47	2.50	2.67
FT-48	N/A	N/A	N/A
FT-64	N/A	N/A	N/A

Figure 12-57 (page 6). FT Meter Magnetic and RF Pickoff Selection Chart and Dimensional Drawings, Liquid

12.1.3.3 Gas Flowmeters

[Source: FTI Flow Technology FT Series Turbine Flowmeter Spec Sheet for gas flowmeters]

Figure 12-58. FT Series Gas Turbine Flowmeters

<u>Description</u>

Flow Technology's FT Series turbine flowmeters utilize a proven flow measurement technology to provide exceptionally reliable digital outputs. Because of their versatility, these flowmeters are the solution for a variety of process and test gas flow sensing applications. FT Series turbine flowmeters, which range in size from 1/2 inch to 4 inches, offer a high turn-down capability, repeatability of ±0.1% of reading, and a linearity of less than 0.1% when mated to linearizing electronics.

The precision, axial-mounted rotor design of the standard turbine flowmeter allows it to operate effectively in flow rates from 0.09 to 1,500 ACFM, with the linearity rated at ±1.0% of full scale over the normal 10:1 turn-down range. All turbine flowmeters can achieve ±0.1% linearity over the full operating range with linearizing electronics. Typical operating pressures for the standard meters are 5,000 PSIG with custom configurations capable of 30,000 PSIG.

A choice of construction materials can be specified for the turbine flowmeter's housing, rotor and bearings, with the standard being stainless steel and ball bearings.

<u>Features</u>

- Linearity < 0.10% with linearizing electronics
- High turn-down capability, up to 50:1.
- Excellent repeatability, less than +/- 0.1%.
- Extensive primary standard NIST traceable calibration capability, offering a wide range of flow rates and pressure. Accuracy less than +/-0.30 to +/-0.50%, dependent on calibrator.
- Standard materials of construction are 316 SS housing and 430F SS rotor.
- Robust, compact design capably of compliance to severe shock and vibration requirements.
- Standard pressure capabilities up to 5000 PSIG.
- Custom designs to meet the specific application are routine, not the exception.

<u>Specifications</u>

Table 12-6. Gas Flowmeter Specifications

Description	Value
Calibration accuracy	±0.30% of reading, traceable to NIST
Repeatability	±0.10% of reading
Linearity	±0.10% with linearizing electronics
Housing material	316 stainless steel, standard
Rotor material	430F stainless steel, standard
Temperature range	-450 to 300°F
Operating pressure	Up to 30,000 PSIG, dependent on fitting
Ball bearing material	440C stainless steel
Pick-off's	Modulated carrier and magnetic
Straight Run	10D upstream and 5D downstream minimum
Recommended filtration	Ball bearings: 10 to 100 microns (less filtration with larger sizes)

12.1.3.4 Gas Turbine Flowmeter Model Number Selection and Sizing Guidelines

[Source: FTI Flow Technology FT Series Turbine Flowmeter Spec Sheet for gas flowmeters]

<u>General</u>
There are 4 major steps in defining a turbine flow meter; these are:

- Choosing the flow meter size
- Bearing selection
- Pick-off selection
- Calibration requirements

These components are interrelated and should be considered as a system to obtain optimum meter performance. Additional options need to be selected that are related more to personal preference. These are end fitting type, materials of construction, and units of measure.

<u>Step 1: Meter size and flow range selection</u>
Detailed below are the considerations that should be taken into account when sizing a flow meter.

- Due to the laws of physics, for optimum results any flow meter (including turbine flow meters) should be operated as high up in their turndown range as possible.
- Clearly, there is a trade off between your allowable pressure drop and the size of meter that you can install into your process. In other words, at a given flow rate, a smaller meter will operate higher up in its flow rate range, but will generate a higher pressure drop.
- When selecting the size and flow range of the meter the pick-off selection must be considered. RF pick-offs place no drag on the rotor while a magnetic pick-off sensor creates a small amount of drag on the rotor as each blade passes through the magnetic field.
- Ideally, it is beneficial to stay within a 10:1 turndown range. However, the phenomenal repeatability and primary calibration accuracy's enable the Flow Technology turbine to provide outstanding performance over a 50:1 turndown.
- See Figure 12-59 for available flow ranges.

<u>Step 2: Pickoff Selection</u>
Reasons to choose a RF pickoff

- Use on FT-24 and smaller meters.

- Use when extended flow range is required.
- Use when real time temperature and pressure correction (UVC calibration) is required.
- Flow meter does not require recalibration when pick-off is changed.
- Must be used in conjunction with an amplifier to produce a square wave frequency output.
- Cannot be used above an FT-40 size flow meter.

Reasons to choose a Magnetic pick-off

- Use on FT-32 and larger meters.
- Use when a direct millivolt output is required.
- Flow meter should be recalibrated when pick-off is changed.
- Can be used on smaller flow meters with reduced flow range.

Pick-off Options

- Standard pick-offs have upper operating temperature of 350°F.
- Most electronics are available in hazardous area rated enclosures. If system certification is required, pick-offs are available with various ratings.
- Amplified pick-offs are available that house circuitry in the pick-off body to provide a high level 0 – 5 volt square wave pulse output. DC power is required.
- See Figure 12-60 for pick-off selection options.

  Pick-off Mounting Configuration

  MS connector

  - Pick-offs have two or three pin MS connectors.
  - Connection to the pick-off is via a mating MS connector with soldered connections and loose wire.
  - Typical installation is on test stands or on board applications.
  - A junction box or conduit **cannot** be attached to this pick-off style.
  - This pick-off is used on flow meters that **do not** have 1" MNPT nipples welded to the meter body surrounding the pick-off. Flow meters with threaded end connections typically do not have the 1" nipple.

  Flying leads with threaded connection

  - Pick-offs have flying leads extending from the potted pick-off body.
  - Mechanical connection to the pick-off is via a ½" MNPT thread integral to the top of the pick-off body or the 1" MNPT thread of the flow meter nipple.
  - This pick-of style is required when a junction box and rigid or flexible conduit is to be mounted directly to the pick-off body.
  - Typical installation is a more industrial environment.
  - This threaded body pick-off is used on flow meters that **do not** have 1" MNPT nipples welded to the meter body surrounding the pick-off. A flying lead pick-off with smooth body are used on flow meters that **do** have the 1" MNPT nipple. Flow meters with threaded end connections typically do not have the 1" nipple. Flow meters with flanged end connections typically do have the 1" nipple.

Step 3: Bearing Selection

- Bearings are available in two styles. Standard ball with 440C stainless races, balls, and cage or 440C stainless races, balls, and a phenolic resin cage.

Ball bearings (model # code "A")

- Standard bearing option.
- Materials of construction are 440C SS races, balls and loose crimp stainless cage.
- Bearing has open race and requires clean, dry operating fluid.
- Low frictional drag provides the widest possible flow range.
- Ball bearing set can be replaced in the field.
- 10 to 50 micron filtration required, dependent on meter size.
- Operating temperature range of -450° to 300° F.

Ball bearings (model # code "H")

- Materials of construction are 440C SS race and balls with a phenolic resin cage.
- Bearing has open race and requires clean, dry operating fluids
- The phenolic cage provides a degree of lubricating property to the bearing, increasing durability and life.

- Slightly more bearing drag is created by the phenolic cage vs. the loose crimp cage of the standard ball bearing.
- Ball bearing set can be replaced in the field.
- 10 to 50 micron filtration required, dependent on meter size.
- Operating temperature range of -450° to 300° F.

Step 4: Calibration Selection

- Flow Technology has one of the world's largest liquid and gas primary calibration facilities.
- The ability to accurately calibrate a flow meter with trace ability to international standards is one of the fundamental requirements in any flow metering application.
- Flow Technology offers a range of gas calibration technologies and sizes, including Bell Provers, Piston Provers and flow transfer stands.
- A 10 data point calibration is offered as standard, 20 and 30 point calibrations are offered as options. A higher number of data points will define the calibration curve in more detail. If linearizing electronics will be used a mini mum of a 20 point calibration is recommended.
- Pressure and temperature variation, thus density and viscosity changes do shift the flow meter calibration curve.
- Calibration in air at standard conditions is the most economical option, FTI does offer the capability to calibrate the meters in a pressurized environment to simulate actual operating conditions.

Actual vs. Standard units of measure

- Turbine flow meters measure the actual volume of gas passing through the meter at the operating temperature and pressure, They are therefore sized in Actual Cubic Feet per Minute (ACFM).
- Standard Cubic Feet per Minute (SCFM) is the equivalent volume of gas referenced back to standard temperature and pressure.
- The perfect gas law used to convert between ACFM and SCFM is:
  ACFM=SCFM(14.7 PSIA / P1)(T1 / 520° R)
  P1 = Operating pressure in PSIA
  T1 = Operating temperature in deg R

Standard air calibration

- The most common and economical calibration is in air at standard conditions. Data can be presented in actual units of measure or converted to standard units using the operating temperature and pressure.

Pressurized gas calibration to simulate a constant operating conditions.

- If the operating temperature and pressure are relatively constant and a higher level of accuracy is required, a single pressurized gas calibration can be performed to simulate the operating gas and conditions.

Application will cover a range of operating temperature and viscosity

- If the gas temperature and pressure is changing by a significant amount and the highest level of accuracy is require, a multiple pressurized gas calibration can be performed.
- A multiple pressure calibration allows the used to perform real time corrections for variations in operating temperature and pressure.
- The SL9200 flow computer offered by FTI can be used to perform these corrections with inputs from temperature and pressure transducers.

FT Meter Sizing and End Fittings

Series / Order Code	End Fitting Nominal Inches	ID	10:1 Standard Range		Extended Flow Range: Ball Bearing / RF Pickoff	Extended Flow Range: Ball Bearing Mag Pickoff	Extended Flow Range: Max	K Factor	Maximum Frequency Approx.
			Min ACFM	Max ACFM	Min ACFM	Min ACFM	ACFM	P/ft^3	Frequ.
FT 2-8	1/2	** 0.37	0.10	1.0	0.09	N/A	1.25	93000	1550
FT 4-8	1/2	** 0.30	0.25	2.5	0.20	N/A	3	45000	2000
FT 6-8	1/2	** 0.37	0.50	5.0	0.25	0.40	5	24000	2000
FT 8-8	1/2	** 0.40	0.75	7.5	0.40	0.50	8	16000	2000
FT -08	1/2	0.44	1.00	10	0.50	0.75	10	12000	2000
FT-10	* 3/4	0.50	1.25	12.5	0.60	1.0	15	9600	2000
FT-12	3/4	0.56	2.0	20	1.0	1.5	25	6000	2000
FT-16	1	0.86	5.0	50	1.5	2.5	60	2400	2000
FT-20	11/4	1.00	9.0	90	2.5	5.0	100	1300	1950
FT-24	11/2	1.32	15.0	150	4.0	6.0	160	600	1500
FT-32	2	1.75	22.0	225	5.0	8.0	250	350	1300
FT-40	21/2	2.22	40.0	400	9.0	10.0	450	180	1200
FT-48	3	2.87	65.0	650	N/A	15.0	750	75	812
FT-64	4	3.87	125.0	1250	N/A	30.0	1500	30	625

* AE fitting= 5/8"
** 0.440 bore when used with "H" bearing code

Order Code	End Fittings
AE	AN (or MS) external straight threads - 3/8" to 2 1/2 nominal size - 37° flare
NE	NPT external threads - 1/2" to 4 nominal size
HB	Hose Barb - 13 to 51 mm/ 1/2" to 2
WF	Wafer type - serrated surface - 13 to 76 mm/1/2" to 3 nominal size
C1	150# Raised Face Flange
C2	300# Raised Face Flange
C3	600# Raised Face Flange
C4	900# Raised Face Flange
C5	1500# Raised Face Flange
C6	2500# Raised Face Flange
J2	300# Ring Joint Flange
J3	600# Ring Joint Flange
J4	900# Ring Joint Flange
J5	1500# Ring Joint Flange
J6	2500# Ring Joint Flange
T1	Tri-Clamp 1/2" to 3/4
T2	Tri-Clamp 1" to 1 1/2

Part Number Structure

F	T	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Meter Size					End Fittings		Calibration			Tap	Material	Bearing	Pickoff		Optional Designators		

Figure 12-59. FT Meter Sizing and End Fittings, Gas

Magnetic and RF Pickoff Selection Selection

Order Code	RF (Modulated Carrier)
-1	MS connector
-5	Flying leads/threaded connection
-8	MS connector, 330 µH coil
-9	MS connector, 5/8"-18 thread, 1mH coil
-Y	CSA X-Proof
-X	I.S. approved, MS connector
SS	I.S. approved, flying leads/smooth body
XX	I.S. approved, flying leads/threaded body

Order Code	Magnetic
-2	MS connector
-3	Flying leads/threaded connection
-7	CSA X-Proof
-U	I.S. approved, MS connector
PP	I.S. approved, flying leads/smooth body
TT	I.S. approved, flying leads/threaded body

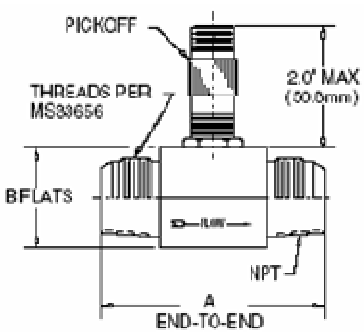
Notes: 1. Maximum temperature rating of pick-offs are 350° F unless otherwise noted.
2. See Amplified Link literature for amplified pick-off codes.

Part Number Structure

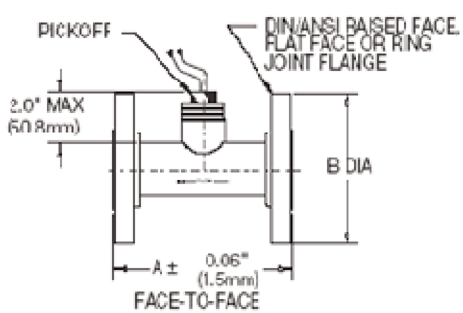
F	T	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Meter Size					End Fittings		Calibration			Tap	Material	Bearing	Pickoff		Optional Designators		

Dimensional Drawings

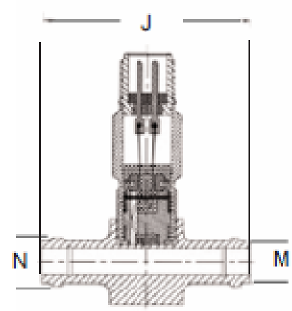
MS / NPT Fitting



Flange Fittings



Hose Barb Fitting



Series	A	B
	in.	in.
FT4-8	2.45	1
FT--8	2.45	1
FT-10	2.72	1.38
FT-12	3.25	1.38
FT-16	3.56	1.63
FT-20	4.06	1.88
FT-24	4.59	2.25
FT-32	6.06	2.75
FT-40	8.9	3.5
FT-48	N/A	N/A
FT-64	N/A	N/A

Series	150#		300#		600#		900#	
	A	B	A	B	A	B	A	B
FT-_8	5	3.5	5	3.75	5	3.75	7	4.75
FT-10	5.5	3.88	5.5	4.63	5.5	4.63	5.5	5.13
FT-12	5.5	3.88	5.5	4.63	5.5	4.63	7	5.13
FT-16	5.5	4.25	5.5	4.88	5.5	4.88	8	5.88
FT-20	6	4.63	6	5.25	6	5.25	8	6.25
FT-24	6	5	6	6.13	6	6.13	9	7
FT-32	6.5	6	6.5	6.5	6.5	6.5	9	8.5
FT-40	7	7	7	7.5	9	7.5	9	9.5
FT-48	10	7.5	10	8.25	10	8.25	10	9.5
FT-64	12	9	12	10	12	10.75	12	11.5

Series	J	M	N
	in.	in.	in.
FT4-6	2.45	0.50	0.58
FT--8	2.45	0.50	0.58
FT-10	2.72	0.63	0.70
FT-12	3.25	0.75	0.83
FT-16	3.56	1.00	1.12
FT-20	4.06	1.25	1.37
FT-24	4.59	1.50	1.64
FT-32	6.06	2.00	2.16
FT-40	6.47	2.50	2.67
FT-48	N/A	N/A	N/A
FT-64	N/A	N/A	N/A

Figure 12-60 Magnetic and RF Pickoff Selection and Dimensional Drawings, Gas

12.1.4 Accelerometers

12.1.4.1 Piezoelectric Accelerometers

[Source: Endevco Model 2272 Piezoelectric Accelerometer Spec Sheet]

Figure 12-61. Endevco Model 2272 Piezoelectric Accelerometer

Description
The Endevco® model 2272 is a piezoelectric accelerometer designed specifically for vibration measurement at temperature extremes. The unit is hermetically sealed for use in harsh environments and features long term stability. Its unique sensing elements offer an unusually flat temperature response over a broad range. The accelerometer is a self-generating device that requires no external power source for operation.

The model 2272 features Endevco's Piezite® Type P-10 crystal element, operating in compression mode. This unit exhibits excellent output sensitivity stability over time. Signal ground is connected to the outer case of the unit. When used with an isolated mounting stud, the accelerometer is electrically isolated from ground. The accelerometer features a 10-32 UNF-2A side-connector. A low-noise coaxial cable is supplied for error-free operation.

Endevco signal conditioner models 133, 2775A or Oasis 2000 computer-controlled system are recommended for use with this high impedance accelerometer.

Features
- Long term stability
- Hermetically sealed
- Operational to -452°F (-269°C)
- Requires no external power
- Vibration measurement at extreme temperature

Specifications
The following performance specifications conform to ISA-RP-37.2 (1964) and are typical values, referenced at +75˚F (+24˚C) and 100 Hz, unless otherwise noted. Calibration data, traceable to National Institute of Standards and Technology (NIST), is supplied.

Table 12-7. Accelerometer Specifications

Description	Units	2272
DYNAMIC CHARACTERISTICS		
Charge sensitivity Typical Minimum	 pC/g pC/g	 13 10.4
Frequency response	See typical amplitude response	
Resonance frequency	kHz	30
Amplitude response [1] ±5% ±1dB	 Hz Hz	 1 to 5000 .5 to 7000
Temperature response	See typical curve	
Transverse sensitivity	%	≤ 3 (≤ 1 on special order)
Amplitude linearity [2] Per 1000 g, 0 to 2000 g	 %	 1
ELECTRICAL CHARACTERISTICS		
Output polarity	Acceleration directed into the base of the unit produces positive output	
Resistance	GΩ	≥ 10
Capacitance	pF	2700
Grounding	Signal ground connected to case	
ENVIRONMENTAL CHARACTERISTICS		
Temperature range [3]	-452°F to +500°F (-269°C to +260°C)	
Humidity	Hermetically sealed	
Sinusoidal vibration	g pk	1000
Shock limit	g pk	2000
Base strain sensitivity	equiv. g pk/µ strain	0.04
Thermal transient sensitivity	equiv. g pk/˚F (/˚C)	0.08 (0.144)
Electromagnetic sensitivity	equiv. g rms/gauss	0.0002
PHYSICAL CHARACTERISTICS		
Dimensions	See outline drawing	
Weight	gm (oz)	27 (0.95)
Case material	Stainless steel	
Connector	10-32 UNF-2A Thd, mates with Endevco 3000 series cable	
Mounting torque	lbf-in (Nm)	18 (2)
CALIBRATION (SUPPLIED)		
Charge sensitivity	pC/g	
Capacitance	pF	
Maximum transverse sensitivity	%	
Charge frequency response	% dB	20 Hz to 5000 Hz 5000 Hz thru resonance

Notes:

1. Low-end response of the transducer is a function of its associated electronics.
2. Short duration shock pulses, such as those generated by metal-to-metal impacts, may excite transducer resonance and cause linearity errors. Send for TP290 for more details.
3. Exposure to rapid temperature changes greater thatn 100°F (38°C) per minute may cause the device to produce spurious high frequency discharges for several minutes.
4. Maintain high levels of precision and accuracy using Endevco's factory calibration services. Call Endevco's inside sales force at 800-982-6732 for recommended intervals, pricing and turnaround time for these services as well as for quotations on our standard products. calibration services. Call Endevco's inside sales force at

800-982-6732 for recommended intervals, pricing and turn-around time for these services as well as for quotations on our standard products.

Included accessories	
Model 3090DV-120	cable assembly
Model 2981-12	mounting stud, 10-32 to 10-32
P/N EHM64	hex key wrench
Optional accessories	
Model 2981-4	mounting stud, 10-32 to M5
Model 2771AM3	in-line charge convertor for use with constant current source
Model 2950	triaxial mounting block
Model 2980B	mounting stud, isolated
Optional calibration	
CS330	cryogenic temperature response

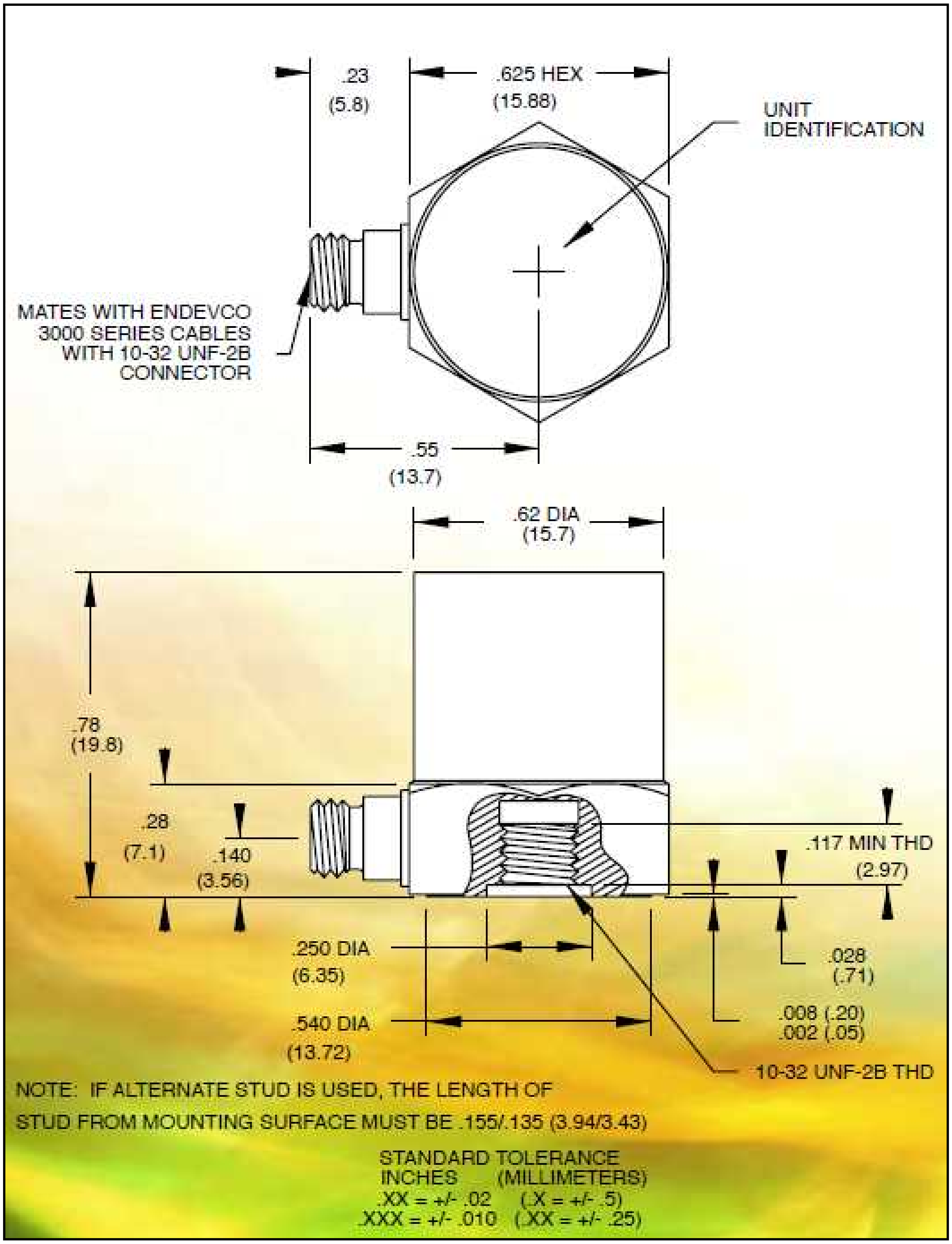


Figure 12-62. Endevco Model 2272 Piezoelectric Accelerometer Dimensional Drawing

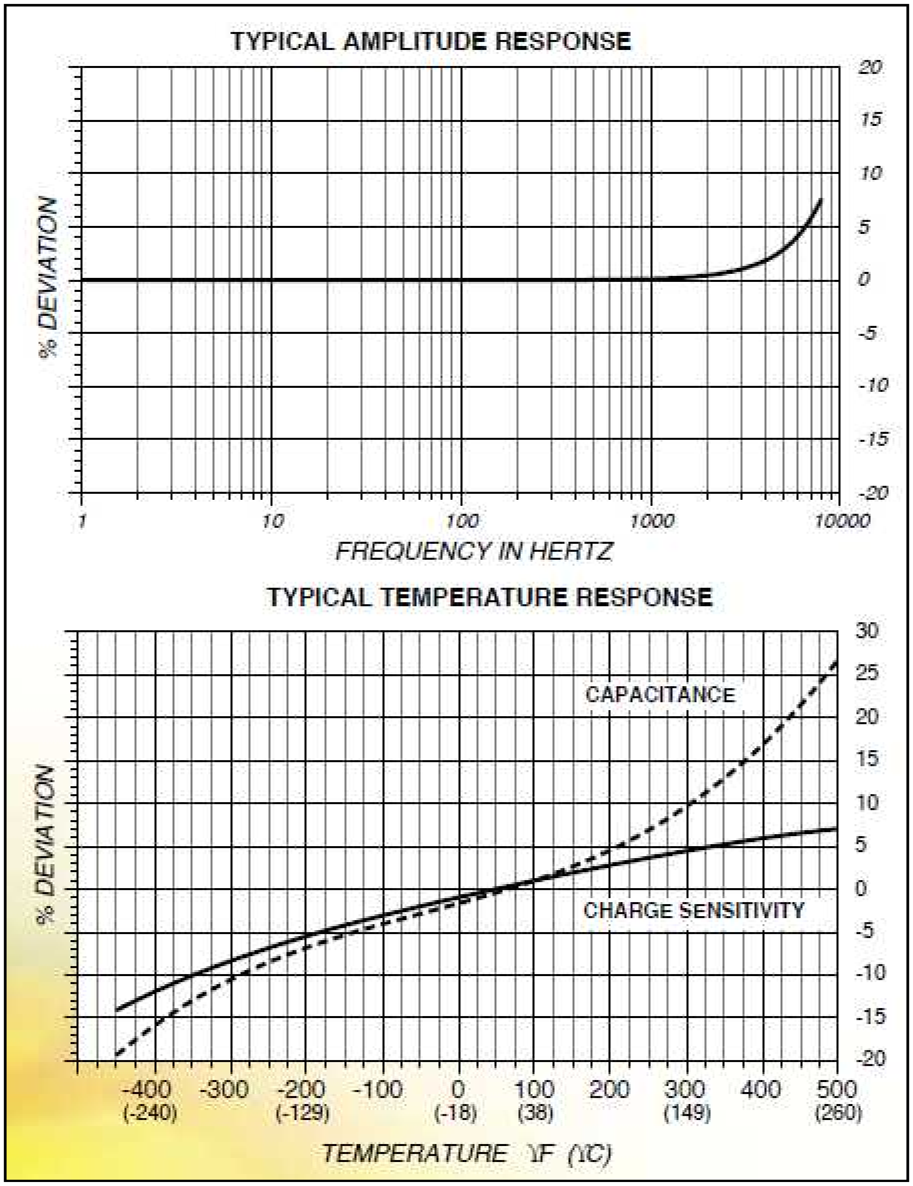


Figure 12-63. Endevco Model 2272 Piezoelectric Accelerometer Amplitude and Temperature Response Charts

12.2: Wiring Diagrams

12.2.1: Pressure Transducer

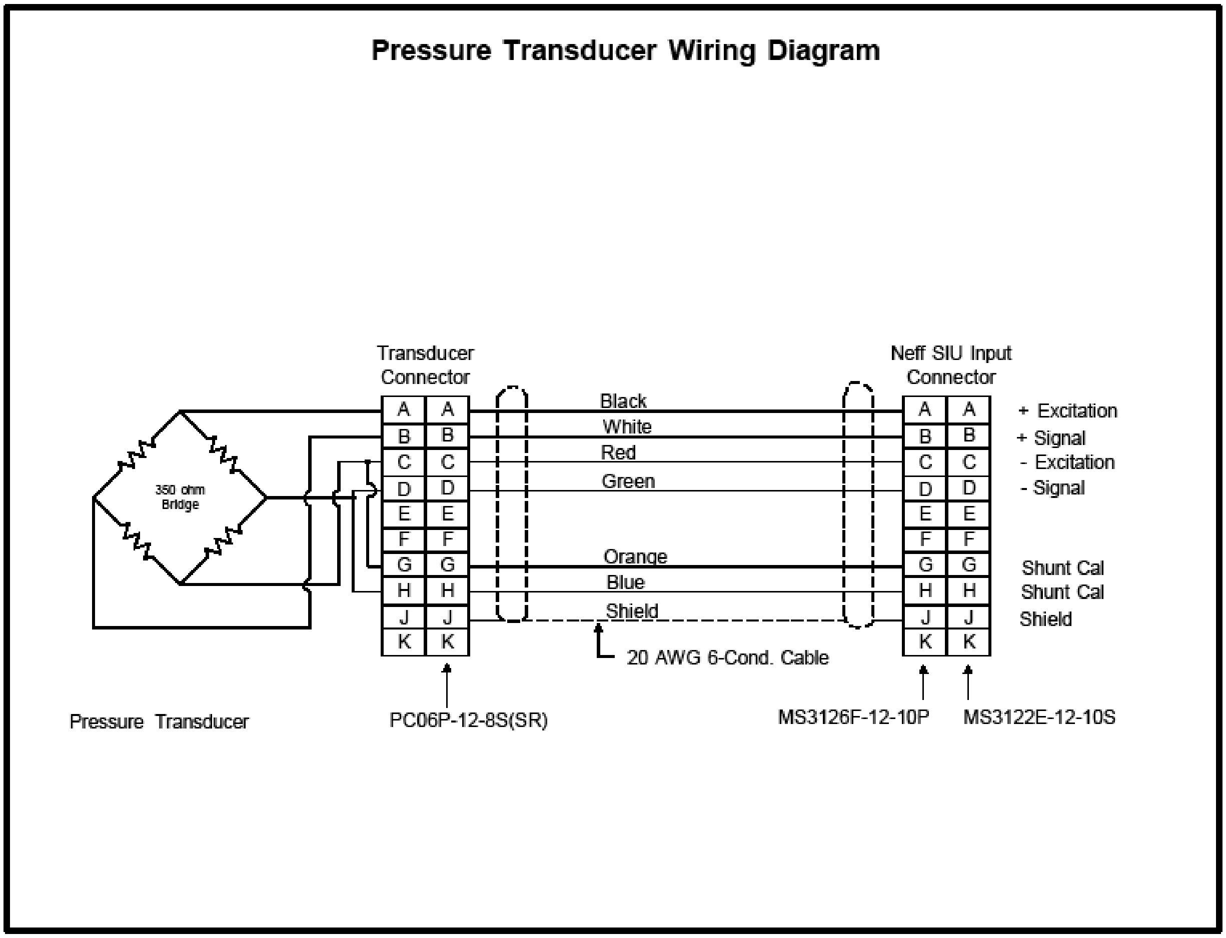


Figure 12-64. Pressure Transducer Wiring Diagram

12.2.2: Type E Thermocouple

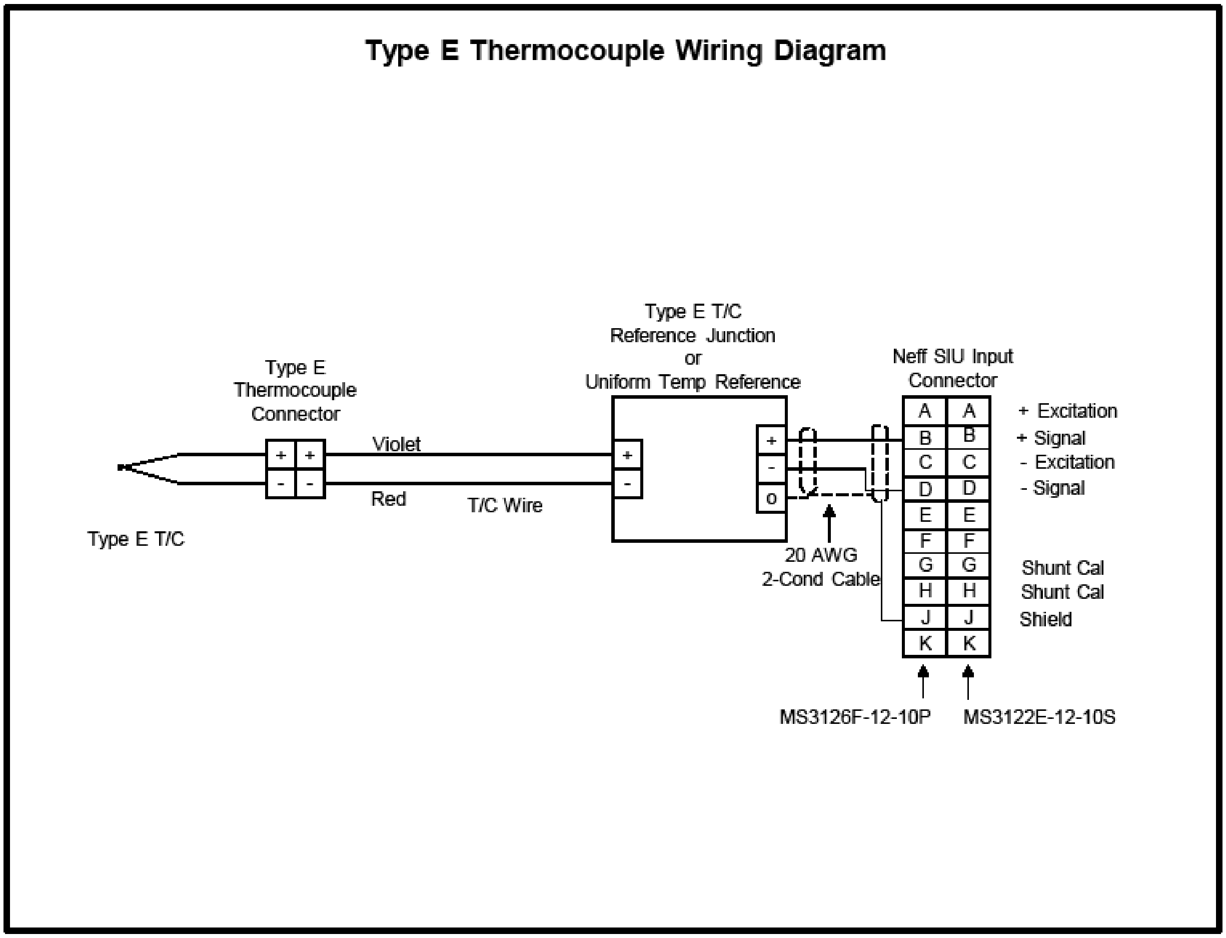


Figure 12-65. Type E Thermocouple Wiring Diagram

12.2.3: Type K Thermocouple

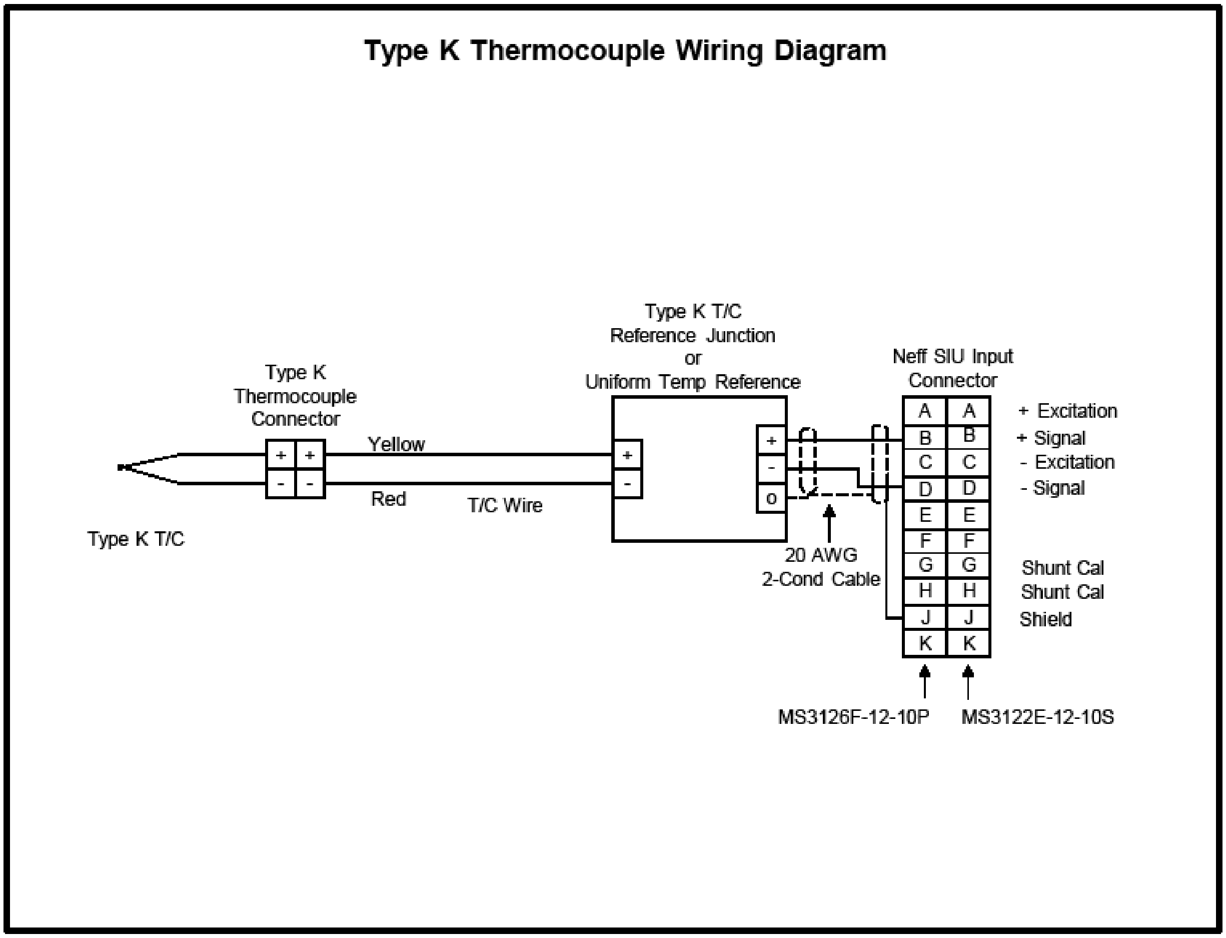


Figure 12-66. Type K Thermocouple Wiring Diagram

12.2.4: Resistance Temperature Devices

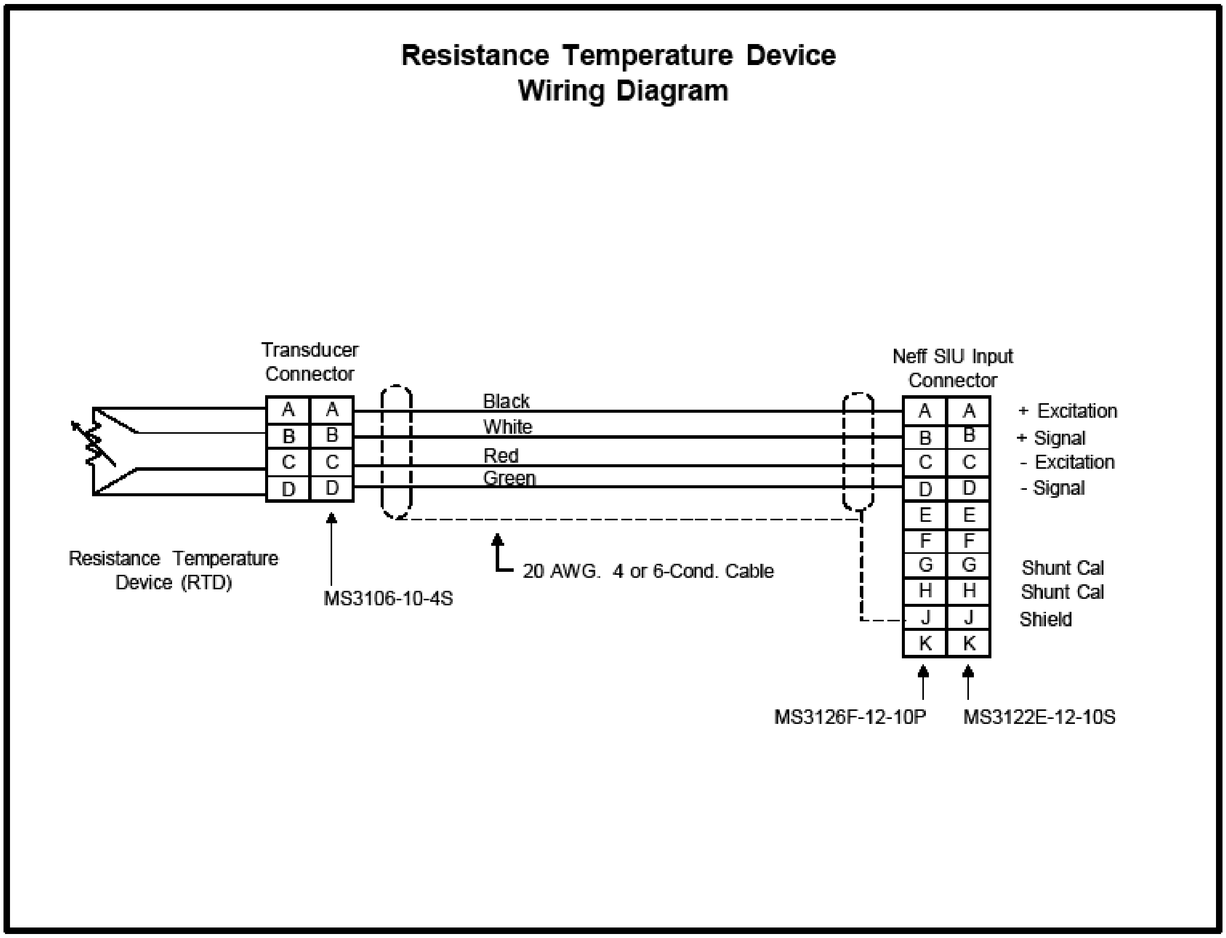


Figure 12-67. Resistance Temperature Device Wiring Diagram (1 of 2)

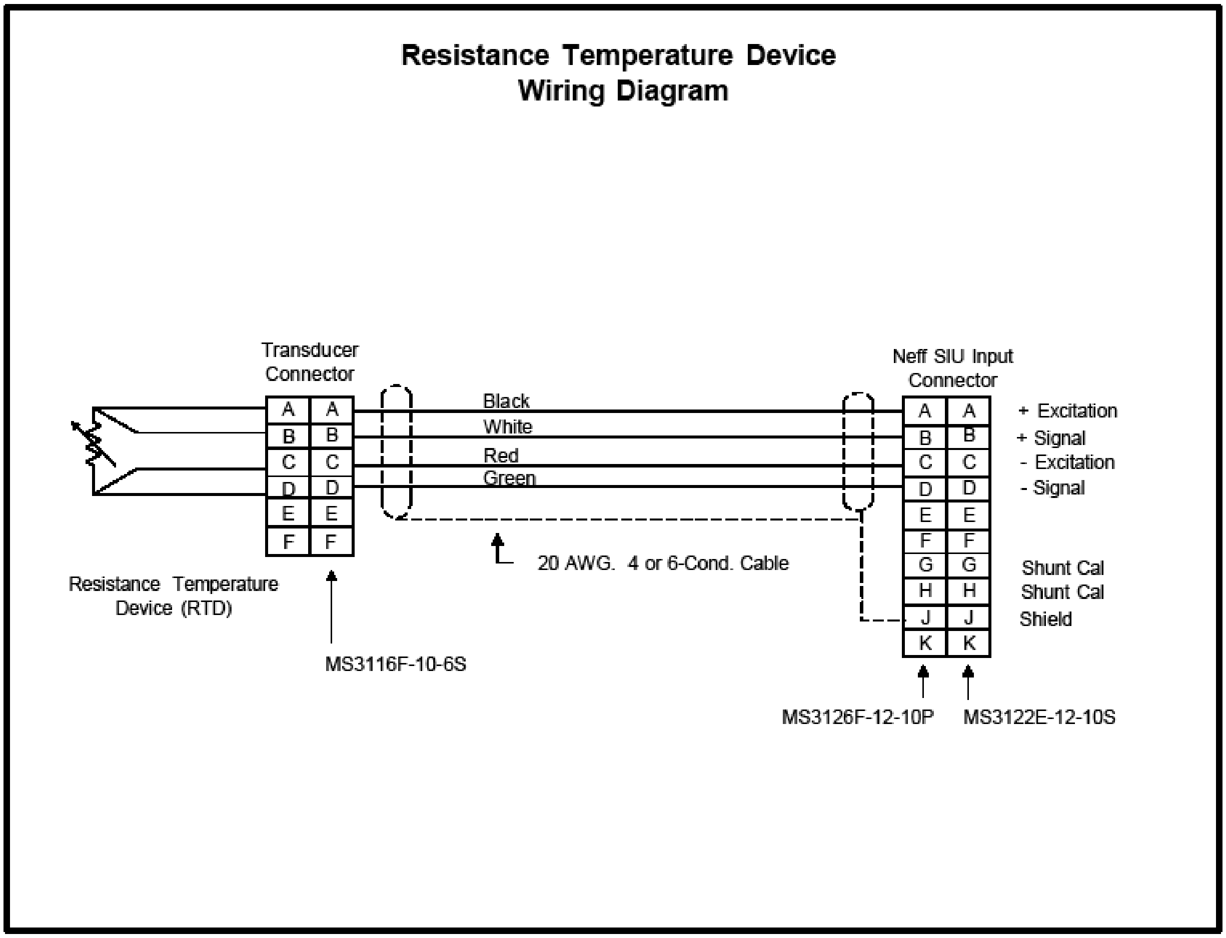


Figure 12-68. Resistance Temperature Device Wiring Diagram (2 of 2)

12.2.5: Flow Meter

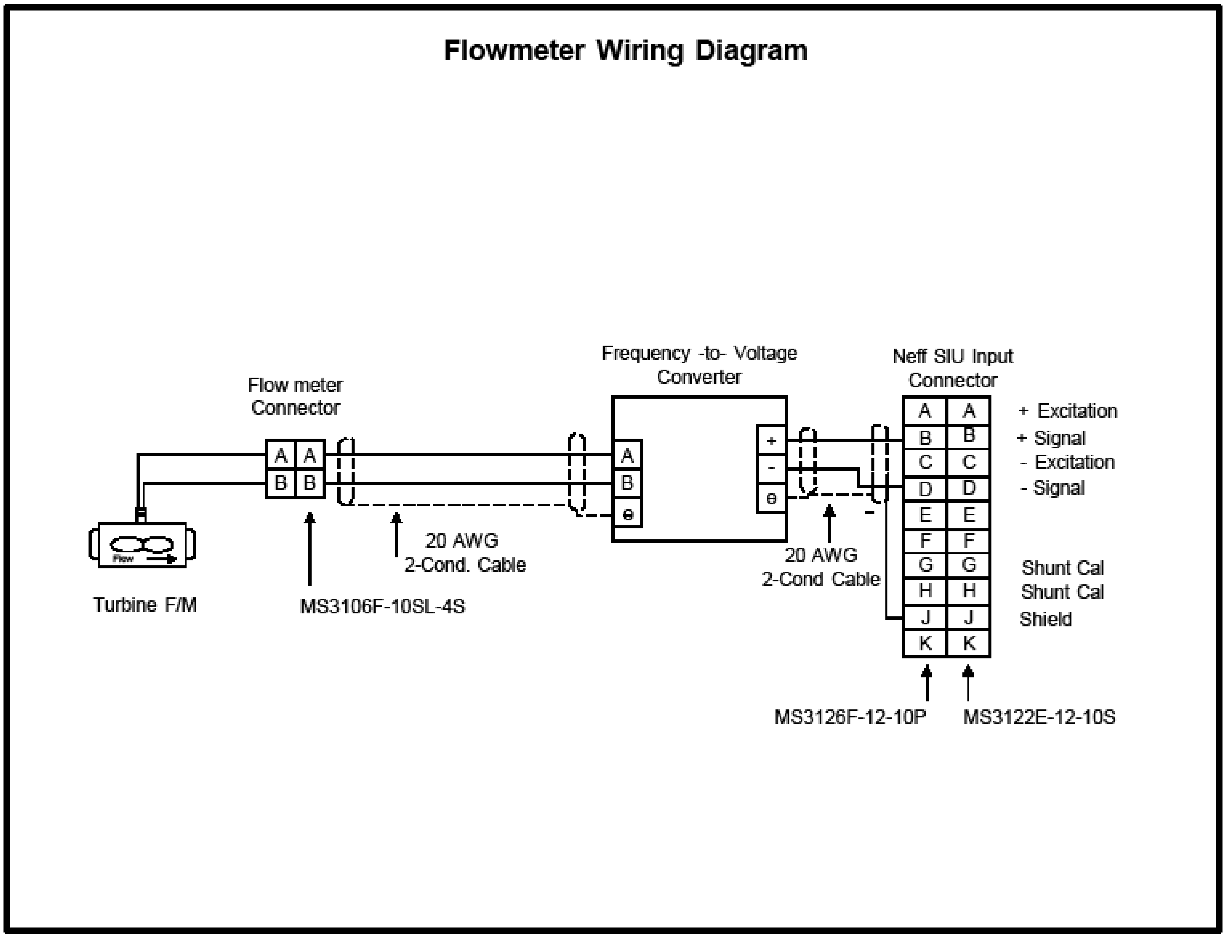


Figure 12-69. Flowmeter Wiring Diagram

12.2.6 Silicone Diode

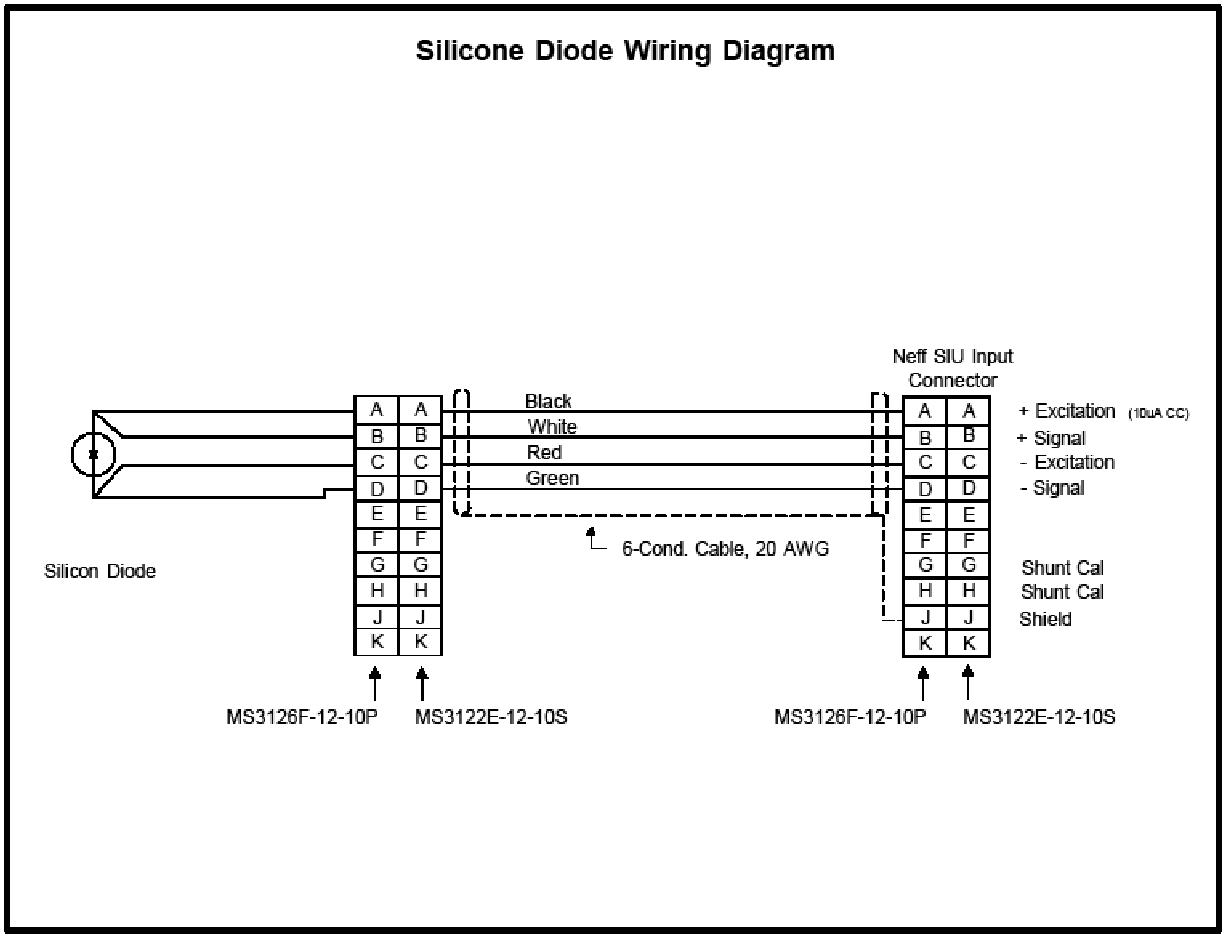


Figure 12-70. Silicone Diode Wiring Diagram

12.2.7 Strain Gage

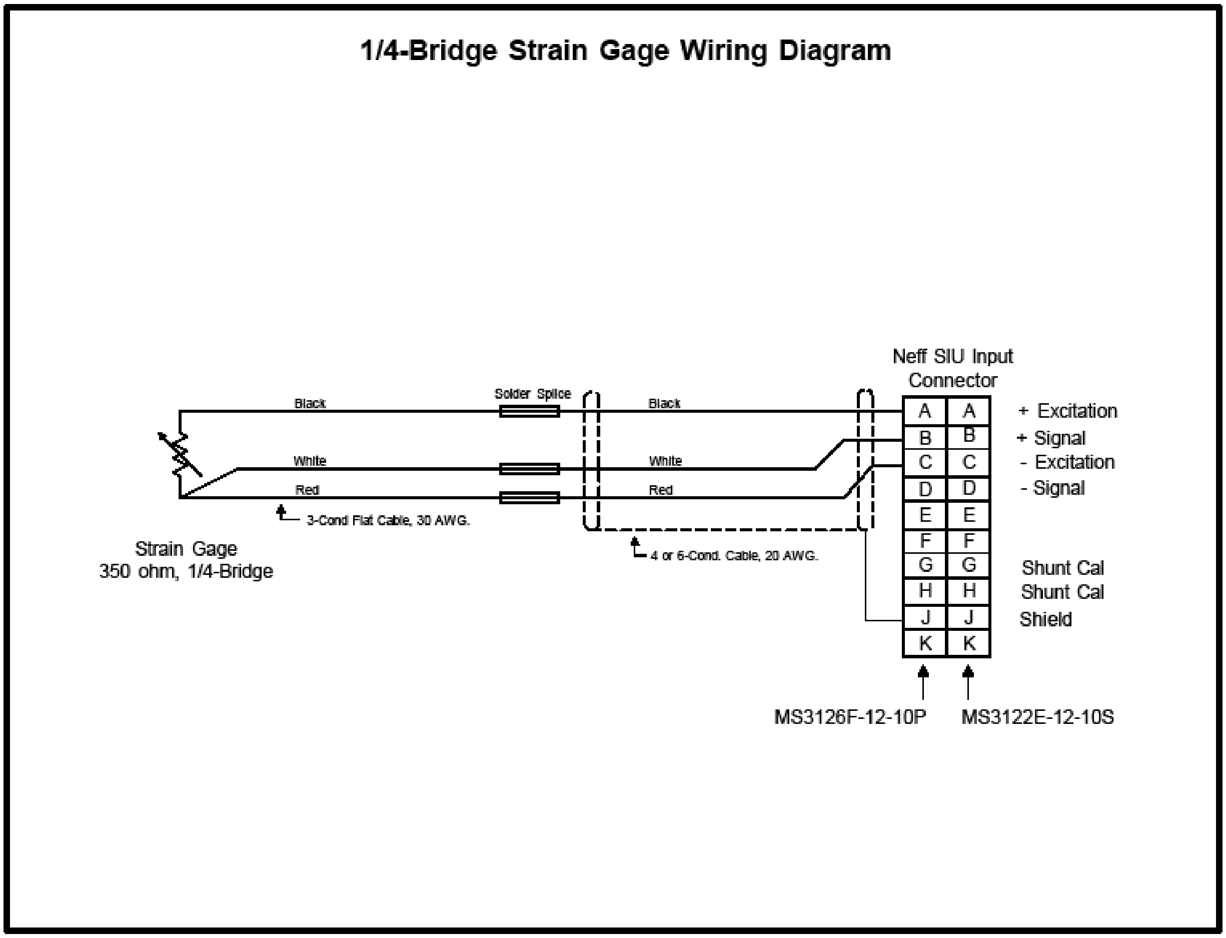


Figure 12-71. 1/4-Bridge Strain Gage Wiring Diagram

Data Acquisition
Contents

13.1: Low-Speed Data Acquisition System

13.1.1: Description

TBD

13.1.2: Specs

TBD

13.1.3: Block Diagram

TBD

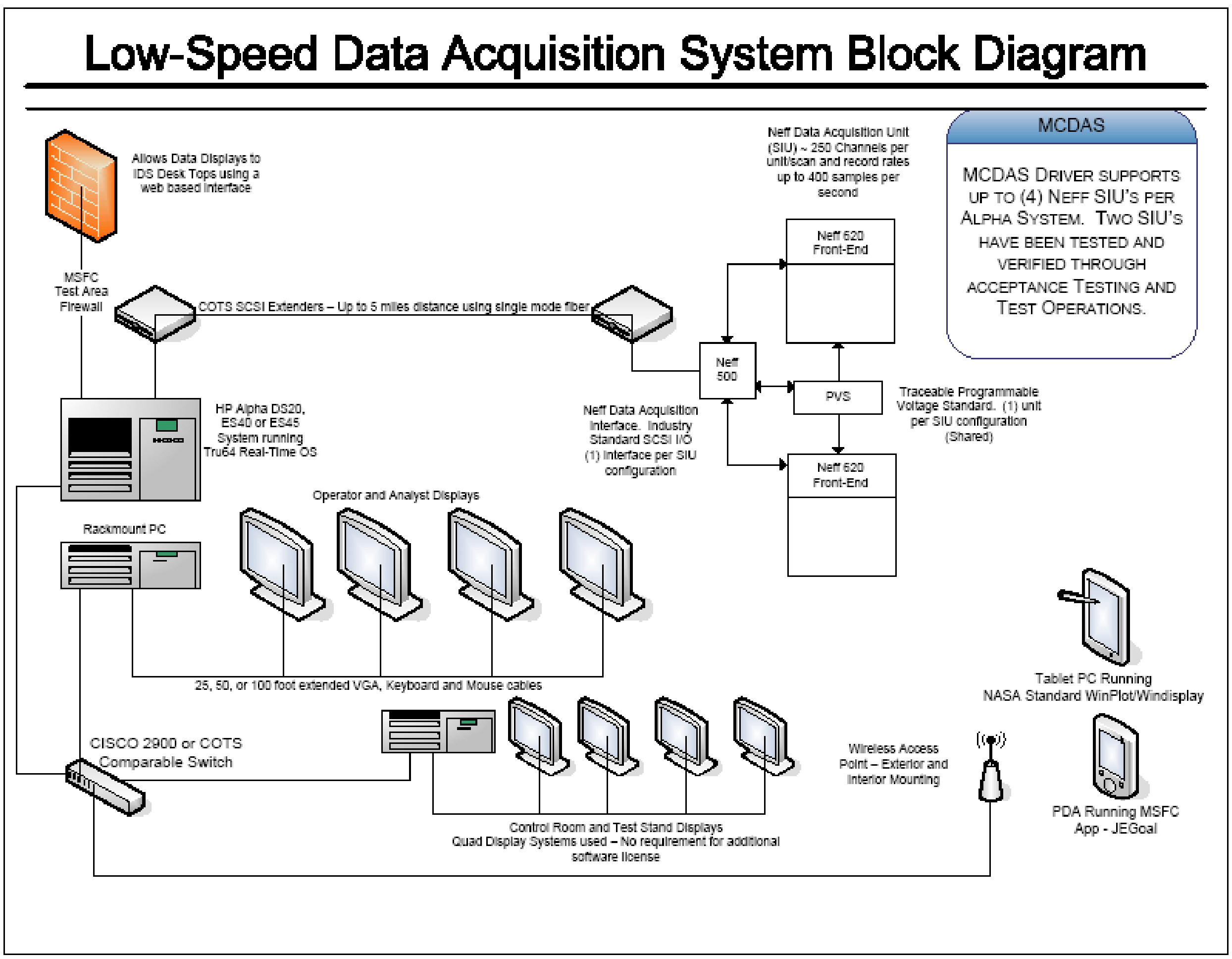


Figure 13-1. Low-Speed Data Acquisition System Block Diagram

13.2: High-Speed Data Acquisition System

13.2.1: Description

TBD

13.2.2: Specs

TBD

13.2.3: Block Diagram

TBD

13.3: Signal Conditioning Equipment

13.3.1: Description

TBD

13.3.2: Specs

TBD

13.3.3: Block Diagram

TBD

Safety
Contents

14.1: General

14.1.1: Test Area Access Training

The Test Areas are controlled access areas, due to the inherent dangers associated with test operations and the hazardous conditions present throughout the Test Area. Successful completion of the Test Area Access Training Course is required for all personnel who are permanently assigned to work in the Test Area or those personnel who have periodic work assignments within the Test Areas. Test Area Access privileges must be requested and approved by NASA ET10 Branch Management.

14.1.2: Access Categorizations

a. Category 1 personnel have unescorted access privileges in the Test Area. Generally, these are personnel who are permanently assigned to work within the Test Areas. Personnel who have frequent work assignments in the Test Area may also be granted Category 1 access. All Category 1 personnel will be assigned a backdrop badge for accessing the Test Area.
b. Category 2 personnel must check in at the Test Area Visitor's Center to receive a "Cat 2" visitor's badge. Category 2 personnel are required to coordinate their visits to the Test Area by contacting the appropriate Test Area personnel. Be advised: failure to coordinate your visit may delay your ability to gain access to the Test Areas.
c. Category 3 personnel are also required to check in at the Test Area Visitor's Center to receive a "Cat 3" visitor's badge and are required to be escorted while visiting the Test Areas. These personnel have not completed Test Area Access Training.
d. Category 2 and 3 personnel will be required to sign-in when they check-in at the Test Area Visitor's Center when they receive their Cat 2 or Cat 3 Test Area Visitor's Badges. Category 2 and 3 personnel are only permitted to visit pre-approved areas within the Test Areas. Should you need to gain access or visit other locations within the Test Areas, you are required to get permission from the appropriate personnel.

14.1.3: General Safety Considerations

a. Personnel must park GSA vehicles, personal vehicles, or rental vehicles in designated areas only.
b. Smoking is allowed in designated smoking areas only.
c. Personal Protective Equipment (PPE), such as hardhats, safety glasses, and hearing protection, may be required to safely perform certain tasks. It is your responsibility to know the requirements and to wear the appropriate PPE for the conditions.
d. High Heel or Open Toed Shoes must not be worn in the Test Areas due to the industrial nature of the work environment. Steel Toe Safety Shoes are strongly recommended for personnel performing hazardous operations within the Test Areas. Otherwise, general duty leather shoes, including tennis shoes are acceptable footwear.
e. Snakes, spiders, red wasps, and other wildlife are known to inhabit the Test Areas. Always pay attention to your surroundings, and do not place your hands or feet into blind areas!

14.1.4: Common Hazards in the Test Areas

a. Cryogenic Fluids – Extremely cold liquids down to - 423 degrees Fahrenheit. Severe Frostbite Hazard causing irreversible tissue damage. Appropriate Cryogenic PPE is required when handling these materials. Additionally, specific training and certifications are required to perform work activities involving cryogenic materials.
b. Flammable and Combustible Liquids/Gases. Flammable and Combustible Hazards include Hydrogen, Methane, Propane, Oxygen.
c. Pyrophoric Chemicals include TEA/TEB.
d. Toxic Chemicals include Monomethyl Hydrazine (MMH) and Nitrogen Tetroxide.
e. Asphixiant Hazards – Presence of Nitrogen, Helium. These hazards can cause asphyxiation, where there is no warning of danger or no “scared” feeling. Death can come quickly.
f. High Pressure Systems ranging from 150 psi to 10,000 psi.
g. Propellant & Explosives – Propellant and Explosives are present within the Test Areas. Working with Propellant & Explosives requires specific safety training and certification. All personnel working with Propellant & Explosives are required to have the requisite training and certification to participate in propellant and explosive handling operations.
h. Working at Heights – Working on the Test Stands may require you to work at heights of up to 400 feet. Fall Protection equipment may be required to perform work in these environments.
i. Noise – Your work in the Test Areas may warrant the use of ear plugs or ear muffs to protect your hearing. Hearing Damage is permanent and painless.
j. Slip, Trip, Fall Hazards – Due to the industrial nature of the work performed in the Test Areas and the configuration of the Test Stands, slip, trip, and fall hazards are common in the Test Areas. It is imperative that you be attentive to your surroundings while working in the Test Areas.
k. General Industrial Work – Welding, Fabrication, Electrical Work. Welding requires a Hot Work Permit, Fabrication requires PPE, and Electrical Work requires using Lockout/Tagout.

14.1.5: Emergency Response

a. Dial 911 from any NASA phone. At MSFC, use a Marshall phone to summon the Redstone Arsenal Fire Department. When dialing from a cell-phone make sure to tell the 911 dispatcher that the emergency is on the NASA facility, such as Redstone Arsenal at **MSFC**. This will expedite emergency response from Redstone Arsenal emergency personnel.
b. Report the nature of the emergency: Fire, Medical, or Security
c. Be prepared to provide the Building Number and the location of the emergency.
d. Provide your name and organization/company and the phone number you are calling from.
e. Provide details of the emergency situation if the conditions permit.

14.2: Hazard Communication

14.2.1 Visual Warning Signals

a. Red Light: A red light indicates that the area is dangerous, and hazardous test operations are in progress. Only designated test support personnel are allowed to be within the area. All other personnel are required to evacuate the area to a protective area.
b. Yellow Light: A yellow light indicates the area is semi-hazardous. Personnel may access the Test Stands during a Yellow Light event, but must get permission from the Test Stand personnel before entering.

c. Flashing Yellow with Chime: Propellant Transfer in progress and only designated test support personnel may be in the area.
d. Green Light (Strobe): A flashing green light indicates that lightning is within 5 miles of the Test Areas and all personnel must evacuate the test stand and area to a protective area indoors. No outdoor work is permitted during a Green Light (Lightning) event.

14.2.2 Barricades

Types: Drop Gates, saw horse barricades, roll around signs, and red or yellow tape barricades

Do not violate or bypass any barricade! Barricades are set-up to protect personnel against hazards. Bypassing a barricade could result in personnel injury or death.

14.2.3 Warning Signs

Types: TEA/TEB, Hardhats required, Confined Space Entry-Permit Required, Danger High Pressure Hydrogen Gas, Propellant & Explosives Signage at SPTA

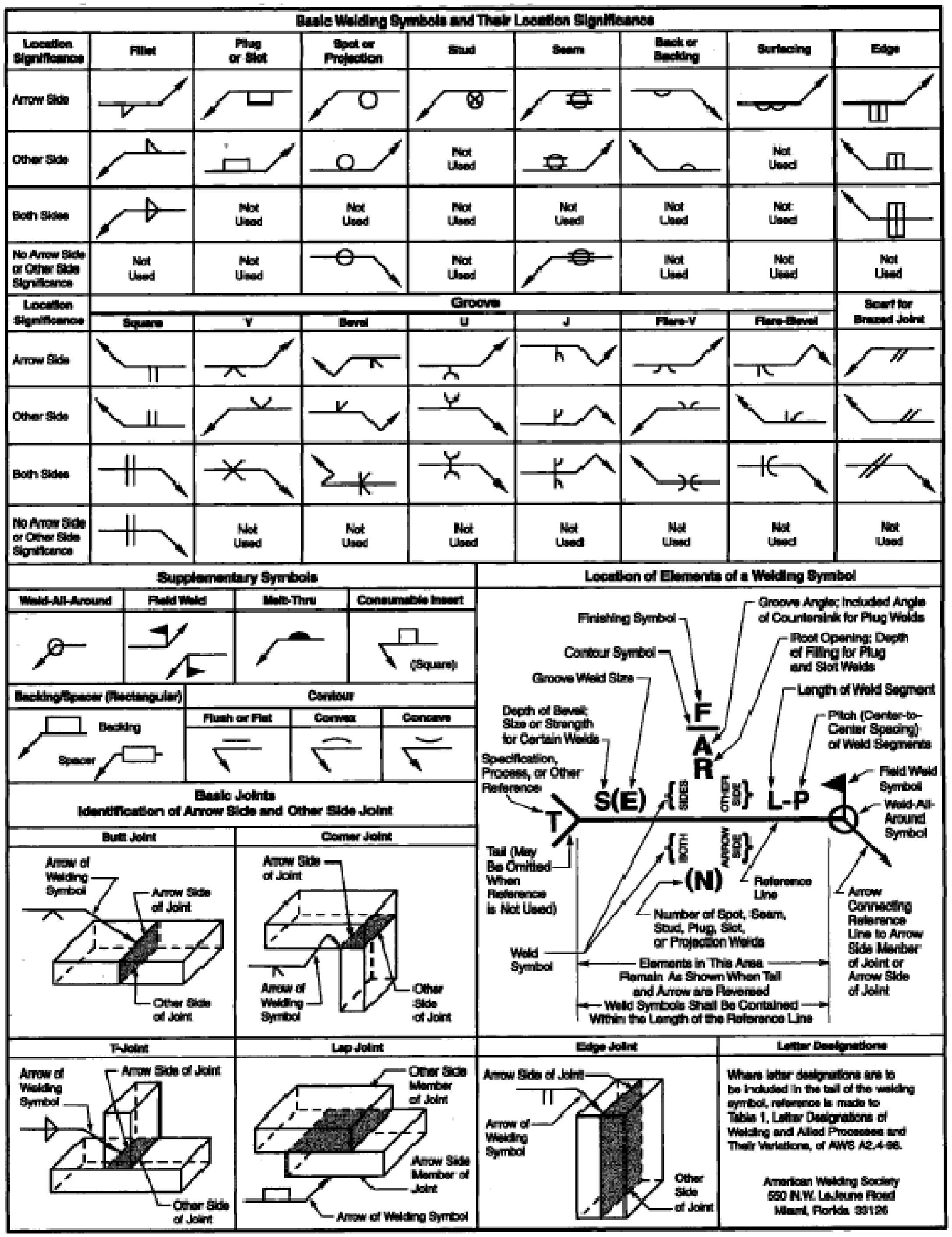
Detailed signs are located throughout the Test Areas to warn personnel of specific hazards.

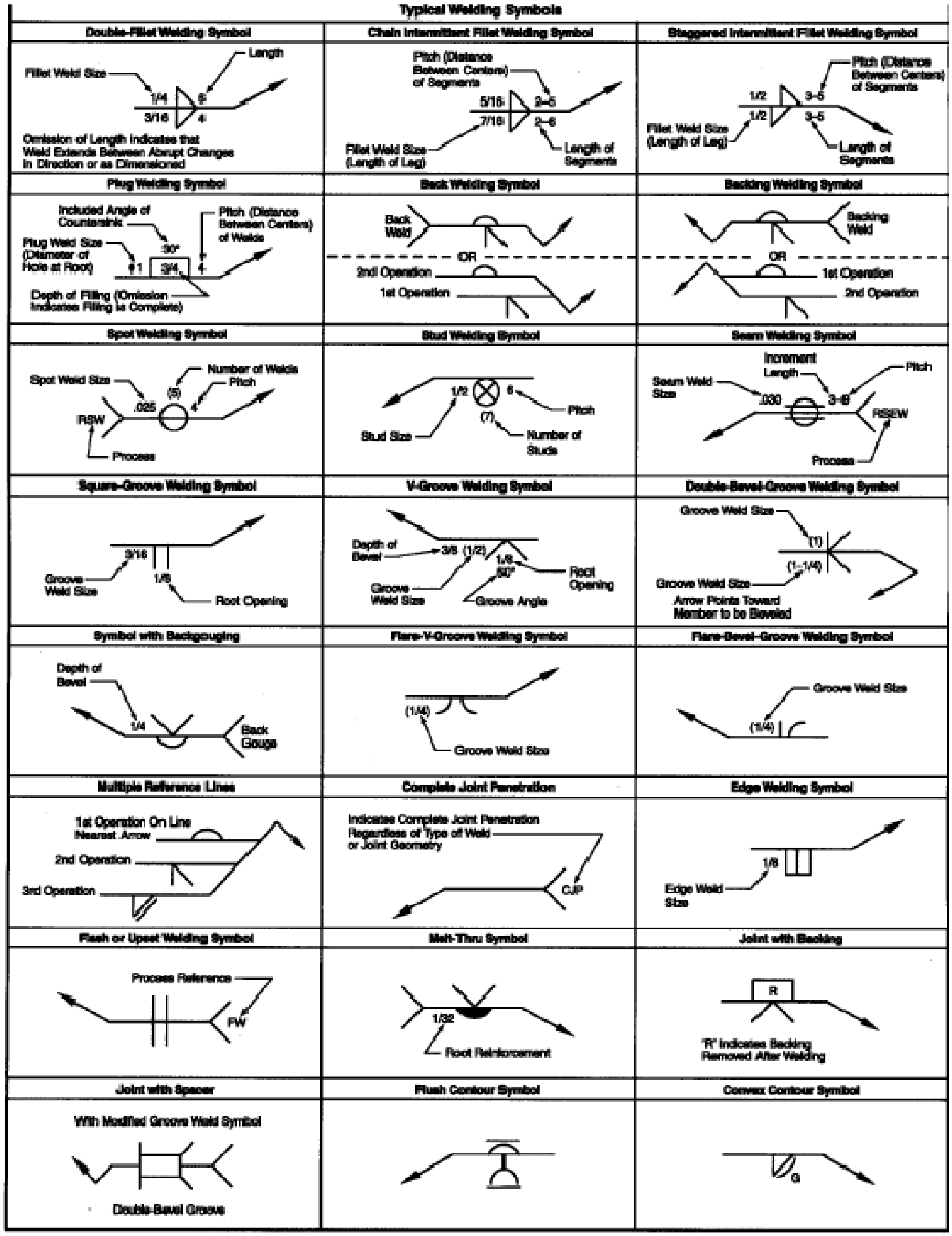
14.2.4 Area Announcements

The Test Area Coordinator makes specific real time announcements to inform personnel of the activities occurring within the Test Areas including the specific hazardous test-related operations taking place at each of the Test Stands. The information in these announcements is critical to your understanding of the activities and hazards in the Test Areas and all appropriate safety precautions that should be taken.

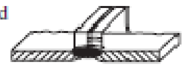
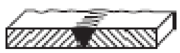
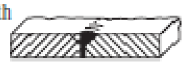
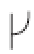
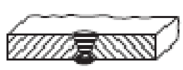
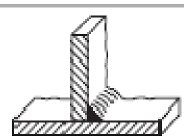
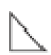
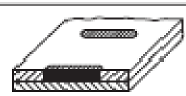
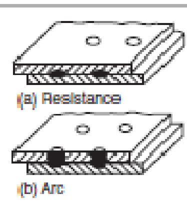
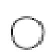
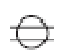
Environmental
Contents

Welding Symbols





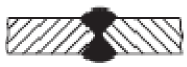
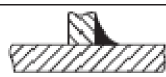
It should be understood that these charts are intended only as shop aids. The only complete and official presentation of the standard welding symbols is in AWS A2.4-98, Standard Symbols for Welding, Brazing, and Nondestructive Examination.

From of weld	Illustration	BS symbol
Butt weld between flanged plates (the flanges being melted down completely)		
Square butt weld		
Single-V butt weld		
Single-bevel butt weld		
Single-V butt weld with broad root face		
Single-bevel butt weld with broad root face		
Single-U butt weld		
Single-J butt weld		
Backing or sealing run		
Fillet weld		
Plug weld (circular or elongated hole, completely filled)		
Spot weld (resistance or arc welding) or projection weld		
Seam weld		

Excerpt from: Manual of Engineering Drawing_British Standards & International Standards_Colin H Simmons and Dennis E. Mag
http://www.scribd.com/doc/7749562/Manual-of-Engg-DrawingBritish-Standards-International-StandardsColin-H-Simmons-and-Dennis-E-Maguire
text pages: 211-212

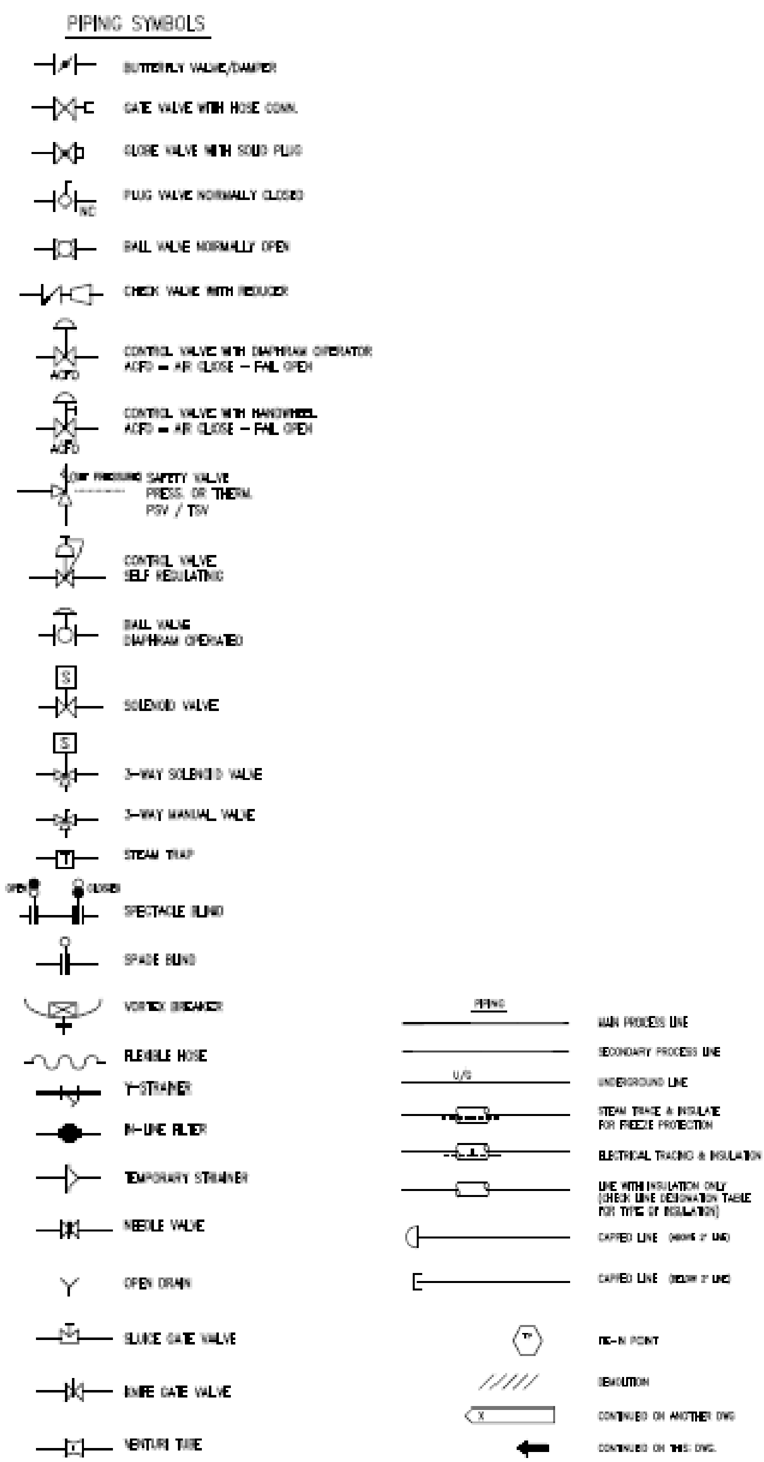
Shape of weld surface	BS symbol
flat (usually finished flush)	—
convex	⌒
concave	‿

Supplementary symbols

Form of weld	Illustration	BS symbol
Flat (flush) single-V butt weld		
Convex double-V butt weld		
Concave fillet weld		
Flat (flush) single-V butt weld with flat (flush) backing run		

Some examples of the application of supplementary symbols

Piping Symbols



Material Selection and Compatibility

METALS, O-RINGS, HOSE LINERS, GASKETS, AND PACKINGS										
SERVICE	NICKEL	ALUMINUM	CARBON STEEL	COPPER	18-8 STAINLESS	O-RINGS DYNAMIC	O-RINGS STATIC	HOSE LINERS	GASKETS	PACKING
NOTE: See code at end of this table.										
Pneumatic	S									
Air	S	S	S	S	S	1,2,3	4,10	1,2,3,4,10	4,8,9,28,10	4,10,11
Helium	S	S	S	S	S	1,2,3	4,10	4,10	4,8,9,28,10	4,10,11
Hydrogen	S	S	L	S	L	1,2,3	4,10	1,2,3,4,10	4,8,9,28,10	4,10,11
Nitrogen	S	S	S	S	S	1,2,3	4,10	4,10	4,8,9,28,10	4,10,11
Oxygen	S	S	L	S	S	None	4,10	4,10	4,8,9,28,10	4,10,11
Hydraulic	S									
Hydraulic Fluid	S	S	L	S	S	1	4,10	1,3,4,10	4,7,8,10	4,10,11
Lubricating Oil	S	S	S	S	S	1,5	4,10	1,3,4,10	4,8,9,10	4,10,11
Water	S	S	S	S	S	1,2,3	4,10	1,2,3,4,10	4,7,9,10	4,10,11
Cryogenic	S									
Fluorine (Liquid)	S	S	U	L	L	None	None	None	21,22,23	4
Hydrogen (Liquid)	S	S	U	S	S	None	4,10	None	4,7,9,10	4,10,11
Nitrogen (Liquid)	S	S	U	S	S	None	4,10	None	4,7,9,10	4,10,11
Oxygen (Liquid)	S	S	U	S	S	None	4,10	4,10	4,7,9,10	4,10,11
Other Fluids										
Oxidizers										
Chlorine Trifluoride	S	L	U	L	L	None	None	4,10	21,22,23	4,10
Fluorine (Gas)	S	L	S	S	S	None	None	4,10	21,22,23	4,10
Hydrogen Peroxide	U	S	U	U	L	24	4,10	4,10	4,7,10	4,10
•Nitric Acid (Fuming)	U	L	U	U	S	24	4,10	4,10	4,7,10	4,10
Nitrogen Tetroxide	L	L	L	U	S	6	4,10	4,10	4,7,10	4,10
Fuels										
Ammonia	L	L	L	U	S	1,2,3,5	4,10	1,2,3,4,10	4,8,10	4,10,11
Gasoline	S	S	S	S	S	1	4,10	2,3,4,10	4,8,9,10	4,10,11
Hydrazine, UDMH Hydyne	U	S	U	U	L	2	1,4,10	4,10	4,7,10	4,10
Kerosene, JP-1, JP-4, JP-5, and RP-1	S	S	S	U	S	1,5	4,10	1,3,4,10	4,8,9,10	4,10,11
Methyl and Ethyl Alcohol	S	S	L	S	S	1,2	4,10	1,2,4,10	4,7,10	4,10
Pentaborane	S	S	S	S	S	5,24	4,10	None	4,7,8,10	4,10,11
Others										
Acetone	S	S	S	S	S	2,3	4,10	2,4,10	4,7,8,10	4,10
Ethylene Oxide	S	U	U	U	S	3	4,10	4,10	4,10	4,10
Trichloroethylene	S	S	S	S	S	24	4,10	4,10	4,8,9,10	4,10
Nitric Acid Solution	U	U	U	U	S	24	4,10	1,4,10	4,7,10	4,10
•Ratings based on 100º F										
METALS, O-RINGS, HOSE LINERS, GASKETS, AND PACKINGS										

SERVICE	NICKEL	ALUMINUM	CARBON STEEL	COPPER	18-8 STAINLESS	O-RINGS DYNAMIC	O-RINGS STATIC	HOSE LINERS	GASKETS	PACKING
Others (Cont.)										
Hydrochloric Acid	U	U	U	U	U	24	4,10	2,4,10	4,7,10	4,10
Sulphuric Acid	U	U	U	L	L	24	4,10	4,10	4,7,10	4,10
Triethyl Aluminum	S	U	U	S	S	24	4,10	4,10	4,7,10	4,10
Triethylamine	S	S	S	U	S	2	4,10	4,10	4,7,10	4,10
Alkylborance	S	S	S	U	S	4	4,10	4,10		

LUBRICANTS AND SEALS					
LUBRICANTS			LUBRICANTS, SEALS, AND ANTISEIZE		
SERVICE	O-RINGS AND GASKETS (STATIC AND DYNAMIC	SLIDING SURFACES	STRAIGHT THREADS STATIC	STRAIGHT THREADS DYNAMIC	TAPERED THREADS
NOTE : See code at end of this table.					
Pneumatic					
Air	12,13,14	12,13,14	17	19	20
Helium	12,13,14	12,13,14	17,28	19	20
Hydrogen	12,13,14	12,13,14	17	19	20
Nitrogen	12,13,14	12,13,14	17,26	19	20
Oxygen	13,14	13,14	17,26	18,19	20
Hydraulic					
Hydraulic Fluid	15	15	15	15	20
Lubricating Oil	13	13	17	19	20
Water	13,16	13,16	17	16	20
Cryogenic					
Fluorine (Liquid)	None	None	20	None	None
Hydrogen (Liquid)	17 static	18	14,17	18	20
Nitrogen (Liquid)	17 static	18	14,17,26	18,19	20
Oxygen (Liquid)	17 static	18	14,17,26	18,19	20
Other Fluids					
Oxidizers					
Chlorine Trifluoride	None	None	20	None	27
Fluorine (Gas)	None	None	20	None	None
Hydrogen Peroxide	25	25	17,25,26	25	20
Nitric Acid (Fuming)	14	18,25	17	19	20
Nitrogen Tetroxide	14,25	18,25	17	19,25	20
Fuels					
Ammonia	25	14	17	19	20
Gasoline	13	13	17	19	20
Hydrazine, UDMH, Hydyne	13,25	13,25	17	25	20
Kerosene, JP-1, JP-4, JP-5, and RP-1	13	13	17	19	20
Methyl and Ethyl Alcohol	13	13	17	19	20
Pentaborane	14	14	14	19	20
Others					
Acetone	None	18	17	18	20
Ethylene Oxide	14	14	19	19	20
Trichoroethylene	None	18	17	18	20
Nitric Acid Solution	14	14	17	19	20
Hydrochloric Acid	14	14	17	19	20
Sulphuric Acid	14	14	17	19	20
Triethyl Aluminum	14	14	17	14	20
Triethylamine	13	13	17	19	20

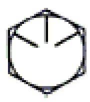
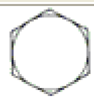
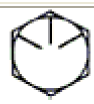
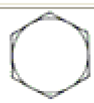
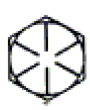
CODE		
S – SATISFACTORY	L – LIMITED	U – UNSATISFACTORY
1 – BUNA N		15 – SPECIFICATION MIL-H-5606
2 – BUTYL RUBBER (SR613 75)		16 – SPECIFICATION MIL-G-3278
3 – NEOPRENE		17 – NA7 20502
4 – TEFLON		18 – MOLYKOTE TYPE 2 POWDER
5 – VITON-A (SR270 70)		19 – FLUOROLUBE GREASE (GR 362)
6 – FLURO SILICONE (TH 1081)		20 – TEFLON TAPE, SPECIFICATION MIL-T-27730
7 – FLEXITALLIX WITH TEFLON FILLER		
8 – JM-76		21 – ALUMINUM 2S
9 – FLEXITALLIC WITH TEFLON OR ASBESTOS FILLER		22 – SOFT COPPER
10 – KEL-F		23 – STAINLESS STEEL
11 – ASBESTOS (NO LONGER IN USE)		24 – VITON-A (SR275-70)
12 – MIL-G-4343		25 – DC-11
13 – DC-55		26 – HOKE SLIC SEAL
14 – FLUOROLUBE (LG 160)		27 – PERMATEX NO. 2
		28 – HIGH DENSITY POLYETHYLENE (SPECIFICATION MIL-H-26666 AND MIL-H-27462)

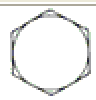
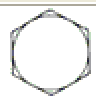
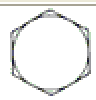
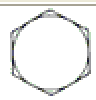
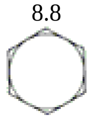
ASTM, SAE AND ISO GRADE MARKINGS AND MECHANICAL PROPERTIES FOR STEEL FASTENERS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	Yield Strength Min (psi)	Tensile Strength Min (psi)
No Grade Mark	SAE J429 Grade 1	Bolts, Screws, Studs	Low or Medium Carbon Steel	1/4 thru 1-1/2	33,000	36,000	60,000
	ASTM A307 Grades A&B		Low Carbon Steel	1/4 thru 4	--	--	
	SAE J429 Grade 2		Low or Medium Carbon Steel	1/4 thru 3/4 Over 3/4 to 1-1/2	55,000 33,000	57,000 36,000	74,000 60,000
No Grade Mark	SAE J429 Grade 4	Studs	Medium Carbon Cold Drawn Steel	1/4 thru 1-1/2	--	100,000	115,000
B5	ASTM A193 Grade B5		AISI 501	1/4 Thru 4	--	80,000	100,000
B6	ASTM A193 Grade B6		AISI 410			85,000	110,000
B7	ASTM A193 Grade B7		AISI 4140, 4142, OR 4105	1/4 thru 2-1/2 Over 2-1/2 thru 4 Over 4 thru 7	-- -- --	105,000 95,000 75,000	125,000 115,000 100,000
B16	ASTM A193 Grade B16		CrMoVa Alloy Steel			105,000 95,000 85,000	125,000 115,000 100,000
B8	ASTM A193 Grade B8		AISI 304	1/4 and larger	--	30,000	75,000
B8C	ASTM A193 Grade B8C		AISI 347				
B8M	ASTM A193 Grade B8M		AISI 316				

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	**Yield Strength Min (psi)**	**Tensile Strength Min (psi)**
B8T	ASTM A193 Grade B8T	Bolts, Screws, Studs for High-Temperature Service	AISI 321	1/4 and larger	--	30,000	75,000
B8	ASTM A193 Grade B8		AISI 304 Strain Hardened	1/4 thru 3/4 Over 3/4 thru 1 Over 1 thru 1-1/4 Over 1-1/4 thru 1-1/2	-- -- -- --	100,000 80,000 65,000 50,000	125,000 115,000 105,000 100,000
B8C	ASTM A193 Grade B8C		AISI 347 Strain Hardened				
B8M	ASTM A193 Grade B8M		AISI 316 Strain Hardened			95,000 80,000 65,000 50,000	110,000 100,000 95,000 90,000
B8T	ASTM A193 Grade B8T		AISI 321 Strain Hardened			100,000 80,000 65,000 50,000	125,000 115,000 105,000 100,000
L7	ASTM A320 Grade L7	Bolts, Screws, Studs for Low-Temperature Service	AISI 4140, 4142 or 4145	1/4 thru 2-1/2	--	105,000	125,000
L7A	ASTM A320 Grade L7A		AISI 4037				
L7B	ASTM A320 Grade L7B		AISI 4137				
L7C	ASTM A320 Grade L7C		AISI 8740				
L43	ASTM A320 Grade L43		AISI 4340	1/4 thru 4	--	105,000	125,000

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	**Yield Strength Min (psi)**	**Tensile Strength Min (psi)**
B8	ASTM A320 Grade B8	Bolts, Screws, Studs for Low-Temperature Service	AISI 304	1/4 and larger	--	30,000	75,000
B8C	ASTM A320 Grade B8C		AISI 347				
B8T	ASTM A320 Grade B8T		AISI 321				
B8F	ASTM A320 Grade B8F		AISI 303 or 303Se				
B8M	ASTM A320 Grade B8M		AISI 316				
B8	ASTM A320 Grade B8		AISI 304	1/4 thru 3/4 Over 3/4 thru 1 Over 1 thru 1-1/4 Over 1-1/4 thru 1-1/2	-- -- -- --	100,000 80,000 65,000 50,000	100,000 80,000 65,000 50,000
B8C	ASTM A320 Grade B8C		AISI 347				
B8F	ASTM A320 Grade B8F		AISI 321				
B8M	ASTM A320 Grade B8M		AISI 303 or 303Se				
B8T	ASTM A320 Grade B8T		AISI 316				

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	**Yield Strength Min (psi)**	**Tensile Strength Min (psi)**
	SAE J429 Grade 5	Bolts, Screws, Studs	Medium Carbon Steel, Quenched and Tempered	1/4 thru 1 Over 1 to 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
	ASTM A449			1/4 thru 1 Over 1 to 1-1/2 Over 1-1/2 thru 3	85,000 74,000 55,000	92,000 81,000 58,000	120,000 105,000 90,000
	SAE J429 Grade 5.1	Sems	Low or Medium Carbon Steel, Quenched and Tempered	No. 6 thru 3/8	85,000	--	120,000
	SAE J429 Grade 5.2	Bolts, Screws, Studs	Low Carbon Martensitic Steel, Quenched and Tempered	1/4 thru 1	85,000	92,000	120,000
 A325	ASTM A325 Type 1	High Strength Structural Bolts	Medium Carbon Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
 A325	ASTM A325 Type 2		Low Carbon Martensitic Steel, Quenched and Tempered	1/2 thru 1	85,000	92,000	120,000
 A325	ASTM A325 Type 3		Atmospheric Corrosion Resisting Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
 BB	ASTM A354 Grade BB	Bolts, Studs	Alloy Steel, Quenched and Tempered	1/4 thru 2-1/2 2-3/4 thru	80,000 75,000	83,000 78,000	105,000 100,000
 BC	ASTM A354 Grade BC			4	105,000 95,000	109,000 99,000	125,000 115,000
	SAE J429 Grade 7	Bolts, Screws	Medium Carbon Alloy Steel, Quenched and Tempered 4	1/4 thru 1-1/2	105,000	115,000	133,000
	SAE J429 Grade 8	Bolts, Screws, Studs	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 thru 1-1/2	120,000	130,000	150,000
	ASTM A354 Grade BD		Alloy Steel, Quenched and Tempered 4				

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	**Yield Strength Min (psi)**	**Tensile Strength Min (psi)**
 No Grade Mark	SAE J429 Grade 8.1	Studs	Medium Carbon Alloy or SAE 1041 Modified Elevated Temperature Drawn Steel	1/4 thru 1-1/2	120,000	130,000	150,000
 A490	ASTM A490	High Strength Structural Bolts	Alloy Steel, Quenched and Tempered	1/2 thru 1-1/2	120,000	130,000	150,000 min 170,000 max
 No Grade Mark	ISO R898 Class 4.6	Bolts, Screws, Studs	Medium Carbon Steel, Quenched and Tempered	All Sizes thru 1-1/2	33,000	36,000	60,000
 No Grade Mark	ISO R898 Class 5.8				55,000	57,000	74,000
8.8  or  88	ISO R898 Class 8.8		Alloy Steel, Quenched and Tempered		85,000	92,000	120,000
10.9  or  109	ISO R898 Class 10.9				120,000	130,000	150,000

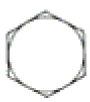
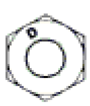
Manufacturer (Fastener Supplier) Identification Markings

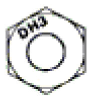
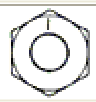
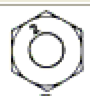
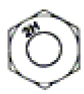
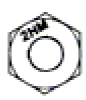
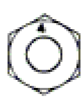
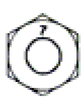
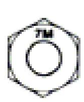
These are symbols unique to the manufacturer to self-identify the fasteners they produce for the purpose of positively identifying the fastener supplying company that accepts the responsibility that the fastener is within the requirements of the engineering standard against which it was manufactured. In effect, the marking says “we are the company guaranteeing this fastener to be correct; if it is found non-conforming, we are accountable."

Reputable North American fastener supplying companies are knowledgeable on the contents of the various engineering standards. They understand the technical requirements and are diligent in their compliance, and they appreciate the risks and exposures associated with nonconformity.

Any solicitation to purchase fasteners which the engineering standards require to be manufacturer identified, and which are not, should be viewed with suspicion. The economics may appear attractive, but in no way will the savings compensate for non-traceability and the ongoing risk of a liability exposure.

FASTENER IDENTIFICATION MARKING

Grade Identification Marking	Specification	Material	Nominal Size In.	Proof Load Stress ksi	Hardness Rockwell Min	Hardness Rockwell Max	See Note
 No Mark	ASTM A563 - Grade 0	Carbon Steel	1/4 thru 1-1/2	69	B55	C32	3,4
	ASTM A563 - Grade A	Carbon Steel	1/4 thru 1-1/2	90	B68	C32	3,4
	ASTM A563 - Grade B	Carbon Steel	1/4 thru 1	120	B69	C32	3,4
			over 1 thru 1-1/2	105			
	ASTM A563 - Grade C	Carbon Steel May be Quenched and Tampered	1/4 thru 4	144	B78	C38	5
	ASTM A563 - Grade C3	Atmospheric Corrosion Resistant Steel May be Quenched and Tampered	1/4 thru 4	144	B78	C38	5,9
	ASTM A563 - Grade D	Carbon Steel May be Quenched and Tampered	1/4 thru 4	150	B84	C38	6
	ASTM A563 - Grade DH	Carbon Steel Quenched and Tampered	1/4 thru 4	175	C24	C38	6

Grade Identification Marking	Specification	Material	Nominal Size In.	Proof Load Stress ksi	Hardness Rockwell		See Note
					Min	Max	
	ASTM A563 - Grade DH3	Atmospheric Corrosion Resistant Steel, Quenched and Tampered	1/4 thru 4	175	C24	C38	5,9
	ASTM A194 - Grade 1	Carbon Steel	1/4 thru 4	130	B70	--	7
	ASTM A194 - Grade 2	Medium Carbon Steel	1/4 thru 4	150	159	352	7,8
	ASTM A194 - Grade 2H	Medium Carbon Steel, Quenched and Tempered	1/4 thru 4	175	C24	C38	7
	ASTM A194 - Grade 2HM	Medium Carbon Steel, Quenched and Tempered	1/4 thru 4	150	159	237	7,8
	ASTM A194 - Grade 4	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 thru 4	175	C24	C38	7
	ASTM A194 - Grade 7	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 thru 4	175	C24	C38	7
	ASTM A194 - Grade 7M	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 thru 4	150	159	237	7
See Note 1,2	10						

NOTES:

1. In addition to the indicated grade marking, all grades, except A563 grades O, A and B, must be marked for manufacturer identification.

2. The markings shown for all grades of A194 nuts are for cold formed and hot forged nuts. When nuts are machined from bar stock the nut must be additionally marked with the letter 'B'.
3. Nuts are not required to be marked unless specified by the purchaser. When marked, the identification marking shall be the grade letter O, A or B.
4. Properties shown are those of non-plated or non-coated coarse thread hex nuts.
5. Properties shown are those of coarse thread heavy hex nuts.
6. Properties shown are those of coarse thread heavy hex nuts.
7. Properties shown are those of coarse 8-pitch thread heavy hex nuts.
8. Hardness's are Brinell Hardness Numbers.
9. The nut manufacturer, at his option, may add other markings to indicate the use of atmospheric corrosion resistant steel.
10. Specifications -- ASTM A563 -- Carbon and Alloy Steel Nuts. ASTM A194/A194M -- Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service.

(Courtesy Industrial Fasteners Institute : http://www.labsafety.com/refinfo/printpage.htm?page=/refinfo/ezfacts/ezf269.htm)

added 2 items (1. Section concerning **Manufacturer (Fastener Supplier) Identification Markings Fastener Identification marking table) and used the Industrial Fasteners Institute "notes" section in place of what was used before**

CONVERSION TABLES
Fractions of an Inch
To Decimals of an Inch and to Millimeters

Fraction					Decimal	Millimeter
			1/64	. . . .	.015625	0.39688
		1/32	. . . .	. . . .	.03125	0.79375
			3/64	. . . .	.046875	1.19063
	1/16	. . . .	. . . .	. . . .	.0625	1.5875
			5/64	. . . .	.078125	1.98438
		3/32	. . . .	. . . .	.09375	2.38125
			7/64	. . . .	.109375	2.77813
1/8	. . . .				.125	3.17501
			9/64	. . . .	.140625	3.57188
		5/32	. . . .	. . . .	.15625	3.96876
			11/64	. . . .	.17875	4.36563
	3/16	. . . .	. . . .	. . . .	.1875	4.76251
			13/64	. . . .	.203125	5.15939
		7/32	. . . .	. . . .	.21875	5.55626
			15/64	. . . .	.234375	5.95314
1/4	. . . .				.25	6.35001
			17/64	. . . .	.265625	6.74689
		9/32	. . . .	. . . .	.28125	7.14376
			19/64	. . . .	.296875	7.54064
	5/16	. . . .	. . . .	. . . .	.3125	7.93752
			21/64	. . . .	.328125	8.33439
		11/32	. . . .	. . . .	.34375	8.73127
			23/64	. . . .	.359375	9.12814
3/8	. . . .				.375	9.52502
			25/64	. . . .	.390625	9.92189
		13/32	. . . .	. . . .	.40625	10.31877
			27/64	. . . .	.421875	10.71565
	7/16	. . . .	. . . .	. . . .	.4375	11.11252
			29/64	. . . .	.453125	11.50940
		15/32	. . . .	. . . .	.46875	11.90627
			31/64	. . . .	.484375	12.30315
1/2	. . . .				.5	12.70002

Fraction					Decimal	Millimeter
			33/64	. . . .	.515625	13.09690
		17/32	. . . .	. . . .	.53125	13.49378
			35/64	. . . .	.546875	13.89065
	9/16	. . . .	. . . .	. . . .	.5625	14.28753
			37/64	. . . .	.578125	14.68440
		19/32	. . . .	. . . .	.59375	15.08128
			39/64	. . . .	.609375	15.47816
5/8	. . . .				.625	15.87503
			41/64	. . . .	.640625	16.27191
		21/32	. . . .	. . . .	.65625	16.66878
			43/64	. . . .	.671875	17.06566
	11/16	. . . .	. . . .	. . . .	.6875	17.46253
			45/64	. . . .	.703125	17.85941
		23/32	. . . .	. . . .	.71875	18.25629
			4764	. . . .	.734375	18.65316
3/4	. . . .				.75	19.05004
			49/64	. . . .	.765625	19.44691
		25/32	. . . .	. . . .	.78125	19.84379
			51/64	. . . .	.796875	20.24066
	13/16	. . . .	. . . .	. . . .	.8125	20.63754
			53/64	. . . .	.828125	21.03442
		27/32	. . . .	. . . .	.84375	21.43129
			55/64	. . . .	.859375	21.82817
7/8	. . . .				.875	22.22504
			57/64	. . . .	.890625	22.62192
		29/32	. . . .	. . . .	.90625	23.01880
			59/64	. . . .	.921875	23.41567
	15/16	. . . .	. . . .	. . . .	.9375	23.81255
			61/64	. . . .	.953125	24.20942
		31/32	. . . .	. . . .	.96875	24.60630
			63/64	. . . .	.984375	25.00317
1	. . . .				1.0	25.40005

WEIGHTS AND MEASURES

Length

1 in. = 25.4 mm
1 mm = .03937 in.
1 ft = 30.48 cm
1 mile = 5280 ft
1 mile = 1.609 kilometers
1 nautical mile = 1.15156 statute miles
1 nautical mile = 6080.27 ft

Area

1 sq ft = 144 sq in.
1 sq in. = 6.4516 sq cm
1 circular mil = .7854 sq mil
[A circular mil is the area of a circle 1 mil (0.001 inch) in diameter]

Volume (Liquid)

1 cu ft = 7.481 U.S. gal.
1 U.S. gal. = 0.1337 cu ft
1 U.S. gal. = 231 cu in.
1 U.S. gal = 3.785 liters

Weight

1 lb = 16 ox
1 lb = 7000 grains
1 lb = 453.6 grams
1 kg = 2.205 lb
1 ton (short) = 2000 lb
1 U.S. gal. of water (15^{o}C) weighs 8.336 lb
1 cu ft water weighs 62.4 lb (15^{o}C)
1 slug (mass) weighs 32.2 lb (where g = 32.2)

Velocity

60 mph = 88 ft/sec
1 mph = 1.467 ft/sec
1 knot = 1.152 mph
1 ft/sec = 30.48 cm/sec
1 rpm = 0.1047 radians/sec

Acceleration Due to Gravity

g_0 = 32.17 ft/sec/sec = 980.7 cm/sec/sec

Pressure

Absolute pressure = gage pressure + ambient pressure
1 atmosphere = 14.696 psia = 760 mm of H_g = 1013.2 mb
1 psia = 144 lb per sq ft
1 psia = 2.036 in. of H_g
1 in. of H_g = 2.540 cm of H_g
1 in. of H_g = 13.6 in. of water
(H_g = mercury at 0^{o}C)
(mb = millibar = 1 dyne per sq cm)

Energy

1 btu = 778.3 ft=lb
1 btu = 1054.8 joules
1 btu = 0.2930 watt hours
1 btu = 0.2520 kilo calories
1 hp hr = 1.98 x 10^6 ft-lb

Power

1 hp = 550 ft-lb/sec
1 hp = 745.7 watts
1 btu/minute = 17.58 watts

Temperature

Fahrenheit Scale:
ice point 32^o F, steam point 212^{o}F
Centigrade Scale:
ice point 0^o C, steam point 100^o C
Rankine Scale:
^{o} R = ^{o} F + 460
Kelvin Scale:
^{o} K = ^{o} C + 273
^{o} F = 9/5 ^{o} C +32
^{o} C = 5/9 (^{o} F – 32)

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Torque

$$T = F \times L$$

T = Torque

F = Applied force

L = Length of the wrench from the center of the nut to the center of the hand applying the force

Torque with an Adaptor

$$S = \frac{T \times L}{L + E}$$

T = Torque desired (actual torque)

S = Dial reading. This is the unknown factor. You want to know what it should be when you use an adaptor.

L = Distance from the square drive for the torque wrench to the center of the operator's hand on the handle of the torque wrench. The pull must be at right angles to the centerline of torque.

E = Extended length of the adaptor parallel to the handle. Measure this from the bolt to the square drive of the torque wrench and use only that distance with is parallel to the torque wrench.

Chapter 5

Chapter 6

Chapter 7

Safe Working Capacity (SWC) for Rigging Equipment

Rigging Equipment	**Safe Load in Tons is Equal To:**	**Remarks**
Eye Bolts	$2D^2$	D = diameter (in inches) of bolt stock where it forms the eye. Not accurate when D is greater than 1 inch.
Manila Rope Sisal Rope	D^2 $0.7\ D^2$	D = diameter (in inches) of rope. Not accurate when D is greater than 1 inch.
Plow Steel Wire Rope	$8D^2$	D = diameter (in inches) of wire rope.
Open Eye Hooks	D^2	D = diameter (in inches) at the point where the inside curve starts its arc. (See Figure page 8-9.)
Shackles	$6D^2$	D = diameter (in inches) of the shackle. Do not use pin diameter. (See figure page 8-18.)
Chain	$6D^2$	D = diameter (in inches) of chain stock.

Chapter 8

Chapter 9

Chapter 10

Chapter 11

Chapter 12

Applied Pressure, Using Calibration Constants

$$P = A\left(1 - \frac{T_O}{T}\right) - B(1 - \frac{T_O}{T^2})$$

P = Applied pressure

T_O = Period of oscillation when the applied pressure is zero.

T = Period of oscillation when the applied pressure is P

A = Calibration constant of the transducer

B = Calibration constant of the transducer

Output Voltage, Affected by Transducer Sensitivity and Supply Voltage

$$V_O = (S)V_S(\frac{Pm}{Pr})$$

V_O = Output voltage

S = Sensitivity of a transducer

V_S = Supply voltage

Pm = Measured pressure

Pr = Rated pressure of the transducer

Chapter 13

Appendix D: Abbreviations

A

AC ..... *Alternating Current*
ACFM ..... *Actual Cubic Feet per Minute*
AN ..... *Air Force-Navy aeronautical standards parts designation*
ANSI ..... *American National Standards Institute*
ASA ..... *American Standards Association*
ASCII ..... *American Standard Code for Information Interchange*
ASME ..... *American Society of Mechanical Engineers*
ASTM ..... *American Society for Testing Materials*

B

C

CC ..... *Control Center*
COTS ..... *Commercial Off The Shelf*
CPU ..... *Central Processing Unit*
CTF ..... *Chlorine Triflouride*

D

DC ..... *Direct Current*
DEE ..... *Discrete Event Emulator*
DER ..... *Discrete Event Recorder*
DETA ..... *Diethylene triamine—a rocket fuel additive*
DHCP ..... *Dynamic Host Configuration Protocol*
DSU ..... *Data Selector Unit*

E

EBW ..... *Exploding Bridgewire*
ECS ..... *Electrical Control Station—an installation adjacent to the test stand, which connects by cable to the control center (CC) (PWR term)*
EFI ..... *Exploding Foil Initiator*
EHV ..... *Electro-Hydraulic Valve*
EMF ..... *Electromotive Force*
ES .....
EWR ..... *Engineering Work Request (PWR term)*

F

FAP ..... *Facility Activation Procedure*
FL ..... *Field Laboratory (-ies) (PWR term)*
FLM ..... *Field Laboratories Manual (PWR term)*
FLOX ..... *Liquid Flourine and Liquid Oxygen mixture*

G

GG .... *Gas Generator—the rocket engine component, which drives the turbo pump*
GN_2.................................. *Gaseous Nitrogen*
GOX .... *Gaseous Oxygen*
GPS.................................. *Global Positioning System*

H

He..................................... *Helium*
H_2O_2 .... *Hydrogen Peroxide*
HMI .... *Human-Machine Interface*
HWS .... *Hardwired Shutdown System*
Hydyne .... *UDMH and DETA mixture*
HZ (N 2 H 4)....................... *Hydrazine (anhydrous)*

I

I/O .... *Input/Output*
ICC.................................... *Interstate Commerce Commission*
ID .... *Inside Diameter*
IRFNA .... *Inhibited Red Fuming Nitric Acid*
IRIG .... *Inter-Range Instrumentation Group*

J

J Box .... *Junction Box—location for making an authorized change in an electrical circuit*
JP...................................... *Jet Propellant*

K

L

LED .... *Light Emitting Diode*
LF_2 .... *Liquid Flourine*
LFMC .... *Liquidtight Flexible Metal Conduit*
LH_2 .... *Liquid Hydrogen*
LN_2 .... *Liquid Nitrogen*
LOX or LO_2........................ *Liquid Oxygen*
LVDT................................. *Linear Variable Differential Transformer*

M

MAC .... *Maximum Allowable Concentration*
MCDAS .... *Measurement and Controls Data Acquisition System*
MIL .... *Military—a prefix*
MNPT ....

MS .... *Military Standard*
MWP .... *Maximum Working Pressure*

N

NAS ....
NC .... *National Course (ref. threads)*
N.C. .... *Normally Closed*
NEMA .... *National Electrical Manufacturers Association*
NF .... *National Fine (ref. threads)*
NFPA .... *National Fire Protection Association*
NIST .... *National Institute of Standards & Technology*
N.O. .... *Normally Open*
NPT .... *National Pipe Thread*
NPSL ....
NPTF .... National Pipe Thread Fuel (e.g., Dryseal thread)
NSI .... NASA Standard Initiator

O

OD .... Outside Diameter
OS .... Operating System

P

PPE .... *Personal Protective Equipment*
PLC .... *Programmable Logic Controller*
PVS .... *Programmable Voltage Source*
PWR .... *Pratt & Whitney-Rockedyne*

Q

R

RD .... *Rocketdyne*
RETMA .... *Radio Electronics Television Manufacturers Association*
RMC .... *Rigid Metal Conduit*
RMS .... *Root Mean Square*
ROV .... *Remote Operated Valve*
RTD .... *Resistance Temperature Device*
RTU .... *Remote Terminal Unit*

S

SIU.................................... *Signal Input Unit*
SBASI................................ *Single Bridgewire Apollo Standard Initiator*
SCFM................................ *Standard Cubic Feet per Minute*
SOV .... *Solenoid Valve*
SWC.................................. *Safe Working Capacity*

T

T/C .... *Thermocouple*
TLV .... *Threshold Limit Value*

U

UVC .... *Universal Viscosity Calibration*

V

VAC .... *Volts Alternating Current*
VDC .... *Volts Direct Current*

W

X

Y

Z

Glossary

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Appendix F: Sources and ISO Document References

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