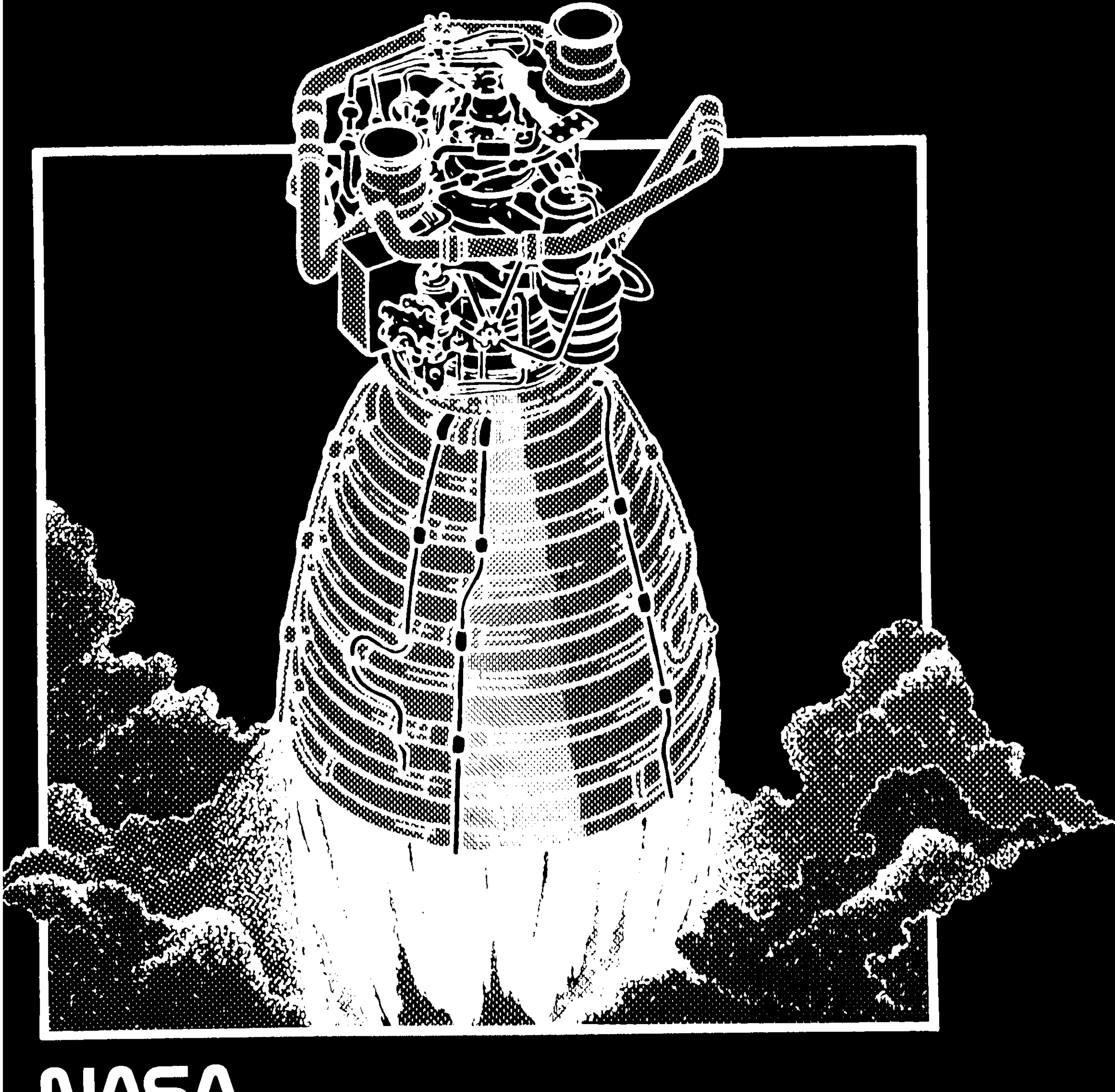
PROPULSION TEST HANDBOOK



NASA

National Aeronautics and
Space Administration

Marshall Space Flight Center

ALL PERSONNEL WORKING WITHIN PROPULSION TEST DIVISION WILL BE AWARE OF AND WILL COMPLY WITH THE FOLLOWING:

IN CASE OF FIRE CALL EXT. 117

FOR AMBULANCE CALL EXT. 112

GENERAL VISUAL WARNING SIGNALS

GREEN:	AREA SAFE
AMBER:	AREA SEMI-HAZARDOUS, PERSONNEL MAY PASS BUT ONLY AUTHORIZED PERSONNEL MAY REMAIN.
AMBER (WITH CHIME) :	PROPELLANT TRANSFER - NO SMOKING OR OTHER FLAME ANYWHERE AT TRANSFER LOCATION.
RED:	AREA HAZARDOUS, ONLY PERSONNEL AUTHORIZED BY TEST ENGINEER MAY REMAIN.
FLASHING AMBER:	AREA IN DANGER DUE TO ANOTHER LOCATION. NO ONE AUTHORIZED TO PASS. MOVE TO OR REMAIN IN AUTHORIZED SAFE SHELTER.
FLASHING RED:	EXTREMELY HAZARDOUS AREA, NO ONE MAY REMAIN, EVACUATE IMMEDIATELY.

SMOKING AUTHORIZED IN DESIGNATED AREAS ONLY.

ABOUT THE COVER

The Space Shuttle Main Engine (SSME) shown is typical of the three SSME's that power the Shuttle Orbiter during launch. The engine was developed in the 1970's and was declared operational in early 1983 after Space Transportation System Flight Six.

The Technology Test Bed (TTB) Facility located in the West Test Area on the Modified S-1C Test Stand will test the SSME. The purpose of the TTB Test Program is the following:

- OBTAIN BETTER UNDERSTANDING OF AN ENGINE SYSTEM'S INTERNAL OPERATING ENVIRONMENT

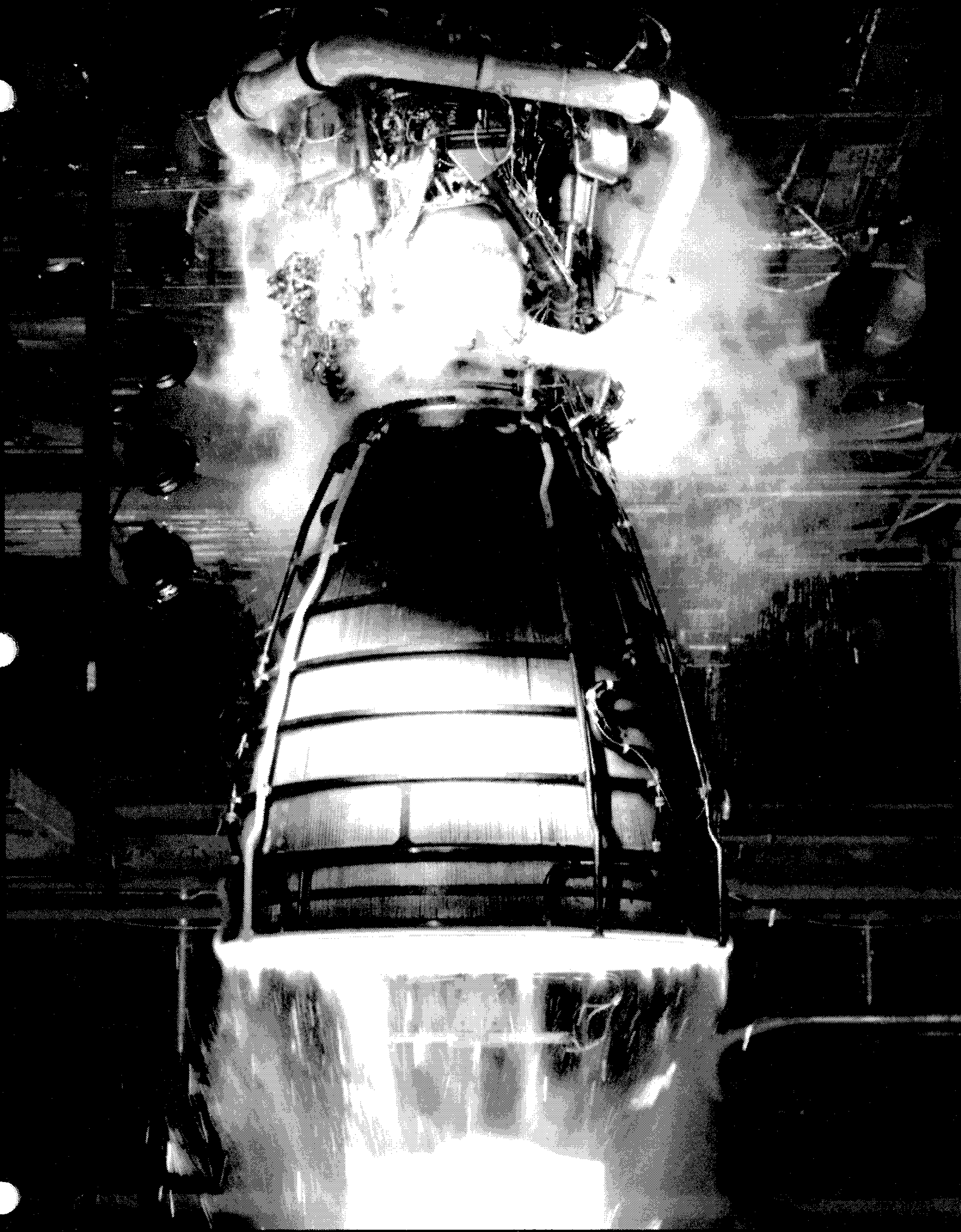
- PROVIDE EXPERIMENTAL MEANS FOR ASSESSING PROTOTYPE REPLACEMENT COMPONENTS

- DEMONSTRATE FEASIBILITY OF MATURE TECHNOLOGY FEATURES IN AN ENGINE SYSTEM ENVIRONMENT

- FACILITATE TRANSFER OF TECHNOLOGY ITEMS TO ON-GOING AND FUTURE PROGRAMS

- REGAIN MSFC INHOUSE ENGINE SYSTEM TESTING CAPABILITY

The SSME is 14 feet high and 7.5 feet in diameter and weighs 7000 pounds. It operates at 3,200 psia chamber pressure resulting in a high altitude thrust of greater than 500K lbf. The engine propellants are liquid oxygen and liquid hydrogen and it has a design life of 27,000 seconds and 55 starts.



space shuttle main engine

space shuttle main engine

The Space Shuttle Main Engine (SSME) has been developed specifically to meet the stringent requirements of the U.S. Space Transportation System. Popularly known as the Space Shuttle, this system provides unique capabilities previously unattainable in expendable launch vehicles. The Space Shuttle features include a payload bay that can accommodate large, single payloads or small, multiple payloads; manned by astronauts; returnable to Earth with minimal shock; and reusability. The SSME meets the high performance required by the Space Shuttle.

Under contract to the National Aeronautics and Space Administration's Marshall Space Flight Center, the Rocketdyne Division of Rockwell International has developed the main engine for NASA's space shuttle orbiter vehicle. The system, which first flew in April 1981 provides the United States with a versatile, economical space transportation system in the 1980's and beyond to the year 2000.

The SSME is a staged combustion cycle engine which operates at extremely high pressures to reduce engine envelope while attaining efficiencies previously unknown in rocket engine technology. Burning liquid hydrogen and liquid oxygen, the three engines in the shuttle orbiter provide the majority of the total impulse (thrust times duration) required to attain orbital velocity. Solid rocket boosters, which provide lift-off thrust are dropped after two minutes operation and later recovered from the sea. The SSMEs are shut down prior to reaching orbital velocity and the external tank which provides the hydrogen and oxygen propellants is dropped safely into a designated, unpopulated area of the ocean.

The high performance of the SSME is the result of major advancements in rocket engine design technology. Low weight and low propellant consumption are accomplished by operating the SSME at pressures and power densities more than three times higher than the Saturn engines used in the Apollo program. Ultra-high-pressure operation of the pumps and combustion chamber allows expansion of all hot gases through a high-area-ratio exhaust nozzle to achieve efficiencies never previously attained in a production rocket engine. These advantages allow a heavier payload to be carried without increasing launch vehicle size.

The completely stacked Space Transportation System stands 184 feet tall without the launch mount, compared to 363 feet for the Saturn V vehicle. The pumps that deliver the propellants to the combustion chamber weigh little more than a truck engine; yet they develop as much as 75,000 horsepower, and could empty a backyard swimming pool in under 30 seconds. The engines must operate over a temperature range from 423°F below zero to over 6,000°F.

Safety is achieved by monitoring conditions within the engine during operation. An engine controller that automatically checks itself and engine conditions fifty times every second, keeps the engine operating within safe limits or shuts it down safely in case of a serious malfunction. With only two of the three engines operating, the orbiter can safely return to the landing strip near the launch site or continue into orbit.

The space shuttle fleet can carry satellites into low earth orbit, or release them for free flight operation. It can also retain payloads such as Spacelab in its cargo bay for on-o experiments and subsequent safe return to earth. The shuttle can also retrieve and repair satellites.

The value of the shuttle to mankind is in the payloads it will carry–weather forecasting, land resources observation, large space telescopes, space-based manufacturing, or release of planet probes for scientific space exploration. Its reusability, flexibility, and manned presence will transport the "next logical step" in the conquest of space, NASA's Space Station, scheduled to be operational withan a decade.

SPACE SHUTTLE MAIN ENGINE PERFORMANCE (FULL POWER LEVEL)

Maximum Thrust: (109% Power Level)		
At Sea Level	408,750 pounds	
In Vacuum	512,300 pounds	
Pressures:		
Hydrogen Pump Discharge	6,872 psia	
Oxygen Pump Discharge	7,936 psia	
Combustion Pressure	3,277 psia	
Flowrates:		
Total	1,130 lb/sec	22,557 gpm
Hydrogen	160 lb/sec	16,436 gpm
Oxygen	970 lb/sec	6,121 gpm

Power:	
High Pressure Pumps	
Hydrogen	74,928 horsepower
Oxygen	28,229 horsepower
Weight:	7,000 pounds
Length:	14 feet
Diameter:	7.5 feet
Propellants:	
Fuel	Liquid Hydrog
Oxidizer	Liquid Oxygen

Pub. 574-E-4 Rev. 9-87

Rockwell International
Rocketdyne Division

NASA
Marshall Space Flight Center

PREFACE

This Mechanic's Handbook was prepared to provide Propulsion Division Personnel a central source of fundamental reference material.

ACKNOWLEDGEMENT

In preparing this handbook we would like to acknowledge Rocketdyne Field Laboratories and, in particular, Mr. Jack Monaghan, for his assistance and cooperation by providing the fundamental reference material.

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SECTION 1

GENERAL INFORMATION

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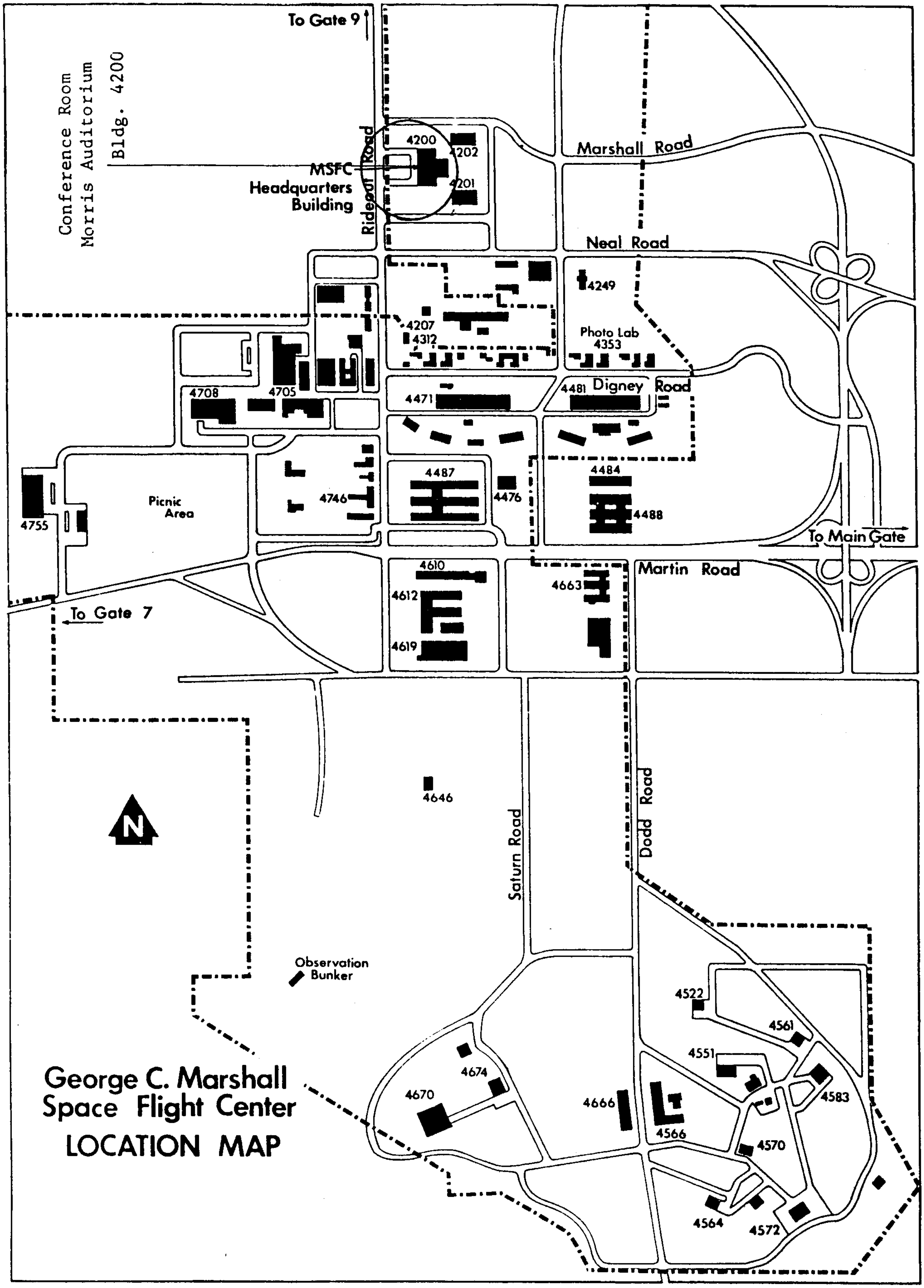
George C. Marshall
Space Flight Center
LOCATION MAP
Conference Room
Morris Auditorium
Bldg. 4200
MSFC
Headquarters
Building
To Gate 9
Rideout Road
Marshall Road
Neal Road
Digney Road
Martin Road
Saturn Road
Dodd Road
To Main Gate
To Gate 7
Photo Lab
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Picnic
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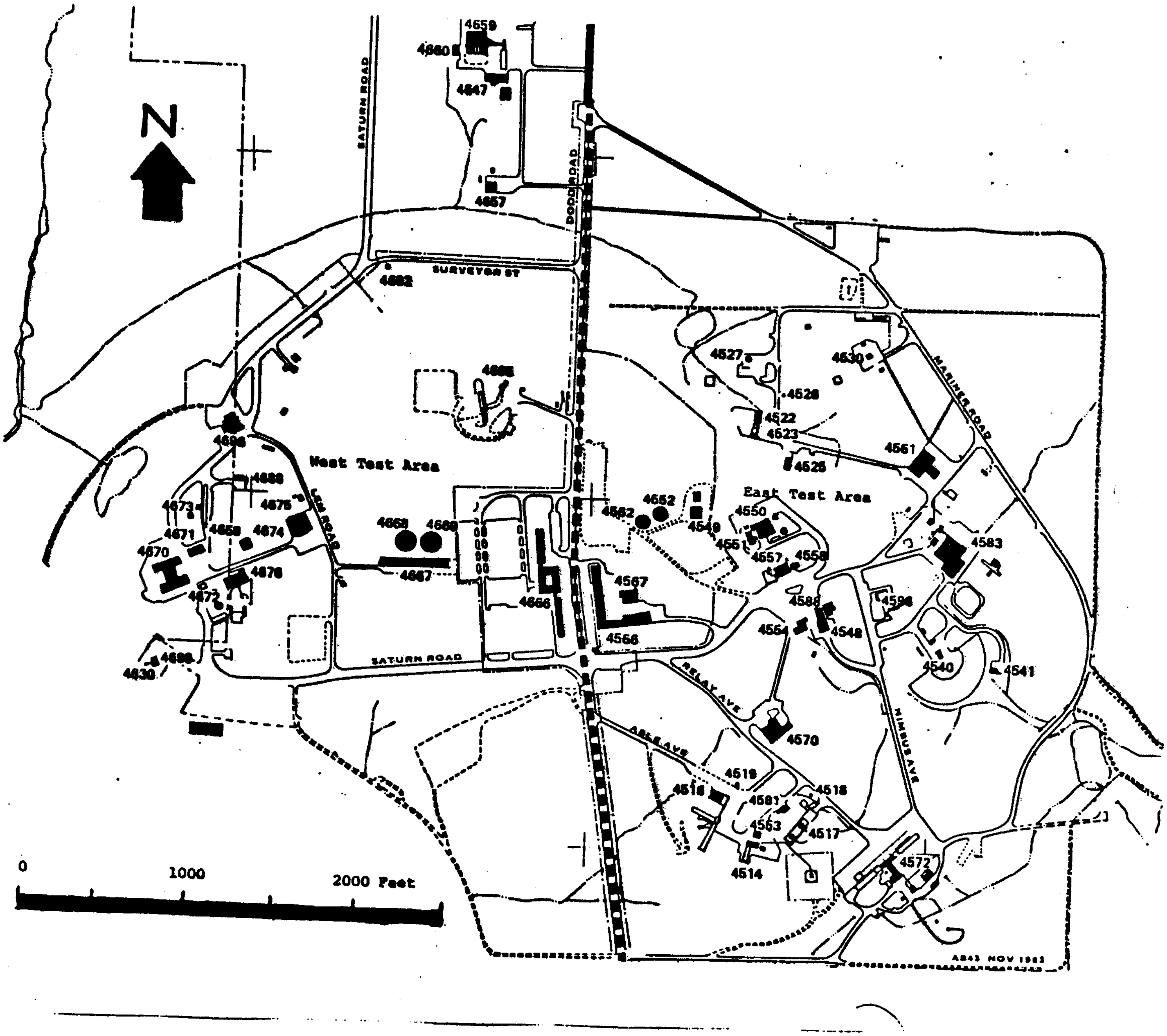
EAST AND WEST TEST AREAS



ABBREVIATIONS AND DEFINITIONS

AN . . . . Air Force-Navy Aeronautical Standard Parts Designation

AND . . . . Air Force-Navy Aeronautical Design Standard

ANSI . . . . American National Standards Institute

ASA . . . . American Standards Association

ASME . . . . American Society of Mechanical Engineers

ASTM . . . . American Society for Testing Materials

CTF . . . . Chlorine Trifluoride

DETA . . . . Diethylene Triamine--A Rocket Fuel Additive

FAP . . . . Facility Activation Procedure

FLOX . . . . Mixture of Liquid Fluorine and Liquid Oxygen

FOP . . . . Facility Operation Procedure

GFP . . . . Government Furnished Property

GG . . . . Gas Generator--The Rocket Engine Component Which Drives the Turbopump

GN_2 . . . . Gaseous Nitrogen

GOX . . . . Gaseous Oxygen

He . . . . Helium

H_2O_2 . . . . Hydrogen Peroxide

Hydyne . . . . Mixture of UDMH and DETA (Propellant)

HZ (N_2H_4) . . . . Hydrazine (Anhydrous)

ICC . . . . Interstate Commerce Commission

ID . . . . Inside Diameter

IRFNA . . . . Inhibited Red Fuming Nitric Acid

JAN . . . . Joint Army - Navy

J Box . . . . Junction Box--A Convenient Place to Make an Authorized Change in an Electrical Circuit

JP . . . . Jet Propellant

LF_2 . . . . Liquid Fluorine

LH_2 . . . . Liquid Hydrogen

LN_2 . . . . Liquid Nitrogen

LOX or LO_2 . . . . Liquid Oxygen

MAC . . . . Maximum Allowable Concentration

MIL . . . . Military--A Prefix

MMH . . . . Monomethylhydrazine

MS . . . . Military Standard--Parts Designation

NAS . . . . National Aircraft Standard

NASA . . . . National Aeronautics and Space Administration

NC . . . . National Course--A Screw Thread Type

NPSH . . . . Net Positive Suction Head

NPT . . . . American National Taper Pipe Thread or American Standard Taper Pipe Thread

NTO (N_2O_4) . . . . Nitrogen Tetroxide

OD . . . . Outside Diameter

PB . . . . Pentaborane

Pc . . . . Chamber Pressure

Purge	A Cleaning Operation for Systems, Engines, and Components in Which a Fluid (Usually Gaseous) is Caused to Flow Through the System
RFNA	Red Fuming Nitric Acid
RP-1	Rocket Propellant
SOP	Standard Operating Procedure
TC	Thrust Chamber
TEA	Triethylaluminum
TEB	Triethylboron
Test Stand	A Large Engine Test Facility
TCP	Test and Checkout Procedure
TLV	Threshold Limit Value
TPS	Test Preparation Sheet
TRIC	Trichloroethylene
UDMH	Unsymmetrical Dimethylhydrazine (Rocket Fuel)
WFNA	White Fuming Nitric Acid

SECTION 2

USEFUL INFORMATION

CONTENTS

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	1.58750
			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	.171875	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
			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

CONVERSION TABLES (Continued)

Fraction				Decimal	Millimeter
		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
		47/64	....	.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 oz
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°C) weighs 8.336 lb
1 cu ft water weighs 62.4 lb (15°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°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

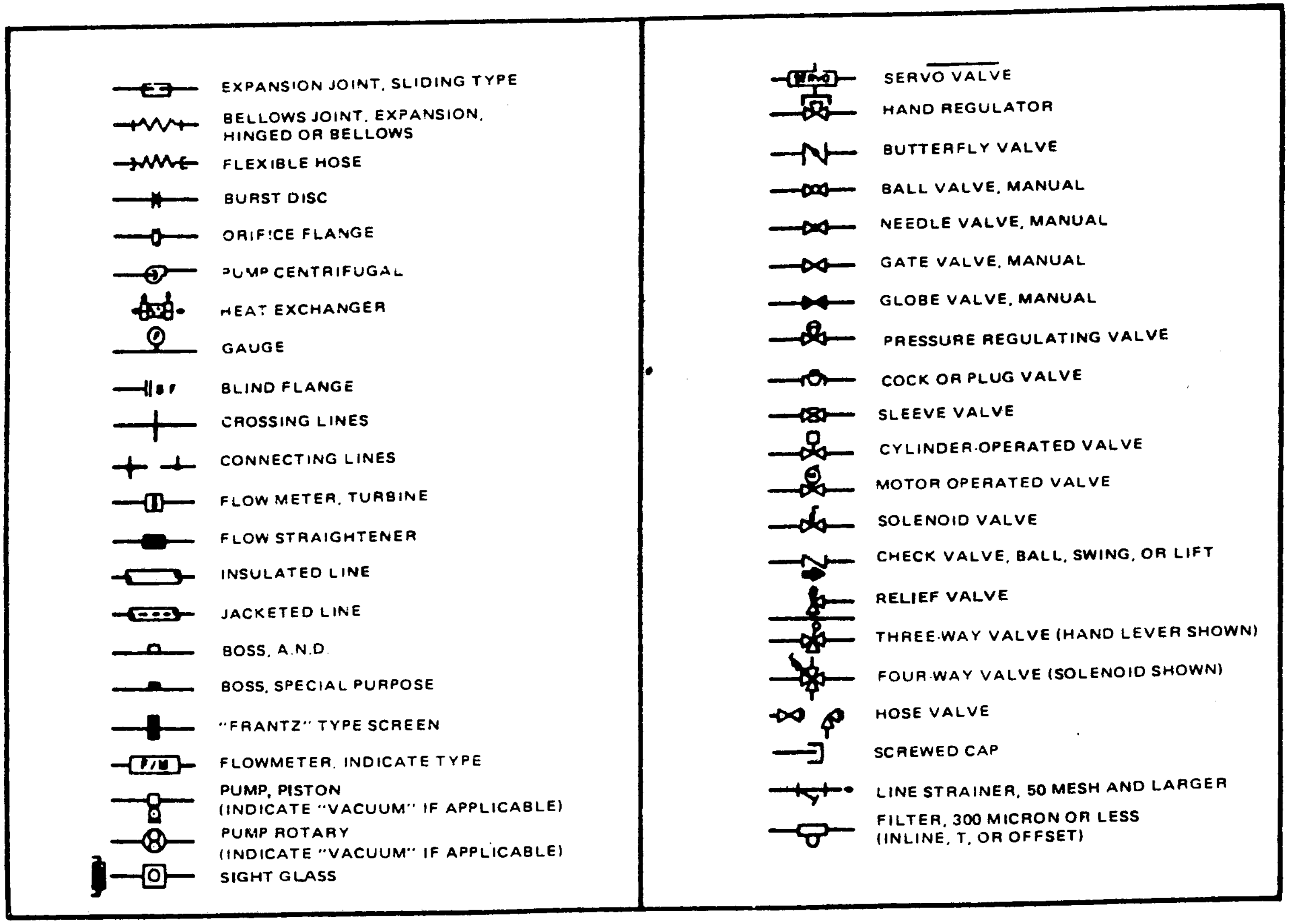
Power

1 hp = 550 ft-lb/sec
1 hp = 745.7 watts
1 btu/minute = 17.58 watts

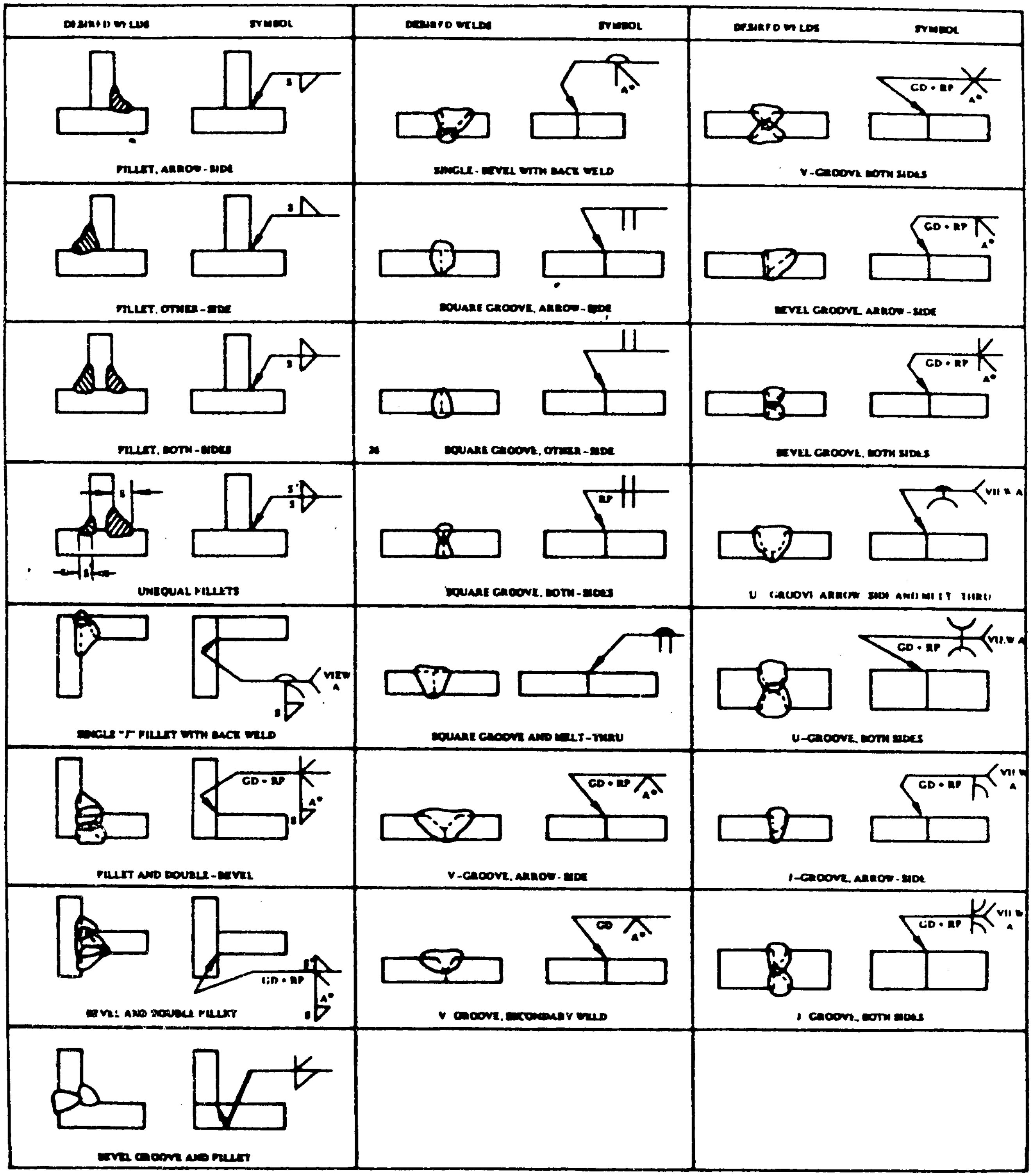
Temperature

Fahrenheit Scale:
ice point 32° F, steam point 212°F
Centigrade Scale:
ice point 0° C, steam point 100° C
Rankine Scale:
°R = °F + 460
Kelvin Scale:
°K = °C + 273
°F = 9/5 °C + 32
°C = 5/9 (°F - 32)

PIPING SYSTEM SYMBOLS



WELDING SYMBOLS



For a complete list of weld symbols, see ST0500002GP, Design Standard

SECTION 3

PIPE, TUBE AND FITTINGS

CONTENTS

Page

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.

SELECTION OF PIPE AND TUBING

PIPE AND PIPE FITTINGS

Figures 3.1 and 3.2 show the allowable pressure 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 which 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.

SEAMLESS UNTHREADED STAINLESS STEEL PIPE

PIPE SIZE		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	10.75	440	540	1220	1680	3950	3480
12	12.75	430	500	1050	1410	3880	2900

NOTE: (1) Allowable working pressure in psi from -325* to 100°F.

(2) Allowable stress = 20,000 psi (Safety factor is 3.75) for ASTM A 312 seamless grade TP 304, 316, 321 and 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 types 200 and 400 are not.

Figure 3.1. Maximum Allowable Working Pressure for Seamless Stainless 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	10.75	250	350	1020	1810	3740	--
12	12.75	270	340	970	1790	3700	--

NOTE: (1) Allowable working 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.

Figure 3.2. Maximum Allowable Working Pressure for Seamless Carbon Steel Pipe

PIPE FITTINGS

Flanges and Flanged Fittings

Flanges and flanged fittings are rated for a primary service at a temperature in the range of 500 to 1125 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 Figure 3.3.

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 maximum 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.

Figure 3.3. Pressure Ratings of ASA Standard Steel Flanges

FLANGED PIPE CONNECTIONS

Standard ASA Flanges

The ASA standard flanges are suitable for use with pressure systems to 6000 psi.

Flanges are available in many types and facings as shown in Figure 3.4.

HIGH PRESSURE FLANGED FITTINGS

For pressures above 6000 psi, Grayloc type flanged fittings should be used.

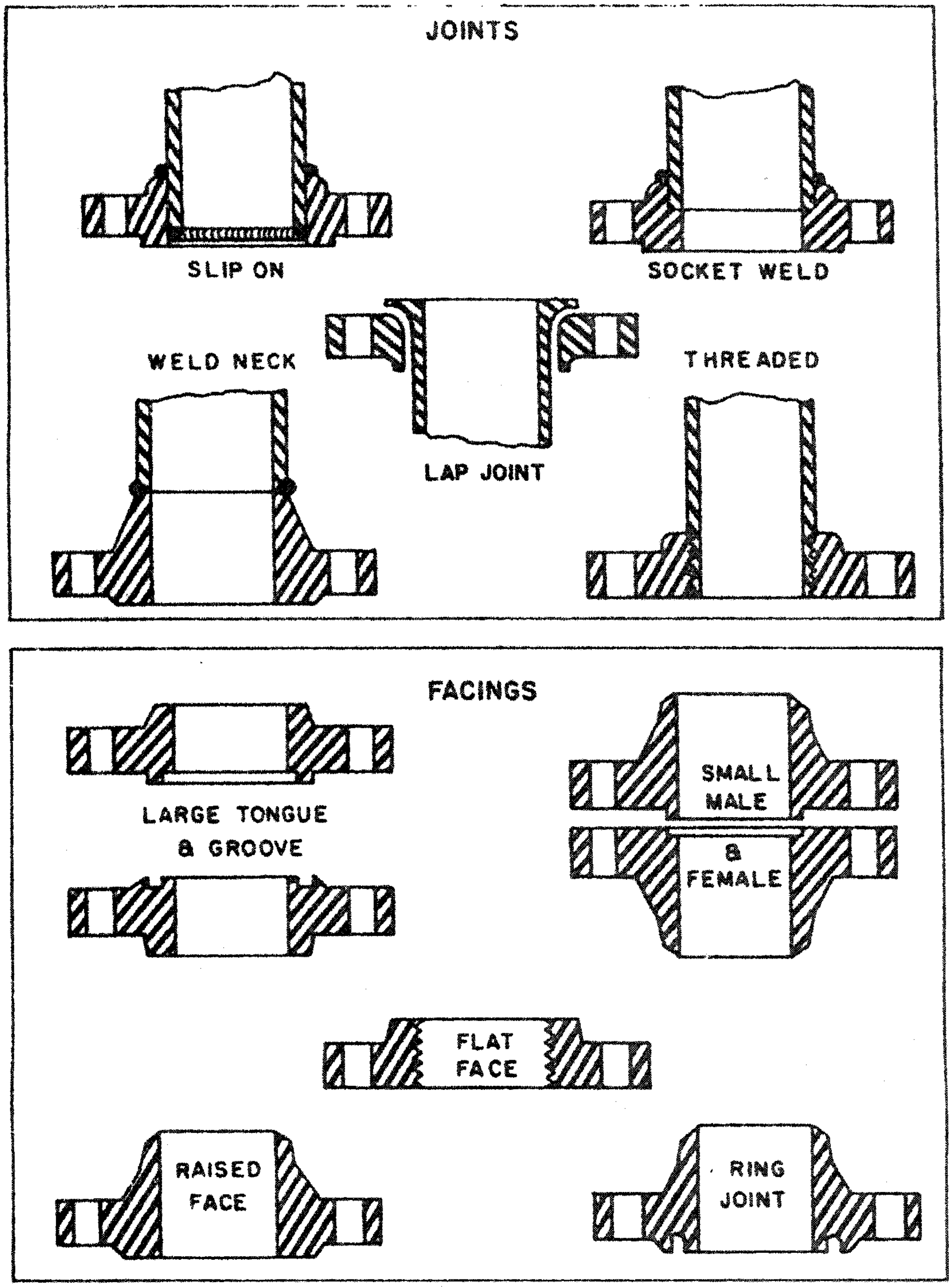


Figure 3.4. American Standard Flanges

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 3-5).

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

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 Table 1 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.

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 Table 2)*

b. Radial - Misalignment ± 0.10".

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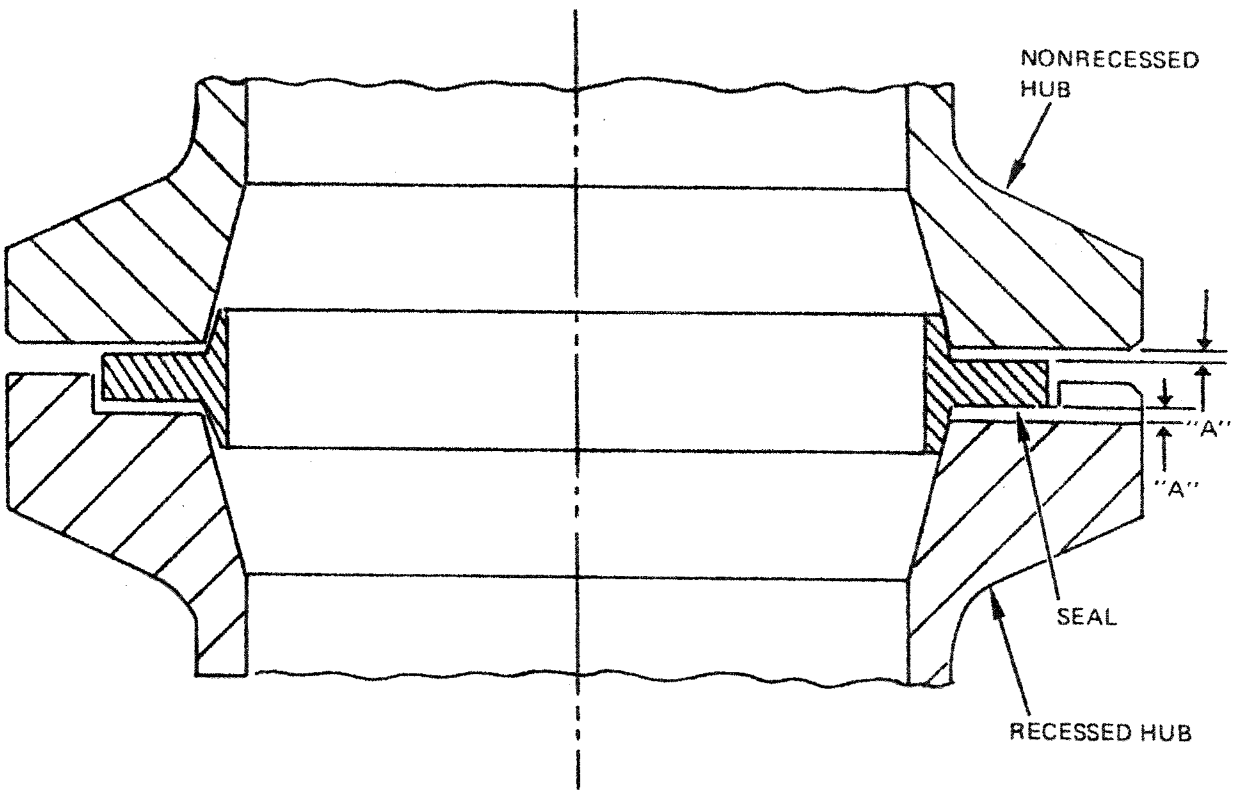
*Allowances should be made for seal recesses.

TABLE 1. MINIMUM STANDOFF DIMENSION



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

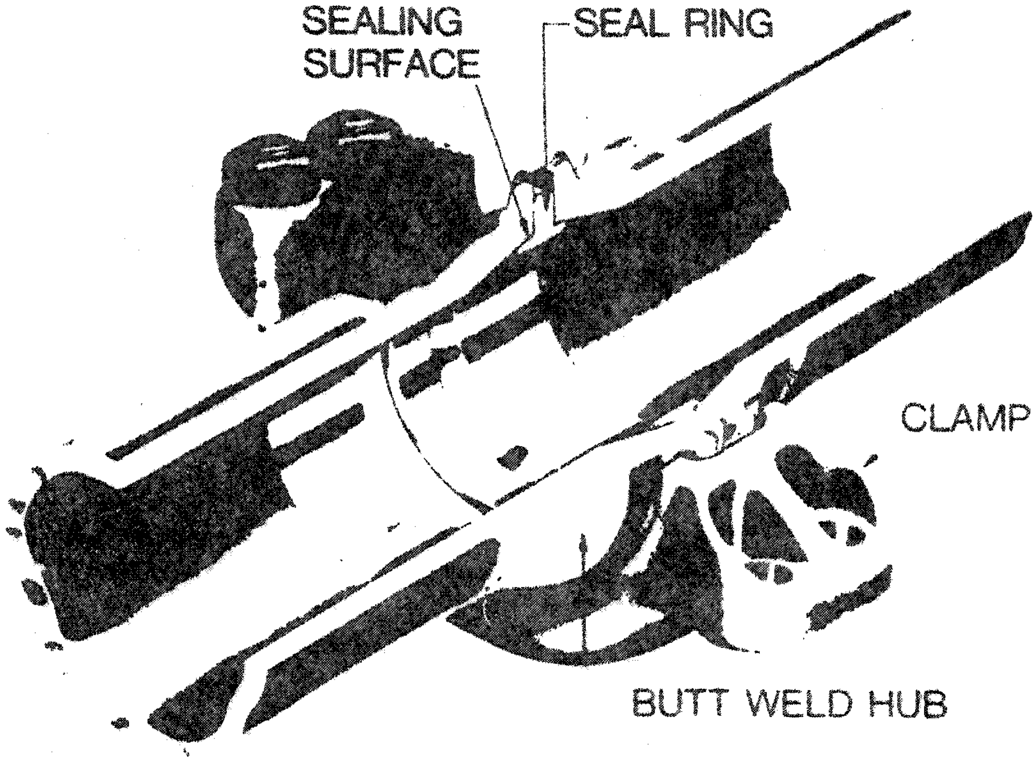


Figure 3.5. Typical Grayloc Connection

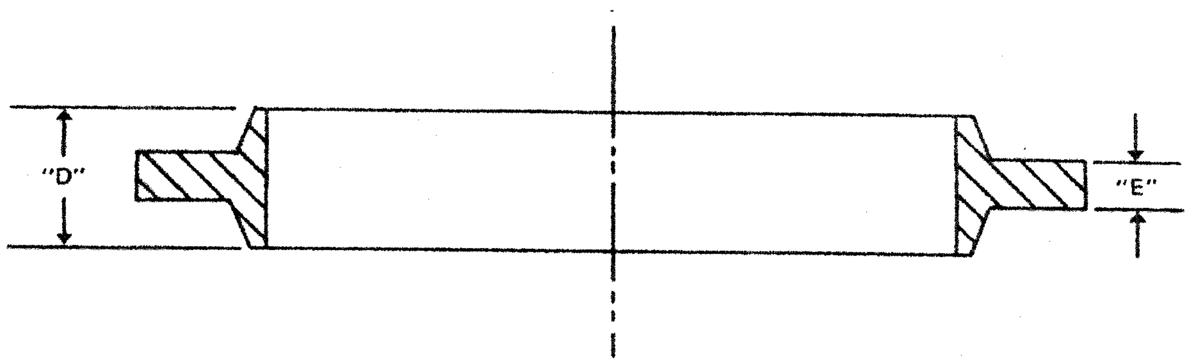
c. Angular - Misalignment - all hubs should be square with the axis of the pipe or equipment item by ± .010" and parallel with .010".

In assembling piping, it should be noted that very rigid systems will require closer tolerance for proper 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 (Table 2). The last joint in each section will be required to make up within the fabrication tolerances with provisions to insert or remove the seal.

In field fabrication, perfect alignment can be achieved by making up 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.

TABLE 2. 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

Preheat

For the normal temperature range of preheat (200 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.*

Welding

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.

Stress Relieving

When stress relieving is required, always protect the Grayloc sealing surfaces to prevent oxidation and scaling.* Heat treatment of any kind above 1100 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 can not be easily removed before assembly, should not be applied to the seal surfaces of either Grayloc rings or hubs.

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 Table 2).

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 requires 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.

TORQUE FT. - LBS.

Stud Bolt Size	Two Bolt Minimum	Two Bolt Maximum	Four Bolt Minimum	Four Bolt 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

Maintenance

When Grayloc connections have been properly installed, they require no special maintenance during normal operations. Never attempt to tighten the studs on a Grayloc connection while the assembly is under internal pressure or is carrying large external mechanical loads.

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.

TUBE AND TUBE FITTINGS FLARED

Only annealed stainless steel seamless tubing should be used in the Field Laboratories. Figure 3.6 show 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. 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 3/4" it is possible to make a

SEAMLESS STAINLESS STEEL TUBING

TUBE O.D. INCHES	WALL THICKNESS, INCH							
	0.010	0.016	0.020	0.025	0.028	0.032	0.035	0.042
1/8	2660	4850	6420	#	#	#	#	#
3/16	1730	3110	4070	5330	6110	#	#	#
1/4	1290	2310	3010	3920	4470	5040	5620	#
5/16	1030	1840	2390	3100	3530	3970	4420	5490
3/8	860	1520	1980	2550	2910	3260	3630	4490
1/2	640	1130	1470	1890	2150	2410	2670	3290
5/8	510	900	1170	1500	1700	1910	2120	2600
3/4	420	750	970	1250	1410	1580	1750	2150
1.0	280	520	680	890	1010	1180	1260	1560
1-1/4	220	410	540	710	800	940	1000	1240
1-1/2	180	340	450	590	670	780	830	1030
1-3/4	150	290	390	500	570	660	710	880
2	130	260	340	440	480	560	600	740

TUBE O.D. INCHES	WALL THICKNESS, INCH						
	0.049	0.058	0.065	0.083	0.095	0.109	0.120
5/16	6610	#	#	#	#	#	#
3/8	5390	6450	#	#	#	#	#
1/2	3930	4680	5260	#	#	#	#
5/8	3100	3680	4130	5500	6460	#	#
3/4	2560	3030	3390	4500	5270	6130	#
1	1850	2200	2500	3300	3850	4460	4990
1-1/4	1470	1740	1980	2610	3040	3510	3910
1-1/2	1220	1440	1640	2160	2510	2890	3220
1-3/4	1040	1230	1405	1840	2130	2460	2730
2	890	1070	1220	1580	1830	2110	2350

NOTE: (1) Allowable working pressure in psi from -325 to 100°F.

(2) Allowable stress = 20,000 psi (Safety factor is 3.75) for MIL-T-8808 seamless grade Type 321 and 347, or MIL-T-8504 (Type 304)

(3) Welding of bosses to tubing is permitted with no reduction in allowable working pressure except where use in corrosive service is intended. Tubing per MIL-T-8504 should not be welded.

(4) #Refer to Para. 3.4 for applications above 6000 psi nominal rating.

(5) Tolerances per MIL-T-8808 were used in calculating allowable pressures.

Figure 3.6. Maximum Allowable Working Pressure in PSI for Seamless Stainless Steel Fully Annealed Tubing

system leak-tight up to 6000 psi by use of copper seals and polished sealing surfaces. Sizes 1" and larger are more difficult to seal. Figure 3.7 indicates pressures which may be achieved in a carefully assembled system.

TUBE SIZE, INCHES	PRESSURE, PSI
1	5000
1-1/2	2000
2	1000

Figure 3.7. Achievable Pressures in Carefully Assembled Tube Systems

TUBE FITTINGS

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 3.8.

AND 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 - 6000 psi

2. 1" through 1-1/4" size - 5000 psi

3. 1-1/2" through 2" size - 4500 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 Section 10.

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.

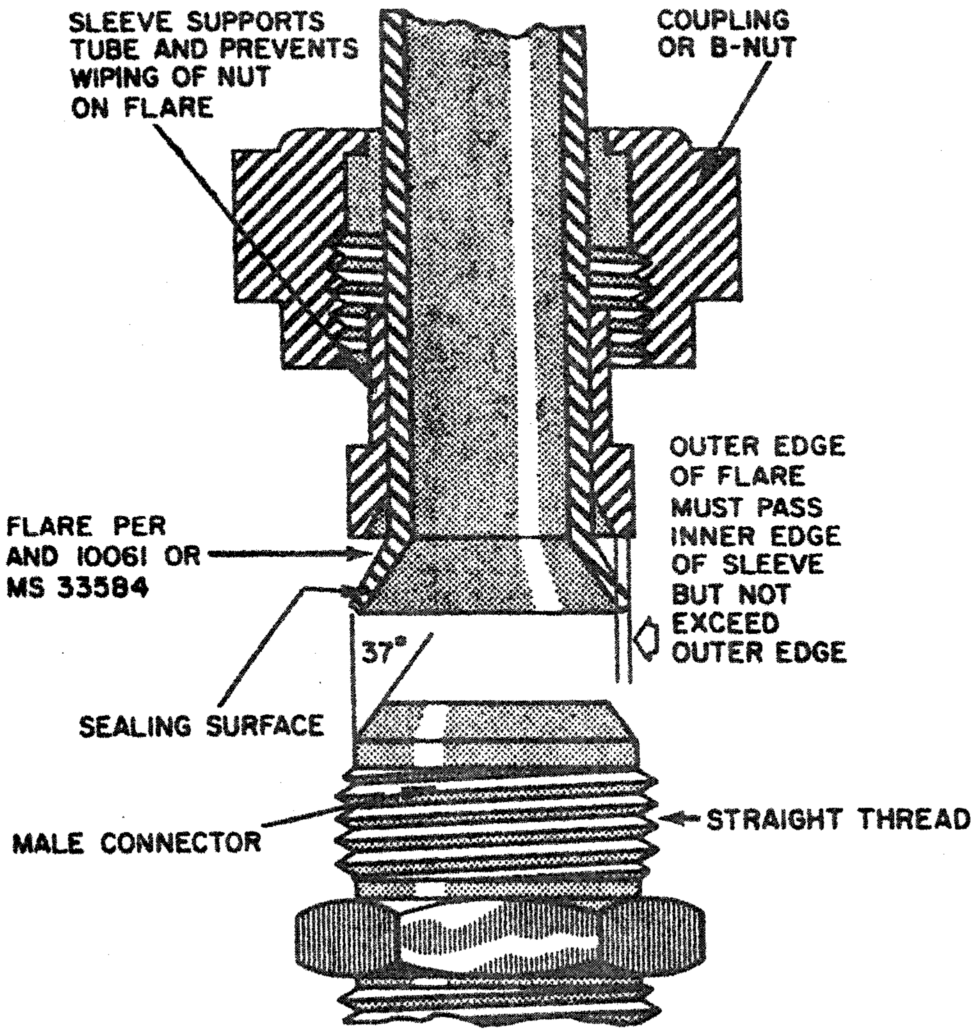


Figure 3.8. 3 Piece AN Flared Tube Fitting Per MS33656

AN and MS Fittings Threads

AN and MS fittings employ two types of thread, the AN or MS straight thread which uses the American National Fine Thread Series and 12 thread series; and 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 than 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 Figure 3.9.

Tubing OD, inch	Fitting Dash 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

Figure 3.9. AN Fittings, Straight Thread Sizes (Per MIL-S-7742)

AN and MS Fitting Designation

Fitting numbers ar made up of the basic number followed by a dash number. See Figure 3.10.

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-base alloys, and corrosion-resistant steel. When the fitting is obtainable in 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 is obtainable in steel or aluminum alloy only:

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

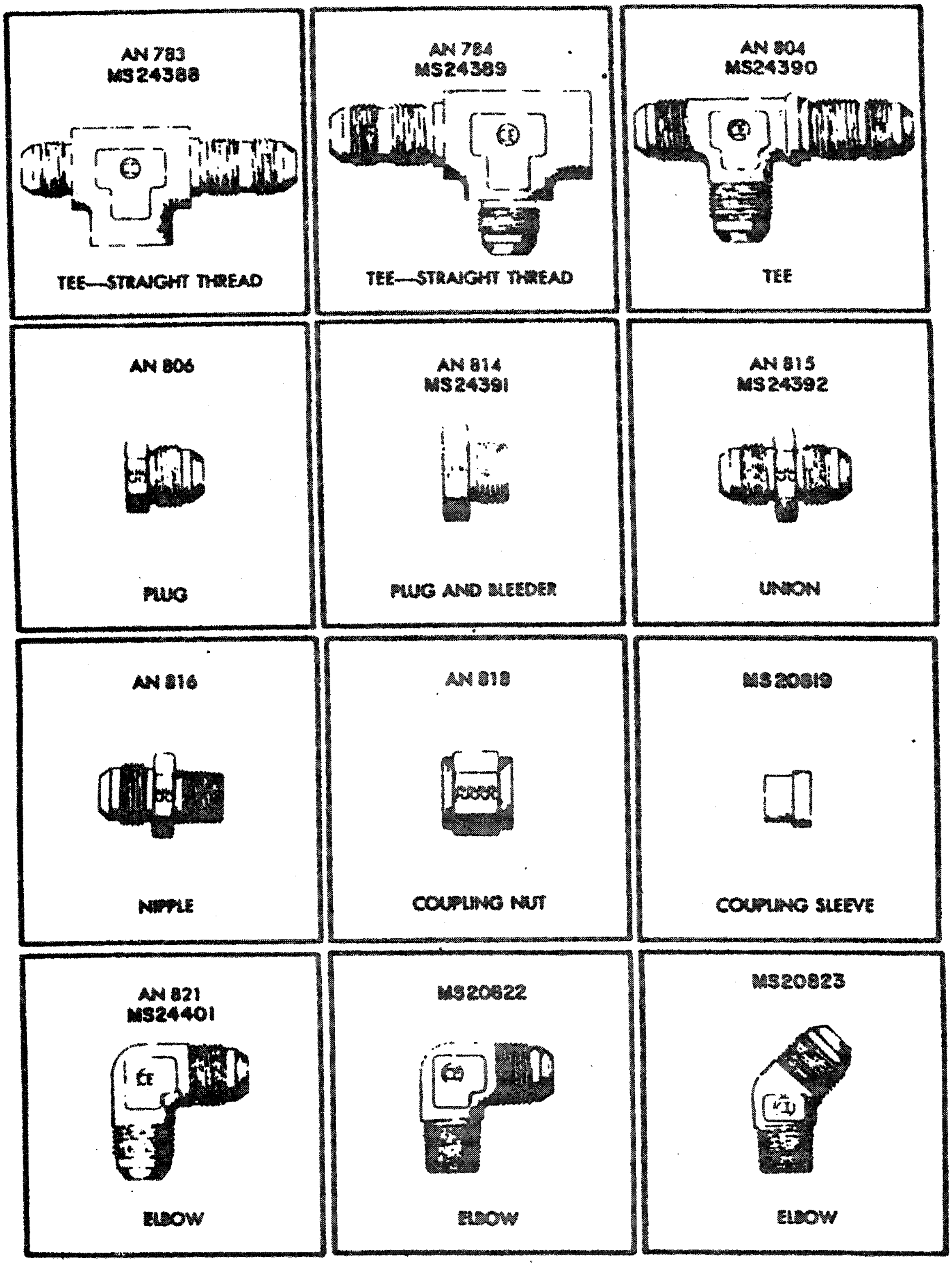


Figure 3.10. Tube Fittings (Sheet 1 of 4)

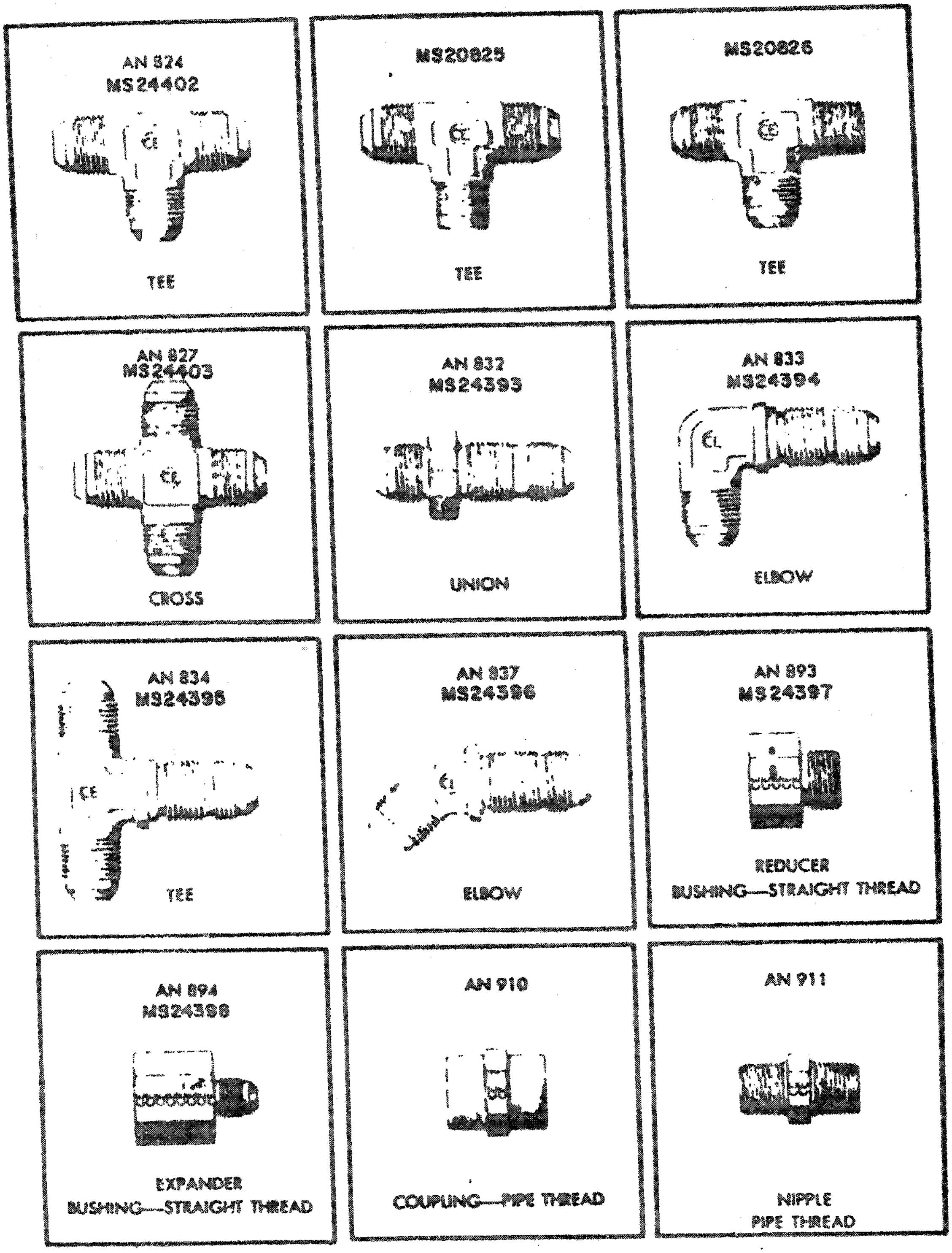


Figure 3.10. Tube Fittings (Sheet 2 of 4)

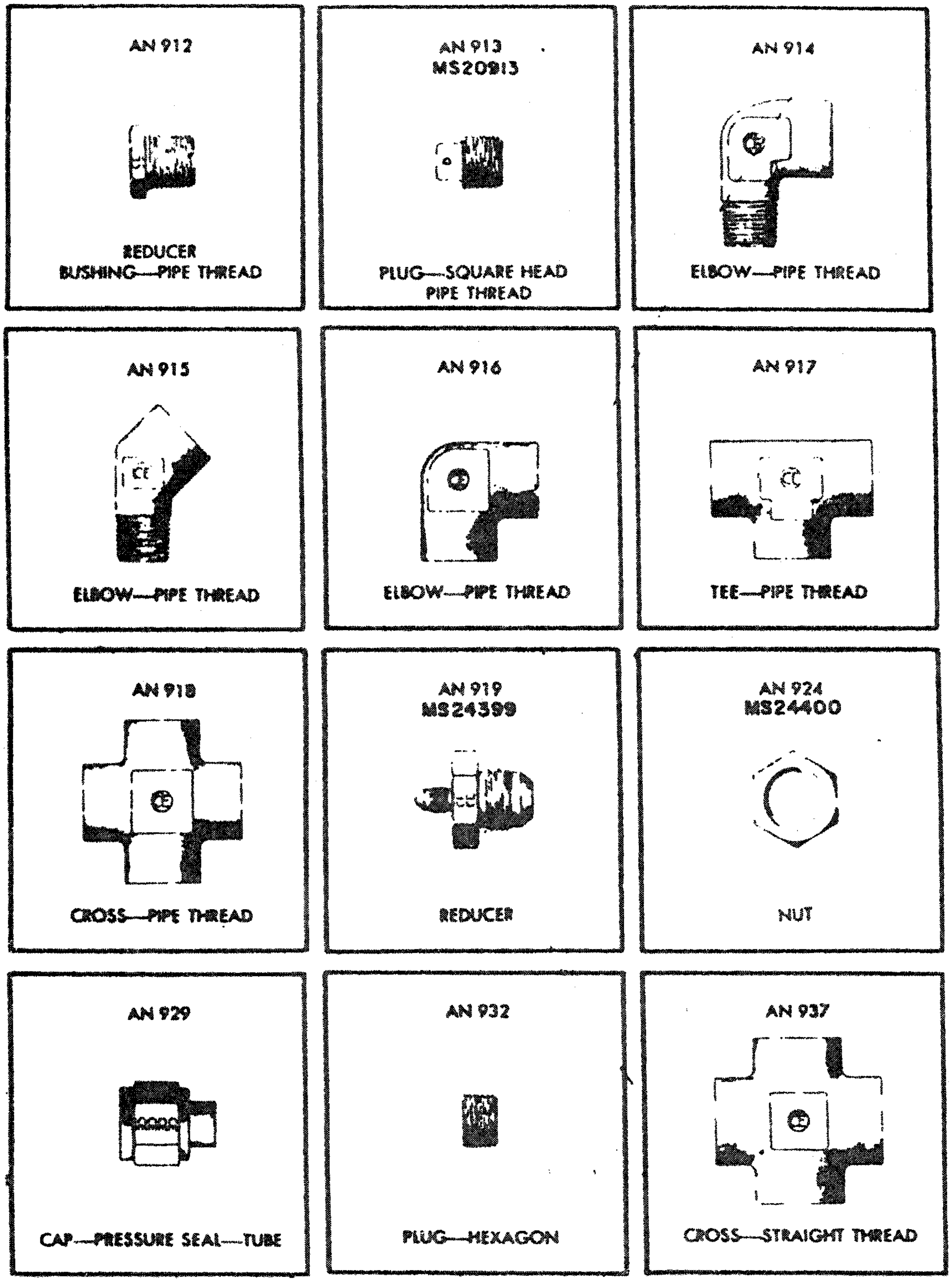


Figure 3.10. Tube Fittings (Sheet 3 of 4)

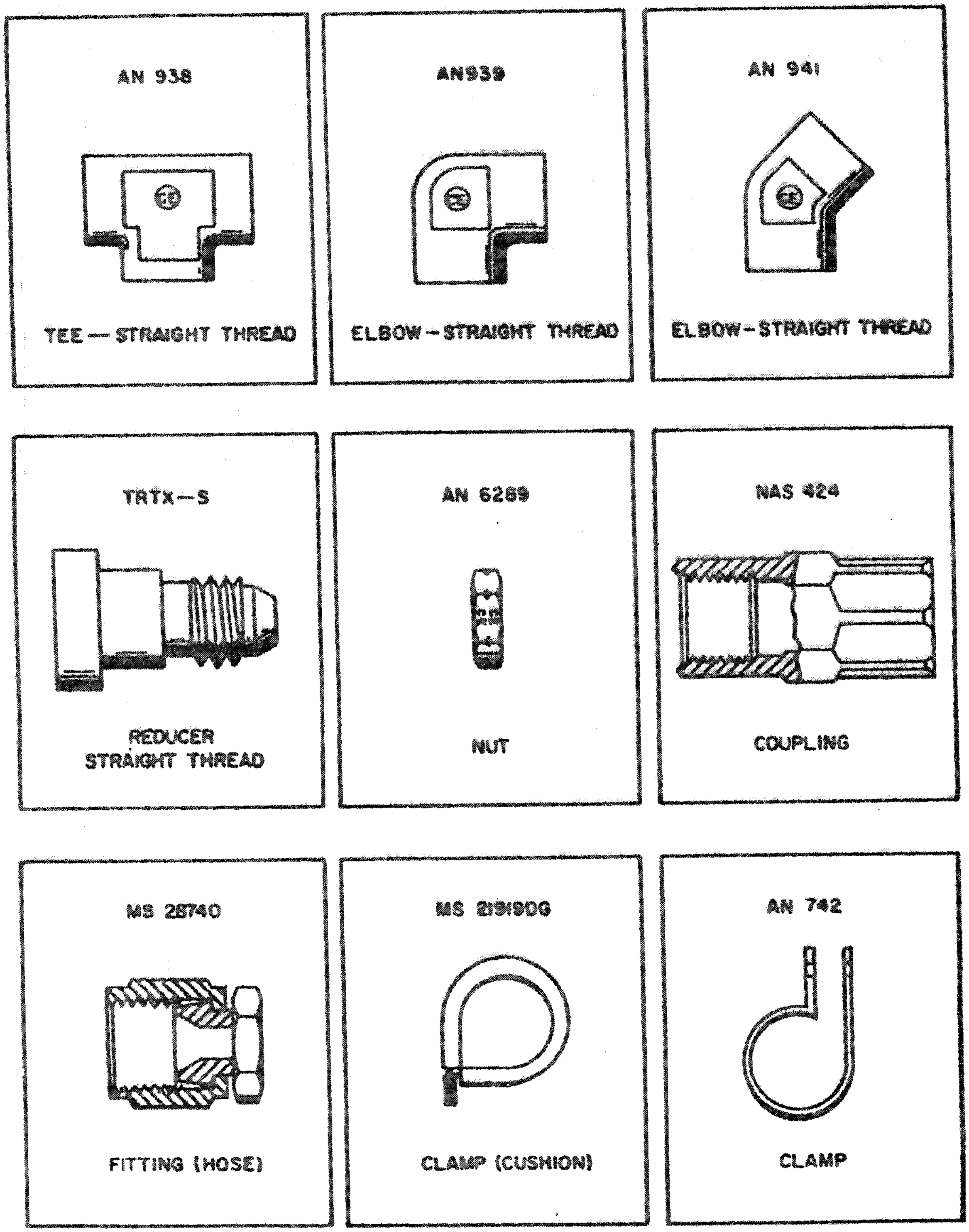


Figure 3.10. Tube Fittings (Sheet 4 of 4)

When the fitting is obtainable in copper alloy or aluminum only:

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 Figure 3.11.

Material	Color	Pressure Limit
Steel (Carbon)	Black	3000 psi
Aluminum Alloy	Blue	3000 psi
Corrosion-Resistant Steel	Natural	6000 psi
Copper Base Alloys	Natural Cadmium Plate	(Not stocked)
Fittings have two types of connector thread ends, straight thread ends, and pipe thread ends.		

Figure 3.11. Tube Fitting Color Code and Pressure Rating

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:

1. Finish
2. Size
3. Configuration
4. Addition of lockwire holes
5. Lubrication (Dry Lubed)
6. Other deviations

The Rocketdyne design numbering system for fittings is shown in Figure 3.12. For further information refer to the Rocketdyne Standards Manual.

SUPERPRESSURE TUBES AND FITTINGS

For pressures above 6000 psi, superpressure tube and fittings should be used.

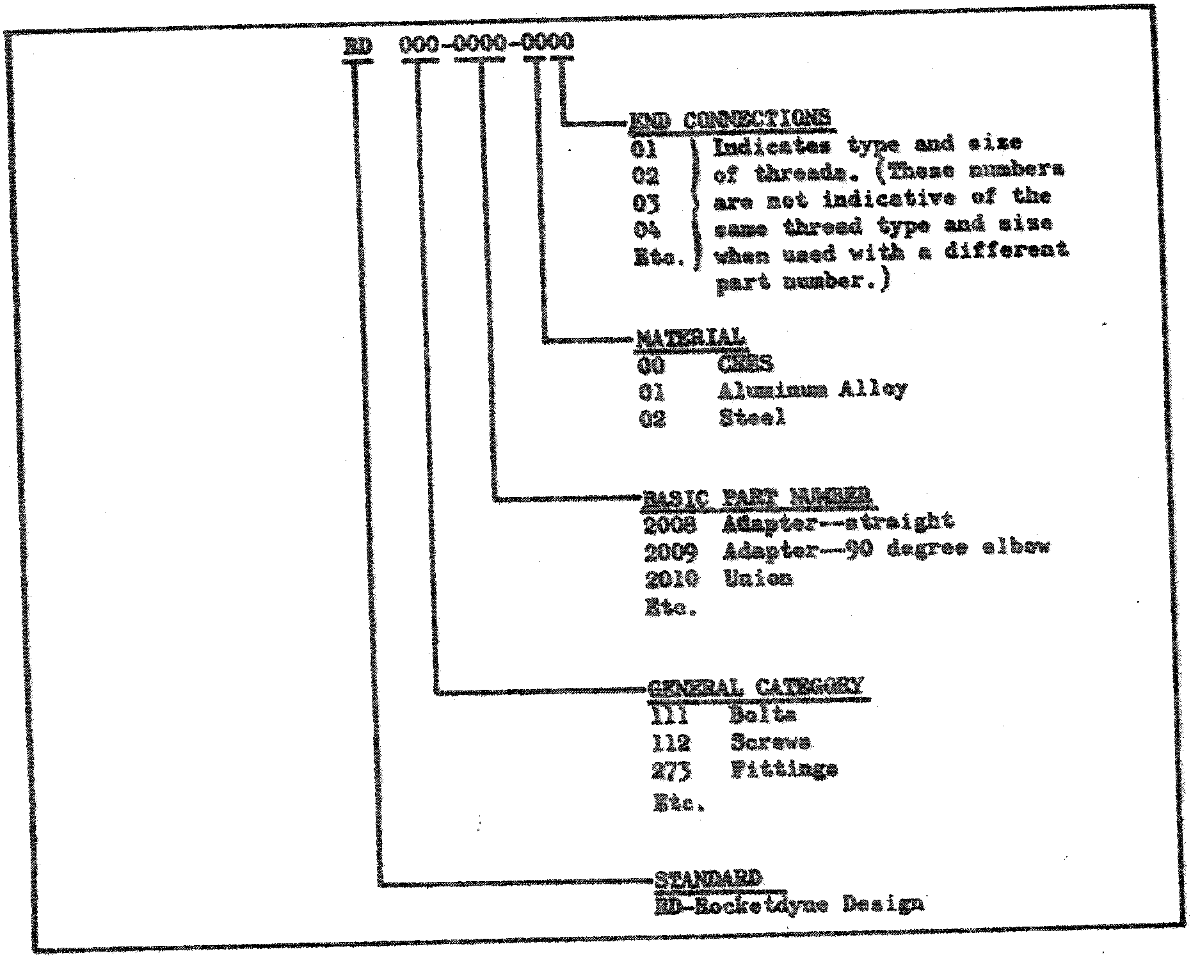


Figure 3.12. Rocketdyne Fittings Design Numbering System

The pressure limitations on special high pressure fittings are:

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	-	1/8	60,000 psi*

*System Pressure Limit determined by associated tubing.

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

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 3.13. See Section 10 for technique to cut cone.

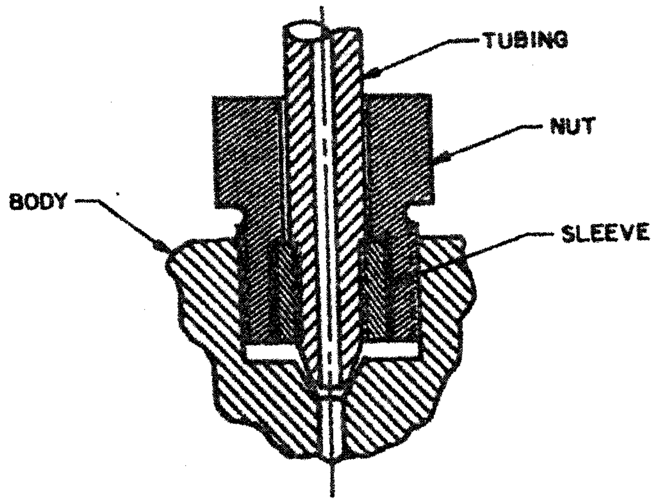


Figure 3.13. Superpressure Fitting

PIPE AND TUBING CONNECTIONS

THREADED PIPE CONNECTIONS

The normal pipe threads used in the Field Laboratories are:

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.

PIPE AND TUBING INSTALLATION

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 for 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.

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 at low as -423 F when subjected to liquid hydrogen. Figure 3.14 shows the contraction that would occur in a 10 foot length of metal line when cooled from 70 to -423 F.

Material	Contraction, Inches
Stainless Steel	0.37
Copper	0.4
Aluminum	0.48

Figure 3.14. Contraction of 10 Foot Length of Tubing at -423 F

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. Figure 3.15 shows some typical Field Laboratory service conditions, and the expansion or contraction that would be expected.

Type System	Inches	
	Contraction	Expansion
5000 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

Figure 3.15. Estimated Expansion or Contraction of a 10 Foot Length of Pipe

TUBING SUPPORTS

Recommended maximum spacing for rigid line tubing assemblies is given in Figure 3.16. 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 Figure 3.16. 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 placed 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.

Tube OD, Inch	LOCATED IN TEST AREA AND/OR SUBJECT TO VIBRATION, INCH: Aluminum	LOCATED IN TEST AREA AND/OR SUBJECT TO VIBRATION, INCH: Stainless Steel	NOT IN TEST AREA NO VIBRATION, INCH: Aluminum	NOT IN TEST AREA NO VIBRATION, INCH: 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

RIGID TUBING SUPPORT SPACING

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. Overhang should be minimized by placing supports as close to bends as possible.

Figure 3.16. Maximum Rigid Tubing Support Spacing

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 Figure 3.17.

	MAXIMUM SPAN (FEET AT 100°F)		
Nominal Pipe Size (Inches)	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

Figure 3.17. Maximum Pipe Support Spacing

BEND RADII OF TUBING

Tubing installations requiring bends must be accomplished with minimum distortion and constriction of the tubine. See Section 10. A satisfactory bend is one which decreases tubing OD less than 6 percent. Figure 3.18 a table of minimum bend radii will yield satisfactory bends when accomplished with the proper tools and methods. 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.

PIPE THREADS

The most 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 thrads (NPTF) (the F indicates fuel) permit less leakage than American Standard Taper Pipe Threat (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.

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

Figure 3.18. Minimum Tube Bend Radii

Thread Assembly

It is advisable to lubricate all pipe threads before assembly (see Section 6). 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 3.19.

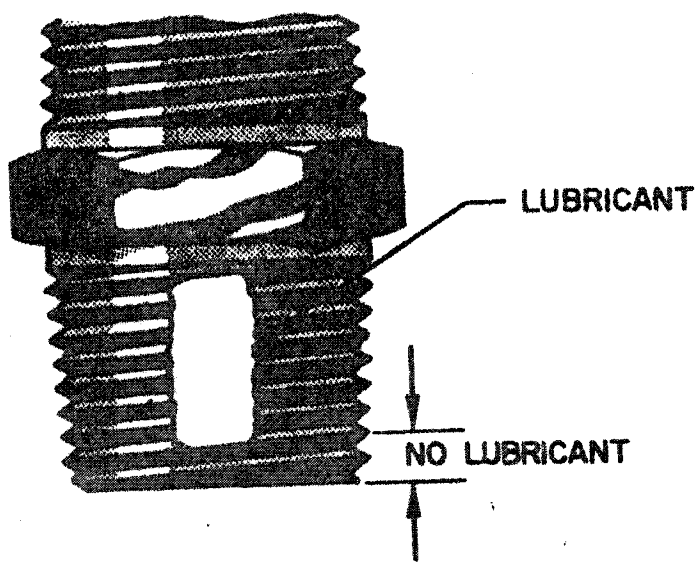


Figure 3.19. Apply Lubricant in Streak Across Male Threads Only

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 2 identical wrappings side by side.

CLEANING

Cleaning of components at the SSFL, that 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 initialled, the intent of the procedure has been implemented.

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.

LEAK TEST

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

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.

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 Figures 3.20 and 3.21.

The size of the tape shall be determined by Figure 3.21.

BASIC IDENTIFICATION

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.

Figure 3.20. Basic Identification

Diameter of Piping or Tubing and Location	Polyester (Mylar) Tape Black Print on Specified Color	
	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

Figure 3.21. Required Tape Width

Location of Color-Coded Tapes

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

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

a. Outlet valves

b. Connections

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

d. Intervals of 125 feet on long runs or at shorter intervals as neces-sary 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 on each side of the bulkhead.

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

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:

a. Outlet valves

b. Connections

c. 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.)

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

Exceptions:

a. Valve actuation tubing

b. Instrumentation tubing

c. Fire extinguishing systems

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 stok numbers of pressure-indicating tapes for commonly used pressures. The Rocketdyne Standards Manual contains a section on tapes with addtional stock numbers for other pressures.

PRESSURE, PSI	ROCKETDYNE STOCK NO.
120	RD172-0018-0120
150	RD172-0018-0150
350	RD172-0018-0350
750	RD172-0018-0750
3000	RD172-0018-3000
5000	RD172-0018-5000

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 paragraph titled Location of Color-Coded Tapes.

Conduit not requiring identification:

a. Conduit installed in control centers

b. Conduit installed in the ECS

c. Flexible conduit (e.g., Plica)

d. Conduit installed in pretest buildings and T-houses

e. Conduit installed in E.L., I.L., and cascade stations

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*.

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.

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 3.22.

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.

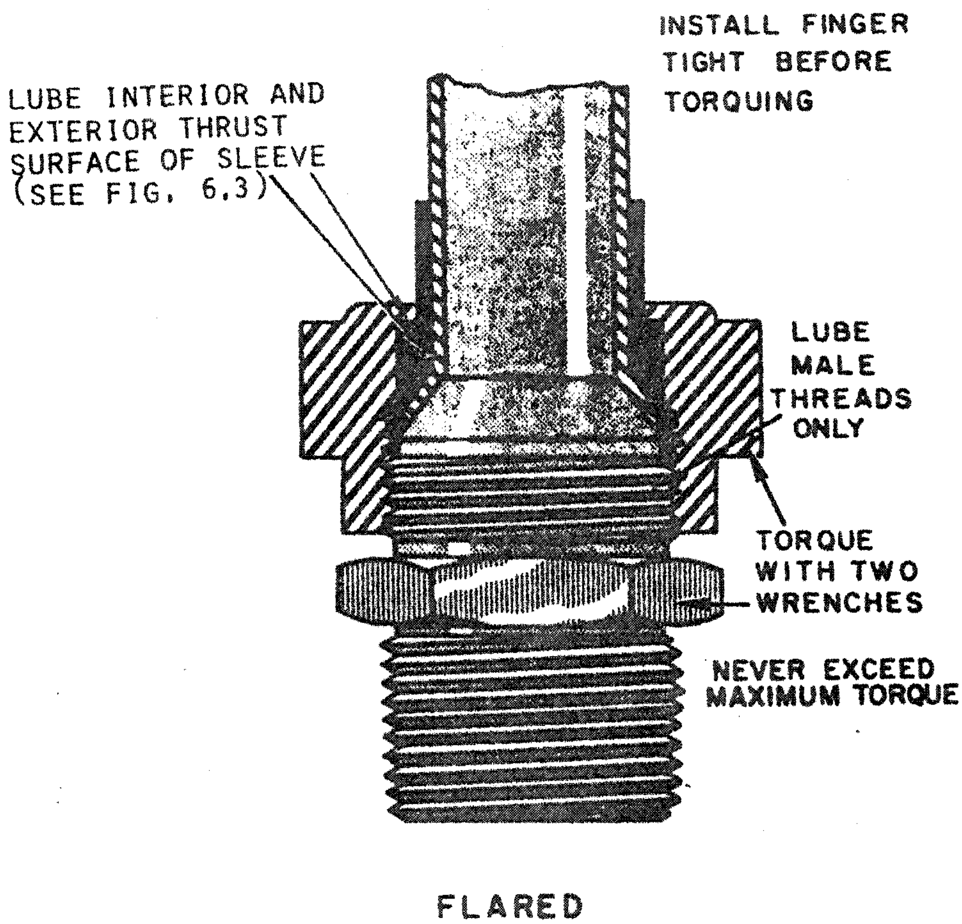


Figure 3.22. Installation of Tube Fittings

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 Figure 3.23 through 3.27.

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.

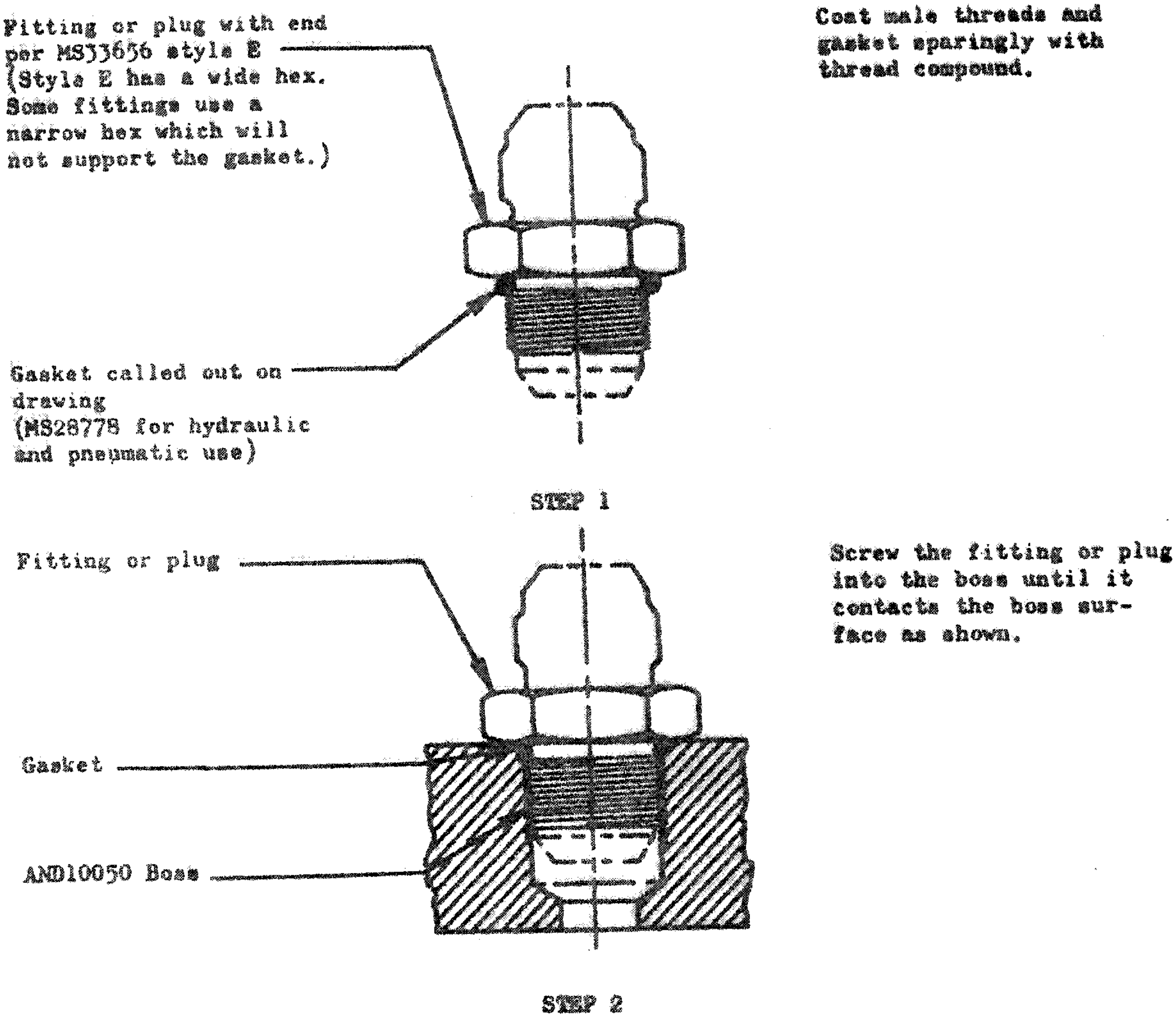
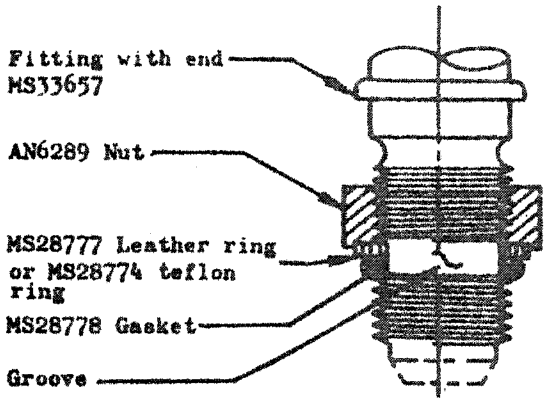
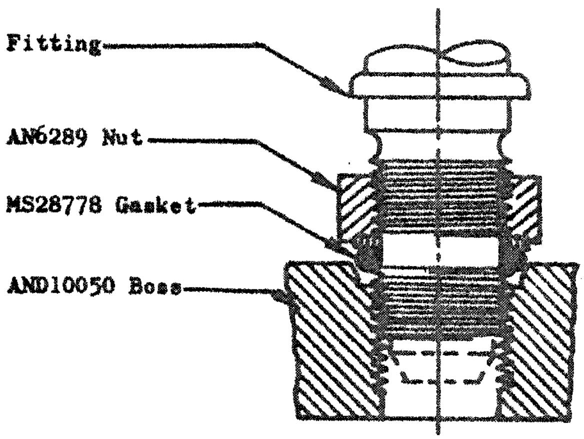


Figure 3.23. Installation o MS33656 Style E Fitting End Into AND10050 Boss



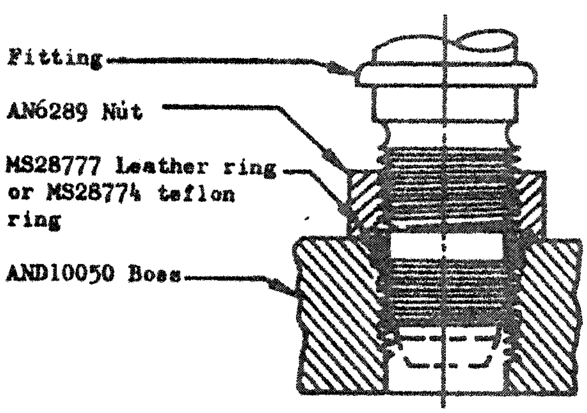
STEP 1

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

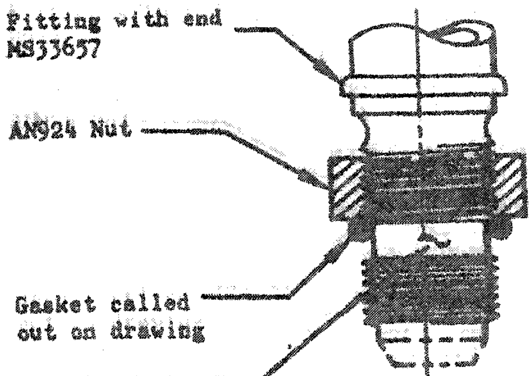
Install the fitting into the AND10050 boss and, at the same time, keep the AN6289 nut turning with the fitting until the MS28778 gasket contacts the AND10050 boss, as shown in step 2. This point can be determined by a sudden increase in torque. With the fitting in this position, put a wrench on the AN6289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



Step 3

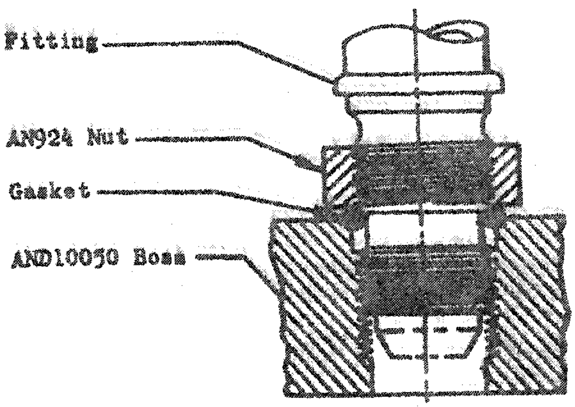
Hold fitting and turn AN6289 nut down tightly against AND10050 boss, as shown in step 3. Slight extrusion of the MS28777 leather ring or MS28774 teflon ring is not detrimental at the initial installation, but they shall not be reused at any re-installation of the fitting in the boss.

Figure 3.24. Installation of MS33657 Fitting End Into AND10050 Boss in Hydraulic and Pneumatic System



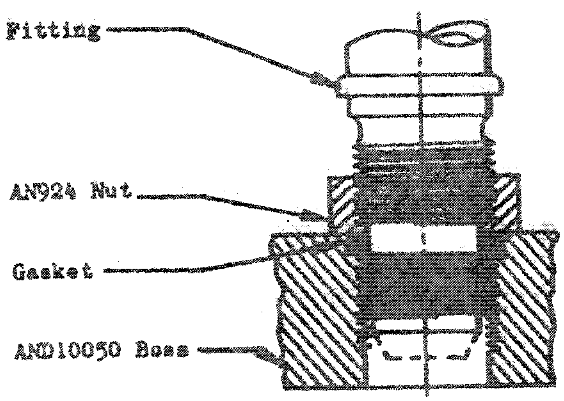
Step 1

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 3.25. Installation of MS33657 Fitting End Into AND10050 Boss in Other Than Hydraulic and Pneumatic Systems

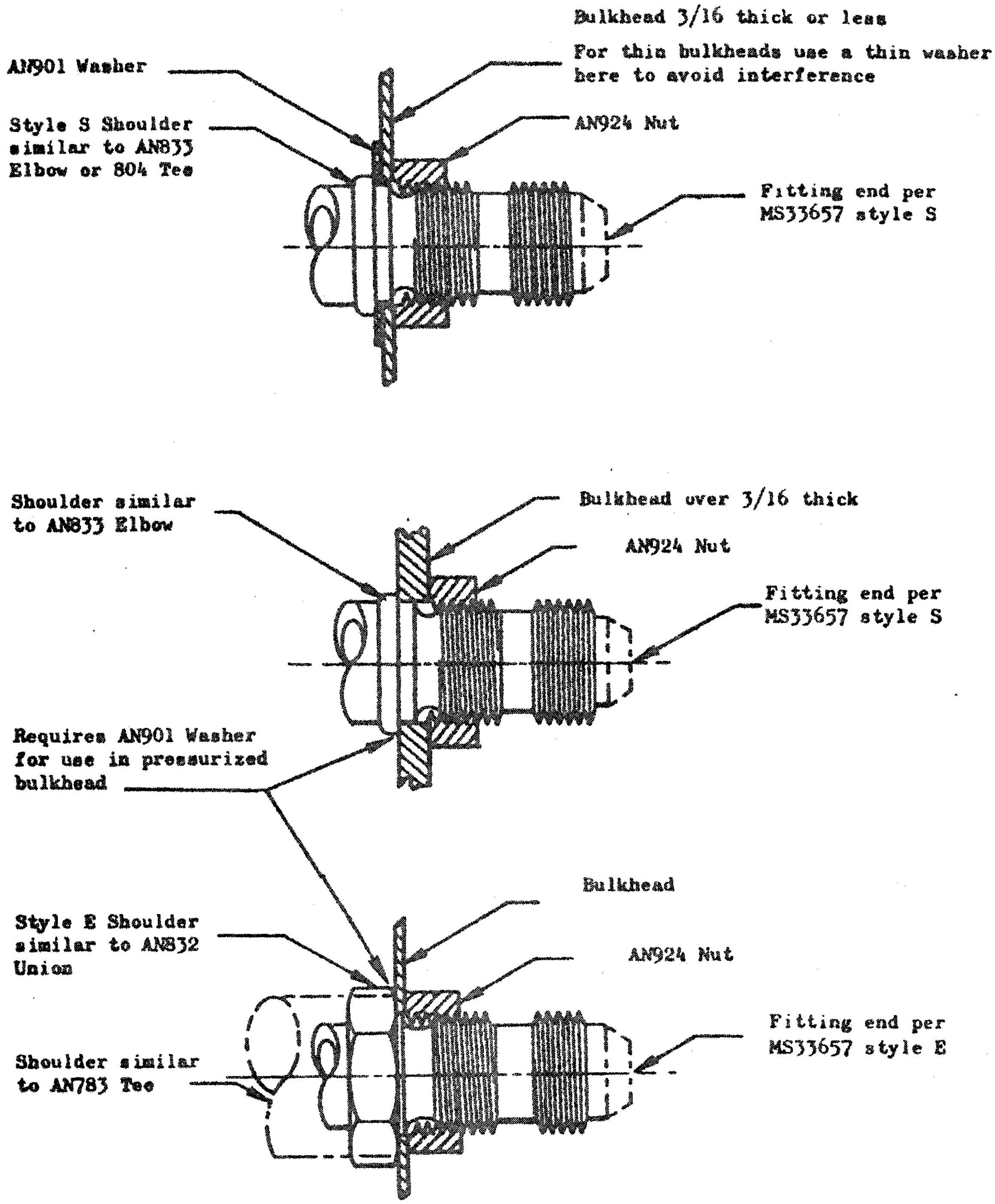


Figure 3.26. Installation of MS33657 Fitting Ends Through Bulkheads or Brackets

Tube Size	Fitting Thread Diameter	Bulkhead Hole Diameter				AN901 Washer (.0508 Thick)	AN924 Nut Size
		Single Sheet		Multiple Sheet			
		Fraction	Decimal	Fraction	Decimal		
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	.594	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 1200 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.

Figure 3.27. Hole Diameters for Bulkhead Fittings

VACUUM PIPING

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.

OPERATING VACUUM PRESSURES 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 Figure 3.28.

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}

Figure 3.28. Vacuum Conversion Units

Insulation systems to be effective must operate in the following ranges:

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

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

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

VACUUM SYSTEMS

In vacuum systems Figure 3.29 there are three important factors to consider:

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. Ih 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.

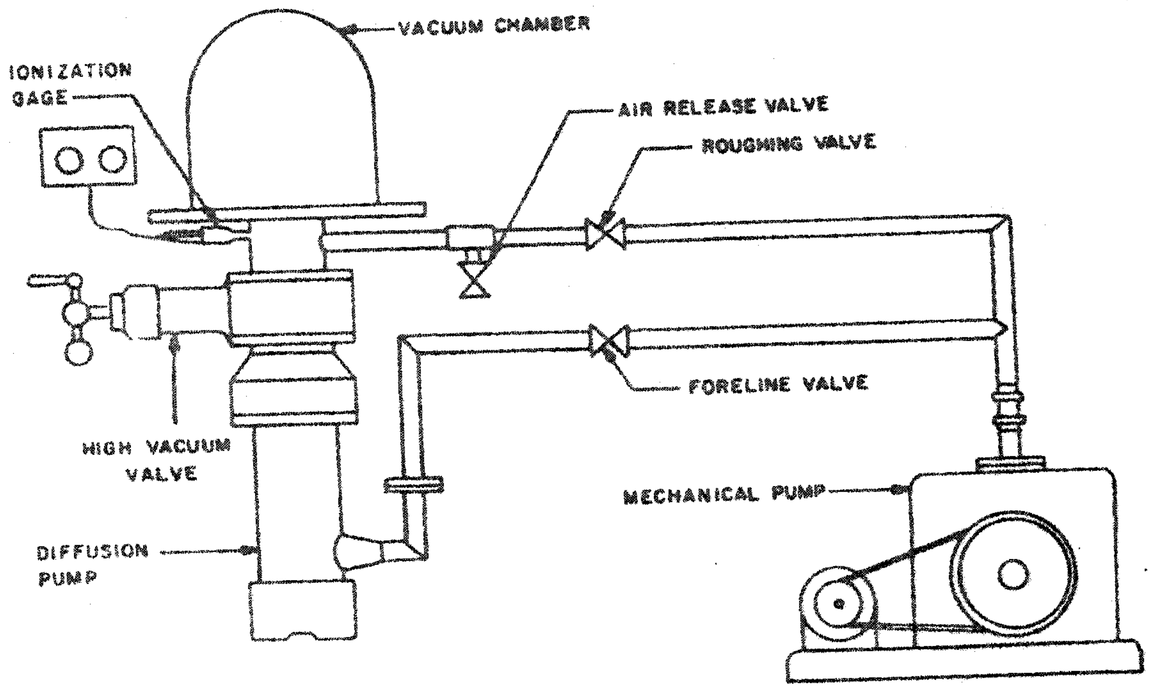


Figure 3.29. Typical Vacuum Pumping System

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.

PIPING COMPONENTS

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.

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. A 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.

Valves

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

1. 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.

2. 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.

3. 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.

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 3.31. Also see Section 6.

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 regreasing gasket. Where soft metal gaskets are used, a leak can sometimes be cured by annealing the gasket.

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 3.30. 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.

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.

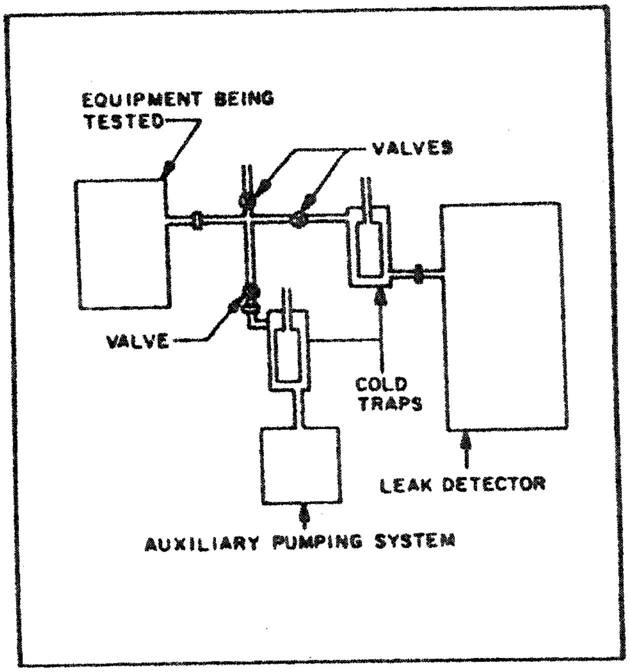
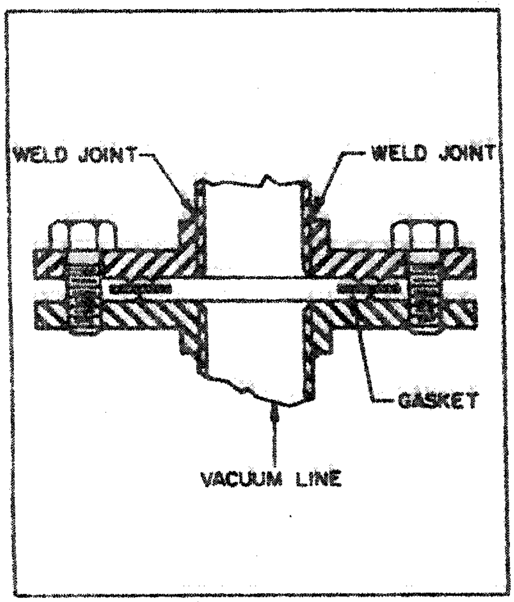
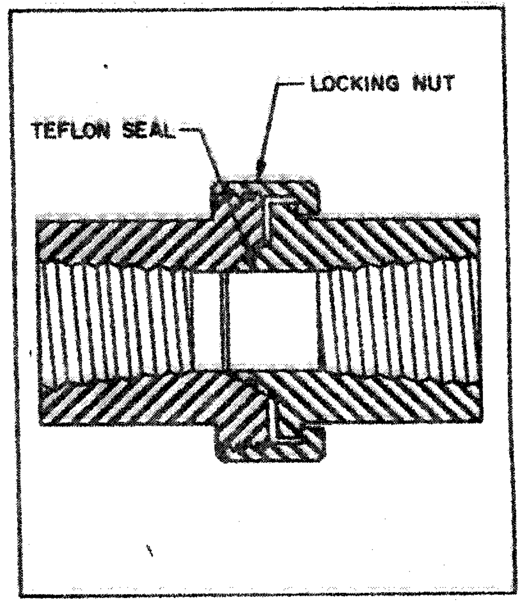


Figure 3.30. Leak Detector Test Setup

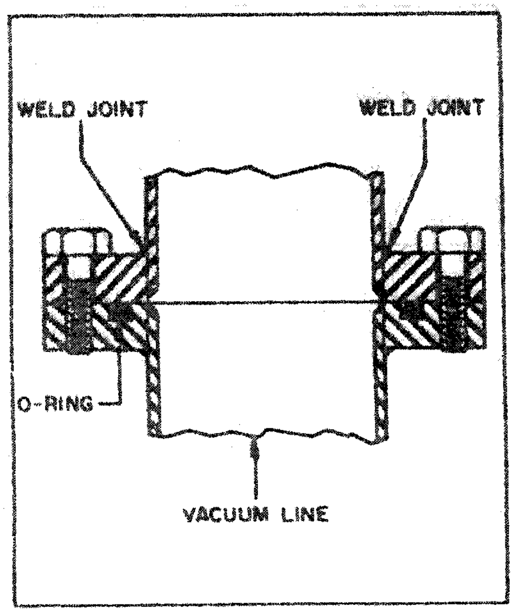
The third method of using the helium mass-spectrometer is to fill the area being tested with helium at a pressure greater than atmospheric and use a sniffer probe that is connected to the leak detector. The sniffer is a fine valve at the end of a probing tube that admits gas very slowly so the leak detector an 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.



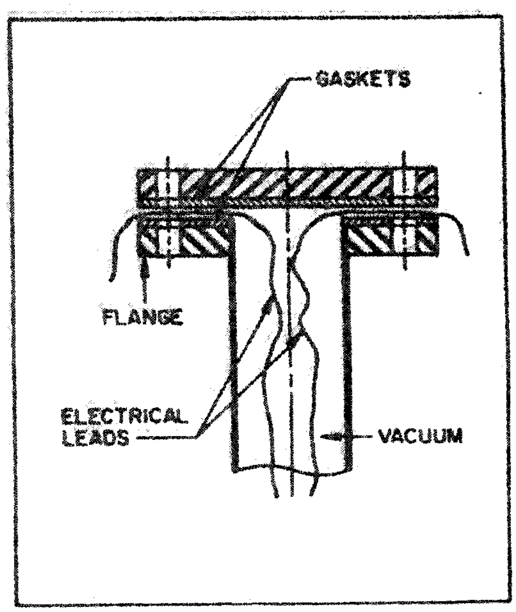
Vacuum Flanged Fitting With Gasket



Threaded Vacuum Line Fitting



Vacuum Flanged Fitting With O-ring



Vacuum Flange Fitting for
Electrical Leads

Figure 3.31. Typical Vacuum Seals and Gaskets

SECTION 4

VALVES AND REGULATORS

CONTENTS

INTRODUCTION

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.

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.

VALVE NOMENCLATURE

The following illustration (Figure 4.1) 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.

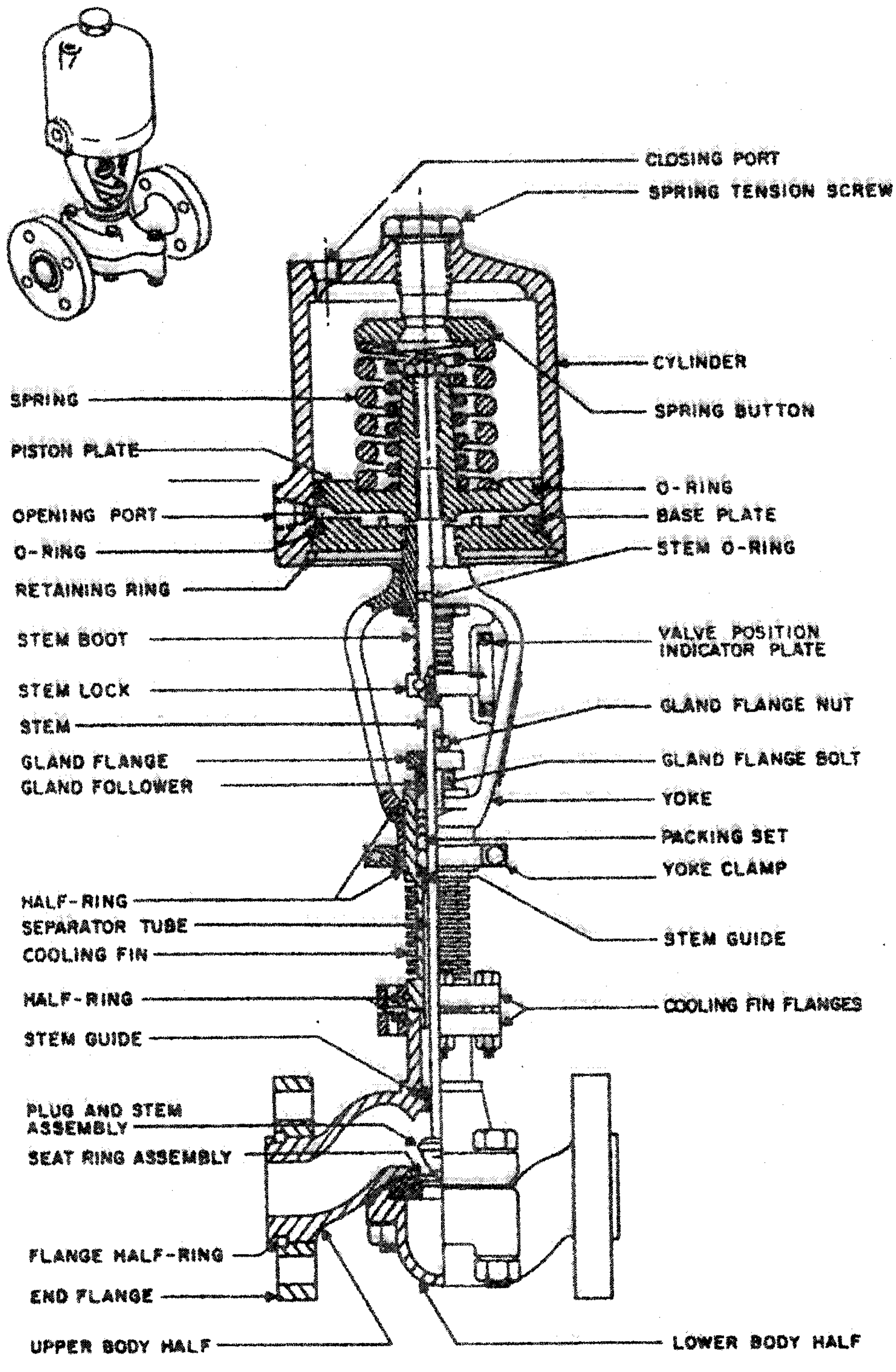


Figure 4.1. Normally Closed-Pneumatic Cylinder Operated Valve (Annin) (With Cooling Fin for Cryogenic or Hot Gas Service)

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.

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.

GATE VALVES

The major advantage of a gate valve is that it allows unrestricted fluid flow. The valve gate seals by a wedging action. (See Figure 4.2.)

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 liquified gas service because of the low temperatures involved. This valve is in the 6000 psi pressure range. Sealing is independent of shutoff forces. (See Figure 4.3.)

GLOBE VALVES

Annin

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

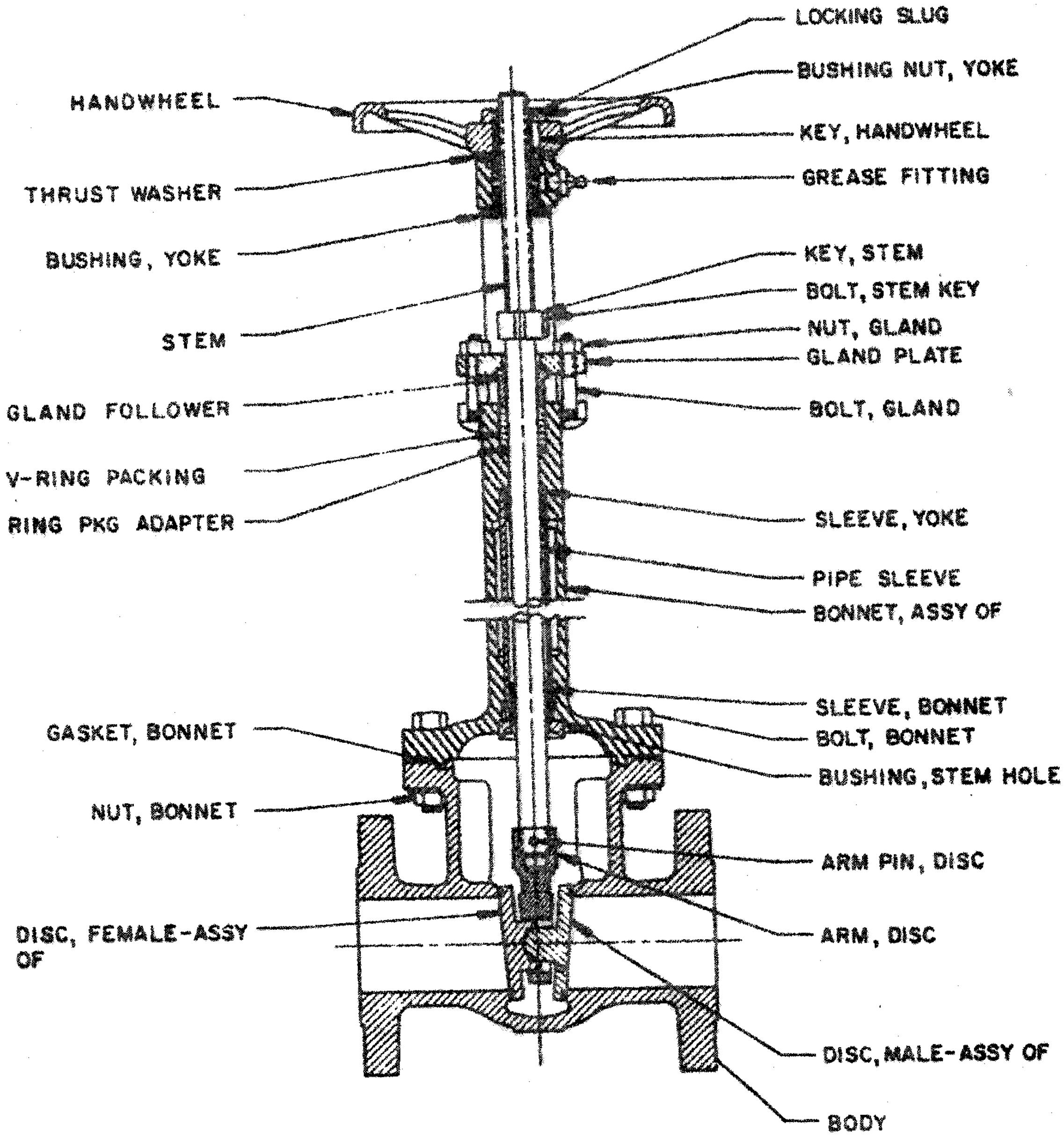


Figure 4.2. Gate Valve (ALOYCO)

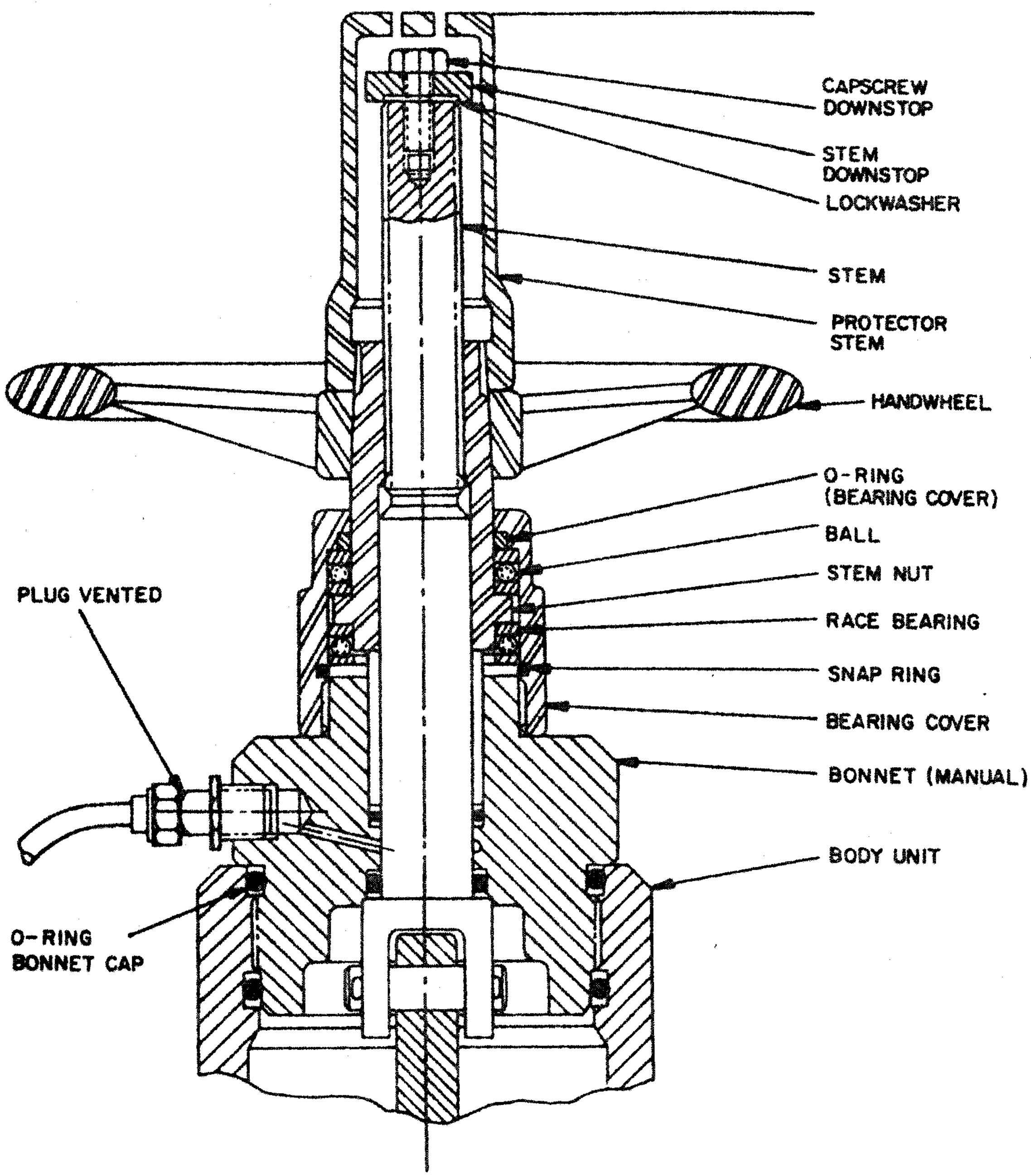


Figure 4.3. Manual Operating Mechanism Gate Valve (Grove Seal O-Ring)

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. (See Figures 4.1 and 4.11.)

Seat Seal Valve (Grove)

The Grove T series (see Figure 4.6) 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 6000 psi.

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

Needle Valve

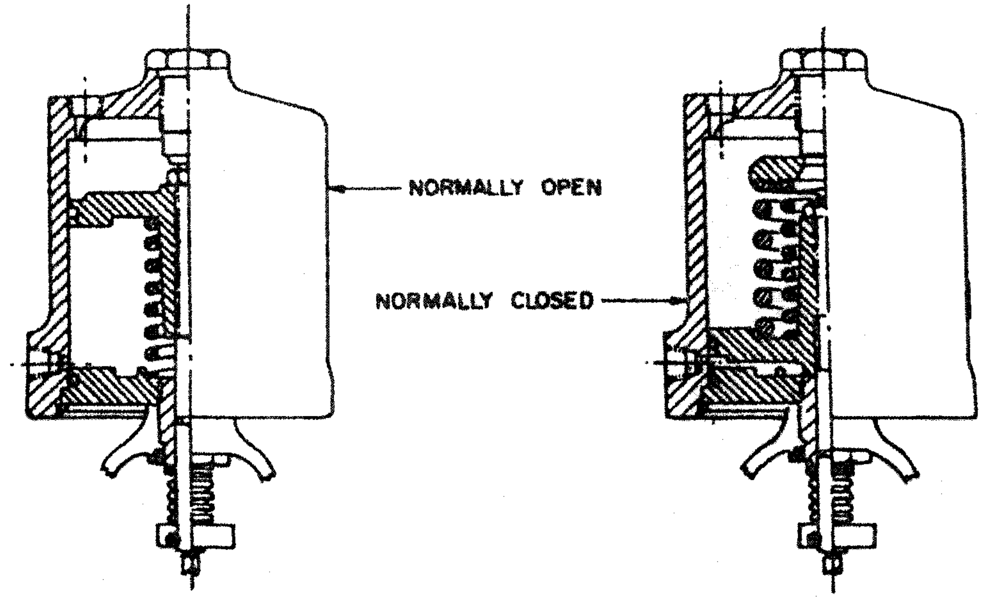
This valve is a modification of a globe valve and is designed for high-pressure use (10,000 psi). The stem is tapered to form a plug and the seat is built with a very small plug contact area. This small contact area is the trim results in high seating pressure from a relatively small force on the stem. Any undue force applied to the valve handle will damage the trim. Two-finger shutoff is sufficient for this type of valve. (See Figure 4.7.)

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.)

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 MV-543 models are examples of this type of valve. (See Figure 4.8.)



PNEUMATIC CYLINDERS

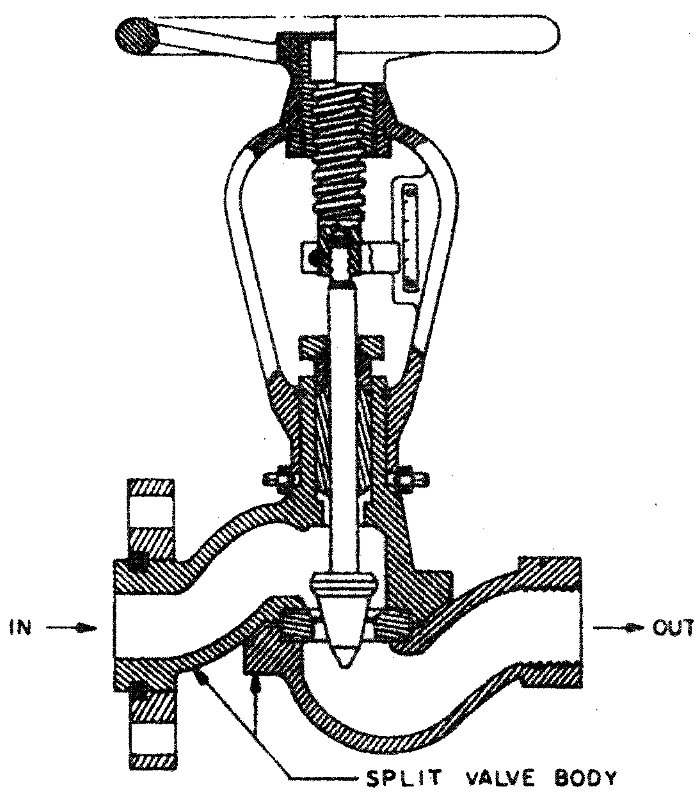


Figure 4.4. Globe Valve (Annin)

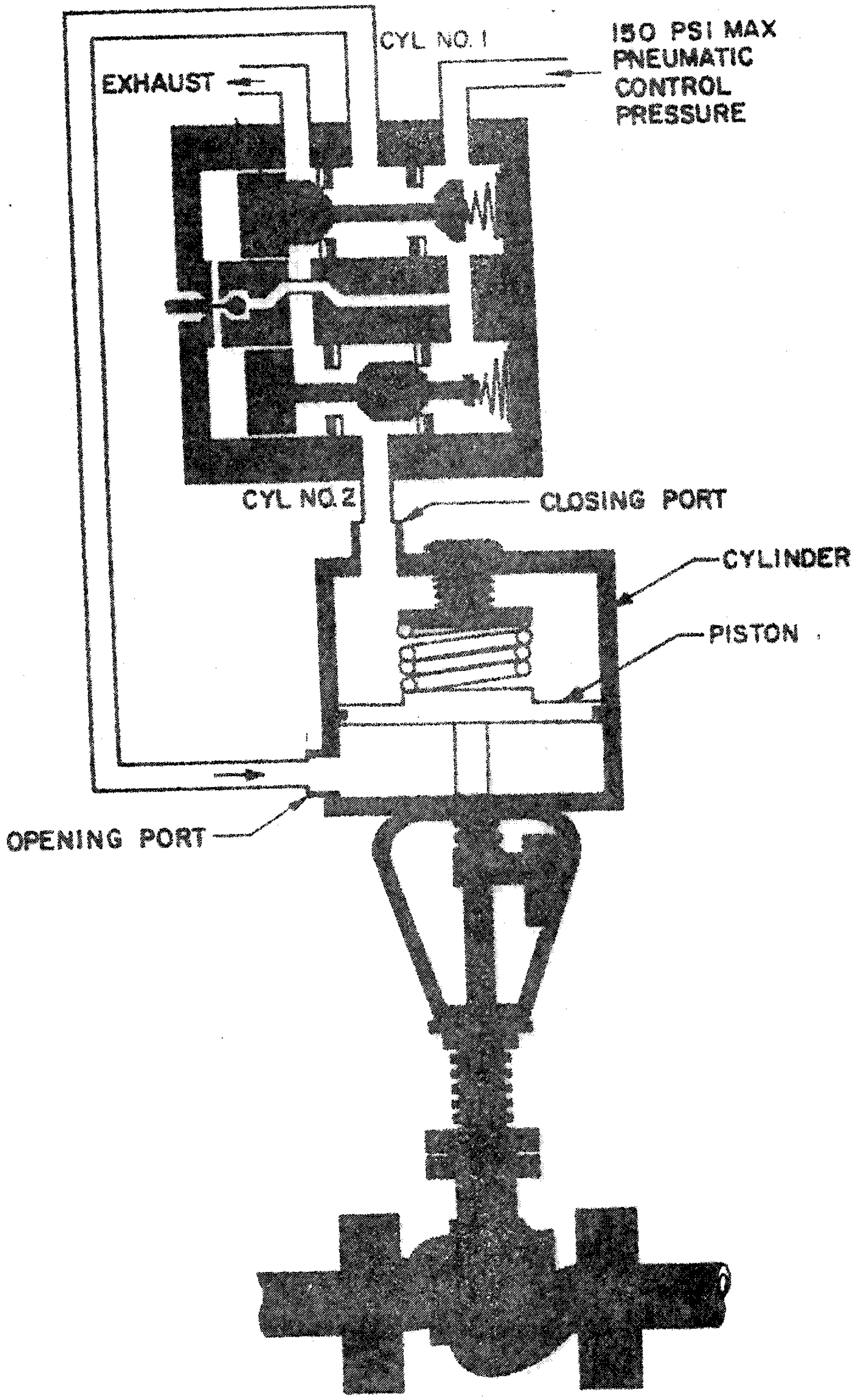


Figure 4.5. Relationship of Annin Valve to 4-Way Solenoid Valve (Solenoid Energized)

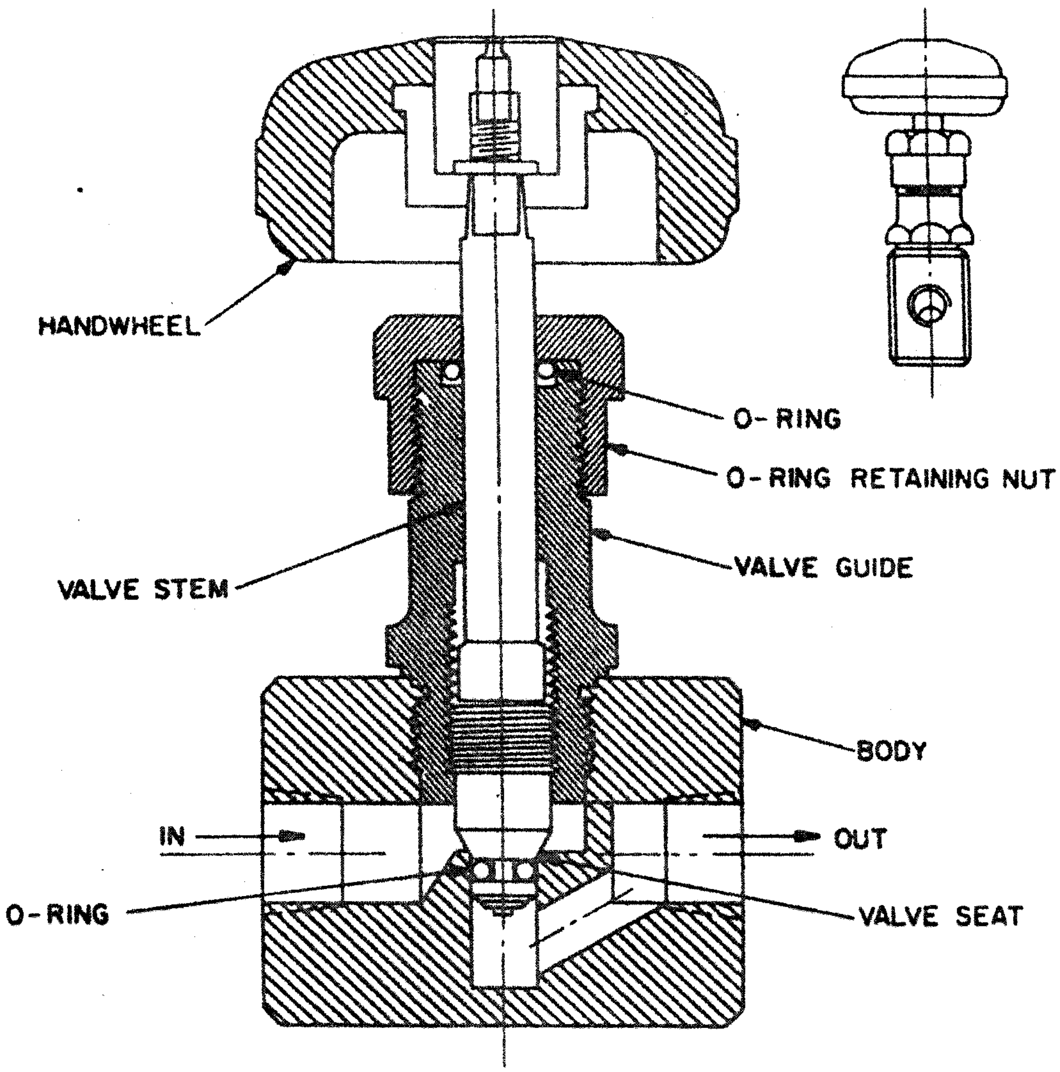


Figure 4.6. Seat Seal Valve (Grove)

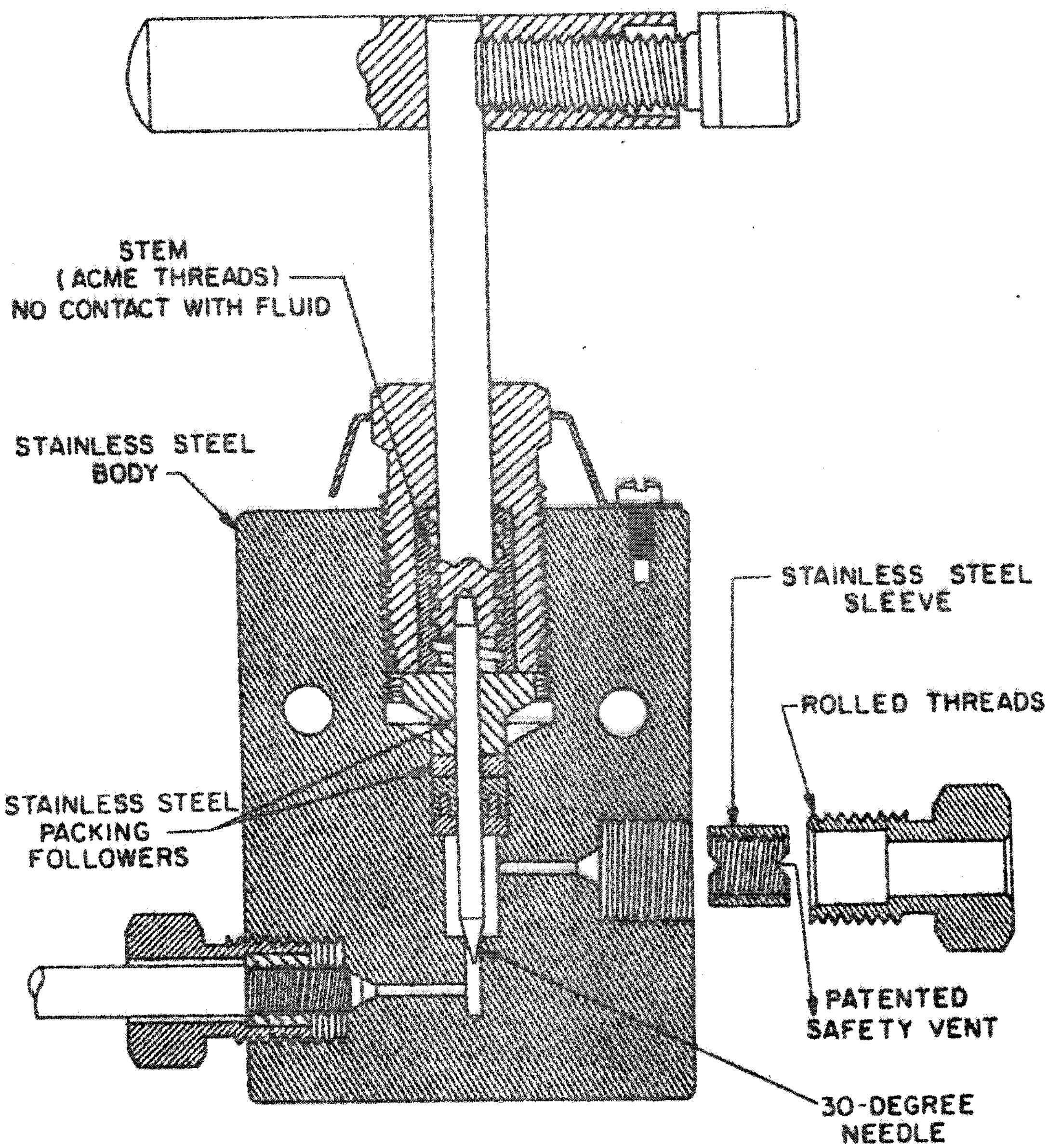


Figure 4.7. Needle Valve

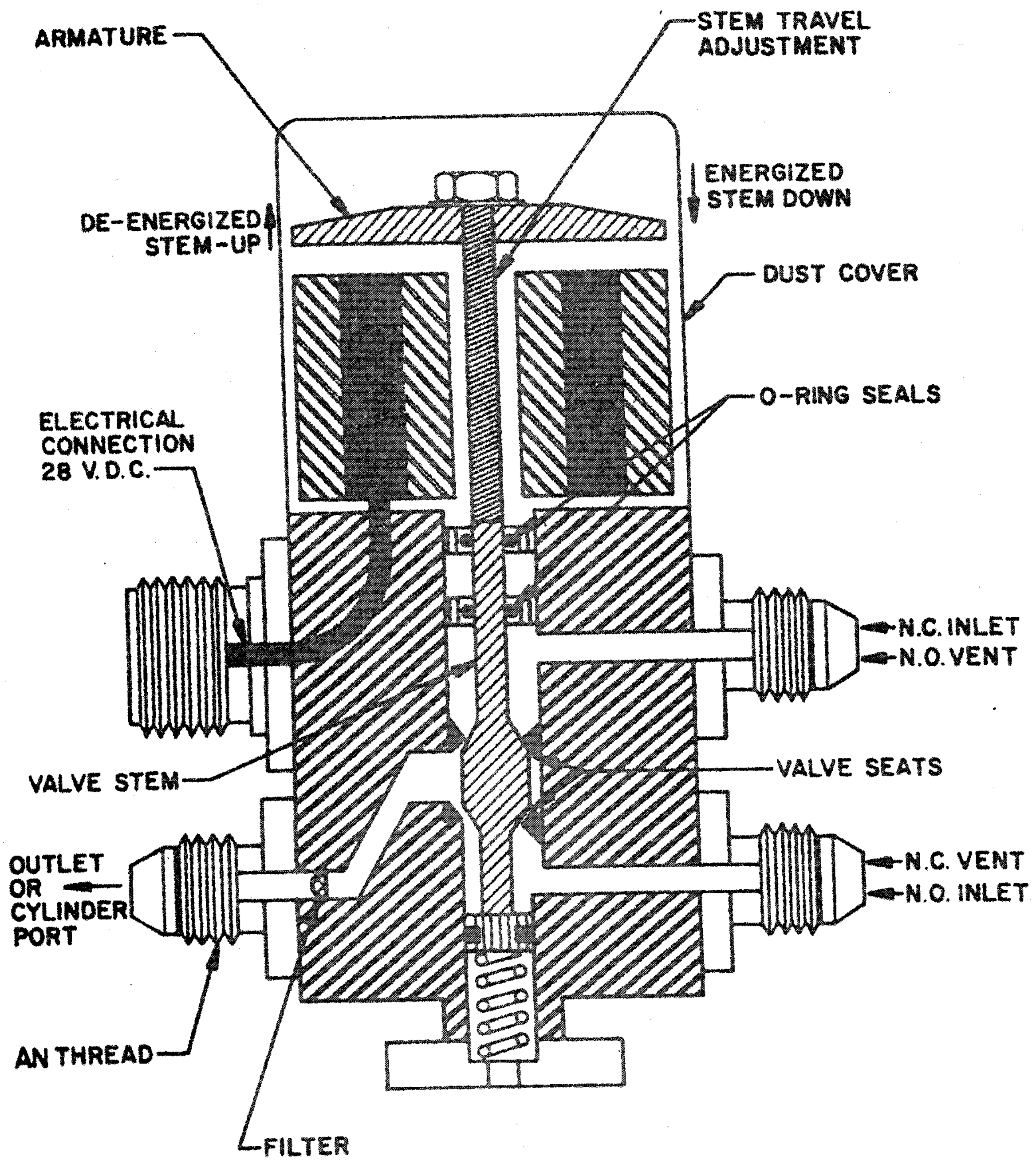


Figure 4.8. Solenoid Valve, 3-Way (Marotta)

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 250 psi and is used to control flow to the Annin pneumatic cylinders. The Barksdale is furnished in two types, N.O. and N.C. (See Figure 4.9.)

SOLENOID VALVES, 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. (See Figure 4.10.)

Barksdale 4-Way

This 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. (See Figure 4.5 and 4.11.) Note: **Do Not** restrict the vent port.

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 4.12.)

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.

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 4.13.)

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 4.14.)

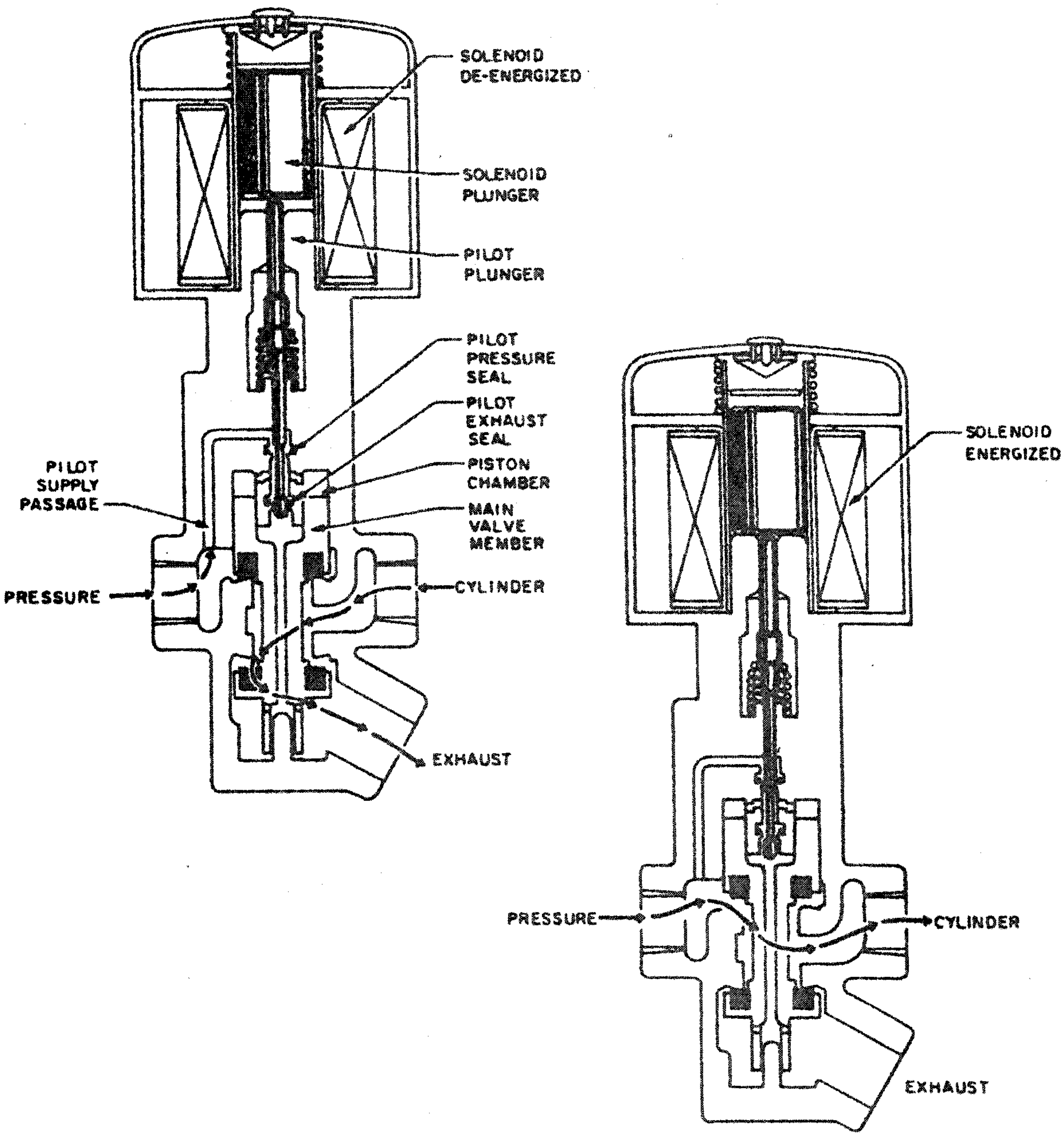


Figure 4.9. Solenoid Valve, Pilot-Operated (3-Way Barksdale)

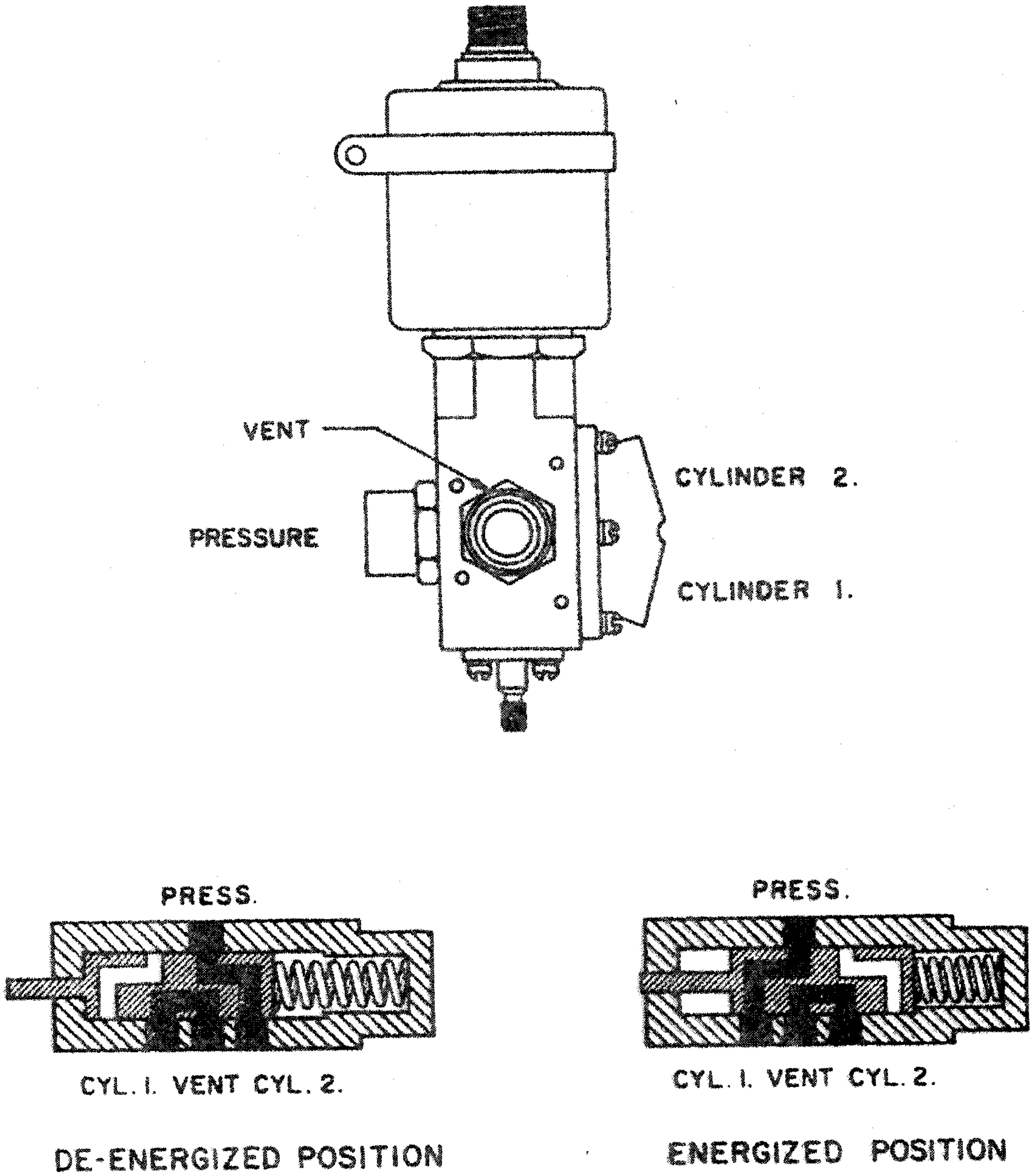


Figure 4.10. Solenoid Valve, 4-Way

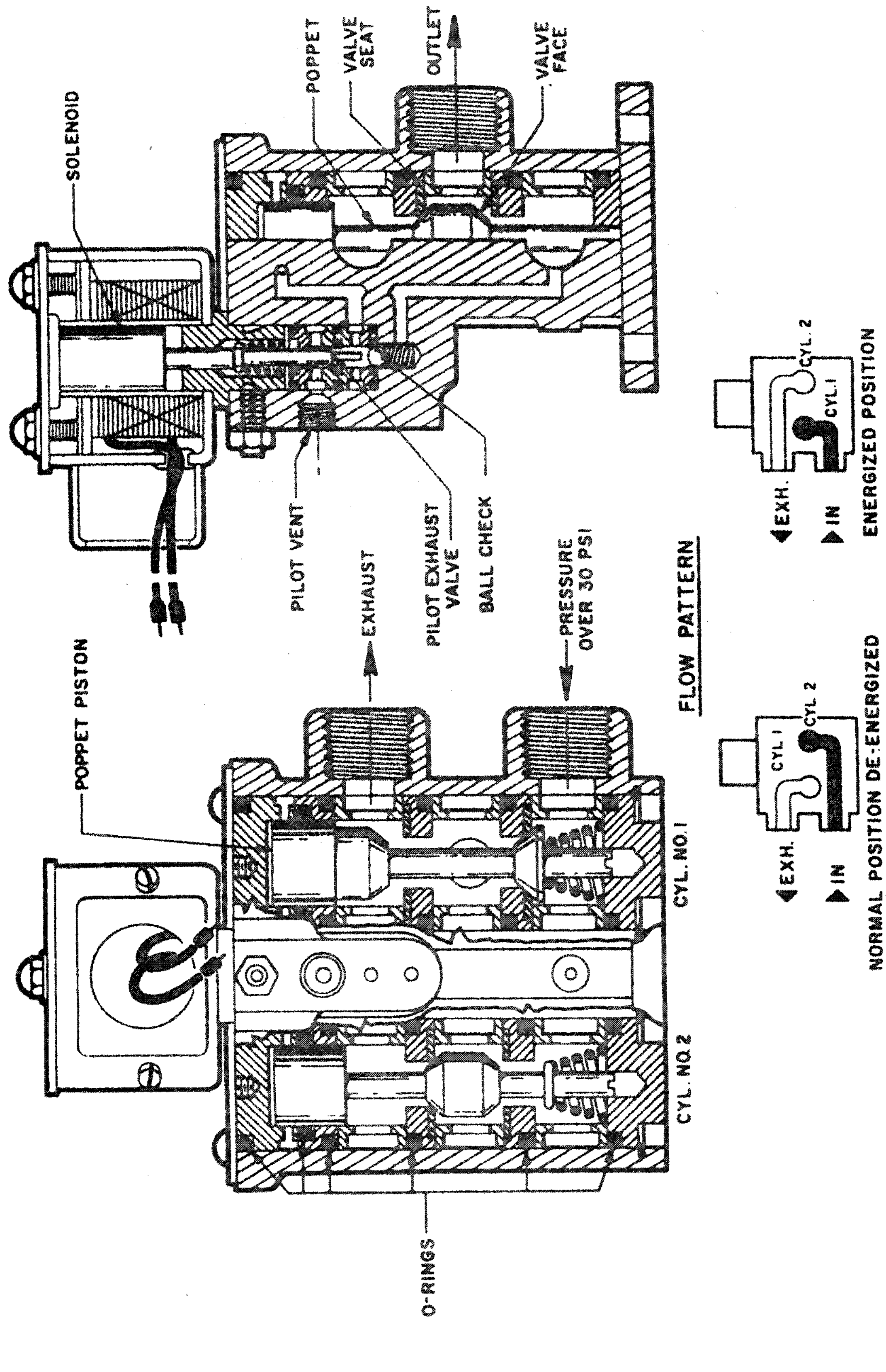


Figure 4.11. Solenoid Valve, 4-Way (Barksdale)

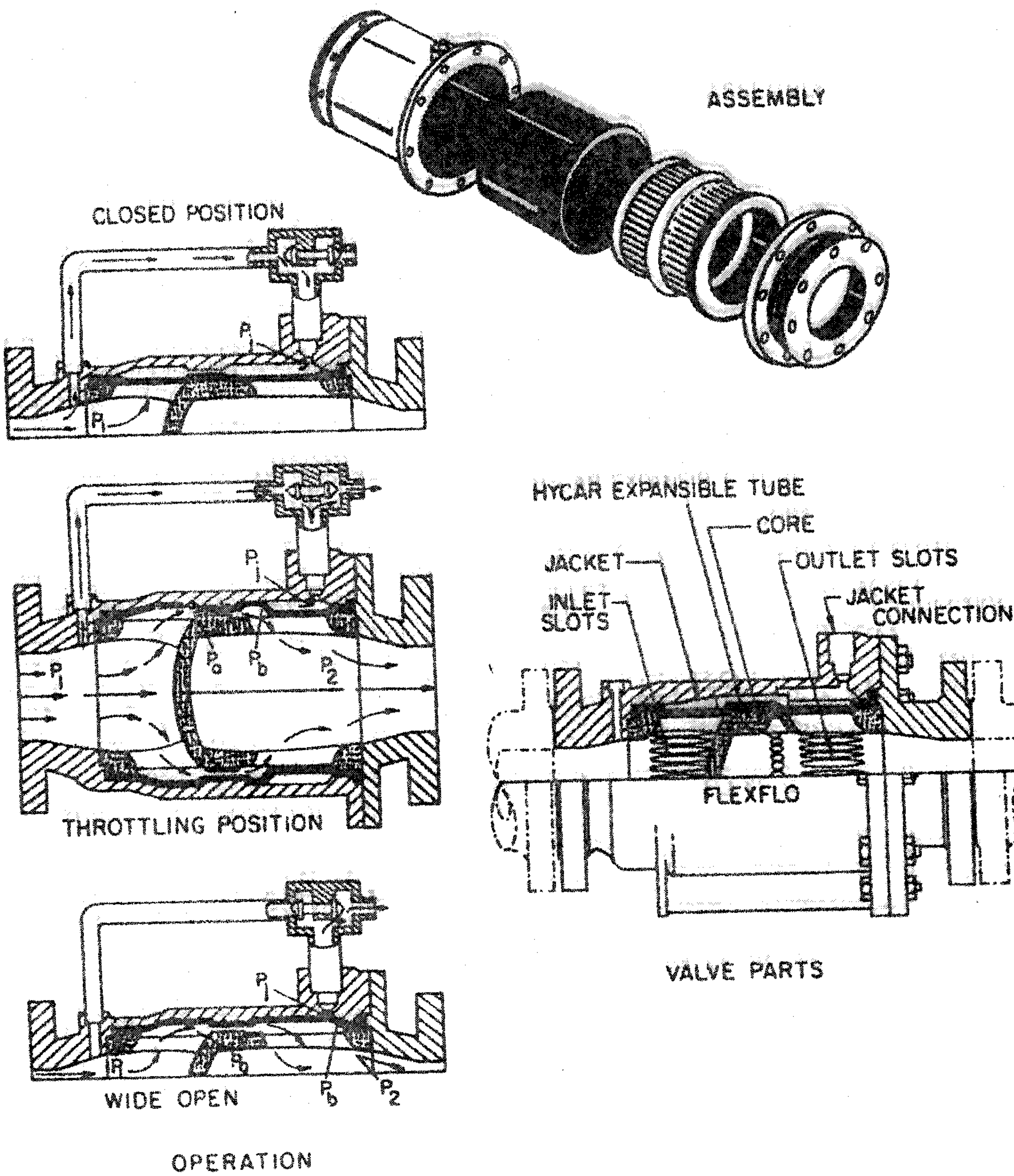


Figure 4.12. **Expansible Tube Valve (Grove Flexflo)**

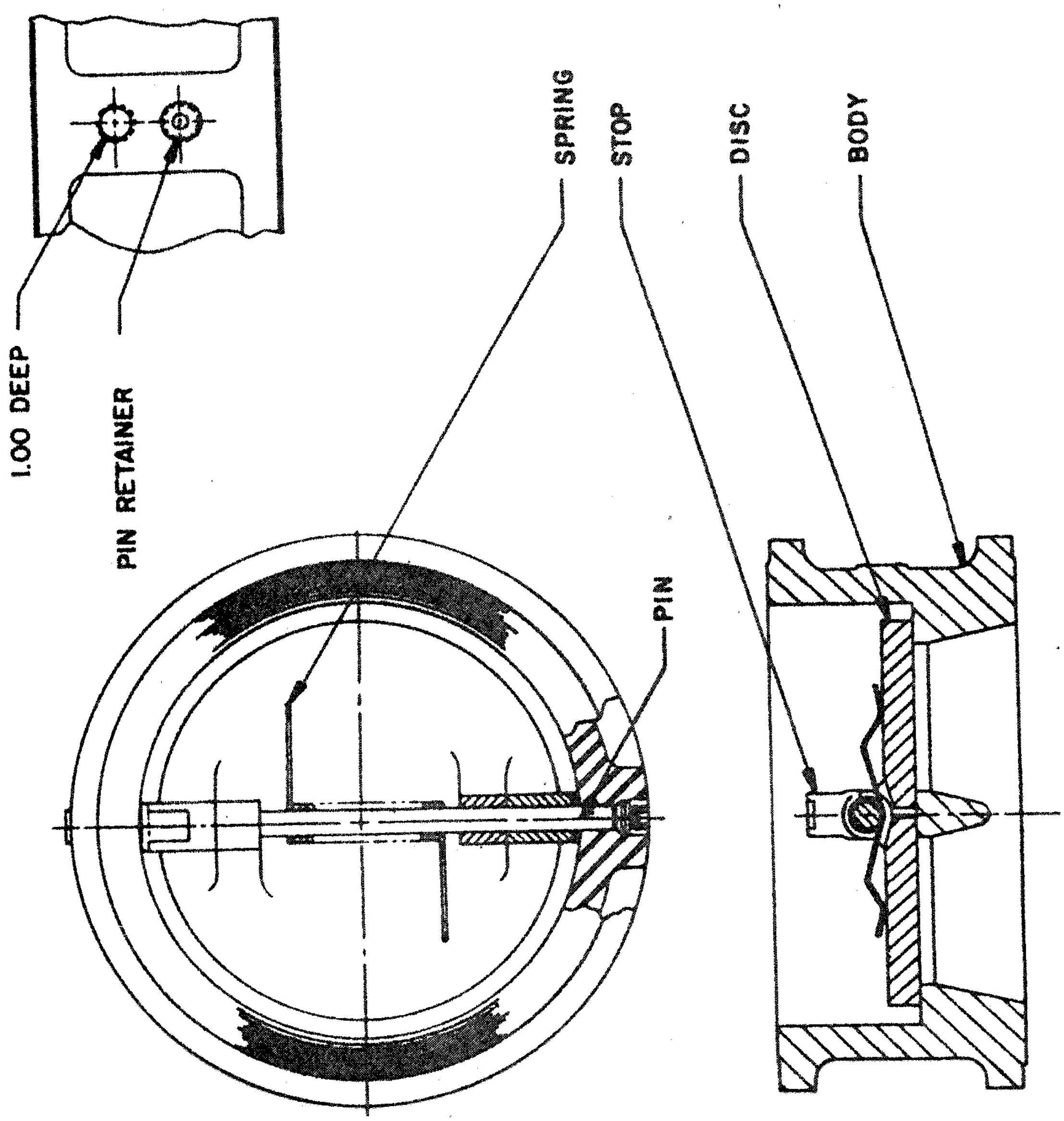


Figure 4.13. Check Valve (Split-Flapper Type)

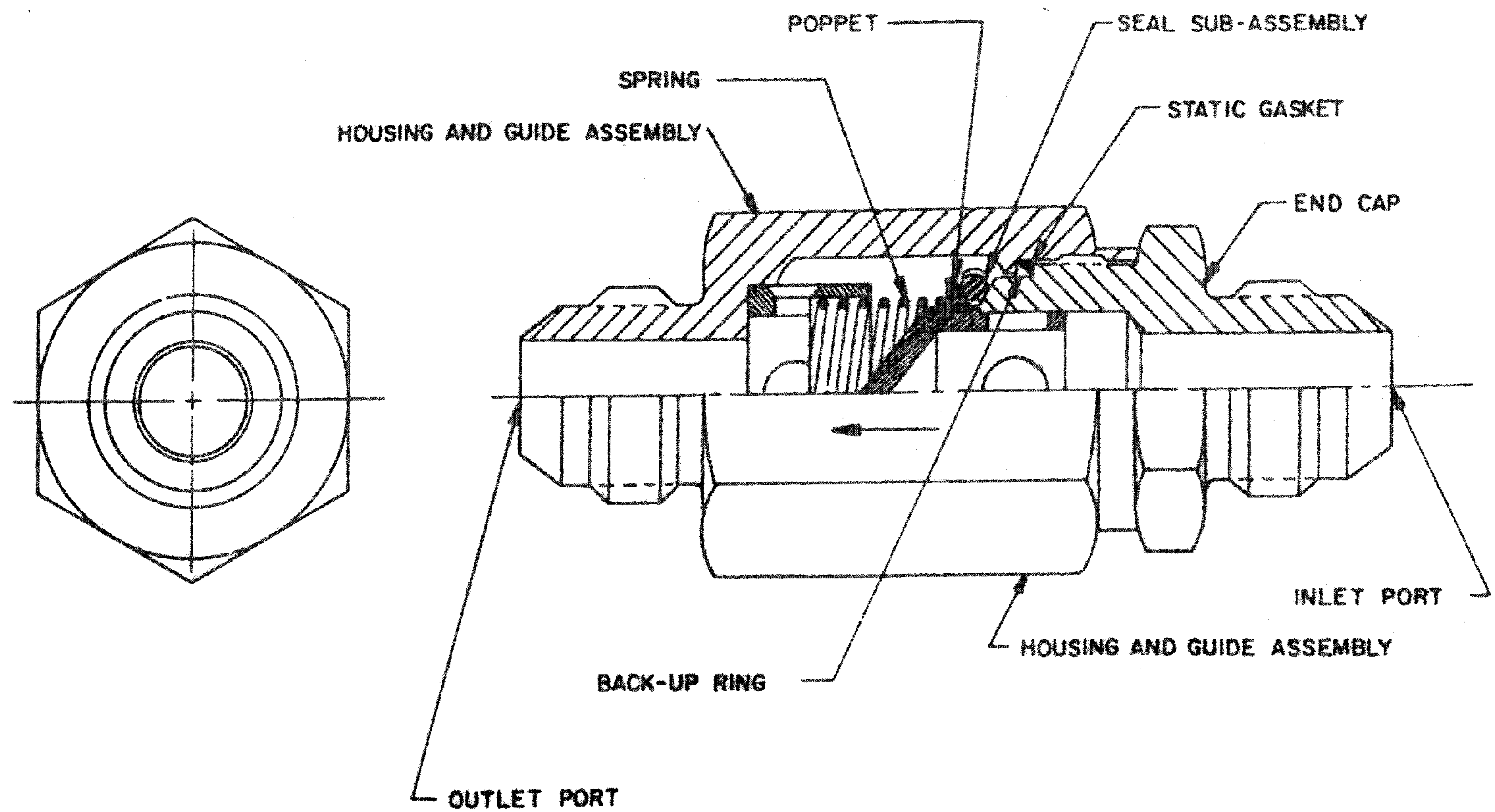


Figure 4.14. Check Valve (Poppet Type)

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 4.15.)

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 4.16.)

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 Figures 4.17 and 4.18.)

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 4.19).

PRESSURE REGULATORS AND
PRESSURE REGULATION SYSTEMS

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.

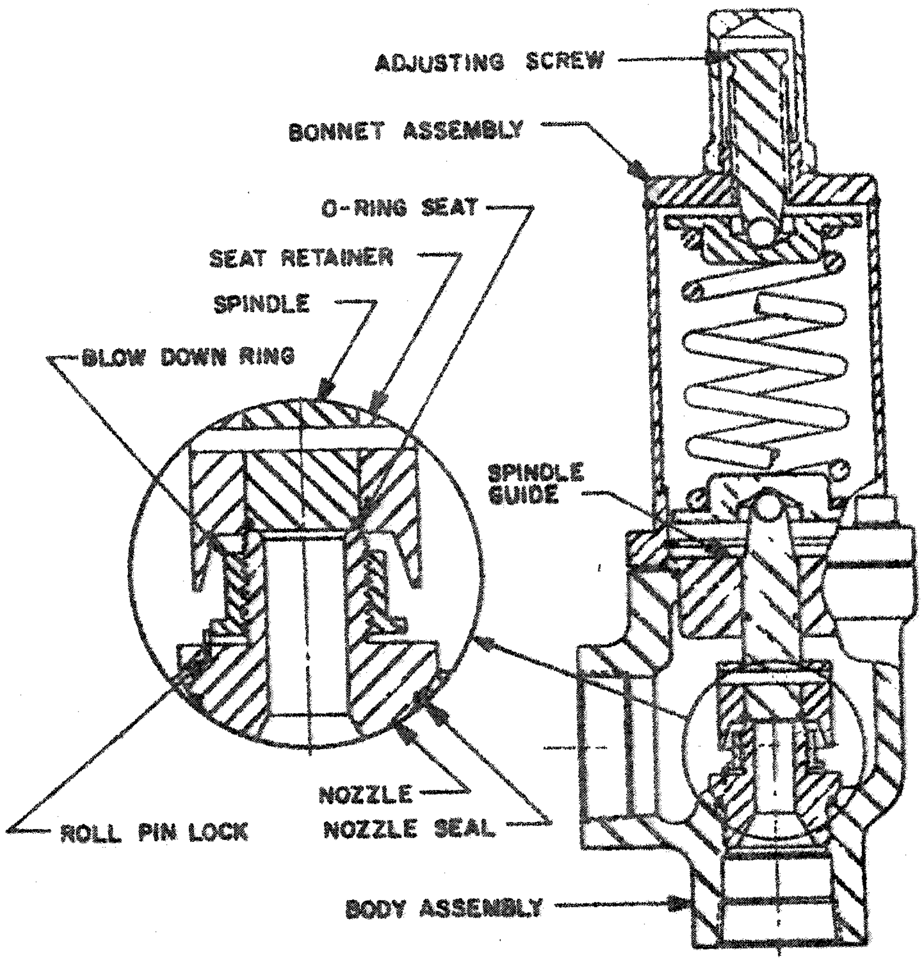


Figure 4.15. Relief Valve (Direct Acting)

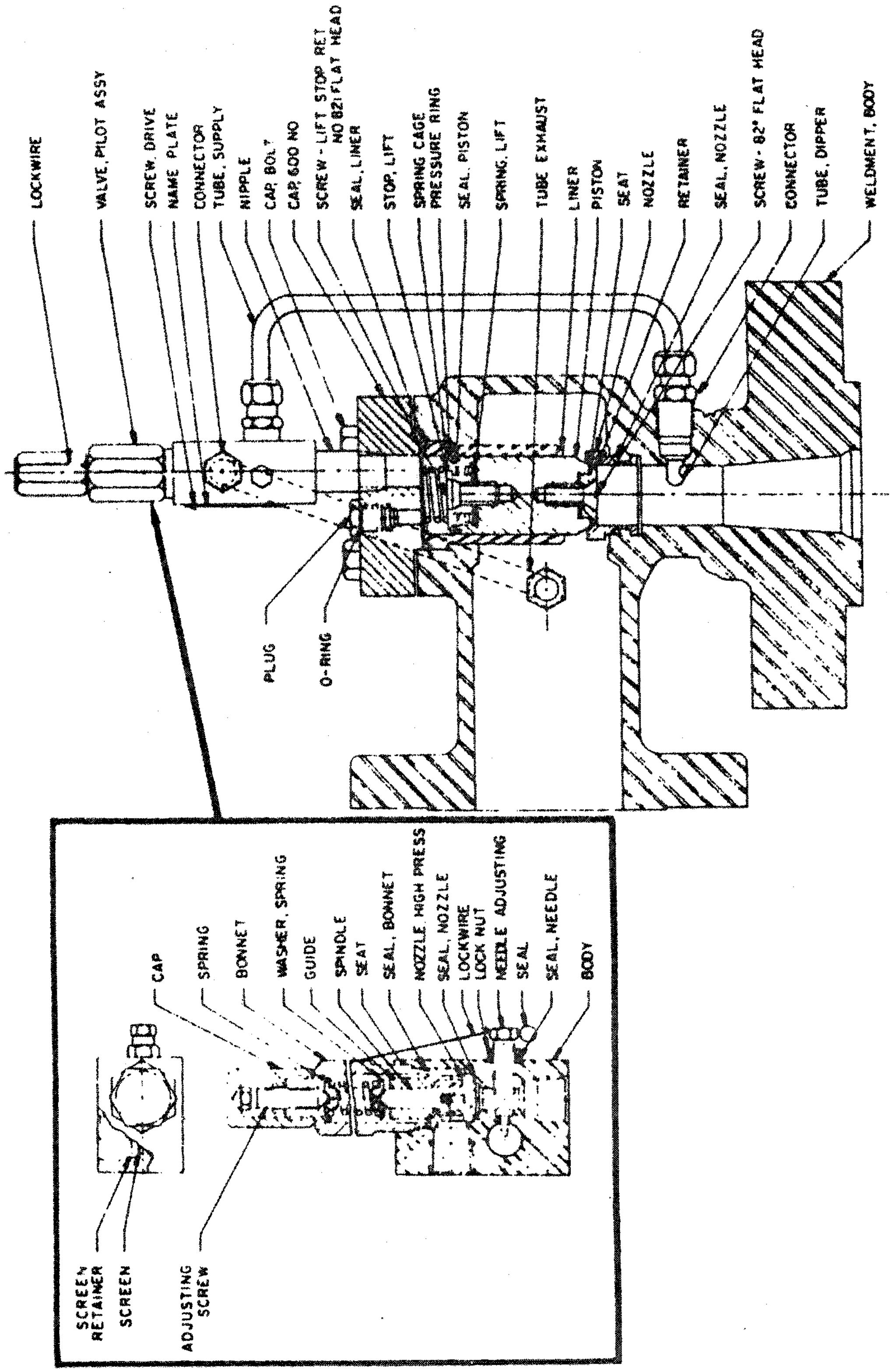


Figure 4.16. Pilot Operated Relief Valve (Agco)

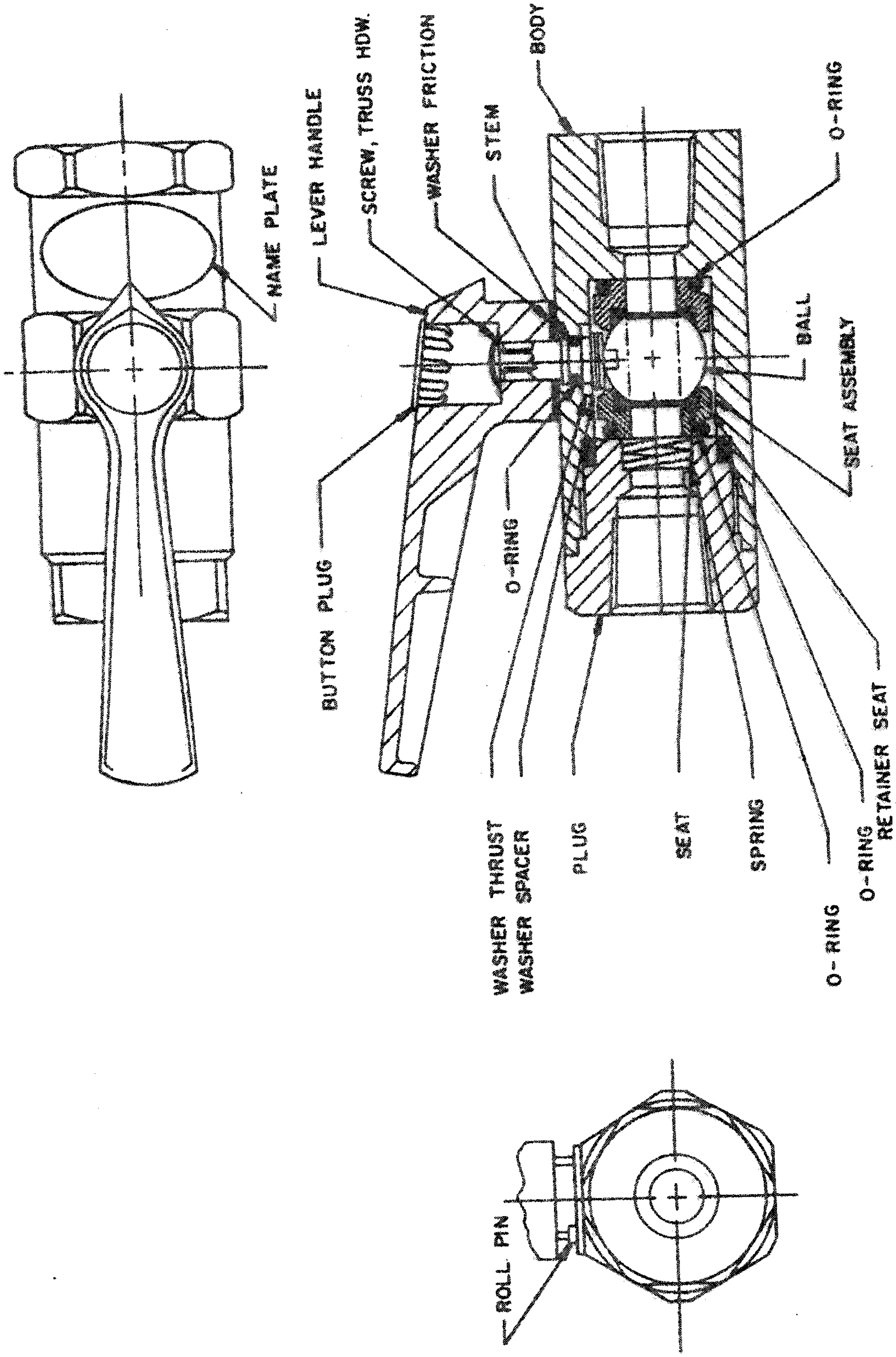


Figure 4.17. Hoke Ball Valve

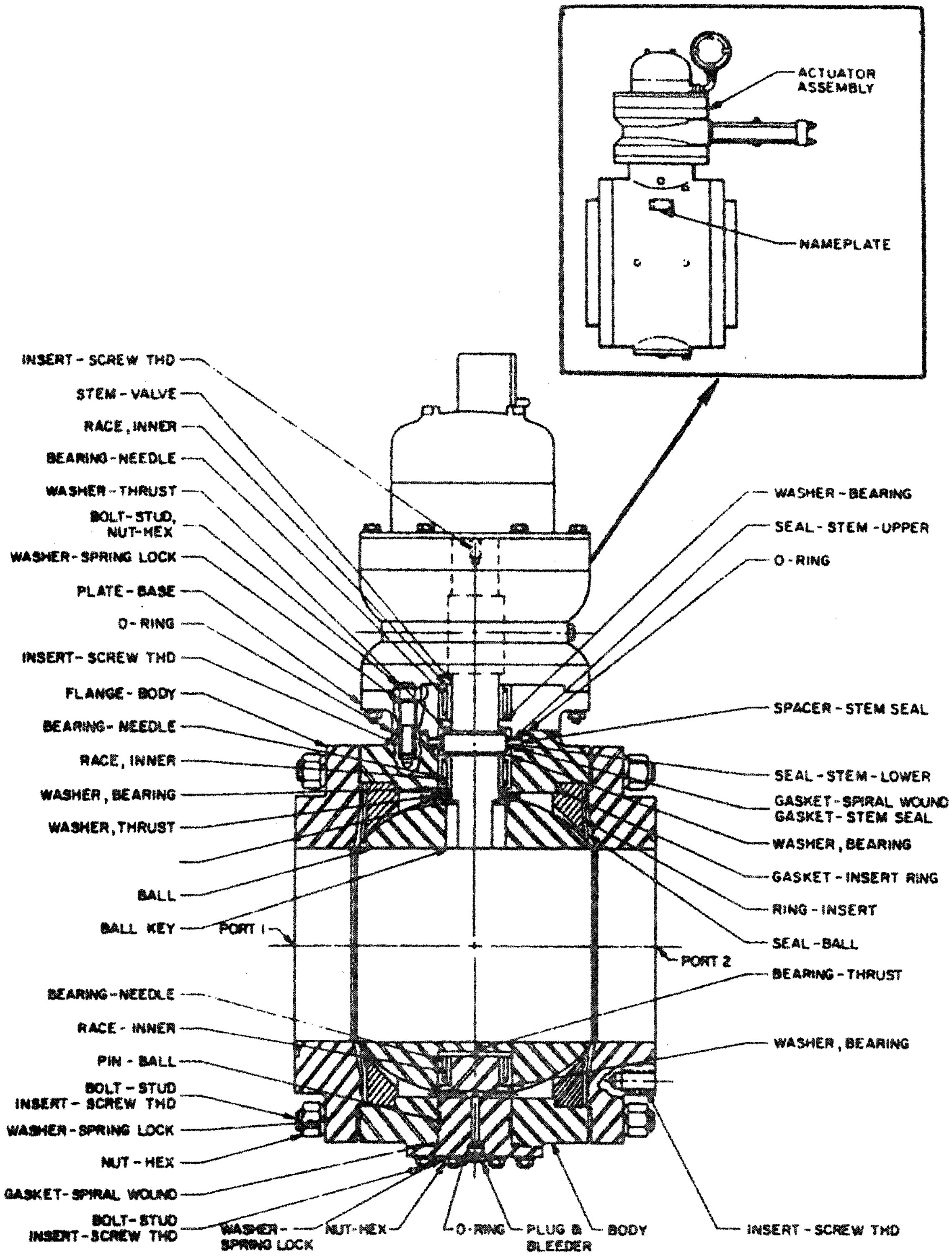


Figure 4.18. Ball Valve With Pneumatic Actuator (18")

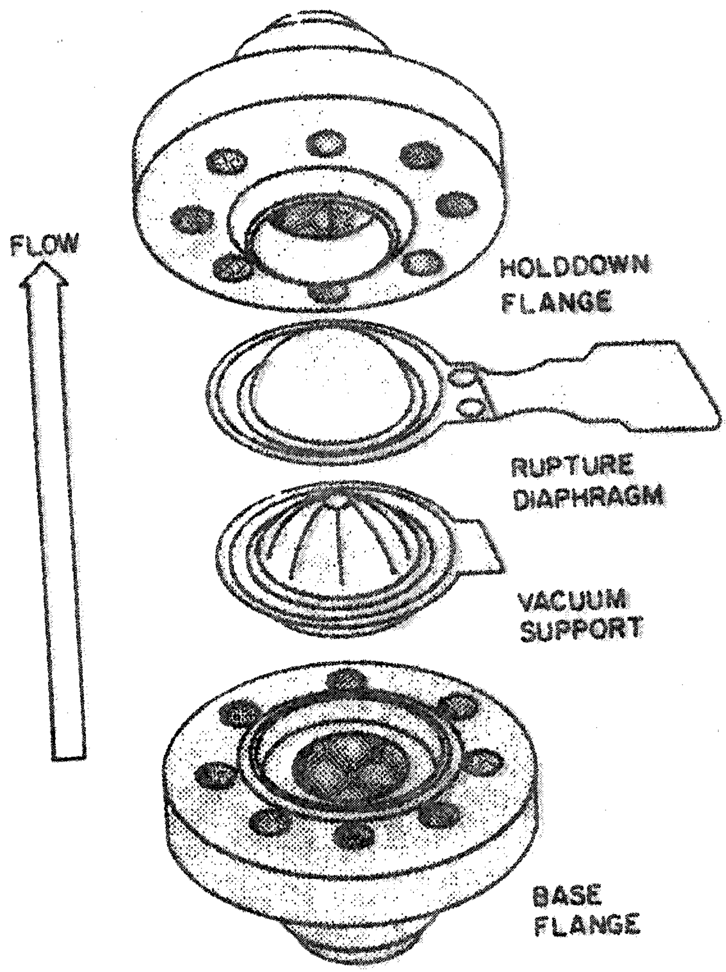


Figure 4.19. Burst Diaphragm

LARGE VOLUME PRESSURE REGULATOR (GROVE DOME)

This regulator is of the diaphragm type and is made in 3 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 4.20.)

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 3000 psi or 6000 psi, while the regulated pressure is available in a wide variety of ranges from 0 to 6000 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 4.21)

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.

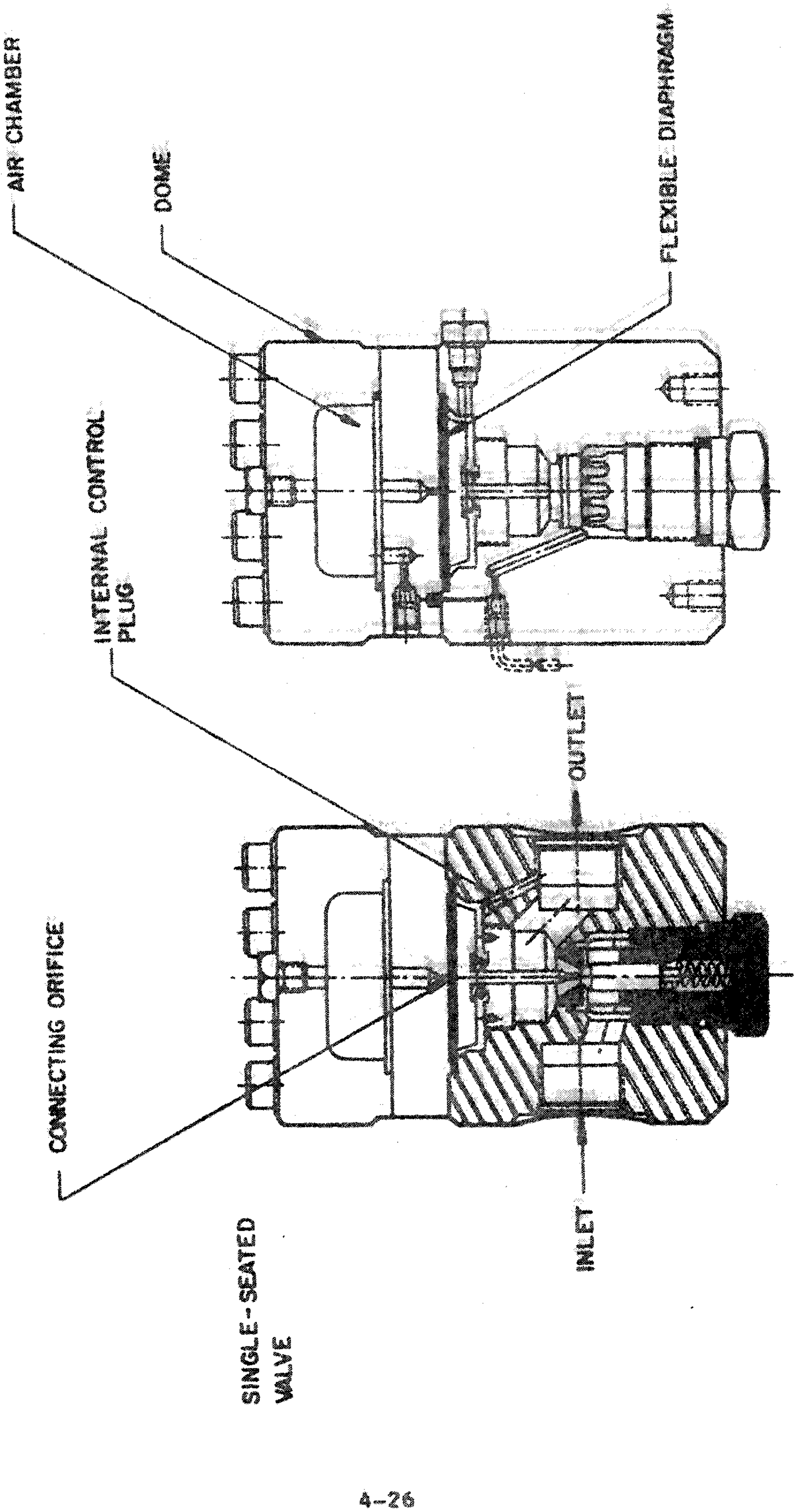


Figure 4.20. Large Volume Pressure Regulator (Grove Dome)

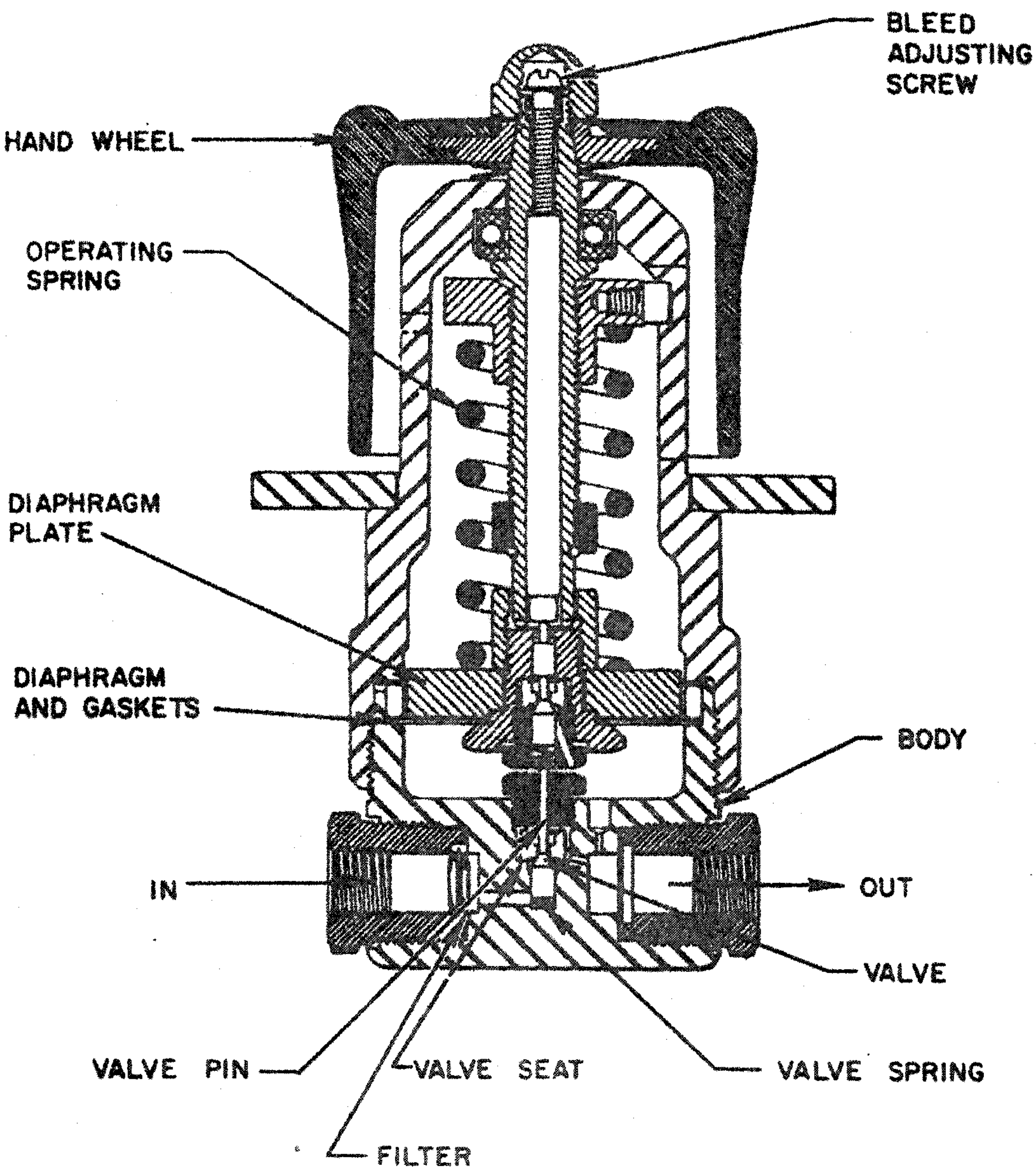


Figure 4.21. Small Volume Pressure Reducing and Relief Regulator (Grove Handloader)

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 5000 psi. The operation of this regulator is similar to the dome regulator with the additional 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 6000 psi. (See Figure 4.22.)

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 4.23).

The three-way solenoid valve shown between the small volume regulator and the large volume regulator (Figure 4.23), may or may not be plumbed into a system. The three-way solenoid is used for remote control of a regulation system.

CONTROL VALVE INSTALLATION

Figures 4.24, 4.25 and 4.26 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.

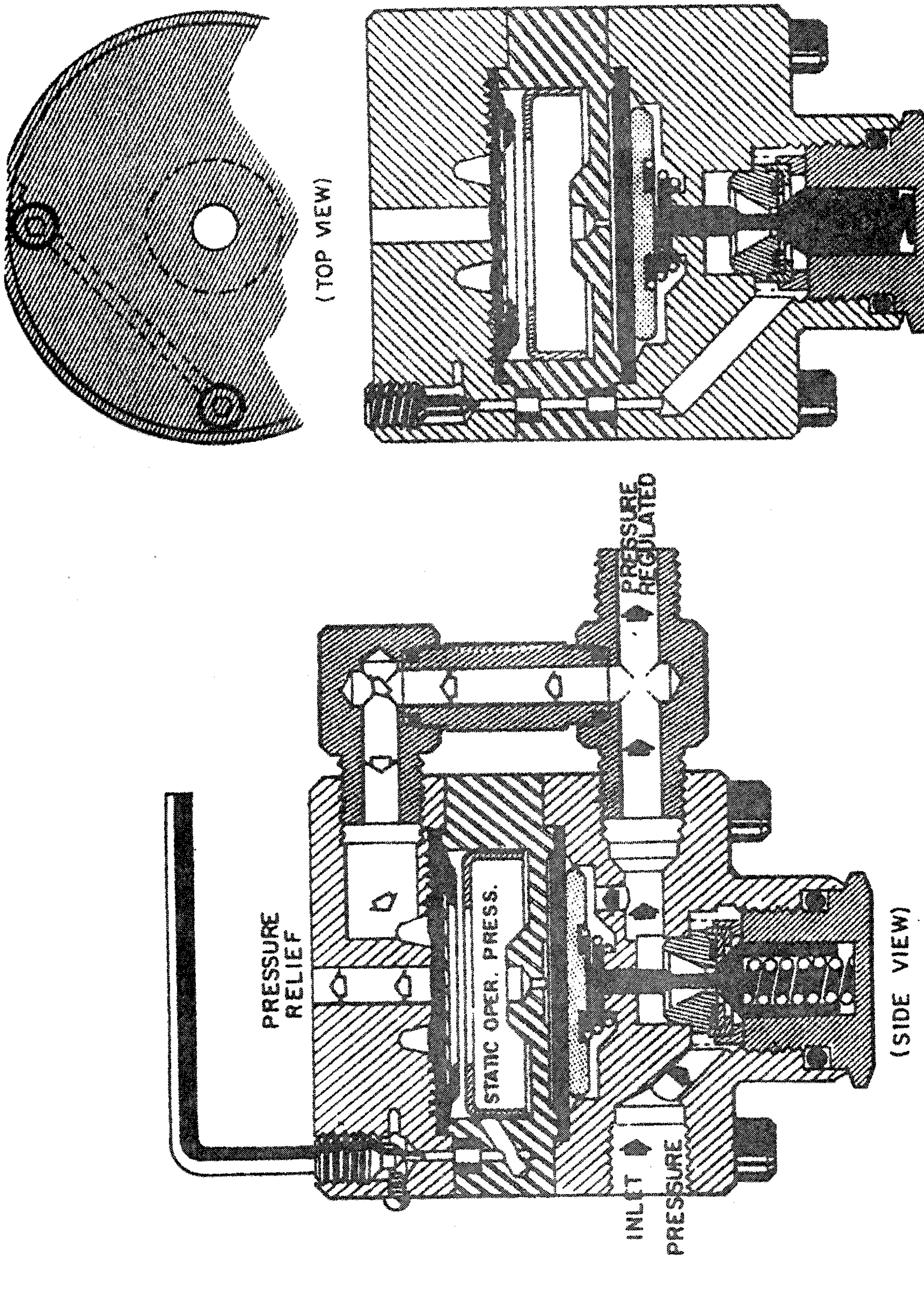


Figure 4.22. Pressure Regulator (Grove Mity Mite)

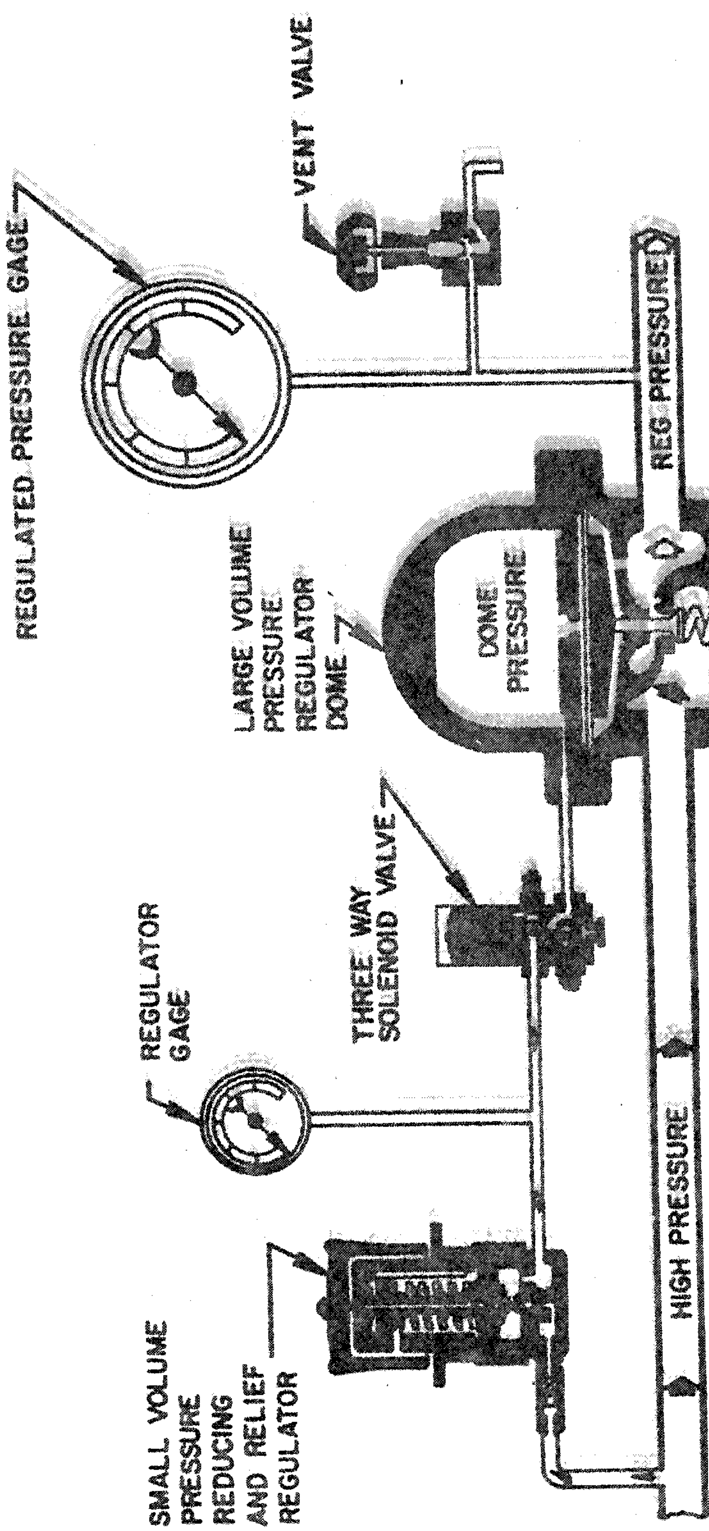
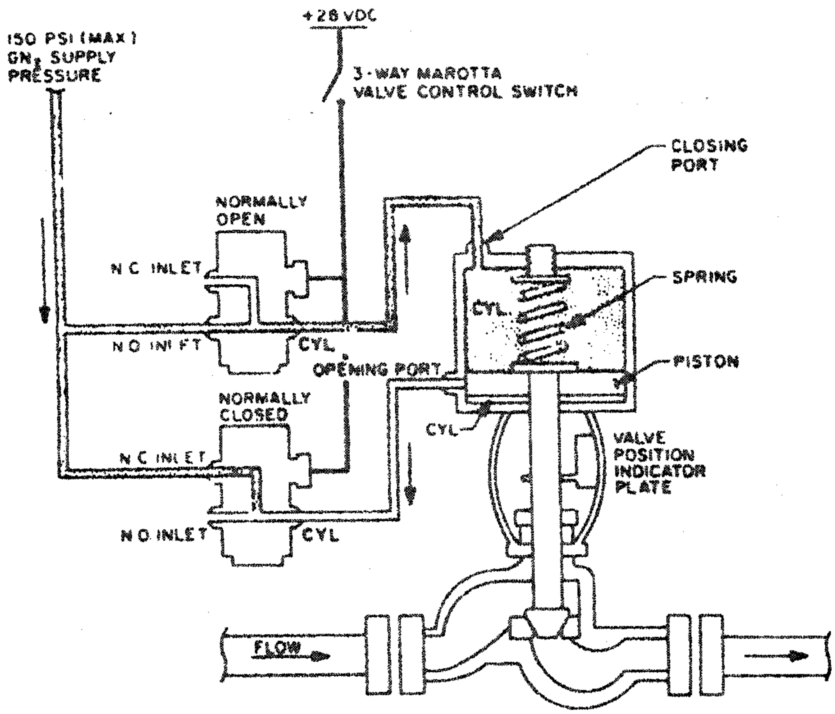


Figure 4.23. Pressure Regulation System (Pneumatic Panel)

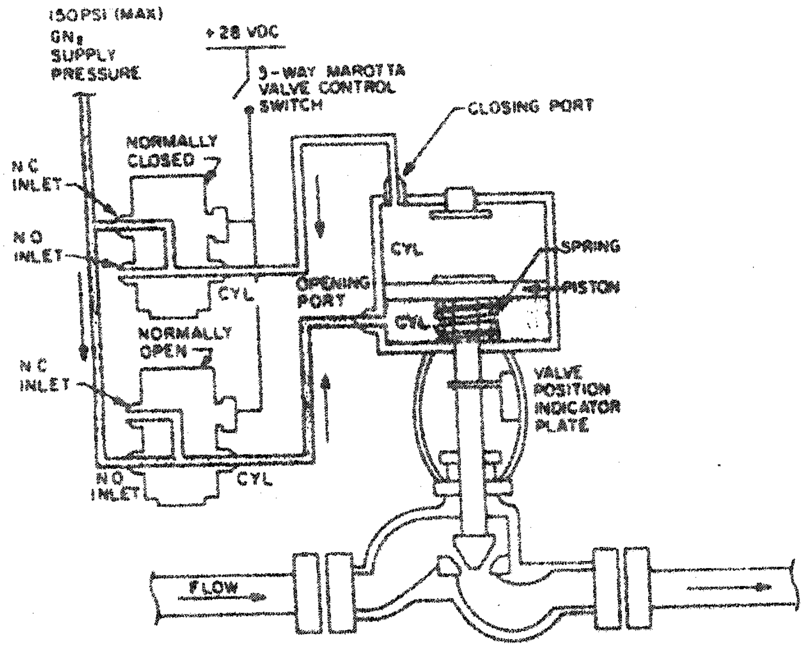


NORMALLY CLOSED VALVE (CLOSED POSITION)

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 Annis 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 4.24. Relationship of Annin and Solenoid Control Valves

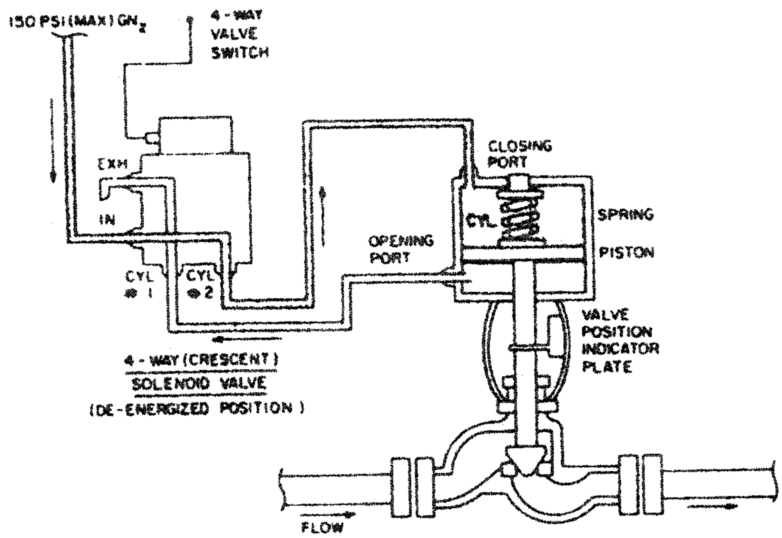


NORMALLY OPEN VALVE (OPEN POSITION)

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 valves 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 GN_2 control pressure failure, the spring installed below the piston in the Annin valve will return the Annin valve to the open position.

Figure 4.25. Relationship of Annin and Solenoid Control Valves



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 GN_2 control pressure failure, the spring installed above the piston in the Annin valve will return the valve to the closed position.

Figure 4.26. Annin Valve (Closed Position)

SECTION 5

FASTENERS

CONTENTS

FASTENERS

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 configura- tion, size and, strength for a particular job.

Nuts are generally used to secure or immobilize some component or assembly. The MS prefix, 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.

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.

FASTENER HEAD STYLES

Some typical fastener head styles are shown in Figure 5-1. For more detail see the Standards Manual and Appendices B and C.

<u>Bolt and Cap Screw Heads</u>

Hexagon Head (Trimmed) . . . .

Square Head (Trimmed) . . . .

Socket Head . . . .

Round Head Square Neck (Carriage) . . . .

Pan Head Oval Neck . . . .

Countersunk Head . . . .

Elevator Bolt Head . . . .

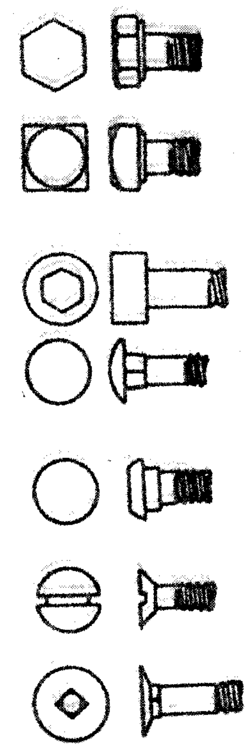
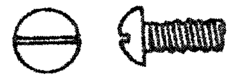


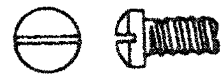
Figure 5-1. Fastener Head Styles (Sheet 1 of 2)
(see Appendix B and C))

Screw Heads (Machine, Wood, Tapping, Stove Bolts)

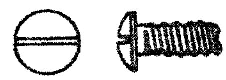
Flat Head . . . . 

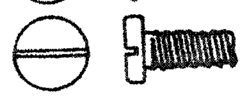
Round Head . . . . 

Oval Head . . . . 

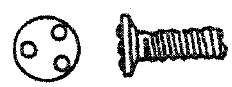
Fillister Head . . . . 

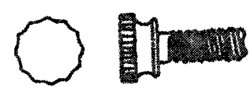
Binding Head . . . . 

Truss Head . . . . 

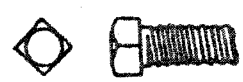
Pan Head . . . . 

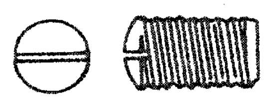
Jackson Head . . . . 

Welding Screw Head . . . . 

Knurled Head . . . . 

Set Screw Heads

Square Head Set Screw . . . . 

Headless Slotted Set Screw . . . . 

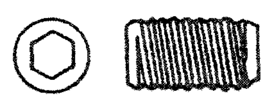
Socket Head Set Screw . . . . 

Figure 5-1. Fastener Head Styles (Sheet 2 of 2)
(see Appendix B and C)

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

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. See Appendix C also.

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

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:

```
A N 3 1 5    C    7    R
    |        |    |    |
    |        |    |    └─Right-hand thread
    |        |    |
    |        |    └─Dash number--nut size
    |        |
    |        └─Material--corrosion-resistant steel
    |          (absence of letter indicates carbon steel)
    |
    └────Basic nut type
```

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

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.

APPLYING FASTENERS

SAFETY WIRING

Where lockwire is specified and aluminim 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 mumber in a series. When safety wiring closely spaced multiple groups, the mumber 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 safety 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 5.2 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.

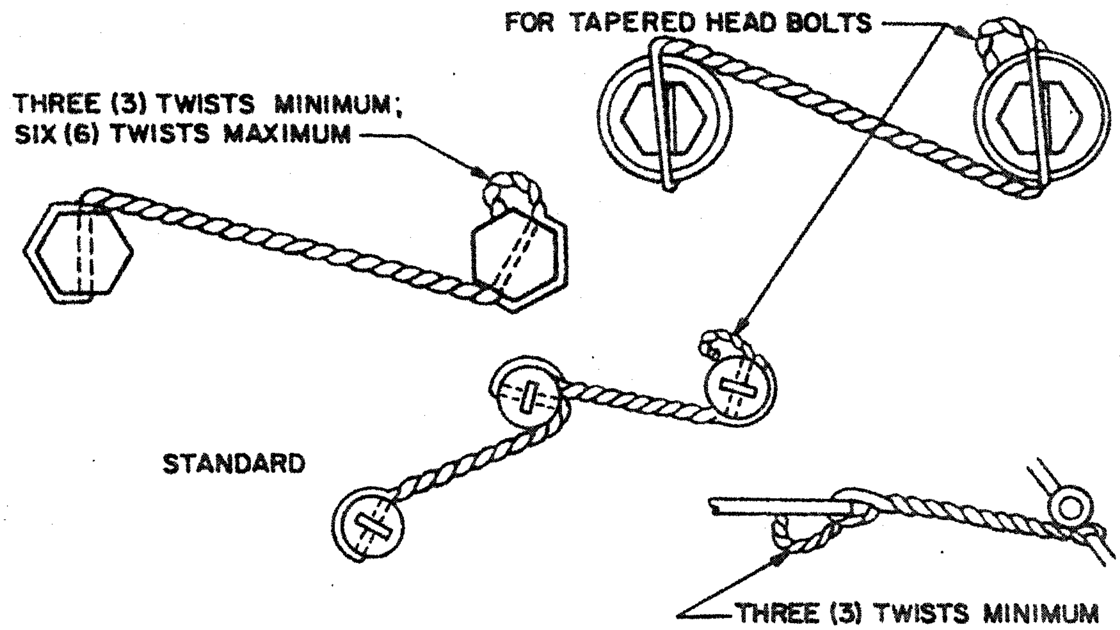


Figure 5.2. Lockwiring

Threaded fasteners in propellant feed systems shall be lock wired (if they are not tack welded) per new FLD006.

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 5.3). 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.

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 5.4.)

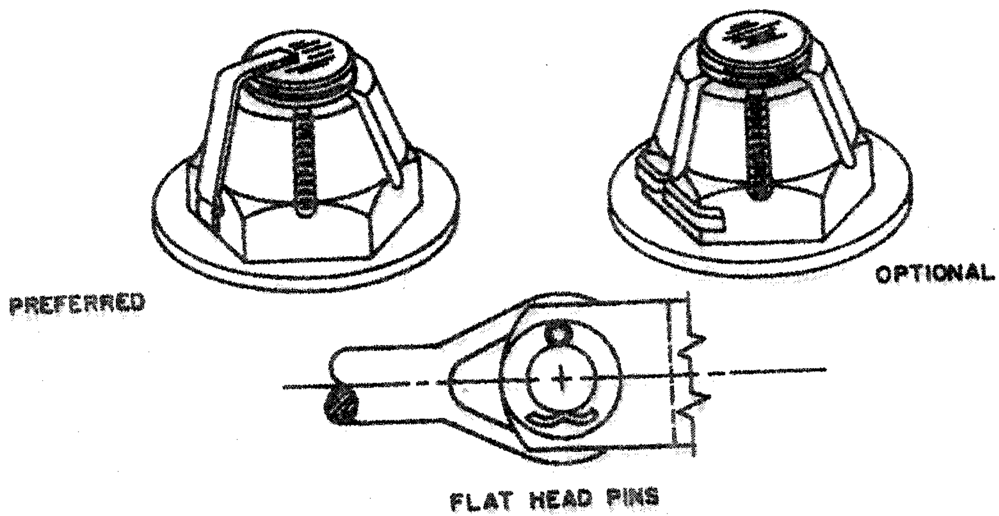


Figure 5.3. Pin Installation

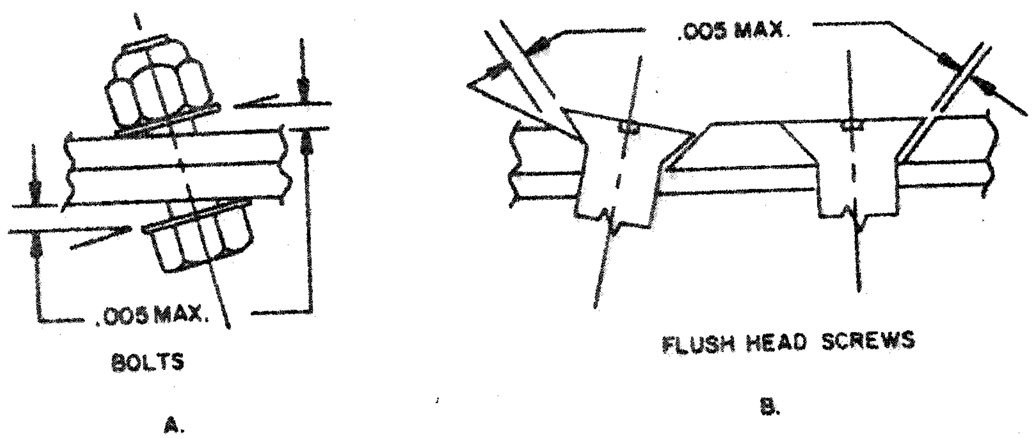


Figure 5.4. Allowable Tilt Under Head of Bolts

LOCATION OF BOLT HOLES

Bolt heads shall be fully bearing on material. (See Figure 5.5.)

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 5.6.)

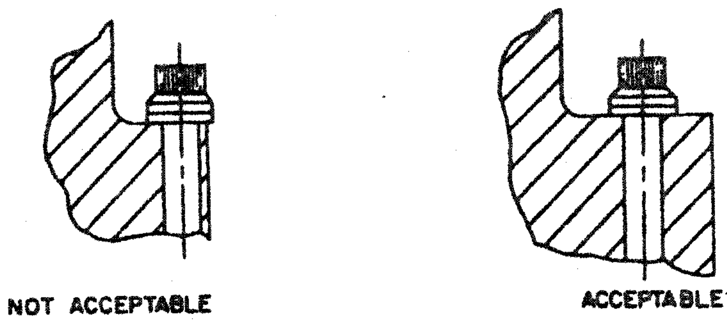


Figure 5.5. Location of Bolt Holes

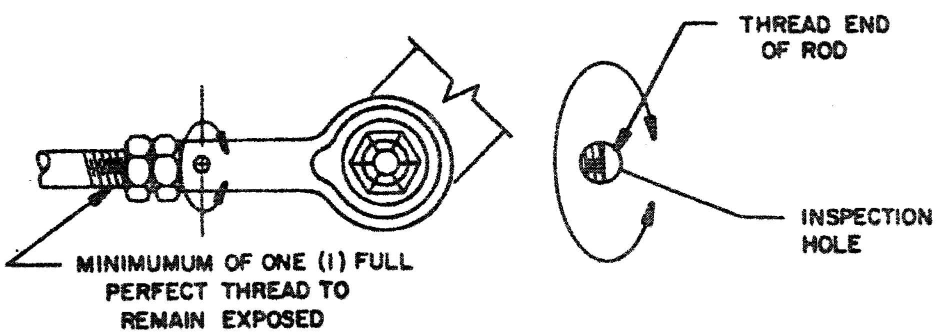


Figure 5.6. Push-Pull Rod Application

CASTELLATED NUTS

SECURING

When securing castellated nuts, the center of the hole in the fastener shall not extend beyond the end of the nut. (See Figure 5.7.)

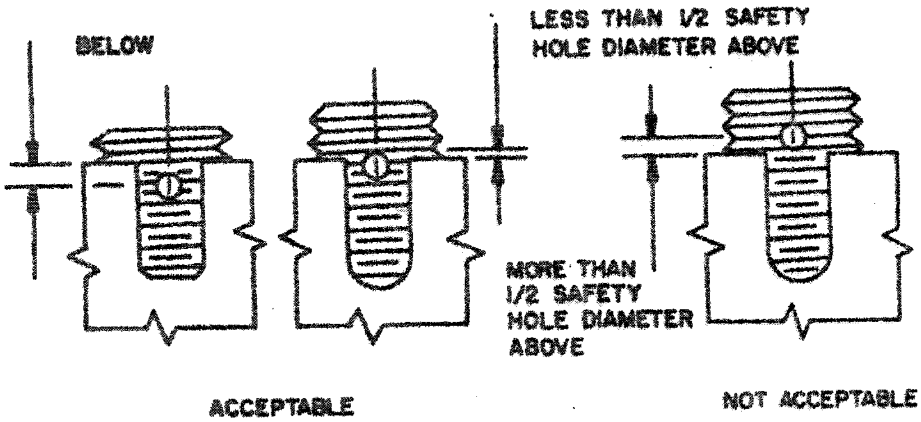


Figure 5.7. Castellated Nut Application

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 5.8.

COUNTER SUNK WASHER APPLICATION

Installation of countersunk washer with high tensile bolt is shown in Figure 5.9.

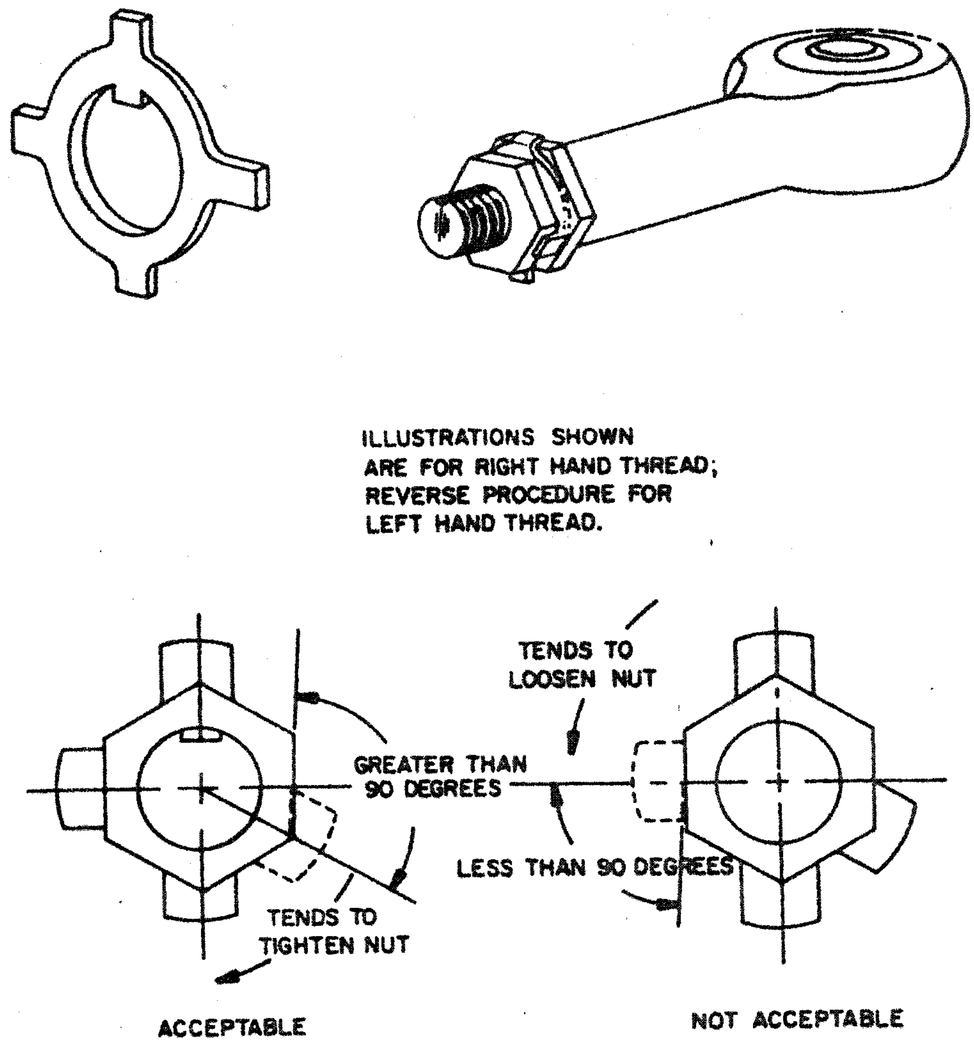


Figure 5.8. Lockwasher Application

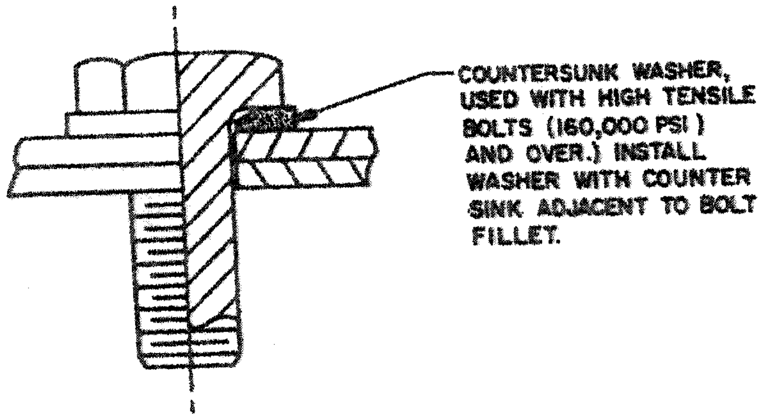


Figure 5.9. Countersunk Washer Application

TORQUING

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 then 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.

TORQUING TUBE FITTINGS

Torque values listed on the drawing or work order should be used. The torque values listed in Figure 5.10 and 5.11 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 Figure 5.10 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 10 for instructions in preparing a flare.

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.

Figure 5.10. Flared Tube "B" Nut Torque Values

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 O-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.

Figure 5.11. Recommended Torque Values for Tube Fittings

TORQUING FLANGED FITTINGS

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 5.12 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.

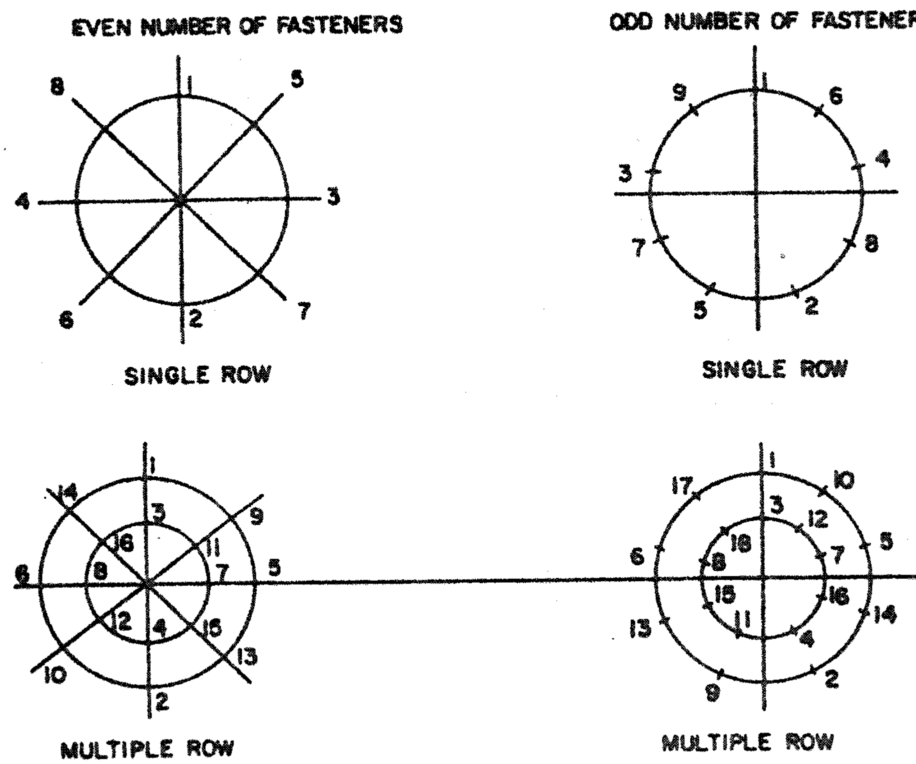


Figure 5.12. Method of Cross Torquing

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 7000 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. As the equipment goes into operation, stress decay takes place, and the installation bolt stress drops off towards the design value.

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

1. Aircraft Type Nuts and Bolts - Use values listed in Figures 5.13 and 5.14

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 Figure 5.15. 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 Figure 5.16 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.

Torque Values in Inch-Ounces (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 I, 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.

Figure 5.13. Torque Values for Tightening Nuts

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.

Figure 5.14. Torque Values for Tensile Fasteners

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					
				7,500 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	16530
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

Figure 5.15. Torque Values for Machine Bolts and Cold Rolled Steel Stud Bolts

Nominal Diameter of Bolt Inches	Number of Threads per Inch	Diameter at Root of Thread Inches	Area at Root of Thread Sq Inch	Stress: 30,000 psi Torque Ft Lbs	Stress: 30,000 psi Compression Lbs	Stress: 45,000 psi Torque Ft Lbs	Stress: 45,000 psi Compression Lbs	Stress: 60,000 psi Torque Ft Lbs	Stress: 60,000 psi 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

Data for Use With ASTM A193 Bolt-Stud and ASTM 193 Nut Combination

Load in Pounds on Stud Bolts when Torque Loads are Applied

Figure 5.16. Torque Values for ASTM 193 and ASTM A194 Nut and Bolt Combinations

TORQUE WRENCHES AND THEIR USE

Several torque wrench types are shown in Figure 5.17. Their use and limitations are:

1. Research has proved that is 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 indicaton 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.

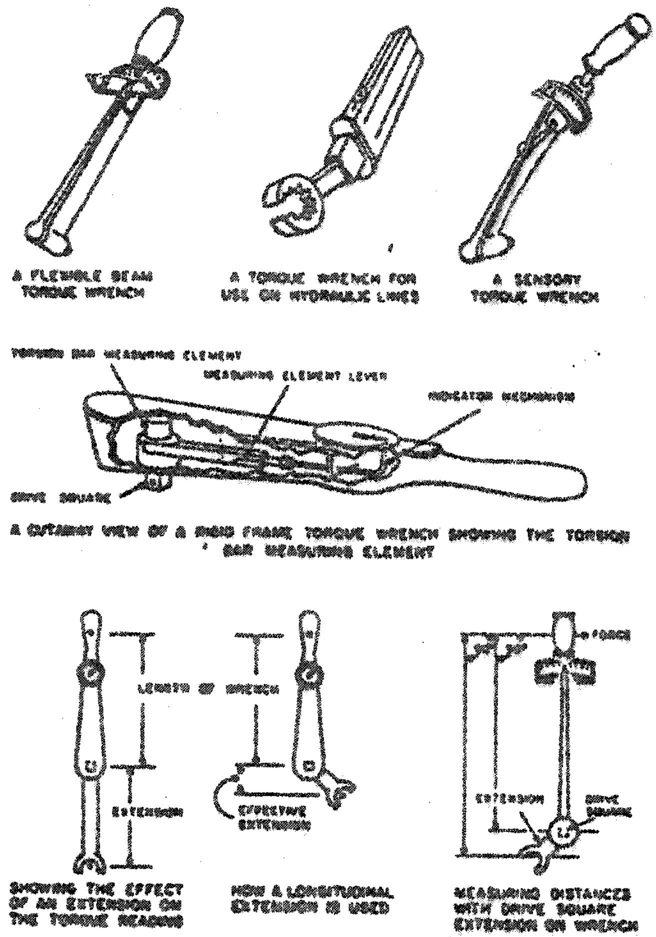


Figure 5.17. Torque Wrenches

HOW ADAPTORS AFFECT TORQUE

1. To understnad why some extensions and adaptors 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 5.18 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: $T = F \times L$.

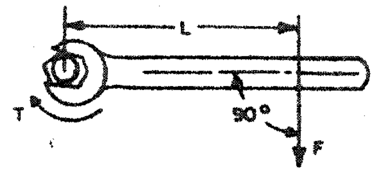


Figure 5.18. Wrench Without Adaptor

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 engle 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 is attached to thesquare drive, which changes th length of the torque wrench, th readings on the dial will not give the actual torque. A simple formula, however, enables one to figur out what the dial should read for a pre-determined torque using any adaptor (Figure 5.19).

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

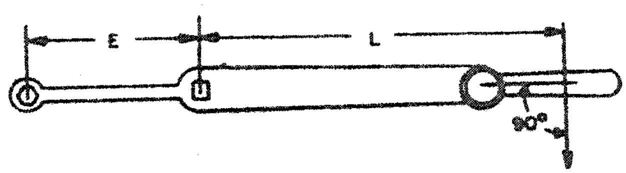


Figure 5.19. Wrench With Adaptor Attached to Square Drive

7. The letters in the formula have the following meaning: (See Figure 5.19)

   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 of 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 which is parallel to the torque wrench.

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

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

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

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 an extension which is perpendicular to the torque wrench, regardless of length does 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 5.20.)

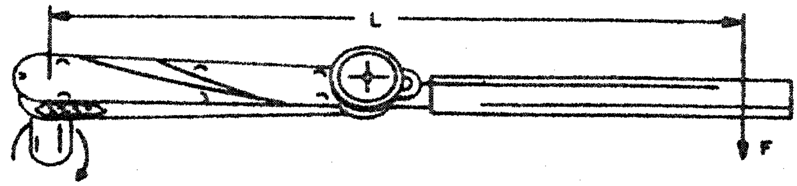


Figure 5.20. Adaptor Attached to Handle End of Wrench

11. This adaptor doubles the length and leverage of the torque wrench. The dial will read only 1/2 of the torque. Note "L" and "E" are equal. (See Figure 5.21.)

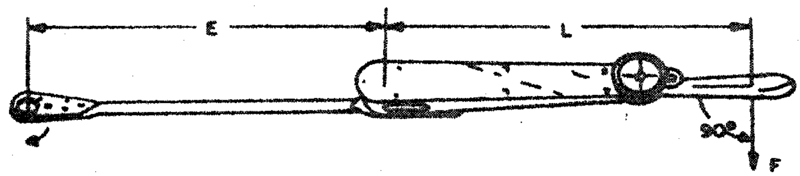


Figure 5.21. Adaptor Attached to Square Drive

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 5.22.)

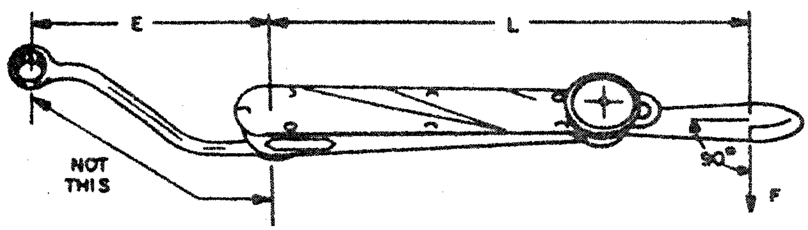


Figure 5.22. Adapter Attached to Square Drive

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 5.23.)

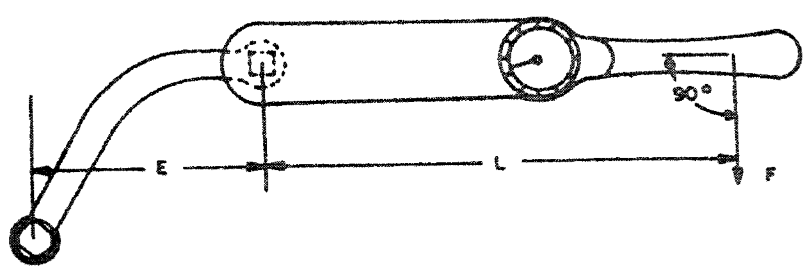


Figure 5.23. Adaptor Attached to Square Drive

SECTION 6

LUBRICANTS, GASKETS, SEALS AND PACKAGING

CONTENTS

LUBRICANTS

DEFINITIONS AND FUNCTIONS

The general term lubricants includes the following specific terms and 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

APPLICATION OF LUBRICANTS

THREAD LUBRICANT APPLICATION

Applied across the threads
(male thread only)

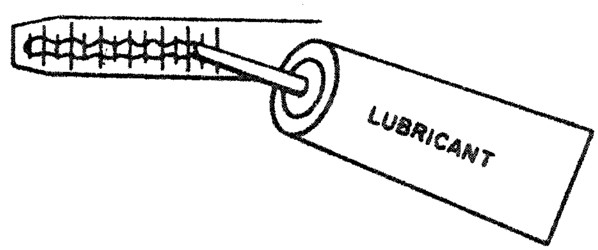


Figure 6.1. Thread Lube Applications

The number of application points will vary with the size of the fitting. (See Figure 6.2.)

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

Thread Diameter, inch	No. of Application 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

Figure 6-2. Lubricant Application

TUBE FITTING LUBRICATION APPLICATION

Lubricate interior and exterior thrust surface of tubing sleeve (see Figure 6-3).

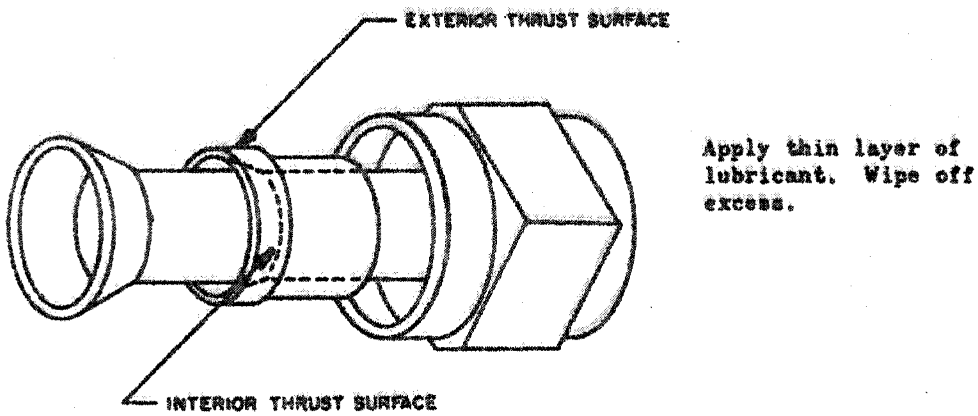


Figure 6.3. Lube Application to Tube Fittings

DYNAMIC O-RING LUBRICANT APPLICATION

1. Pack one-quarter the distance around the groove with the required lubricant prior to installing the O-ring (see Figure 6.4).

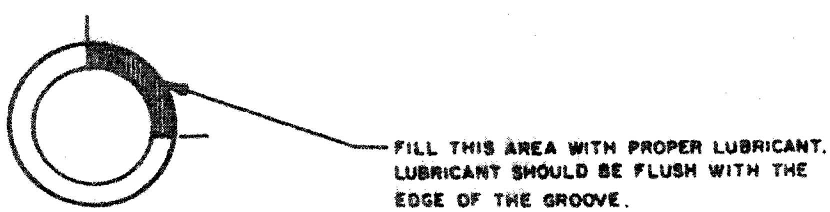


Figure 6.4. Lube Application to O-Ring Grooves

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.

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. 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.

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.

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

   1. 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

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

GASKETS

GASKET TYPES AND MATERIALS

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.

Flat Gaskets

Several types of flat gaskets and their limitations are listed in Figure 6.5.

Ring Joint Gaskets

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

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.

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.

Figure 6.5. Flat Gaskets in Use at the Field Laboratories

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 overcompression 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.

SEALS

BOSS SEALING RECOMMENDATIONS FOR HOT-GAS AND CRYOGENIC APPLICATIONS

The following seals are recommended in a preferred order:

1. Temperature range 500 to 1000 F:

   a. NATORQ P/N VD261-0123 - XXXX (silver plated)

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

2. Temperature range -423 to 500 F:

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

   b. NATORQ P/N VD261-0123 - XXXX

3. All service bulkhead application:

   a. NATORQ VD261-0006 - XXXX

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

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

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

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

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 Figure 6.6.

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.

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

Figure 6.6. Increased Torque Values for Boss Seals

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 noncaptivating seal cavity will allow the initial seal preloading to relax.

O-RINGS

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 6-7. 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 eleents comprise an O-ring seal. The flight tight seal is accomplished by the O-ring deforming into the leak path.

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 presssure 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.

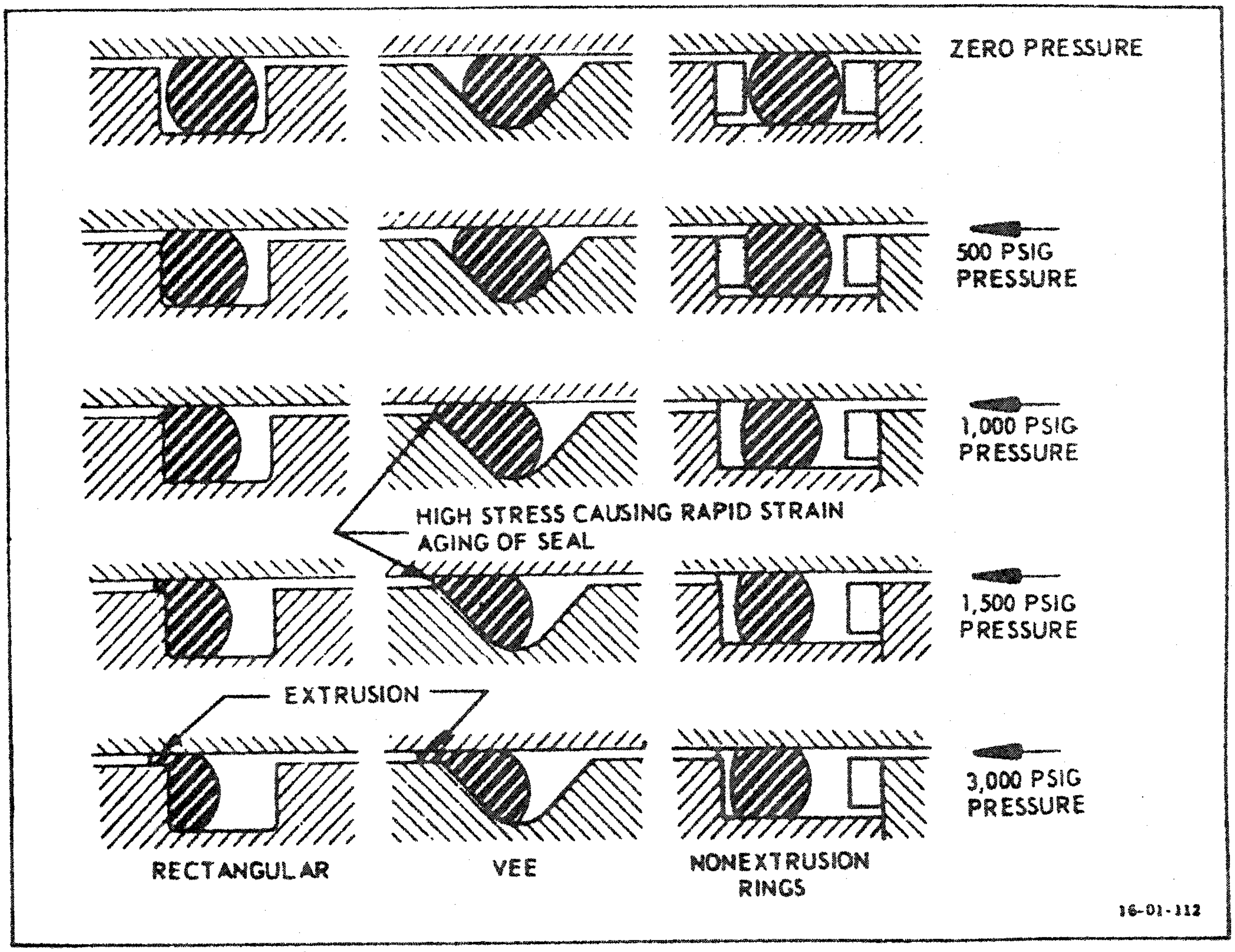


Figure 6.7. O-Ring Extrusion

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. See Appendix A.

STANDARDIZED 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 reidentified 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	MS28775	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		

Parker Compound	Former Specification		
B318	RD262-4007-XXXX RD262-4012-XXXX	B496-70 SR613-75	B591-8
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	AN6227B Size	Parker Size
1	2-006	23	2-218	45	2-342	66	2-439
2	2-007	14	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
6	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	64	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

AN6230B Size	Parker Size	AN6230B Size	Parker Size	AN6230B Size	Parker Size	AN6230B 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
6	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 1500-3000 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 6.7, 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 1500 to 3000 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 1500 to 3000 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. (See page 3-30.)

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 3000 psi, the installation required an AN6289 nut and AN6291 leather rings.

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

Ethylene Propylene	Purple	Neoprene	Red
Fluorocarbon	Brown	Nitrile	Black
Fluorosilicone	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 Figure 6.8.)

PART NUMBER (1)	PART NUMBER (2)	MATERIAL	HARDNESS, SHORE A	TEMPERATURE RANGE, F	PROCUREMENT DOCUMENT	USAGE
MS9021	MS9020	BUNA N	65	65 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	MS29512	BUNA N	70	-60 TO 200	MIL-P-5315	HYDROCARBON FUELS
MS29561	NAS617	BUNA N	70	65 TO 225	MIL-R-7362, 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	BUTYL	70	-65 TO 165	SID130RB0077	SHORT TERM EXPOSURE TO NTO AND HYDRAZINE TYPE FUELS
RD262-4016		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.

Figure 6.8. O-Ring Properties by Part Number

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 6.9.) See Appendix A for compatibility.

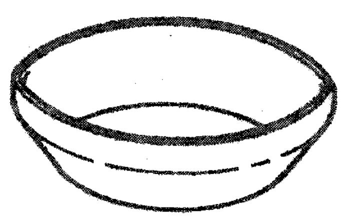


Figure 6.9. Typical Conical Seal

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.

PACKAGING

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.

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 (Figure 6.10). 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.

SELECTION OF CUSHION WRAP MATERIALS
(Minimum Thickness, Inches)

Part Weight, lbs	Polyurethane Foam	Polyethylene 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 thicknesses may be combined to obtain the required thickness.

Figure 6.10. Selection of Cushioning Wrap Materials

SECTION 7

LIQUID PROPELLANTS, PRESSURANTS AND SOLVENTS

CONTENTS

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. See the appendix also.

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

LIQUID PROPELLANT DEFINITIONS

Ambient

Condition of surrounding area. Thus ambient temperature or pressure is the prevailing temperature or pressure surrounding the object in question, usually room condition.

Anhydrous

Free of water.

Atmosphere

A unit of pressure equal to 14.7 psi 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 liquified without regard to the pressure applied.

Cryogenic Temperature

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 or 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 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. The majority of 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.

Oxidizers (or Oxidizing Agents

A chemical that will actively support combustion or oxidation of a fuel.

Padding (or Blanketing)

Filling the void or ullage of a closed container with an inert gas (usually nitrogen) to prevent oxidiation 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 or a 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.

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 fits 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 a 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.

Specific Gravity-Vapor

Is the relative density of a vapor as compared with the density of air which is taken as 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.

	COLOR		ODOR	TOPIC THRESHOLD LIMIT VALUE	TOXIC	IRRITANT	ASPHYSIATING	FLAMMABLE RANGE	SUPPORTS COMBUSTION	CORROSIVE	ODOR THRESHOLD	COMMENTS
	LIQUID	VAPOR										
MMH	COLORLESS	INVISIBLE	AMMONIA	0-2 PPM	YES	YES	NO	25-98%	NC	NO	0-5 PPM LEVEL	TOXIC AT EXTREMELY LOW
NTC	BROWN	BROWN	PUNGENT	5 PPM	YES	YES	NO	NON-FLAMMABLE	YES	YES	0-5 PPM AS MMH	HYPERGOLIC WITH FUEL SUCH
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 MOIS-TURE IN AIR. AVOID DRAW-ING OR WALKING THROUGH IT.
F_2	YELLOW	BROWNISH	PUNGENT	[illegible] PPM	YES	YES	NO	NON-FLAMMABLE	YES	YES	PPG	THE MOST REACTIVE ELEMENT
CTF	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 ACE 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

Figure 7.1. Liquid Propellant, Pressurant, and Solvent Data

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 percent Nickel) ** Stainless Steel 18-8 Copper Brass Bronze Copper-Silicon alloys Monel Aluminum Shredded Lead	Teflon Kel-F Cotton-free Asbestos Graphite (Selected types)	*
Fluorine and 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.

**9 percent nickel limited to -320° F (LN_2)

Figure 7.2. Compatible Materials (Sheet 1 of 4)

STORABLE OXIDIZERS			
Service	Metals	Nonmetals	Lubricants
Nitrogen Tetroxide	Carbon Steels Aluminum Stainless Steel Nickel Inconel	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	Kel-F Teflon Polyethylene	*
Chlorine Trifluoride	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 the appropriate process specification and/or specification drawing.

Figure 7.2. Compatible Materials (Sheet 2 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 300 series	Teflon Kel-F Butyl Rubber JM-76	*
Hydyne	Stainless Steels 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 the appropriate process specification and/or specification drawing.

Figure 7.2. Compatible Materials (Sheet 3 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 Fluorosilicone rubbers Fluoroflex "T" Glass Viton "A" & "B" Dry Asbestos Garlock 230 Carbon	*
Triethylaluminum Triethylboron Triethylaluminum-boron	Stainless Steel Copper Iron	Glass Teflon Kel-F	*
SOLVENTS			
Service	Metals	Nonmetals	Lubricants
Acetone Freons Trichloroethylene	Stainless Steel 300 series Nickel Steel	Teflon Kel-F Polyethylene	*

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

Figure 7.2. Compatible Materials (Sheet 4 of 4)

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						
NTO	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 Alc	Hard Hat	Face Shield (a)	Work Clothes	Vinyl-Coated	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.

Figure 7.3. Safety Clothing Data (Sheet 1 of 2)

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
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.
(d) Required when MAC value is exceeded.
(f) Impregnated asbestos open-back jacket or apron.

Figure 7.3. Safety Clothing Data (Sheet 2 of 2)

FIRST AID TREATMENT

ALL MATERIALS

CRYOGENS, STORABLE OXIDIZERS, STORABLE FUELS, PYROPHORIC FUELS, AND SOLVENTS

SKIN CONTACT:

Flush with large quantities of water for purposes of dilution, warming the affected area in the case of cryogens, cooling the affected area in the case of pyrophoric fuels, and generally washing the area off to remove the material.

EYE CONTACT:

Hold the eyes open and flush with water to wash the liquid out for a minimum period of 15 minutes.

INHALATION:

Remove the person from the contaminated area. Do not allow the person to walk; carry him.

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					
He	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

(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 toxic effluent by controlled reaction.
(b) CO_2 is not as effective as water because of the high temperatures involved.

Figure 7.4. Fire Control Methods (Sheet 1 of 2)

Propellants and Solvents	FIRE CONTROL METHOD					
	Water Cooling and Dilution			Suffocation Method		
	Stream	Spray	Fog	CO_2	Dry Chemical	Foam
Storable Oxidizers						
NTO	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 Alc	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(j)					
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 toxic effluent by controlled reaction.
(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 nonflammable.

Figure 7.4. Fire Control Methods (Sheet 2 of 2)

INGESTION:

Summon medical help.

BREATHING STOPS:

Apply artificial respiration or mouth-to-mouth resuscitation.

In all cases when a person requires First Aid--summon medical help.

SECTION 8

RIGGING

CONTENTS

RIGGING

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.

ESTIMATION OF SAFE LOADS

It is often necessary to make quick estimatations of the load capacity of equipment used in rigging operations. The Figure 8.1 presents methods for quickly determining the safe load capacity of commonly used rigging.

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.

Figure 8.1. Estimation of Safe Loads

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 matrial 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 Figure 8.2). 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.

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

Figure 8.2. Weights of Materials

Steel 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.

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 8.3 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.

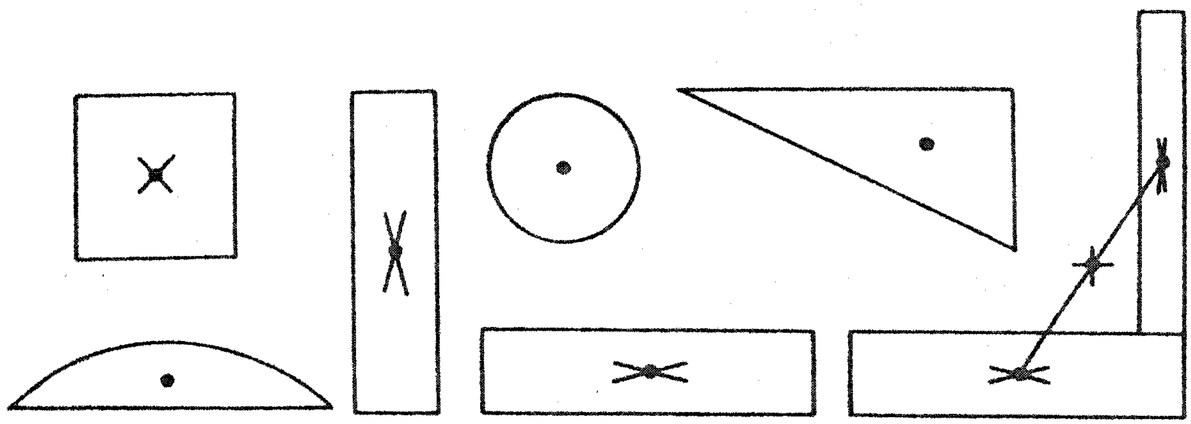


Figure 8.3. Approximating the Location of the Center of Gravity of Plane Figures

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 8.4). 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.
Figure 8.4. Locating Center of Gravity

FLOW STEEL WIRE ROPE

Flow 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 8.6) and for all rough uses requiring maximum strength and toughness. See Figure 8.5 for safe loads.

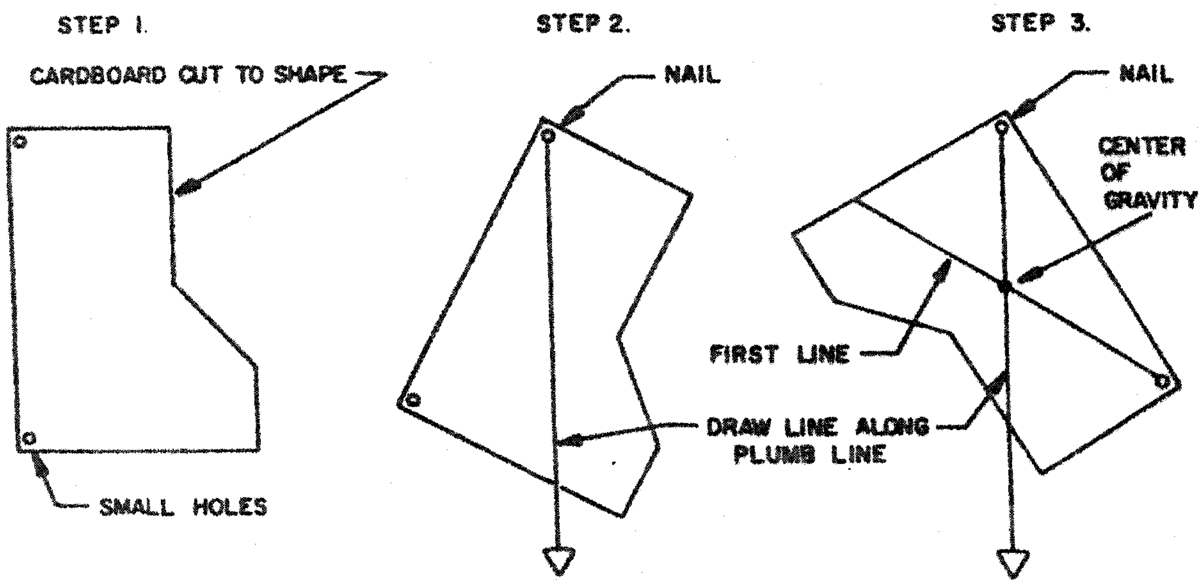


Figure 8.4. Locating Center of Gravity

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

Figure 8.5. Safe Load in Pounds for Plo Steel Hoisting Rope (Six Strands of Nineteen Wires, Hemp Center)

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 8.7). If tension is applied to the rope when loops exist in it, sharp kinks (Figure 8.8) will form resulting in "unlaying" of the rope (Figure 8.9). 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.

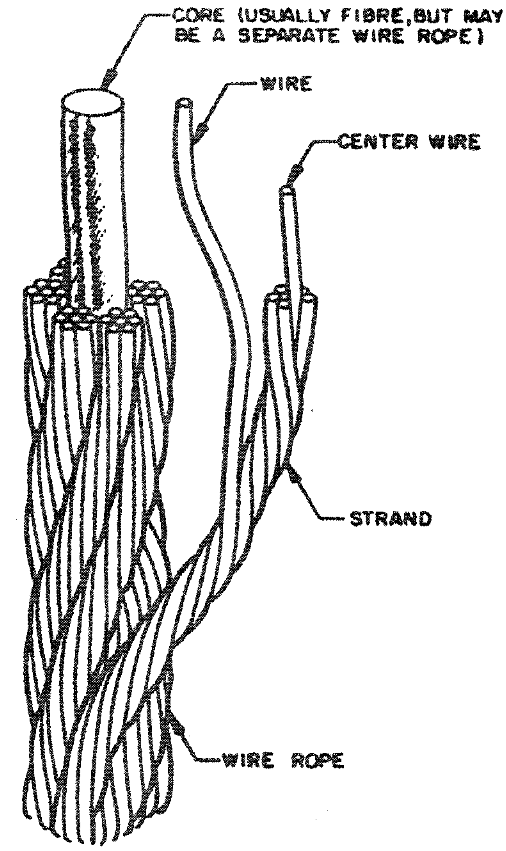


Figure 8.6. Plow Steel Wire Rope

Figure 8.7. Small Loop

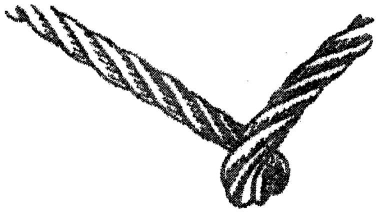


Figure 8.8. Sharp Kink

Figure 8.9. Unlaying

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.

COMMON CAUSES OF WIRE ROPE FAILURES

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 inaa slack rope before applying tension

CHAINS

The safe load limits of chain can be obtained from Figure 8.10 and Figure 8.12. 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 8.11). Useful chain life can be extended by prevention of overloads, protection from rust and by protecting the chain from sharp corners or abrasive applications.

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

Figure 8.10. Table of Safe Loads for Standard Carbon Steel Chain

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

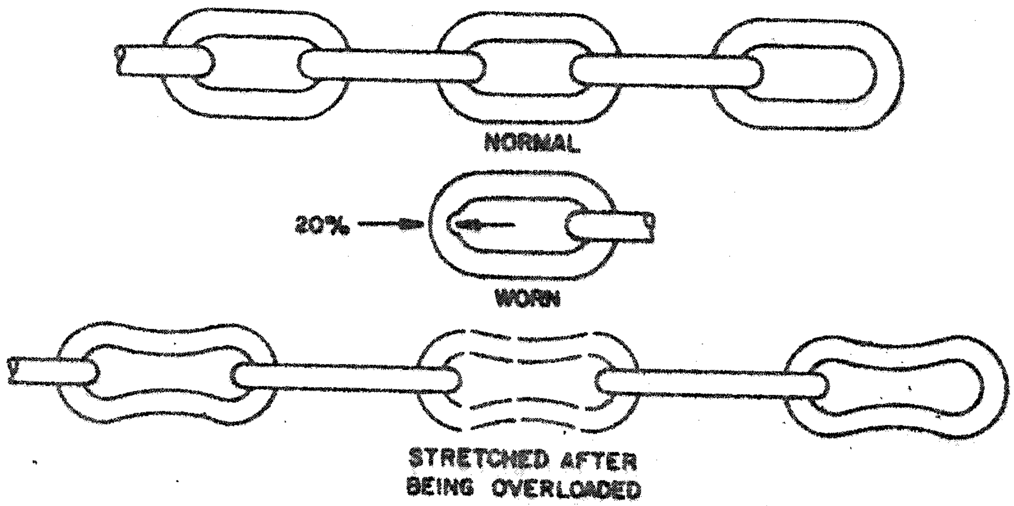


Figure 8.11. Detecting Chain Stretching

Size, Inch	Vertical Load	Loads are Given for Each Leg			Choker Hitch Vertical Load	Basket Hitch Vertical Load
		60° Angle	45° Angle	30° 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 8.12. Safe Loads in Pounds for Alloy Steel Chains

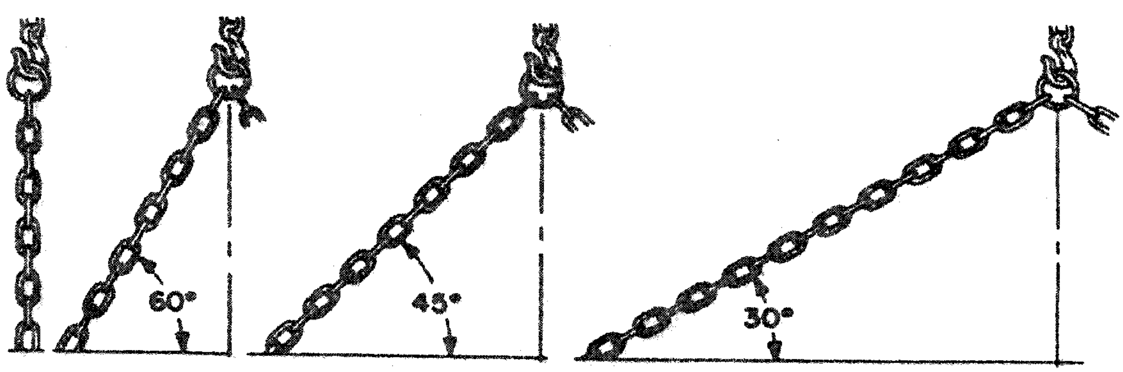


Figure 8.13. Chain Angles

MANILA ROPE

Manila rope requires caution in its use because of the difficulty encountered in determining its condition and because of its lower resistnce 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 Figure 8.14.

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

Figure 8.14. Manila Rope Data
(Based on US Spec. T-R-601)

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 8.15 illustrates various knots and their effect upon the strength of lines follows. It should be used in conjunction with the Manila Rope Data, Figure 8.14.

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

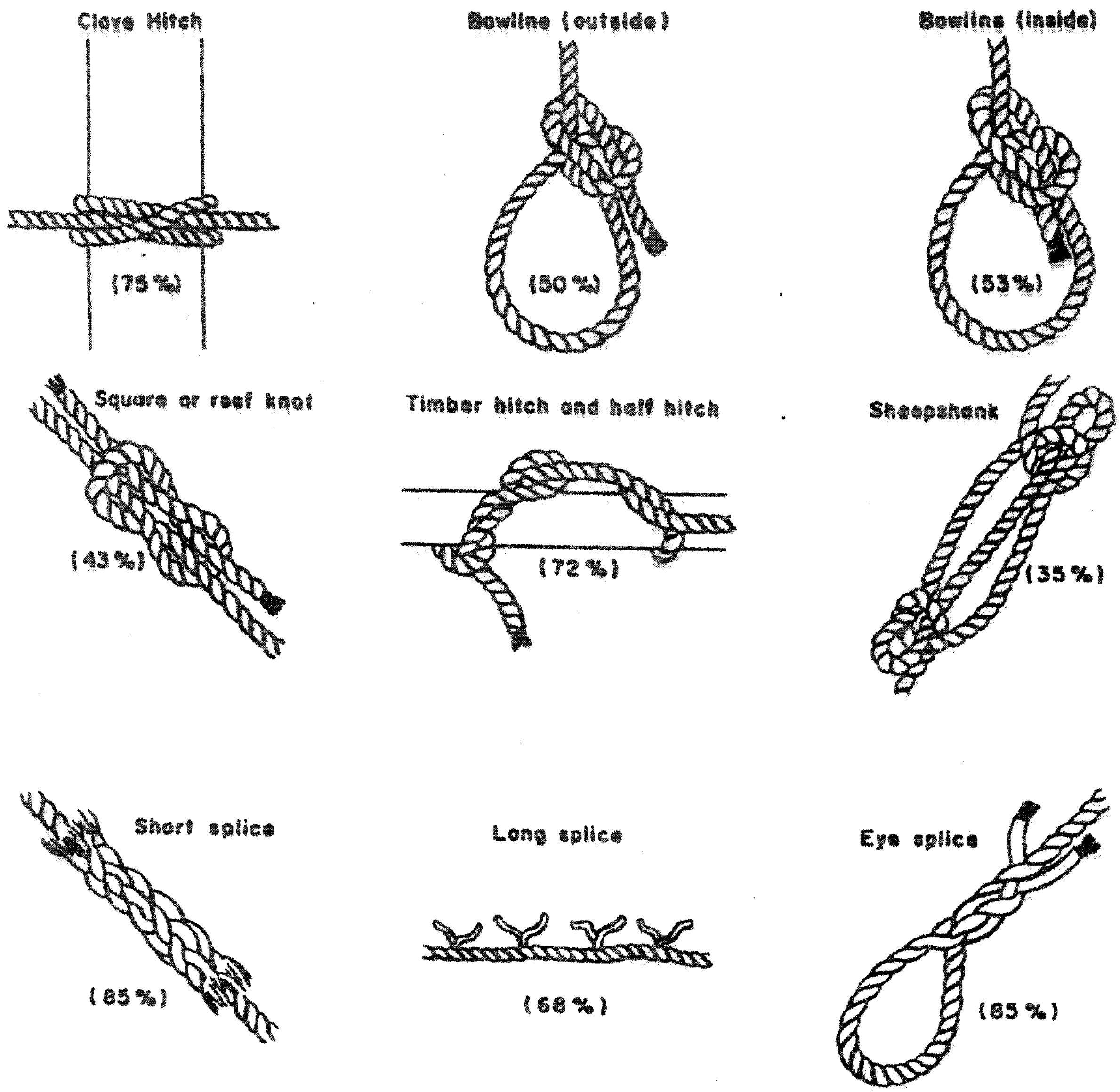


Figure 8.15. Knot Strength of Manila Rope

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 page 8.).

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 Figure 8.18, 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 either the formula or the table on next page.

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.

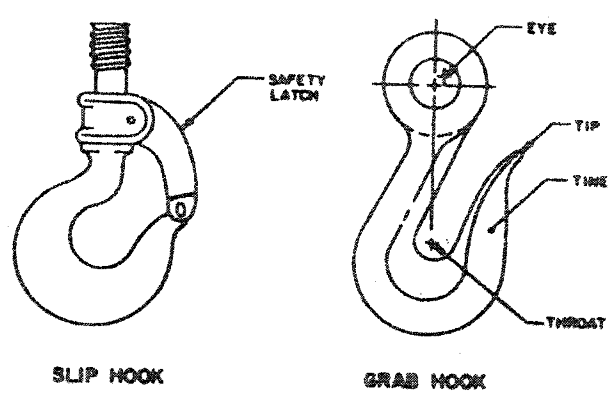


Figure 8.16. Hook Types

The safe working capacity (SWC) of a hook can be 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 = A^2 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 Figure 8.18.

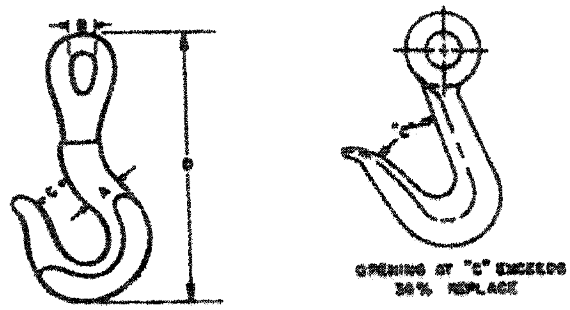


Figure 8.17. Hook Dimensions

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

Figure 8.18. Hoisting Hook Dimensions and Safe Loads

SLINGS

There are many types of slings in use, some of which are illustrated (see Figure 8.19). 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.

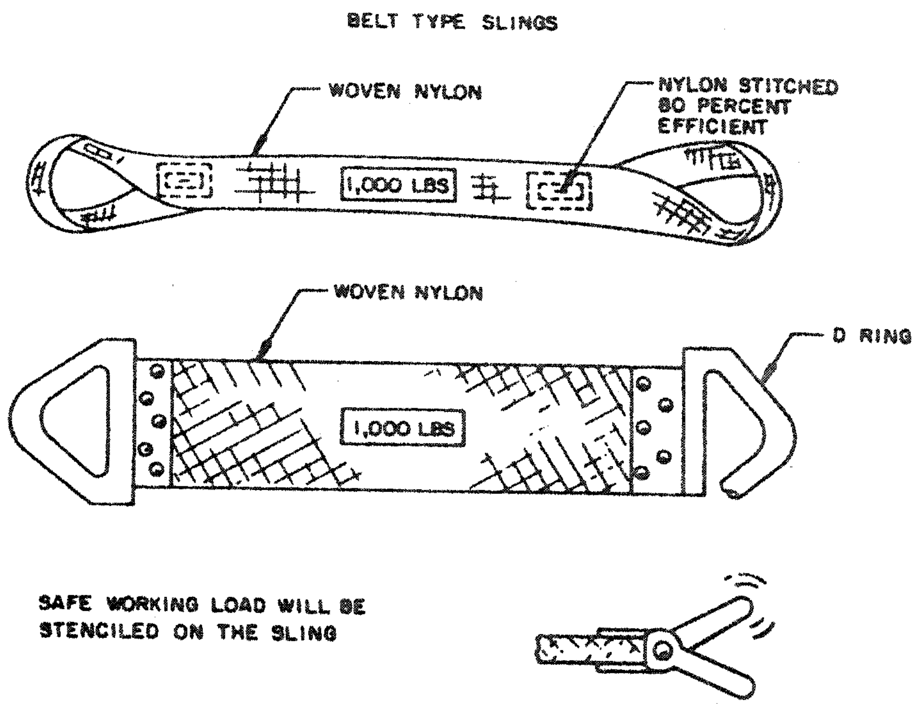


Figure 8.19. Belt Type Slings

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.

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 thgat 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 8.20 for correct attachment).

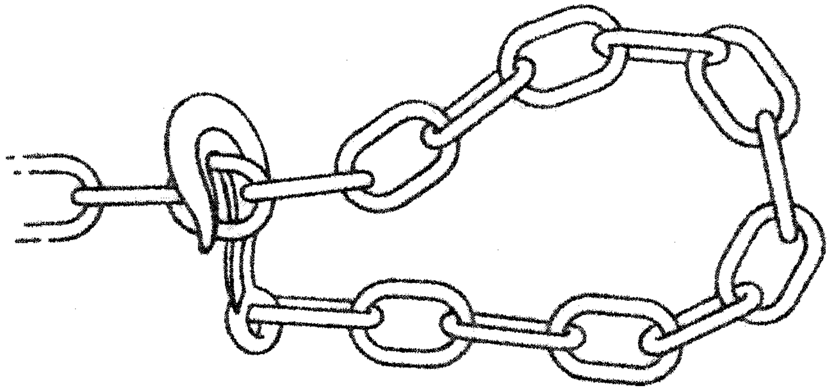


Figure 8.20. Chain Slings

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 becoming 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.

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 excesss 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. Figures 8.22 and 8.23 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)

Safe Working Load, Weight in Pounds

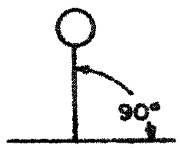
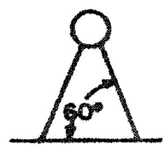
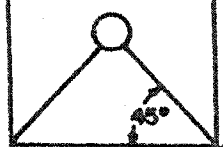
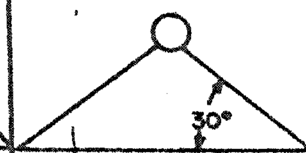
Size Diameter Inch	Single Wire Rope Sling Vertical Lift  Load Angle	Sling or Two Wire Ropes - Used at 60-Degree Angle  Load Angle	Sling or Two Wire Ropes - Used at 45-Degree Angle  Load Angle	Sling or Two Wire Ropes - Used at 30-Degree Angle  Load Angle
3/8	2,500	4,300	3,600	2,500
1/2	4,300	7,400	5,800	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 8.21. Wire Rope Sling Safe Working Loads

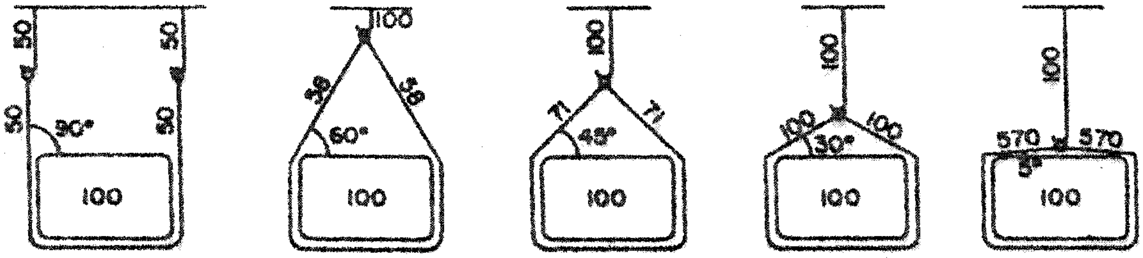


Figure 8.22. Effect of Sling Angle on Sling Tension

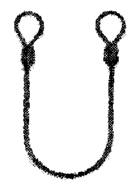
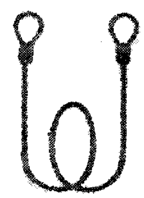
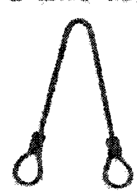
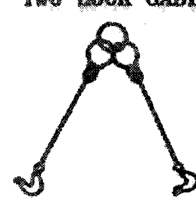
75% FULL LOAD RATING	100% FULL LOAD RATING	200% FULL LOAD RATING
CHOKER HITCH 	SINGLE CABLE HITCH 	BASKET HITCH 
	DOUBLE CHOKER HITCH 	DOUBLE WRAP 
		2 ENDS DOWN 
		TWO HOOK CABLE 

Figure 8.23. Commonly Used Hitches and Approximate Load Carrying Capacity of Hitches

LIFTING ACCESSORIES

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 8.24 and 8.25 for details.)

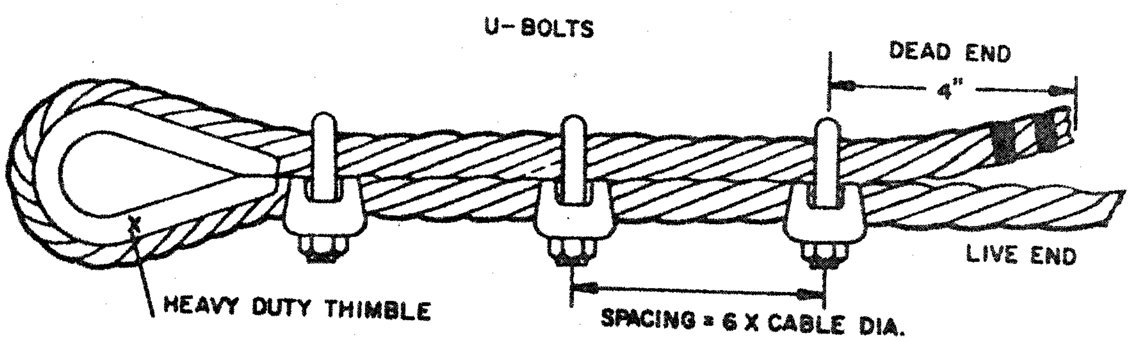


Figure 8.24. Installation of Crosby Clips

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

Figure 8.25. Number of Clips and Distance Between Clips for Safety

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 Figures 8.26 and 8.27.

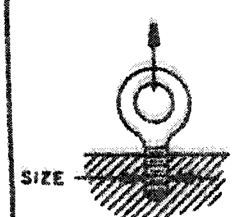
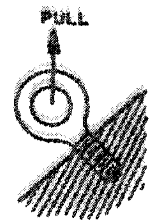
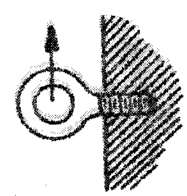
Size, Inch			
1/4	250	40	30
1/2	1,100	50	40
5/8	1,800	90	65
3/4	2,800	135	100
7/8	3,900	210	150
1	5,100	280	210
1-1/4	8,400	500	370
1-1/2	12,200	770	575
1-3/4	16,500	1,080	800
2	21,800	1,440	1,140

Figure 8.26. Ordinary Drop Forged Steel Eye Bolts Recommended Working Load, Pound

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.

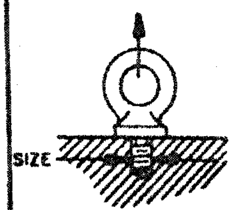
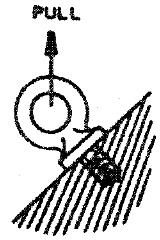
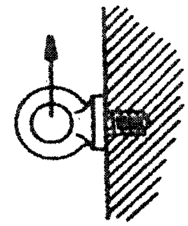
Size, Inch			
1/4	300	30	40
1/2	1,300	140	150
3/4	3,000	250	300
1	6,000	500	600
1-1/4	9,000	800	900
1-1/2	13,000	1,200	1,300
2	23,000	2,100	2,300
2-1/4	37,000	3,800	4,300

Figure 8.27. Drop Forged Steel Shoulder-Type Eye Bolts Recommended Working Load, Pound

Some Do's and Dont's 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 asembly) by the Maintenance Department and one should calculate the approximate safe working load by using the formula (SWL = D^2 x 6) prior to selection and use of the shackle (see Figure 8.28).

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.

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 8.29.)

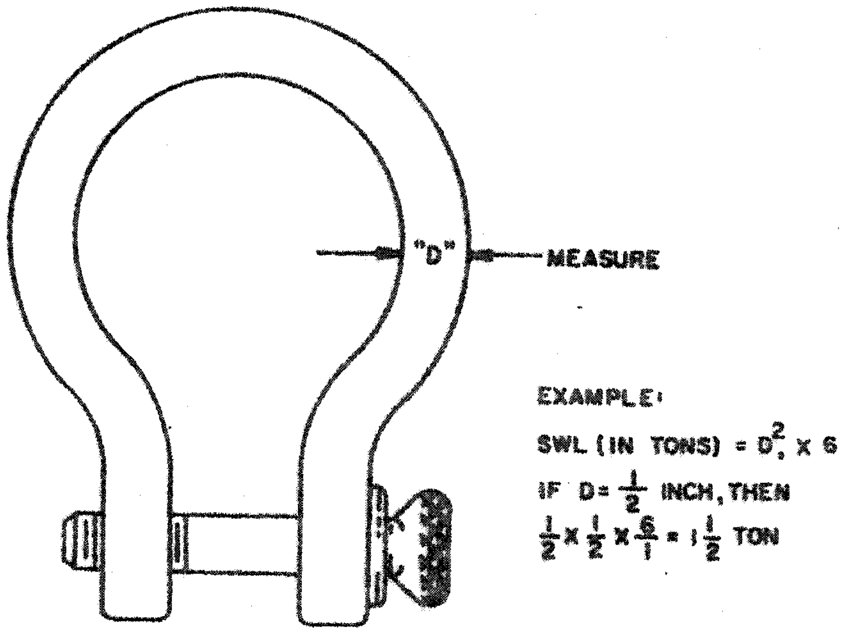


Figure 8.28. Shackle Safe Working Load

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 ton. 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.

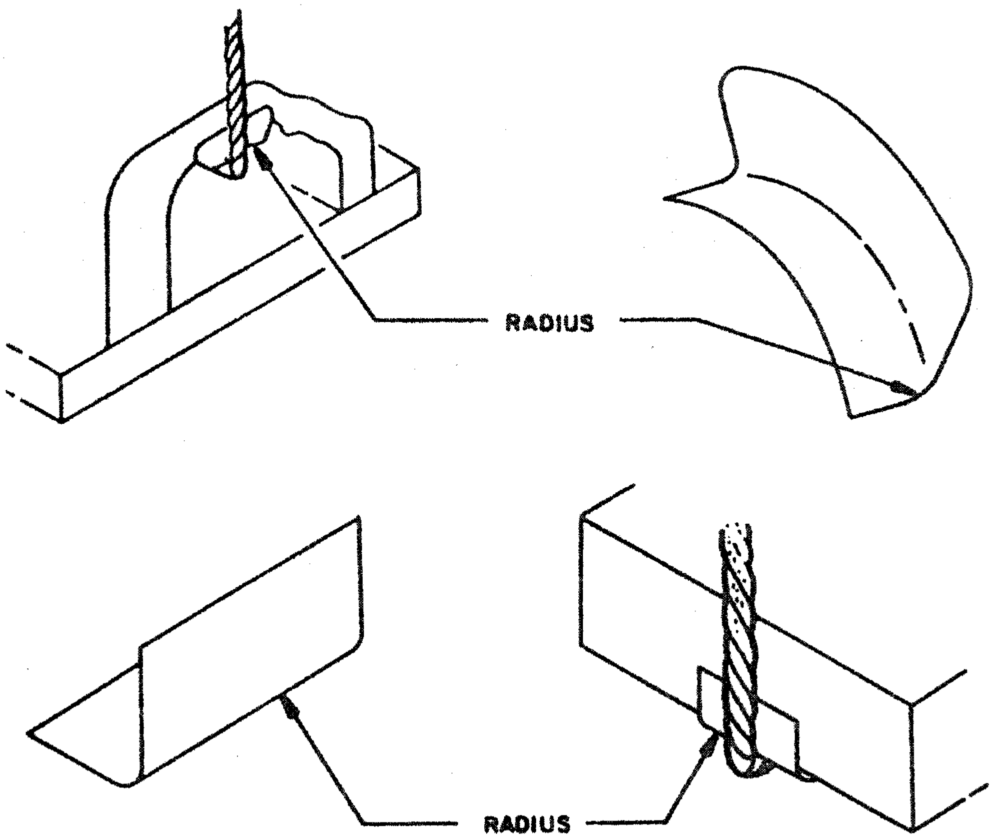


Figure 8.29. Cable Guards

Inspect the top and bottom 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 8.30 and 8.31.)

<u>With Load</u>

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.

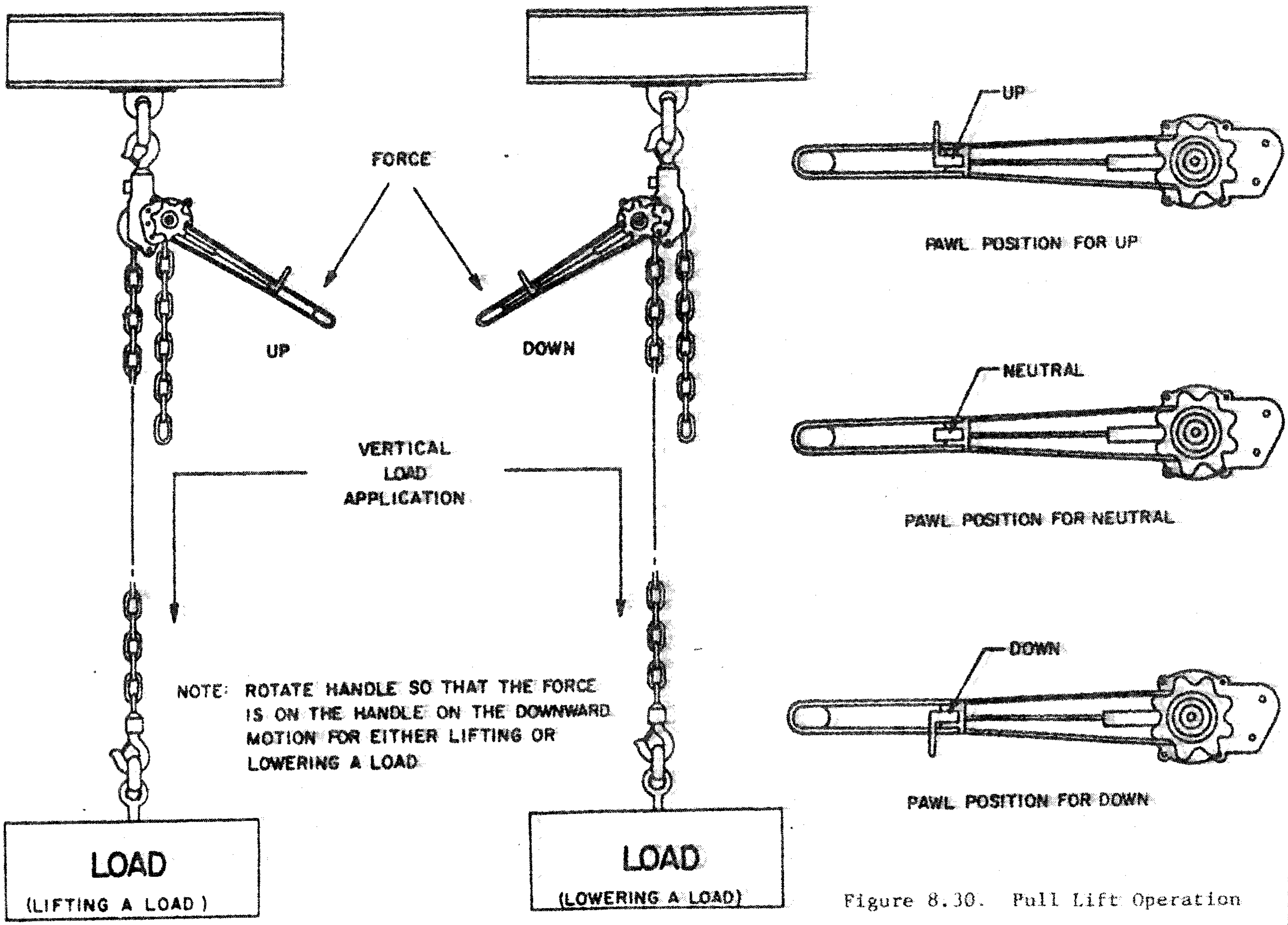


Figure 8.30. Pull Lift Operation

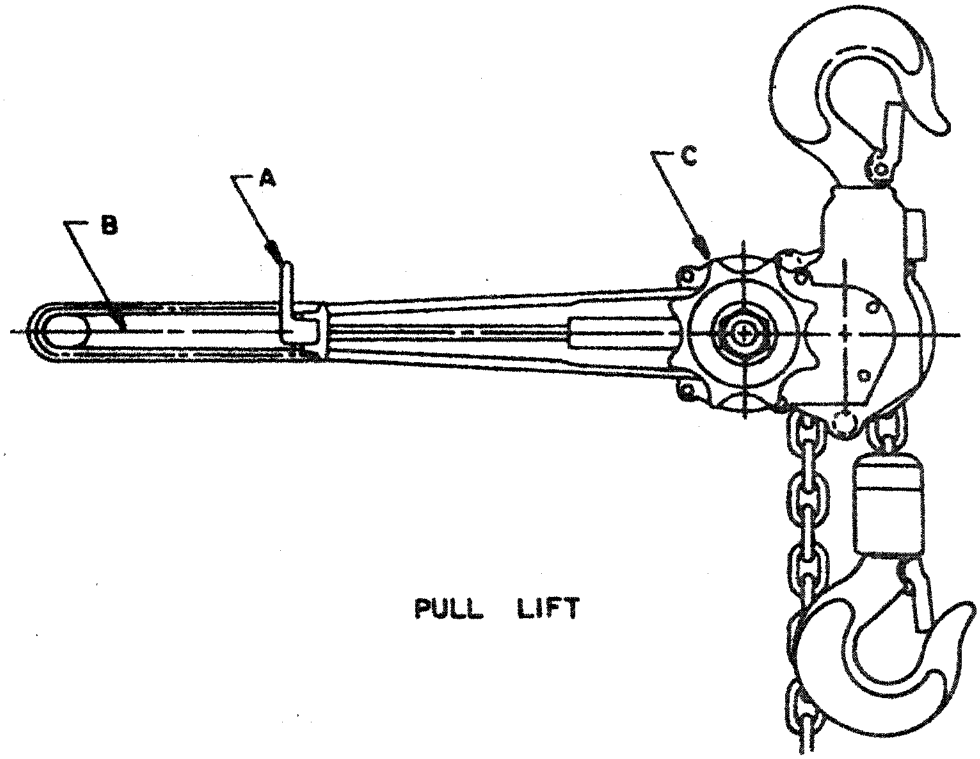


Figure 8.31. Checking Pull Lift Load Brake

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.

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.

Checking 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.

Never Use a "Cheater" on the Handle

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.

ADDITIONAL RIGGING EQUIPMENT

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.

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.

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.

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.

FORK LIFTS

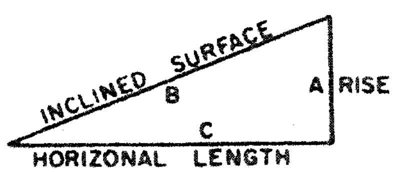
The use of fork lifts is limited to those who have been granted operator's licenses by the Safety Department. These are granted only after a demonstration of ability to handle the equipment.

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.

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.



$$M.A. = \frac{B}{A}$$

$$GRADE\ (\%) = \frac{100A}{C}$$

Figure 8.32. Inclined Plane

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.

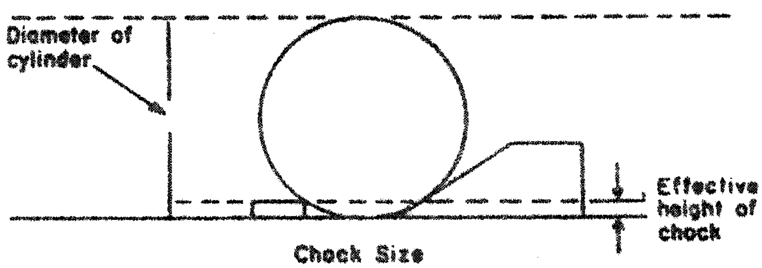


Figure 8.33. Chock Size

HAND SIGNALS

Hand signals are used in winch and crane operation because of the distances and 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 8.34 and 8.35 illustrate commonly accepted hand signals for crane and winch operation.

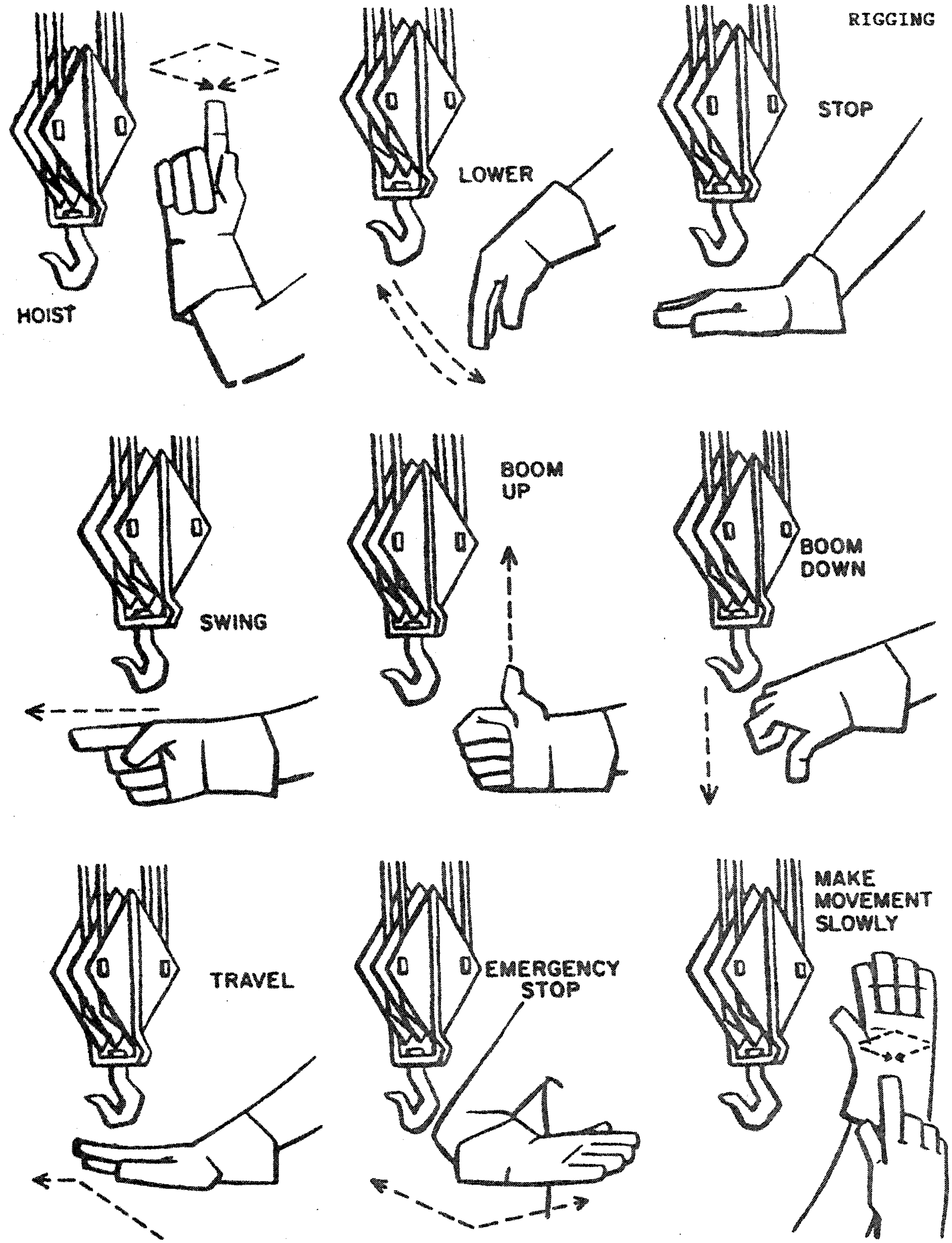


Figure 8.34. Hand Signals for Crane or Swinging Boom Operation

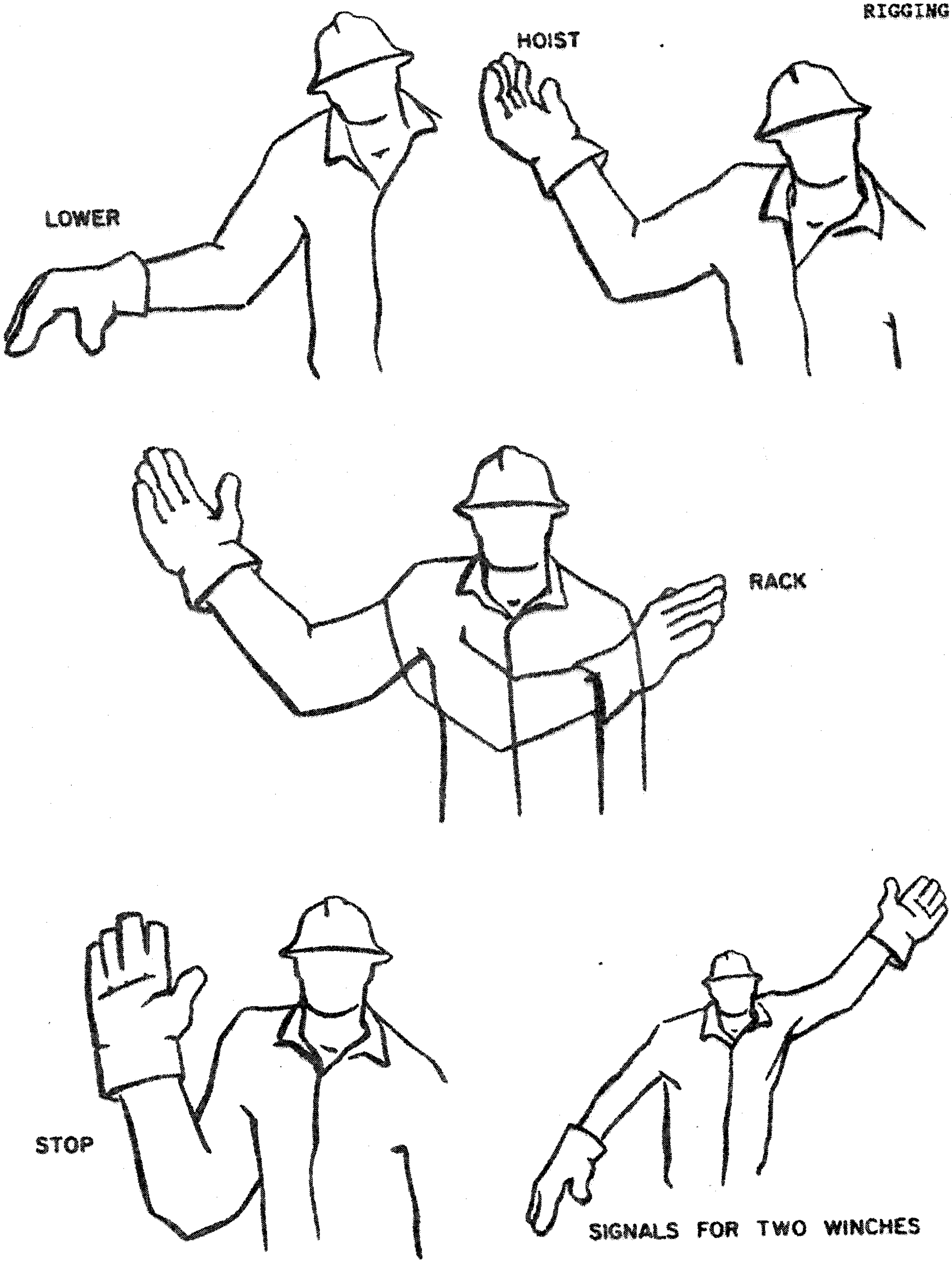
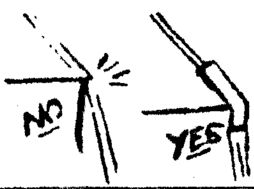


Figure 8.35. Hand Signals for Winch Operation

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!

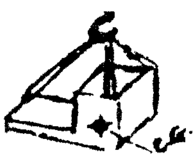
2. CONTROL - Use a hitch that will keep the load under control at all times. A hitch that allows the load to become unbalanced, or to rotate, introduces the possibility of losing control and may cause an accident.



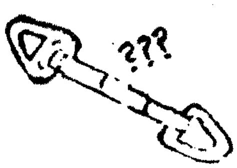
3. PREVENT SLING DAMAGE - It is often said that a rigger is as good as his tools. Take good care of your slings!

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!

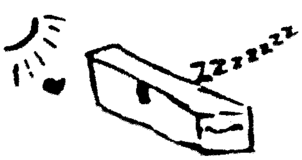


5. KEEP IT BALANCED - Always try to lift the load in a level position, with the crane hook directly over the center of gravity. Careful adjustment of the lengths of the various legs is necessary to do this, but it pays off in excellent control of the load.



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.

SECTION 9

ELECTRICITY

CONTENTS

MAKING ELECTRICAL MEASUREMENTS

The modern hand-held digital multimeter has simplified most electrical measurements. Measurement functions generally found on a multimeter are:

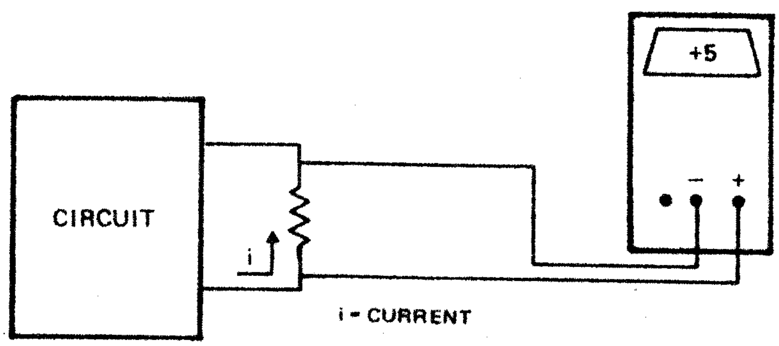
- AC/DC voltage (V)
- AC/DC current (mA)
- Resistance (kΩ) or conductance (nS)

Additional functions of the digital multimeter are:

- Peak detection for positive DC or AC rms level
- Diode junction testing

Voltage Measurement

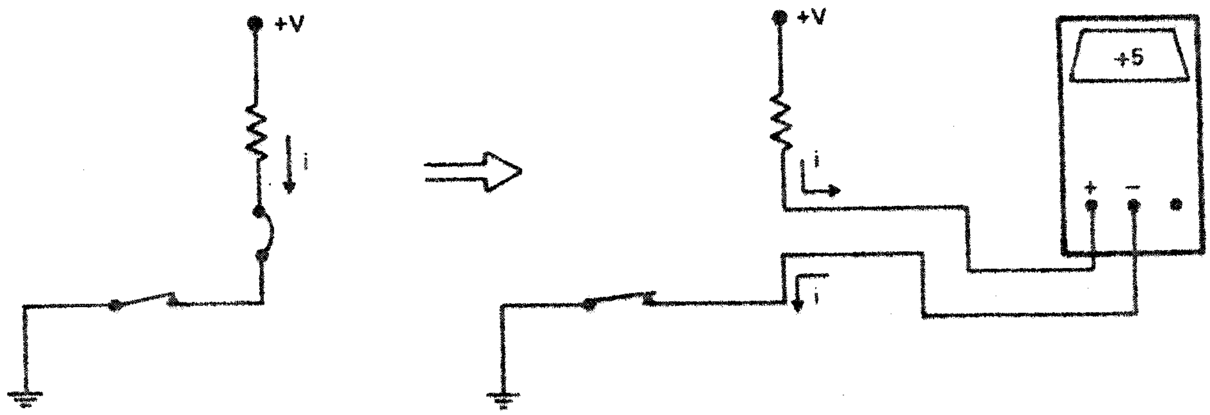
A voltmeter is used to measure the electromotive force (voltage) applied to a circuit or it may be used to measure the drop in voltage caused by a circuit component. The connection of the meter is made in parallel with the measured device.



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.

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 as shown:



CAUTION: Be aware of the ammeter current rating. Measuring current greater than the rated value will blow the internal fuse or damage the meter.

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.

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: $1/\Omega = S$. The connection for measuring conductance is the same as the ohmmeter.

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.

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 0.7VDC. 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.

USE OF THE DIGITAL MULTIMETER (FLUKE MODEL 8024A)

Operating Precautions

The buttons on this hand-held meter are of the push-push type; that is, the buttons are pushed to the right to be turned on and are pushed to the right, the same direction, to be turned off.

Do not operate the meter until the battery cover is in place and fully closed.

Exceeding the maximum input overload limits can damage the instrument. The multimeter has only limited protection for overload signals, so care should be taken in estimating the magnitude of the input.

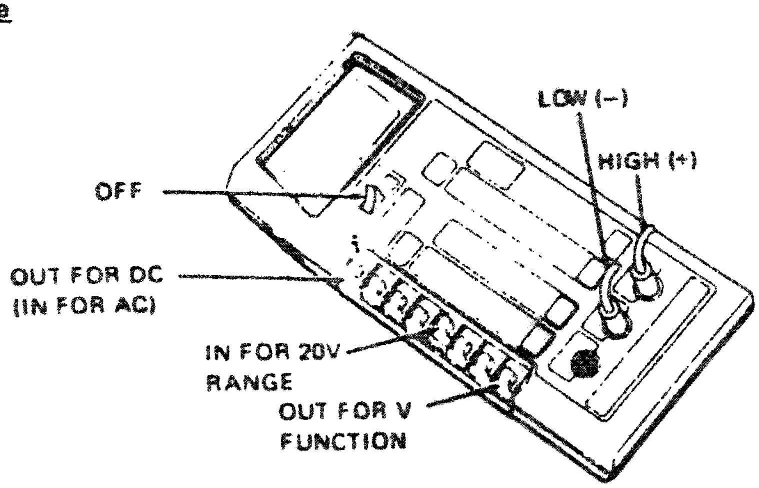
An overrange display is indicated when the input signal being read is greater than the chosen full-scale range. When unsure about the value of the input signal, use the greatest range available and then switch to the lower range, as required.

To avoid electrical shock, battery or fuse replacement should only be performed after the input signal and test leads have been removed from the input terminals and the power switch has been set to off.

All power to the measured circuit should be turned off while using the ohmmeter. The input impedance to the instrument is very low and voltage across the terminals could cause damage.

When using the instrument as a voltmeter (i.e., parallel position), there is a loading down of the circuit from the meter. Usually the effect is negligible, but it should be noted. The input impedance of the FLUKE 8024A multimeter is 10MΩ.

Measuring Voltage



STEPS:

1. Connect the test leads as shown.
2. Depress the switch beside the range desired (20V is shown selected).
3. Set the AC/DC switch out for DC or in for AC (DC is shown selected).
4. Insure that all other switches are at the out or OFF positions.

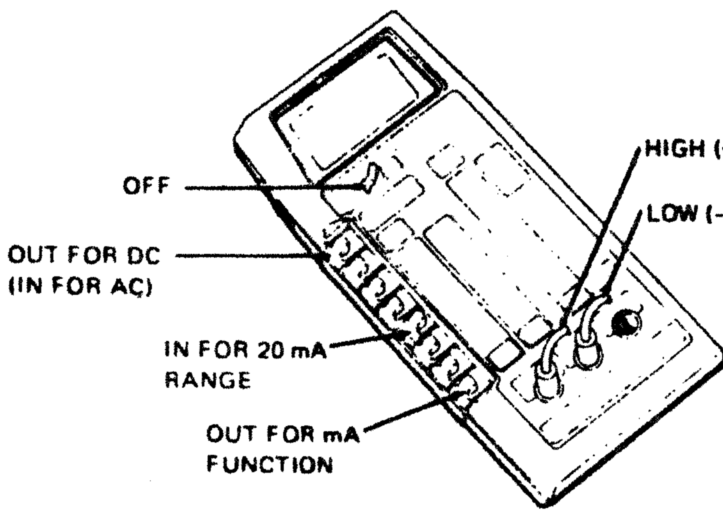
WARNING: To avoid electrical shock and/or instrument damage, do not connect the terminals to sources that exceed the following limits when measuring voltages:

COMMON: 500V DC or AC rms with respect to earth ground.

V-kΩ-nS: 1000V DC or 750V AC rms with respect to the common terminal (in the 200V range, sources greater than 300V DC or AC rms should not be connected longer than 15 seconds).

5. Connect the test leads to the circuit being measured.
6. Read the measured value on the display. The minus sign will appear if the V-kΩ-nS terminal is negative with respect to the common terminal.

Measuring Current



STEPS:

1. Connect the test leads as shown.
2. Depress the switch beside the range desired (20 mA range shown selected).
3. Set the AC/DC switch out for DC or in for AC.
4. Insure than all other switches are at the out or OFF positions.

WARNING: To avoid electrical shock and/or instrument damage, do not connect terminals to sources that exceed the following limits when measuring current:

COMMON: 500V DC or AC rms with respect to earth ground.

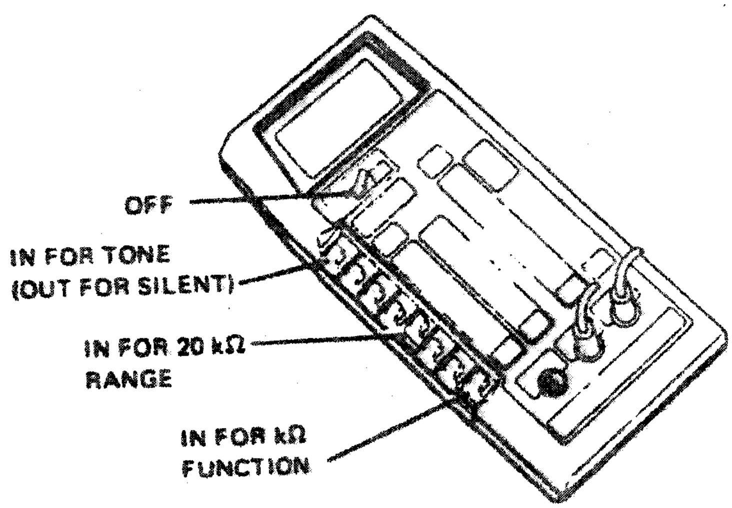
mA-°C: Current of 2 amps or open circuit voltage of 600V DC/AC rms.

5. Connect the test leads to the circuit being measured.

6. Read the measured value on the display. In DC the minus sign will appear if the mA-°C terminal is negative with respect to the COMMON terminal.

CAUTION: Subjecting the instrument to a current draw of more than 2 amps will blow the internal fuse.

<u>Measuring Resistance</u>



WARNING: All power in the circuit must be turned off.

STEPS:

1. Connect the test leads as shown.

2. Depress the mA-°C-V-kΩ-nS switch.

3. Depress the switch beside the range desired (20K is shown selected).

4. Insure that all other switches are at the out or OFF positions.

WARNING: To avoid electrical shock and/or instrument damage, do not connect the terminals to sources that exceed the following limits when measuring resistance or continuity:

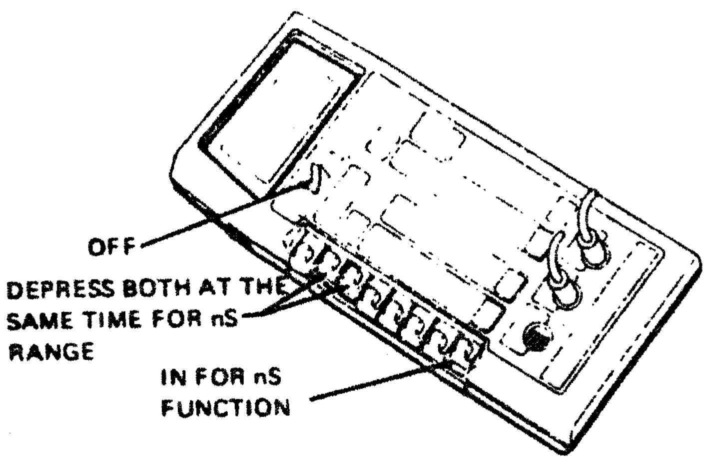
COMMON: 500V DC or AC rms with respect to earth ground.

V-kΩ-nS: 500V DC or AC rms with respect to the common terminal.

5. Connect the test leads across the device being measured.

6. Read the measured value on the display.

Measuring Conductance (Used for measuring resistances above 20 MΩ)



WARNING: All power in the circuit must be turned off.

STEPS:

1. Connect the test leads as shown.

2. Depress the mA-°C-V-kΩ-nS function switch.

3. AT THE SAME TIME, depress both of the nS range switches.

4. Insure that all other switches are at the out or OFF switches.

WARNING: To avoid electrical shock and/or instrument damage, do not connect the terminals to sources that exceed the following limits when measuring conductance:

COMMON: 500V DC or AC rms with respect to earth ground.

V-kΩ-nS: 500V DC or AC rms with respect to the common terminal.

5. Connect the test leads across the device being measured (connect the red test lead to the (+) end of polarized capacitors for leakage measurements).

6. For converting conductance into resistance, use the formula:

$M\Omega x1000 = 1/nS$, where $nS = 10^{-9}$ siemens

Measuring Peak Hold Voltage

STEPS:

1. Set the PEAK HOLD switch to OFF.

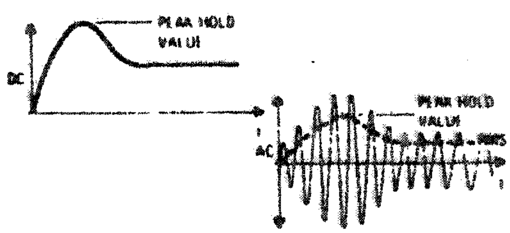
2. Select the DC. V (volts) functions.

3. Insert the red test lead into the V/kΩ/nS input and select the 20V range.

4. Locate the battery eliminator connector on the right side of the unit.

5. Measure the voltage on the side contact (bottom of hole) of the connector (approximately +2.90V).

6. Set the PEAK HOLD switch to ON and momentarily touch the test leads to side contact.



7. The reading should be the same as Step 5, within a few digits.

8. False readings may result if the range or function switches are changed while the PEAK HOLD switch is set to ON. To avoid these errors, reset the circut after each range or function change.

CAUTION: Static electricity and noise pickup may cause errors when using the PEAK HOLD function. While the PEAK HOLD switch is ON, avoid touching the probe tips to fingers or other objects which may contain a static charge.

NOTE: For DC voltage and currents, the peak hold function measures the "most positive" value of the input waveform. If the "most positive" excursion of the waveform is negative with respect to common, a negative sign will be displayed; i.e., when a negative sign is shown, the measured value is not the negative peak, but is the least negative (or most positive) portion of the waveform. It should also be noted that the minimum measurable duration of peak or purge is 150 ms (AC mode), 10 ms (DC mode). Transients in excess of these values may not be detected.

Diode Junction Testing

The ranges of 200k , 20k , and 200 generate an internal voltage too small to overcome the diode cut-in voltage. The ranges of 20M , 200k , and 2k , however, do register a voltage which turn on the PN 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 overrange display. Some devices, such as Light Emitting Diodes (LED's), may not show proper readings due to their high cut-in voltage.

USE OF VOLT OHM MILLIAMMETER (TRIPLETT 630-A)

The Triplett 630-A multimeter is an analog meter capable of measuring voltage, current, and resistance. The multi-scale display is confusing at first, but after some observation, one will see it is divided into five scales used for the three functions. A large knob in the lower center of the panel is used to select all ranges. The markings are self-explanatory.

The jacks marked COM and V-Ω-A located on the bottom right, are used for almost all measurements (COM is negative). The terminals located on the bottom left, are substitutions for the V-Ω-A jack when making measurements of AC and DC voltages between 1200 volts to 6000 volts. To the left of the knob is a recessed ADJ control used when making resistance measurements. The OUTPUT jack is used with the COM terminal to measure the power level (in dB) of amplifiers or telephone work. The dB scale is based on the voltage developed across a 500Ω line when .006 watt is dissipated in the line.

CAUTION: Voltage is generated at the terminals when high resistance scales are used. These values could damage electronic devices, so caution should be taken when touching leads in electronic circuitry.

An operation chart of the Triplett 630-A is shown, displaying the correct terminals to be used after choosing the parameter to be measured.

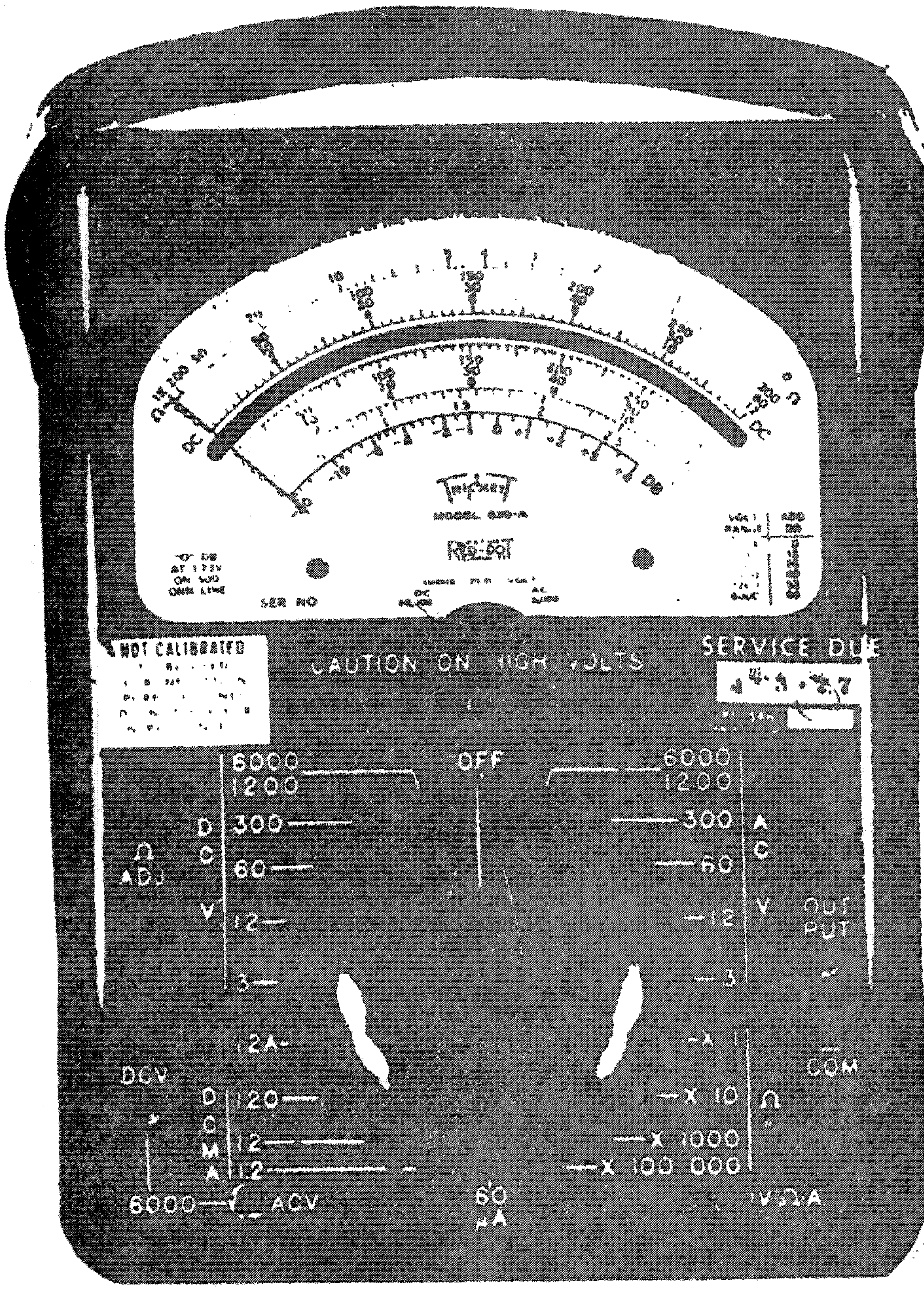


Figure 9-1. Triplett 630-A Volt-Ohm Milliammeter

To measure	Set selector switch to	Plug red* test lead in jack marked	Read on	Each scale div. equals
D-C volts			Black scale	
0-3	3 DCV	V- Ω -A	0-300 DC ÷ 100	0.05 volt
0-12	12 DCV	V- Ω -A	0-12 DC X 1	0.2 volt
0-60	60 DCV	V- Ω -A	0-60 DC X 1	1.0 volt
0-300	300 DCV	V- Ω -A	0-300 DC X 1	5.0 volts
0-1200	1200/6000 DCV	V- Ω -A	0-12 DC X 100	20.0 volts
0-6000	1200/6000 DCV	6000 DCV	0-60 DC X 100	100.0 volts
A-C volts			Red scale	
0-3	3 ACV	V- Ω -A	0-3 AC X 1	0.05 volt
0-12	12 ACV	V- Ω -A	0-12 AC X 1	0.2 volt
0-60	60 ACV	V- Ω -A	0-60 AC X 1	1.0 volt
0-300	300 ACV	V- Ω -A	0-300 AC X 1	5.0 volts
0-1200	1200/6000 ACV	V- Ω -A	0-12 AC X 100	20.0 volts
0-6000	1200.6000 ACV	6000 ACV	0-60 AC X 100	100.0 volts
D-C current			Black scale	
0-60 μa DC	60 μa	V- Ω -A	0-60 DC X 1	1.0 μa
0-1.2 Ma DC	1.2 DCMA	V- Ω -A	0-12 DC - 10	0.02 Ma
0-12 Ma DC	12 DCMA	V- Ω -A	0-12 DC X 1	0.2 Ma
0-120 Ma DC	120 DCMA	V- Ω -A	0-12 DC X 10	2.0 Ma
0-12 AMPS DC	12 AMP	V- Ω -A	0-12 DC X 1	0.2 AMP
Ohms				
0-1000	Ω X 1	V- Ω -A		
0-10,000	Ω X 10	V- Ω -A		
0-1 Meg	Ω X 1000	V- Ω -A		
0-100 Meg	Ω X 100,000	V- Ω -A		
Decibels				
-30 to +4	3 ACV	Output		
-18 to +16	12 ACV	Output		
-4 to +30	60 ACV	Output		
+10 to +44	300 ACV	Output		
+22 to +56	1200/6000 ACV	Output		
+36 to +70	1200/6000 ACV	6000 ACV		

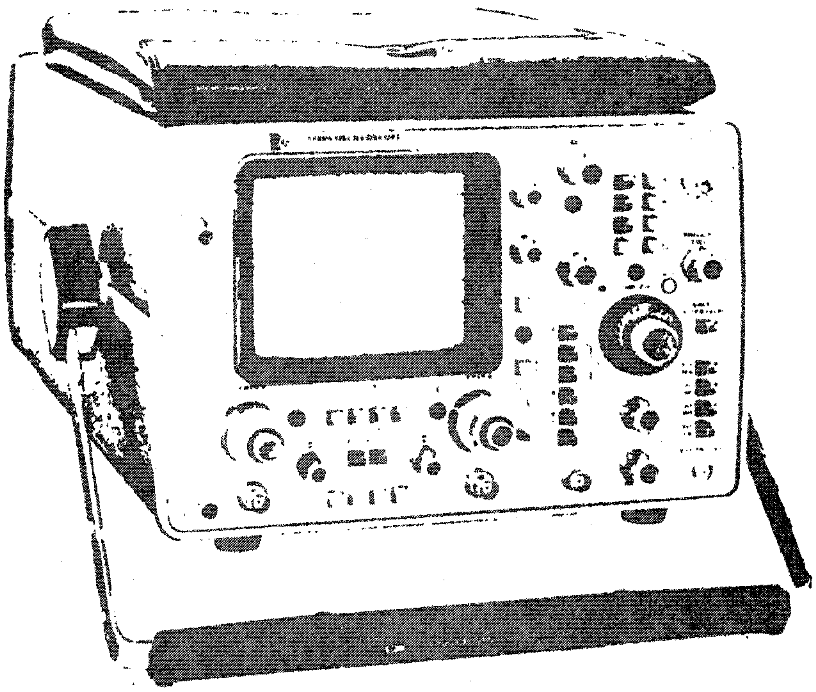
Each scale division equals (in ohms)

Red scale	0-4	4-5	5-10	10-20	20-50	50-200
X1	.1	.2	.5	1	5	50
X10	1	2	5	10	50	500
X1000	100	200	500	1K	5K	50K
X100,000	10K	20K	50K	100K	500K	5 Meg

*Black test lead plugged in COM jack for all measurements

Figure 9-2. Triplett 630-A Volt Ohm Milliammeter Operation Chart

USE OF THE 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.

Oscilloscope Operations

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.

Basic Features of the Oscilloscope

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.

BEAM INTENSITY - Controls the brightness of the CRT display.

FOCUS - Adjusts the writing beam for the sharpest trace. Always keep this display focused to prevent damaging the CRT internally.

CHANNEL A (CHA) - Displays the Channel A input signal.

CHANNEL B (CHB) - Displays the Channel B input signal.

A&B - This feature displays the algebraic sum of the Channel A and Channel B input signals.

ALTERNATE (ALT) - Channel A and B signals (if the oscilloscope has a dual-channel feature) are displayed alternately on consecutive sweeps.

CHOP - Channels A and B signals are displayed simultaneously by switching between channels at a given rate.

TRIGGER A - Selects a sample of the Channel A signal as a trigger signal.

TRIGGER B - Selects a sample of the Channel B signal as a trigger signal.

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.

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.

DC - All elements of the input signal (ac and dc) are passed to the vertical amplifier.

VOLTS/DIVISION - Selects the vertical deflection factor in an organized sequence, usually from 0.005V/div to 20V/div.

TIME/DIVISION - This feature controls the main-sweep rate.

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.

TRIGGER LEVEL - Selects the voltage level on the input trigger signal where the sweep is triggered.

EXTERNAL TRIGGER - This is the connection for an external trigger input. This button is normally not used.

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 micromicrofarads (μμfd). 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 (Figure 9-3) 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 9-4 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.

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

Figure 9-3. RETMA Color Code for Resistors and Capacitors

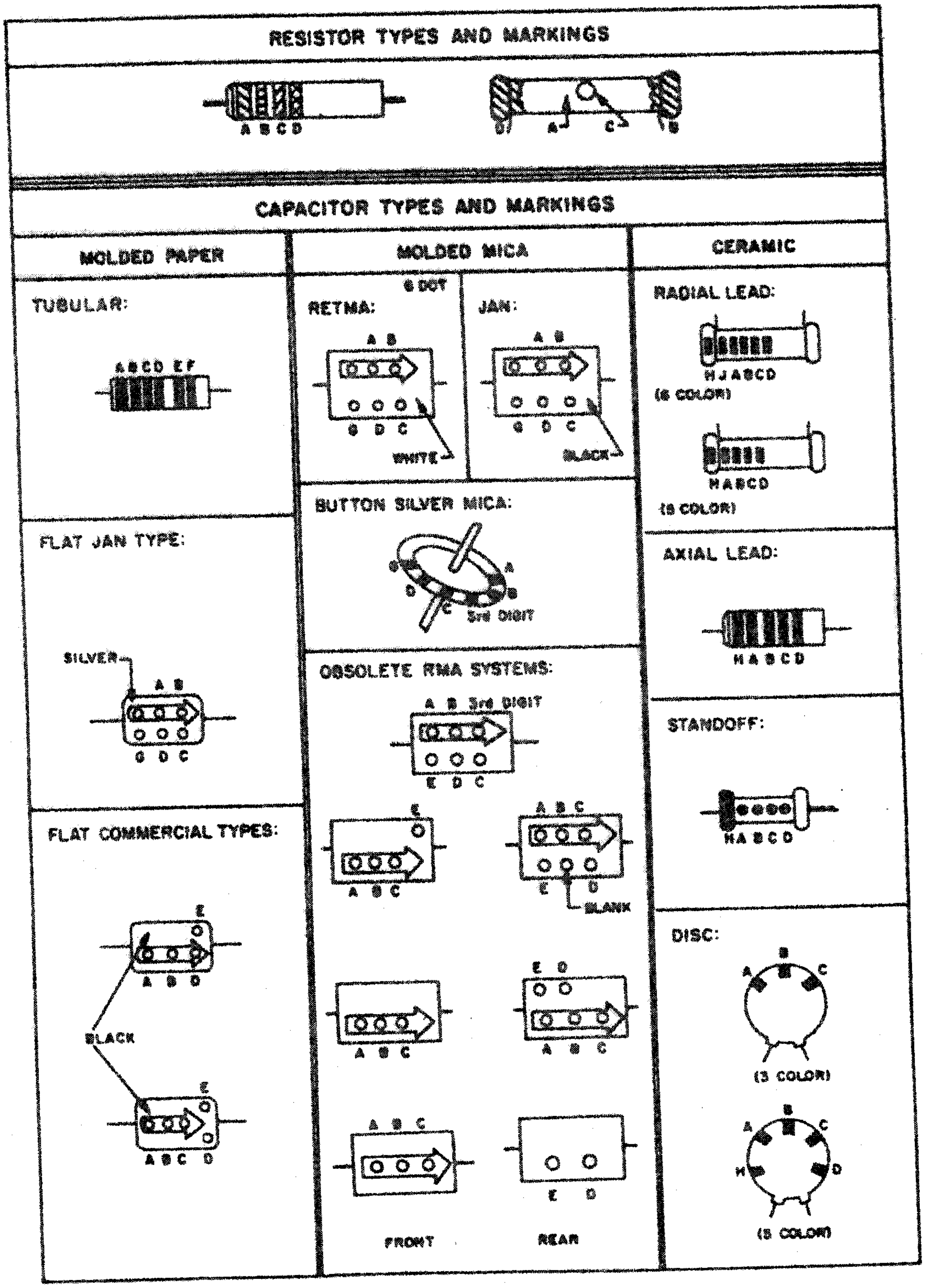


Figure 9-4. Table of Resistors and Capacitors

SOLDERING ELECTRICAL CONNECTIONS

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. Rosen 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 9-5 for proper application of solder to contact pins.

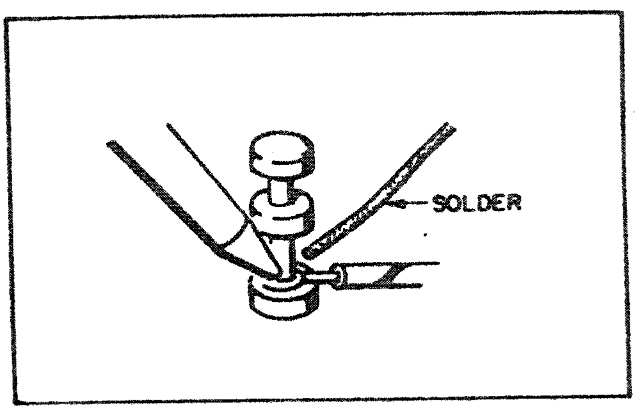


Figure 9-5. Method of Applying Solder to Contact Pins

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 enought 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.

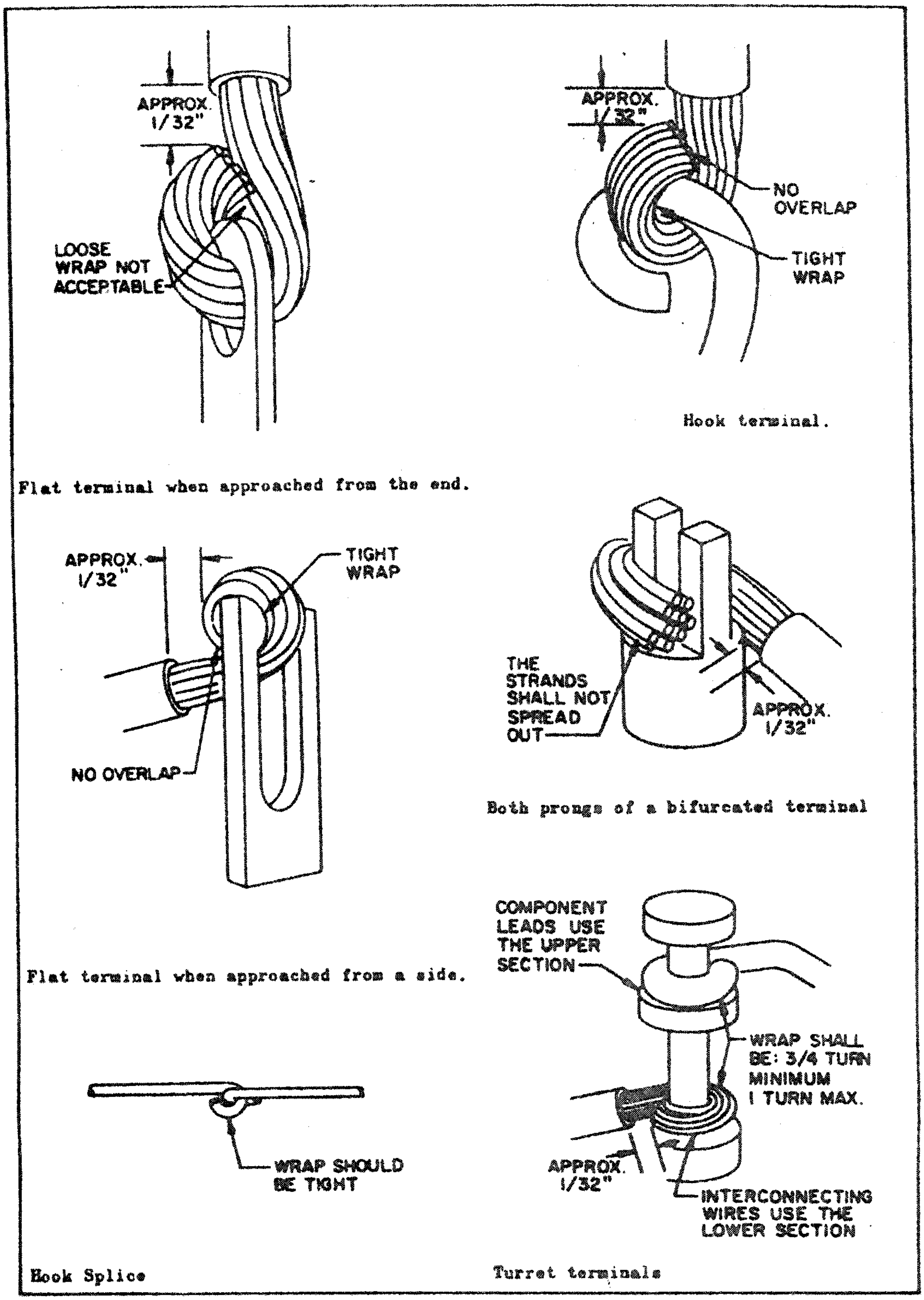
2. The lead must be wrapped sufficiently around the terminal. The lead wrap should be at least three-quarters turn but not in excess of one complete turn.

3. The lead must allow a small degree of flexibility.

Typical methods of wrapping are shown in Figure 9-6.

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 pigtailing, while the other end is terminated by insulating it from possible grounding.



Flat terminal when approached from the end.

Hook terminal.

Flat terminal when approached from a side.

Both prongs of a bifurcated terminal

Hook Splice

Turret terminals

Figure 9-6. Methods of Wrapping Wire Around Terminals or Splices

In the pigtailing 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 to approximately 3/8 in. Using a heat shunt, the shield is then soldered to the ground wire.

As shown in Figure 9-7, 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.

One method of so terminating an ungrounded shield is shown in Figure 9-8 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.

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 9-9 for correct method of preparing connector for soldering.

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 9-10). 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 9-9).

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.

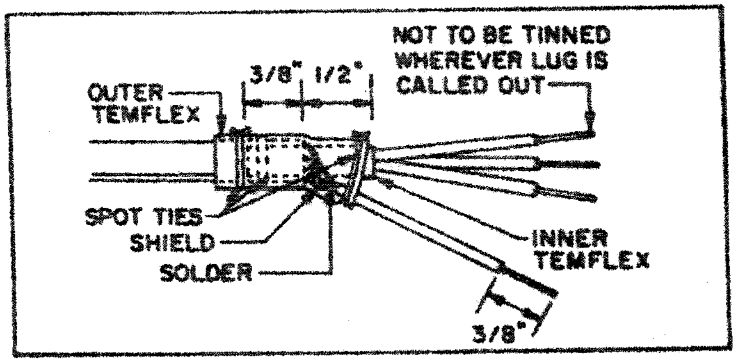


Figure 9-7. Shielded Wire Preparation

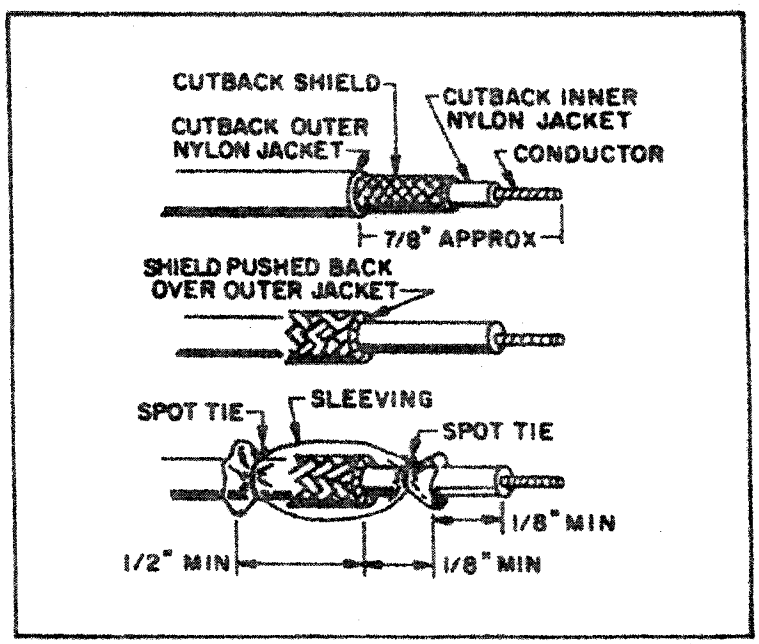


Figure 9-8. Method of Terminating Ungrounded Shield

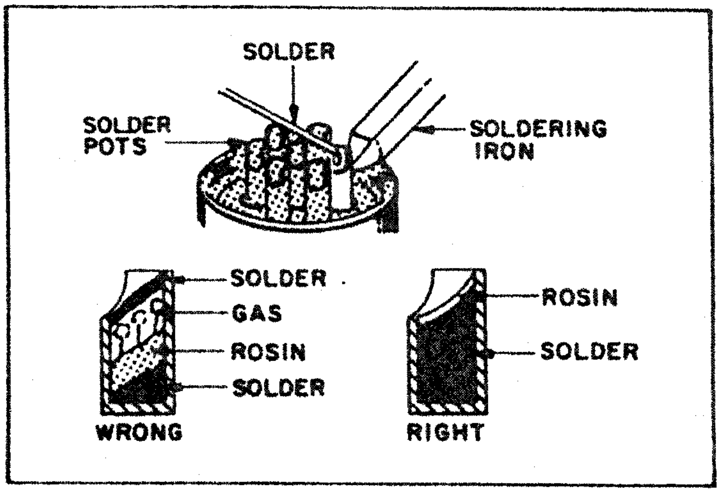


Figure 9-9. Preparation for Soldering on Connectors

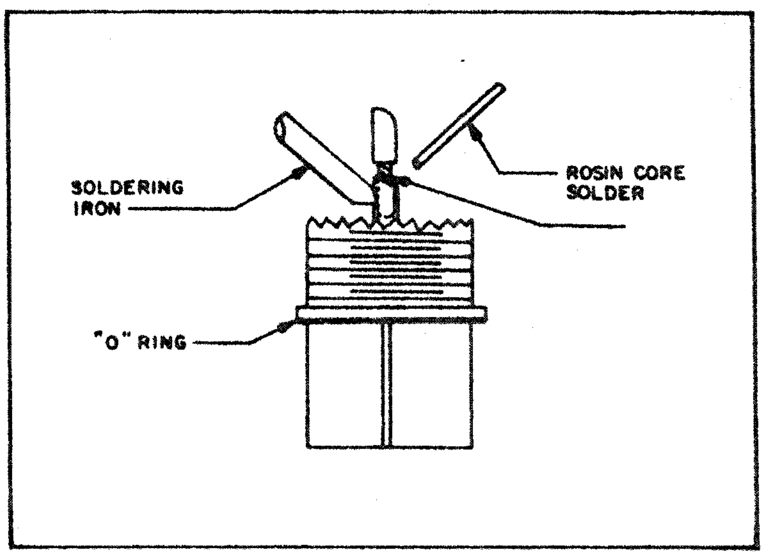


Figure 9-10. Joining Cables to Connectors

SECTION 10

HAND TOOLS

CONTENTS

INTRODUCTION

Tools are the mechanic's best friend. Regardless of the type of job to be done, a mechanic should choose and use the correct tools. Particular care should be taken to preserve them if they are to last. Improper use of tools can cause personal injury, damage to equipment, or damage to the tools.

HACKSAWS

FRAME TYPES

1. Solid
2. Adjustable (8 to 16 inches)

BLADES TYPES

1. Hardened and tempered tool steel (Molybdenum steel is best blade).

   A. <u>All hard</u> (Full blade temper)

   Used on large sections of steel and on skilled work where accuracy is needed.

   B. <u>Flexible</u> (Only teeth tempered)

   General purpose blade.

2. Pitch (Number of teeth per inch) (See Figure 10.1)

   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.

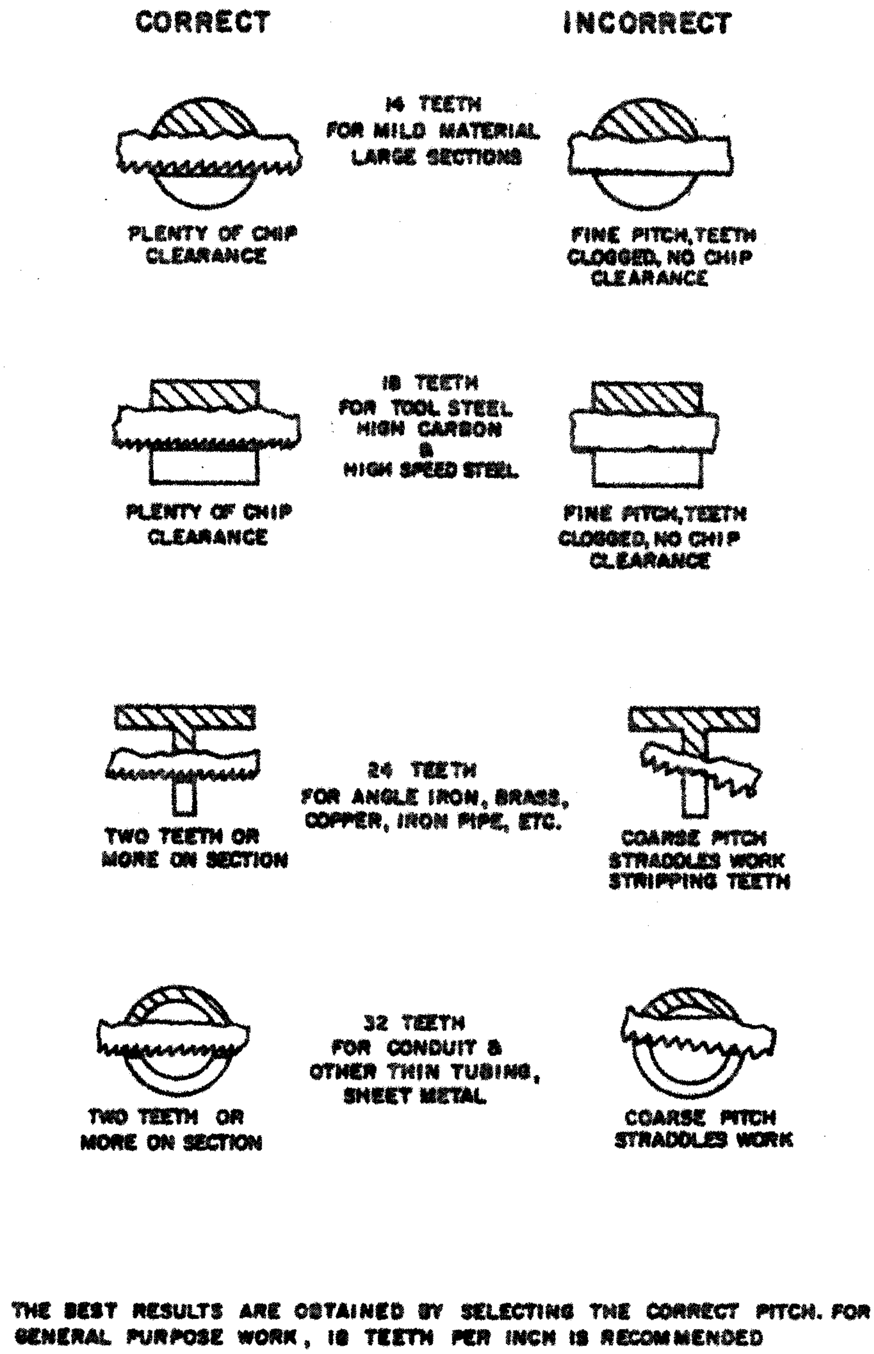


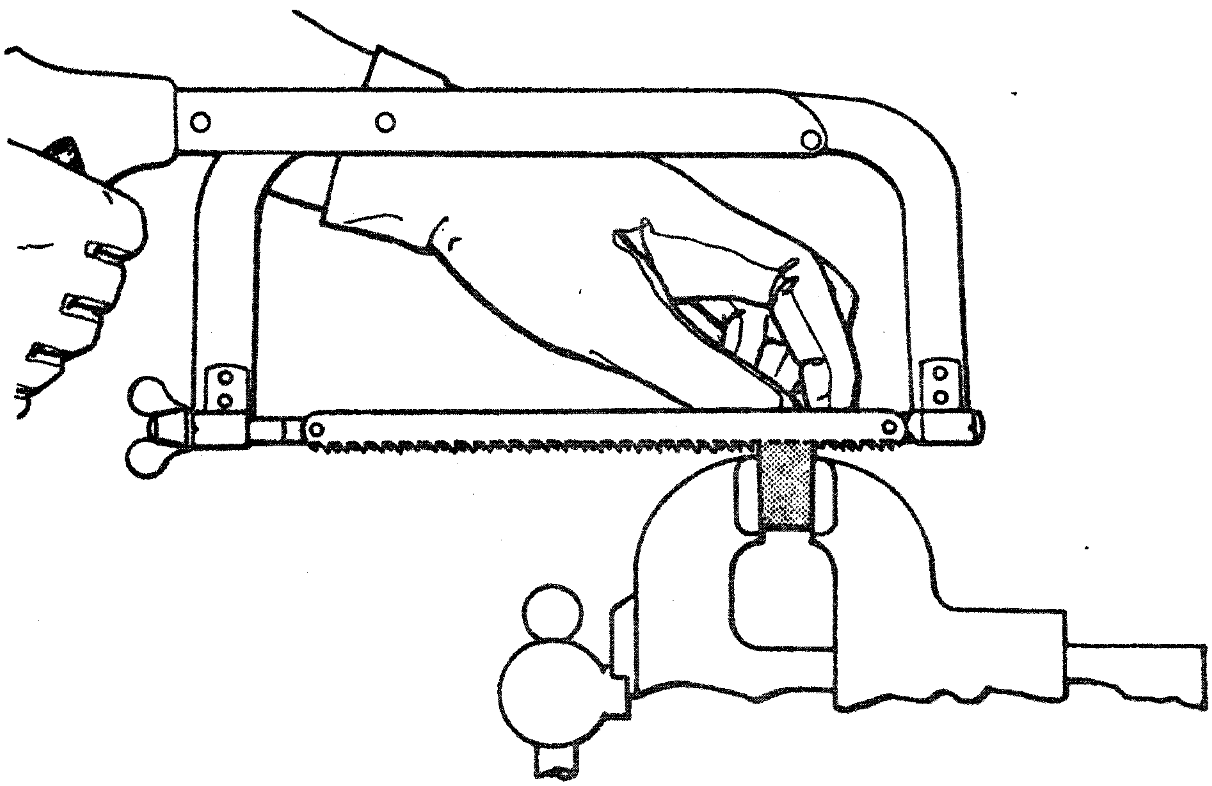
Figure 10.1. Hacksaw Blades

USE OF HACKSAW

1. Teeth should face away from handle when blade is in frame. (See Figure 10.2)
2. Force applied only on the forward stroke, approximately 32 strokes per minute.
3. For deep cuts use a deep frame hacksaw
4. Rule of Thumb:

   A. On soft materal--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: Never use hacksaw with a rapid motion, heat removes temper from teeth.



CORRECT MANNER FOR STARTING BLADE IN WORK

1. KEEP GOOD TENSION ON BLADE
2. USE VERY SHORT STROKES.

Figure 10.2. Use of Hacksaw

FILES

Files are hardened steel tools used for cutting, removing, smoothing or polishing metal. The tank is the only part of a file not tempered. (See Figure 10.3.)

TERMS

1. Coarse
2. Bastard
3. Second cut
4. Smooth
5. Dead smooth

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.

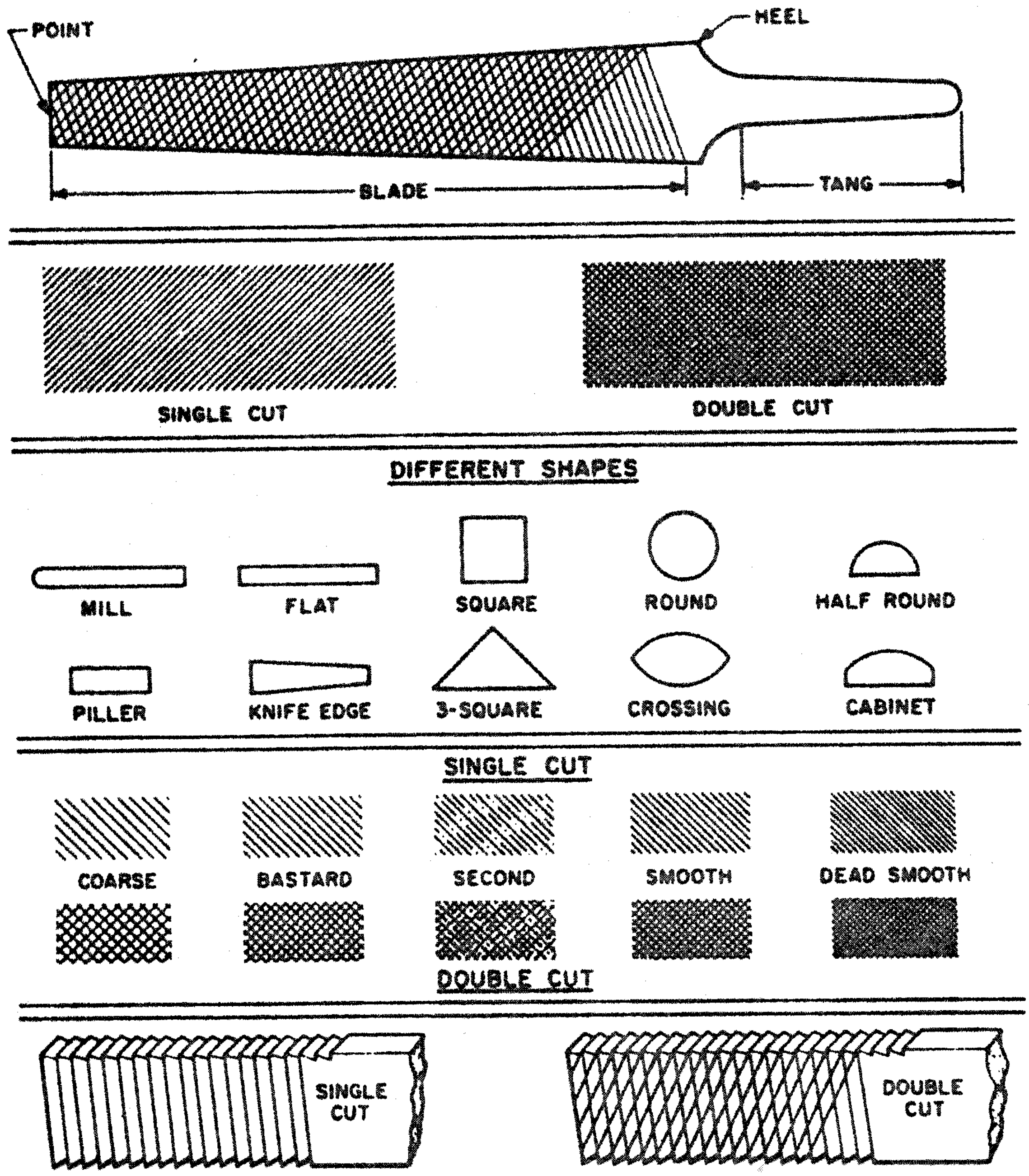


Figure 10.3. Parts of a File

SELECTING 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. Whe 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.

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, should the file meet an obstruction forcing the sharp end of the tang into the hand.
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 10.4.)

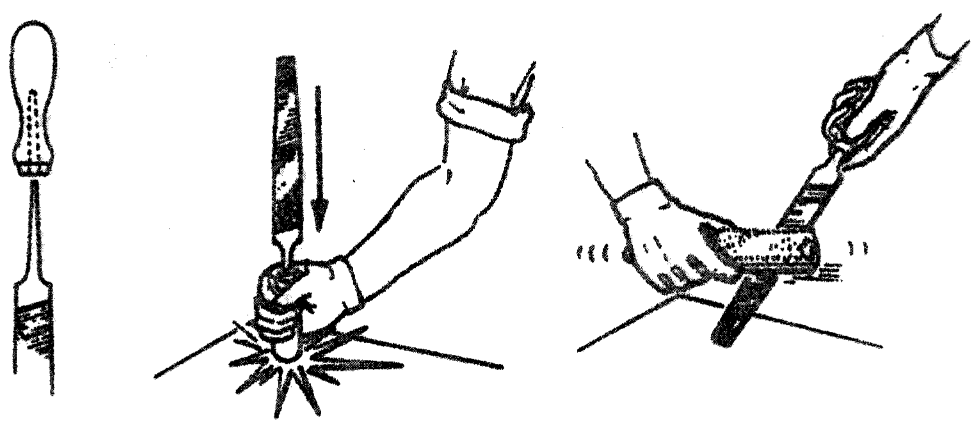


Figure 10.4. Use and Care of Files

3. <u>To remove a file handle</u>; 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. (Figure 10.4.) 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 10.5.

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 best to clean the teeth with a file card. This is a brush with short, stiff, wire bristles. (See Figure 10.4.)

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 wil snap it in two.

9. Never hammer on a file. This is dangerous because it may shatter with chips flying in every direction.

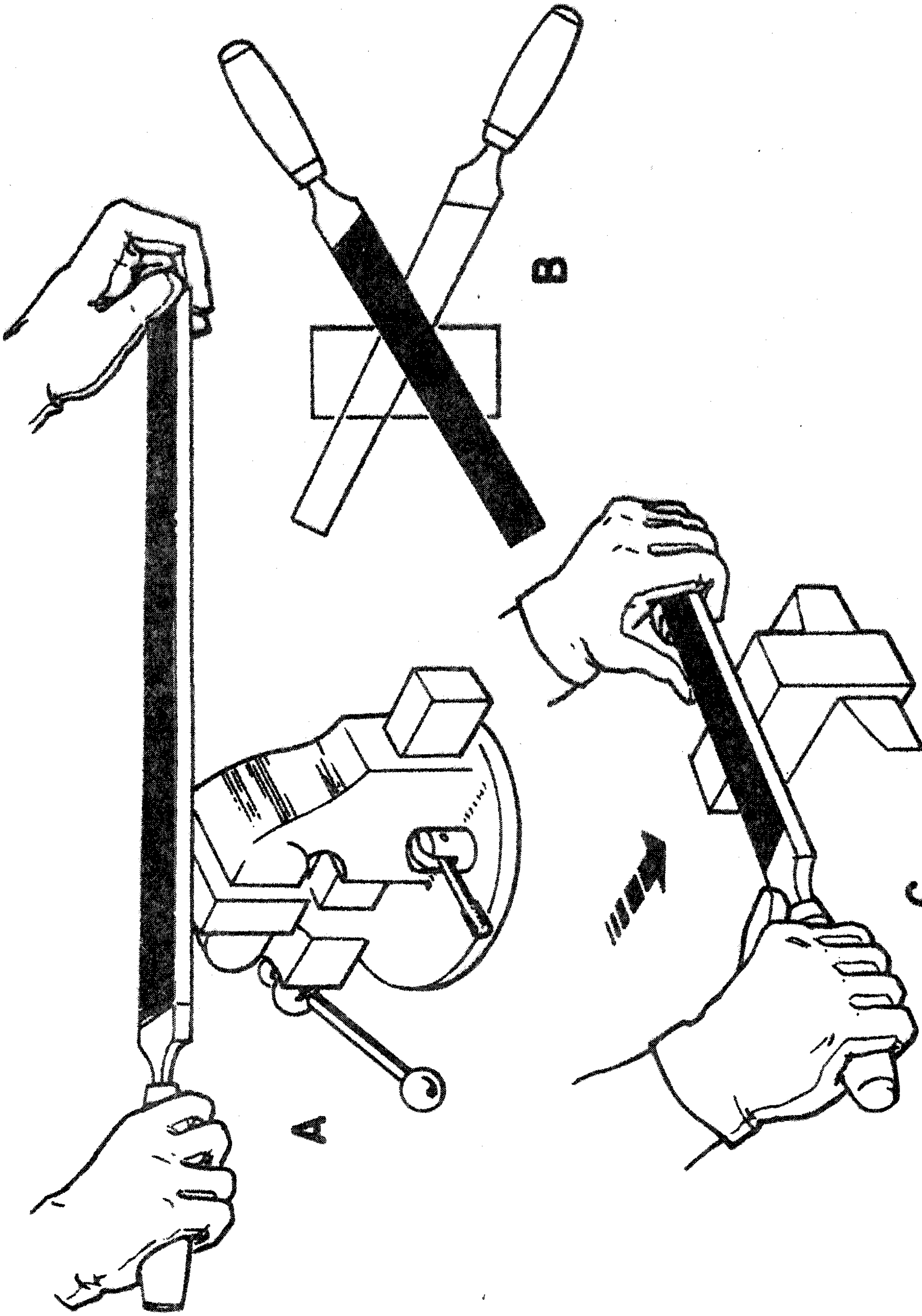


Figure 10.5. Filing Techniques

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 10.6)
   - A. Body (flute or spiral)
   - B. Shank (drill size stamped on it)
   - C. Point

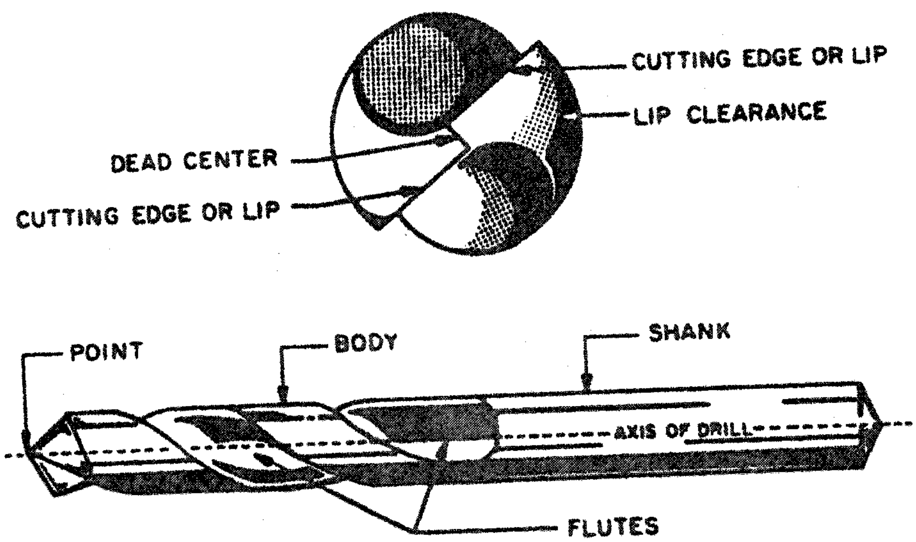


Figure 10.6. Parts of a Drill

4. Drill sizes: (are measured either in fractions, numbers, or letters) (Refer to Figure 10.9)

   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

5. Angles: (See Figure 10.7)

   A. For mild steel:
      1. Lip angle is 59 degrees
   B. For hard steel:
      1. Lip angle is 65 degrees

6. Common drill troubles and causes. (See Figure 10.8.)

7. Suggested speeds and feeds for high speed drills. (Refer to Figure 10.10 through 10.12.)

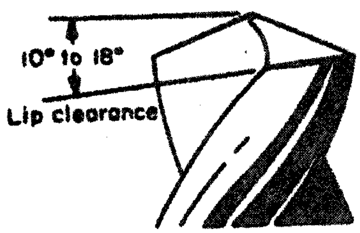
8. Cutting fluids. (Refer to work order or to Figure 10.13 where cutting fluids are not prohibited.)

9. Drilling Tips:

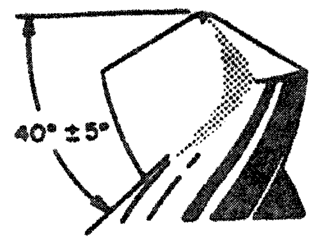
   A. Material should always be center punched to aid in accurately starting drill.
   B. To avoid breaking drills ease up on feed pressure as drill starts to break through.
   C. Material to be drilled should always be clamped to drill press table to prevent material from spinning if drill seizes.
   D. 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.

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.

POINTING

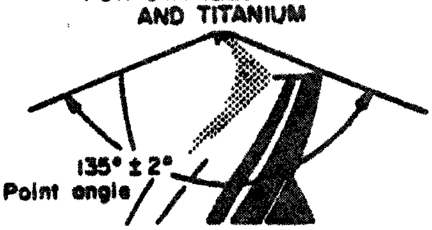


POINT NOTCHING

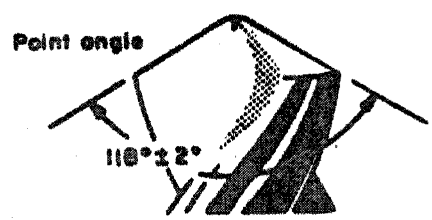


Length and Angle of the Lips- The lips are of equal length and at the same angle with the axis of the drill.

FOR STAINLESS STEEL AND TITANIUM



FOR ALUMINUM



Central Locations of Point and Center of the Drill--If 1 and 2 have been correctly ground, the point and dead center will be centrally located on the axis of the drill.

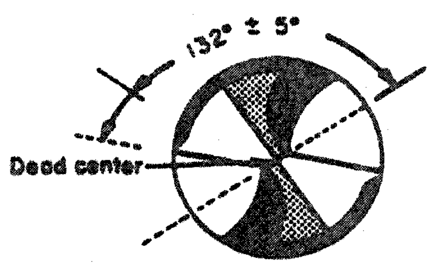


Figure 10.7. Drill Angles

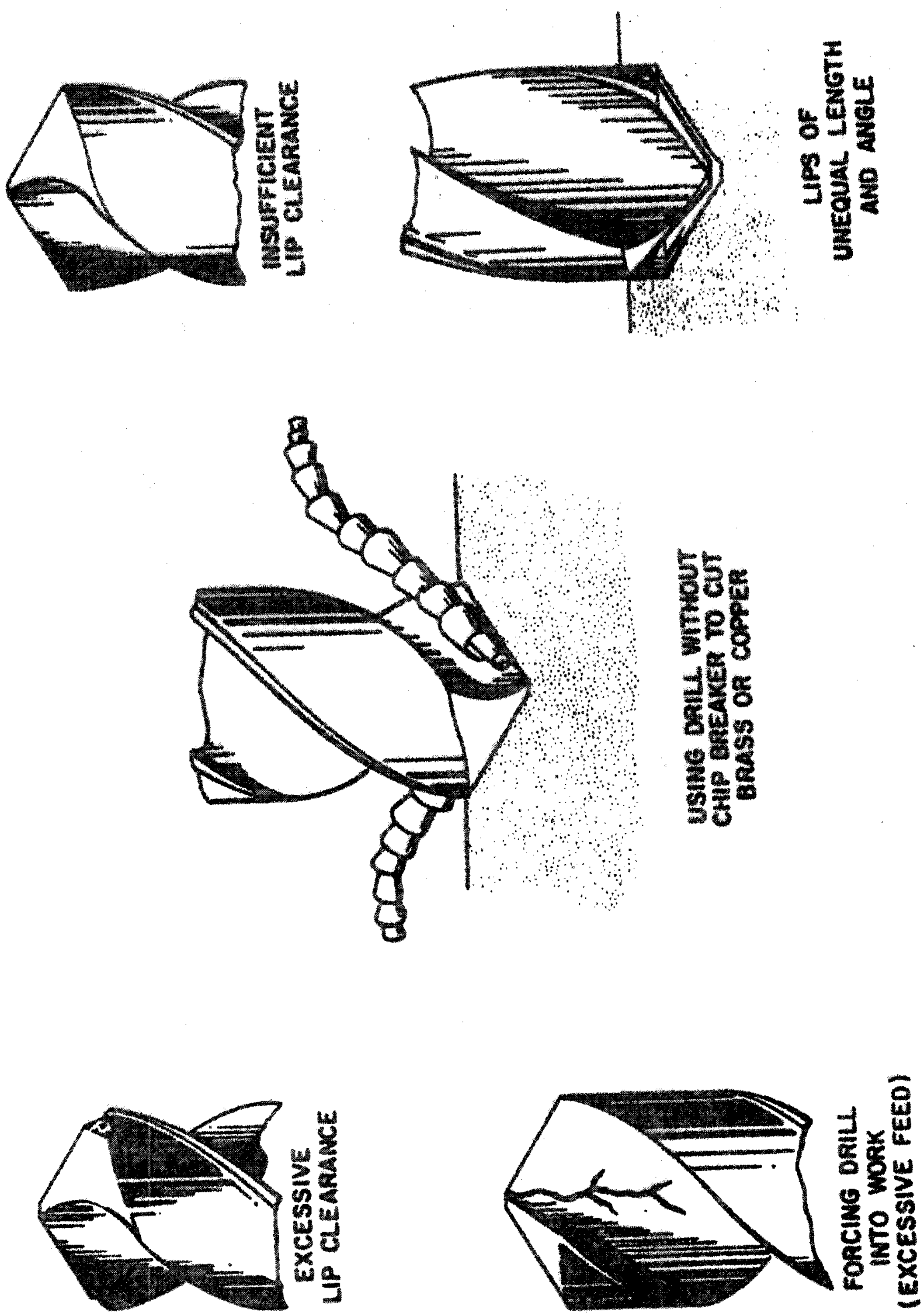


Figure 10.8. Common Drill Troubles and Causes

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	Q	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	[illegible]
51	0.0670	3	0.2130	11/16	0.6875
50	0.0700	7/32	0.2187	45/64	[illegible]
49	0.0730	2	0.2210	23/32	[illegible]
48	0.0760	1	0.2280	47/64	[illegible]
5/64	0.0781	A	0.2340	3/4	0.7500
47	0.0785	15/64	0.2344	49/64	[illegible]
46	0.0810	B	0.2380	25/32	[illegible]
45	0.0820	C	0.2420	51/64	[illegible]
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		

Figure 10.9. Drill Sizes

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

Carbon steel drills should be run at speeds approximately 40 to 50 per cent of those recommended for high speed drills.

Figure 10.10. Suggested Speeds for High Speed Drills

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

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.

Figure 10.11. Feeds for Drills

Size		Surface Feet Per Minute										
Fractional	Decimal Equivalent	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

Figure 10.12. Operating Speeds--Fractional Sizes (Sheet 1 of 4)

Size		Surface Feet Per Minute									
Fractional	Decimal Equivalent	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

Figure 10.12. Operating Speeds--Fractional Sizes (Sheet 2 of 4)

Size		Surface Feet Per Minute									
Letter	Decimal Equivalent	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

Figure 10.12. Operating Speeds--Letter Sizes (Sheet 3 of 4)

Size		Surface Feet Per Minute								
		100	110	120	130	140	150	175	200	250
Letter	Decimal Equivalent	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	1416	1654	1890	2363
Z	.413	925	1017	1110	1202	1295	1387	1618	1850	2312

Figure 10.12. Operating Speeds--Letter Sizes (Sheet 4 of 4)

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.	

Figure 10.13. Recommended Cutting Fluids

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 1000 parts. It has a screw with 40 threads per inch which advances through a nut at .025 of an inch per revolution. (See Figure 10.16 for typical readings.)

CARE AND USE

1. 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.

RATCHET STOP AND CLAMP RING

1. 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.
2. Never tighten clamp ring when spindle is removed. To do so may damage the clamping mechanism.

TYPES

1. Inside micrometer
2. Outside micrometer
3. Depth micrometer

PRINCIPAL PARTS OF A MICROMETER (Figure 10.15)

1. Frame
2. Anvil
3. Spindle
4. Barrel
5. Thimble

TOOLS USED IN CONJUNCTION WITH MICROMETER (Figure 10.14)

1. Ball gauge (inside diameter 1/2 inch or less)
2. "T" gauge or snap gauge (inside diameter 1/2 inch or more)

OTHER GAUGES

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

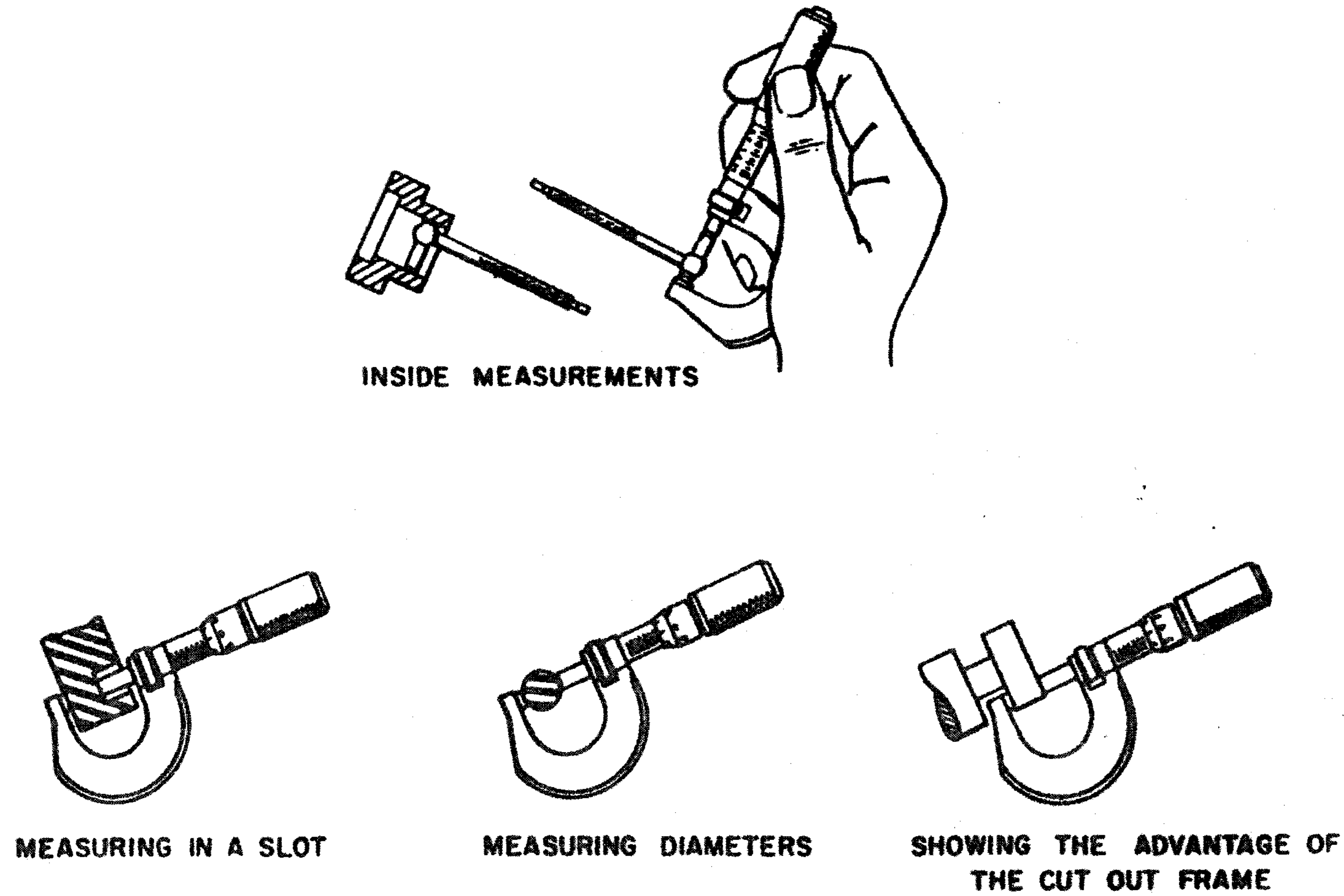


Figure 10.14. Uses for Micrometer Caliper

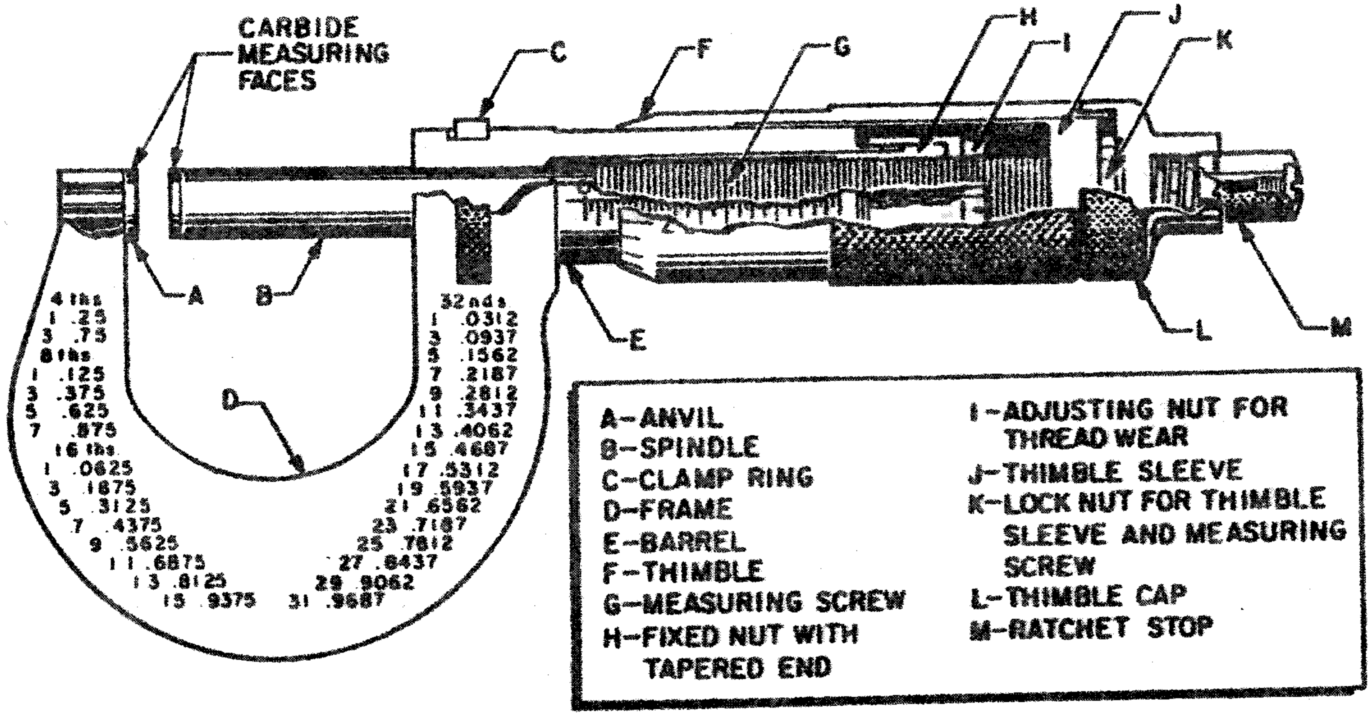


Figure 10.15. Micrometer Caliper Section View

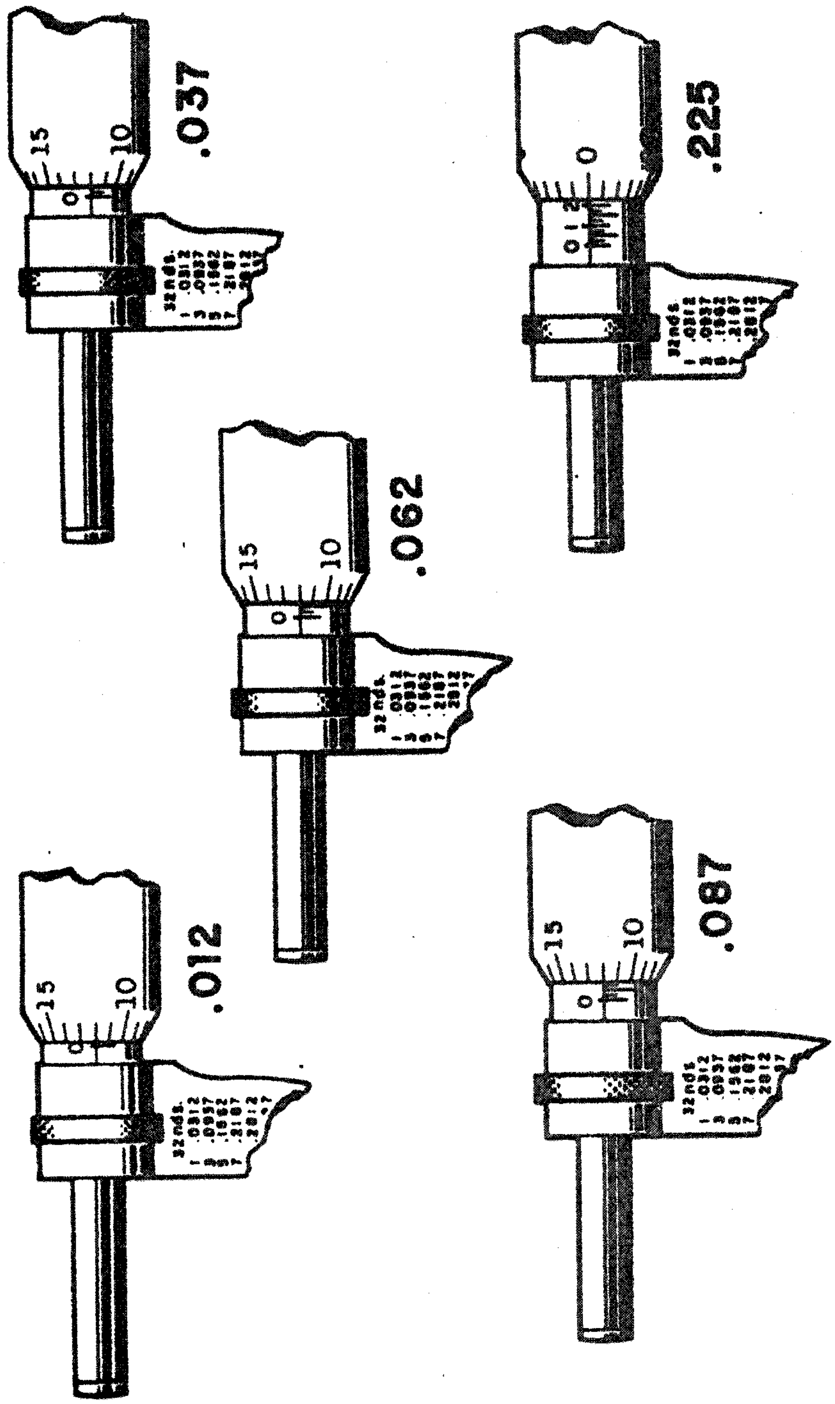


Figure 10.16. Typical Micrometer Readings

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 10.17.)

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.

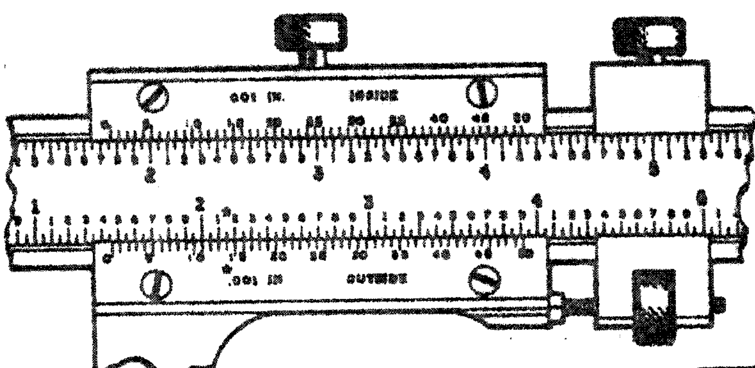
To read the tool, note how many inches, tenths (or .100) and twentieths (or .050) to 0 mark on the Vernier is from the 0 mark on the bar. Then note the number of division on the Vernier from 0 to a line which exactly coincides with a line on the bar.

Example:

In the figure below the Vernier has been moved to the right one and four hun dred 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 are 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.



HOW TO READ A 50-DIVISION
VERNIER CALIPER OR HEIGHT GAGE

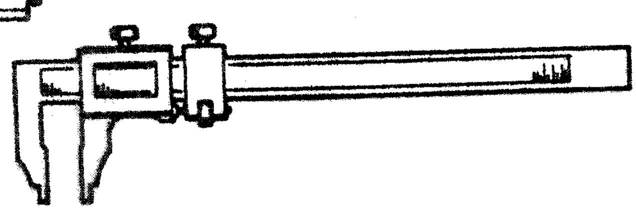


Figure 10.17. Vernier Caliper

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 <u>(1/8 inch or less) (Figure 10.18)</u>.
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 10.18)
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.

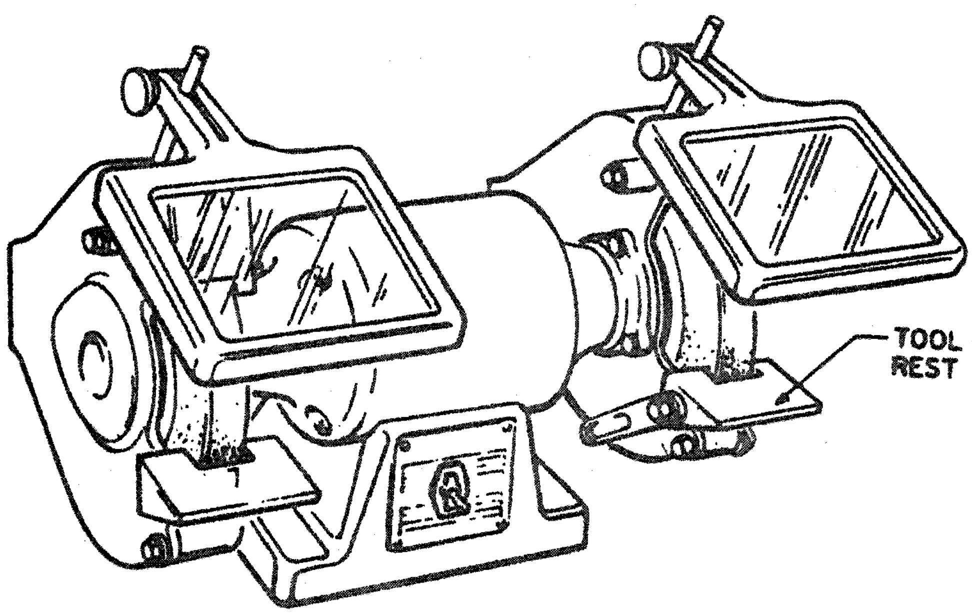


Figure 10.18. Bench Grinder

HOLDING DEVICES

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

CLASSIFICATIONS

1. Machinist vise
2. Utility bench vise (most common)
3. Drill press vise (usually has to be clamped to drill press table)
4. "C" clamps (come in many sizes)
5. Parallel clamps
6. Pipe vise

Note: On bench vises soft jaws are sometimes needed to protect part. (See Figure 10.19.)

PUNCHES AND PUNCHING

Punches are used to locate centers for drawing circles, to start hole for drilling, to punch holes in metal sheets, and to drive out pins or bolts. (See Figure 10.19.)

CLASSIFICATIONS

1.	Prick punch	Used to mark center
2.	Center punch	Used to mark drill point center
3.	Pin punch	Indicates pin diameter, stock diameter
4.	Starting punch	Used to drive out bolts, pins, etc.
5.	Scribes	Used to scribe lines on metal, not used on aluminum
6.	Aligning punch	Used to align flange holes

CHISELS

Chisels are tools used to cut, ship, 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 10.20 for "before" and "after" dressing.

CLASSIFICATIONS

1.	Flat	Used for cutting sheet metal or for chipping
2.	Cape	Used for cutting grooves, slots or keyways
3.	Round nose	Used for cutting round (concave) grooves
4.	Diamond point	Used for cutting V shaped grooves

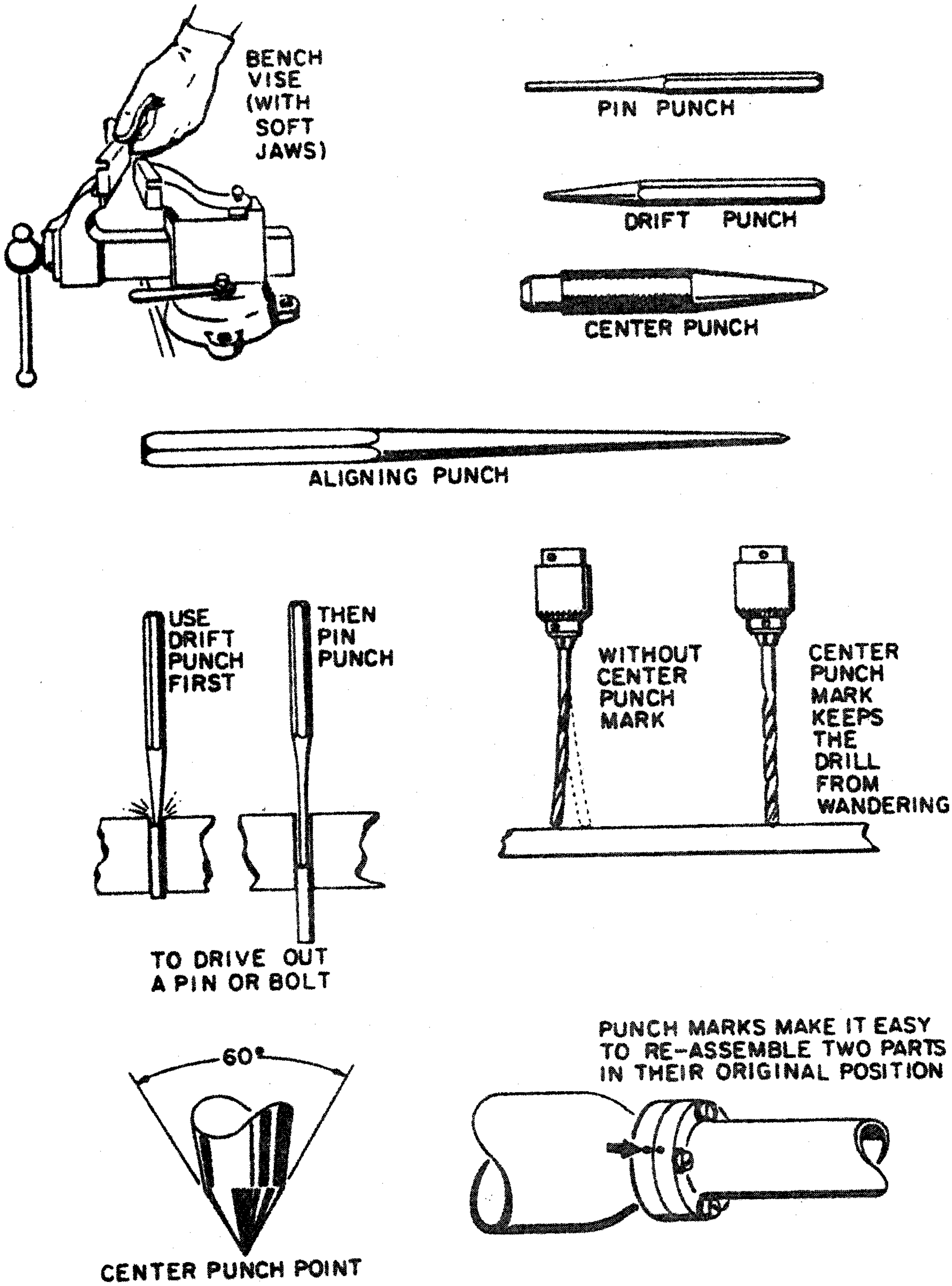


Figure 10.19. Holding Device and Punches

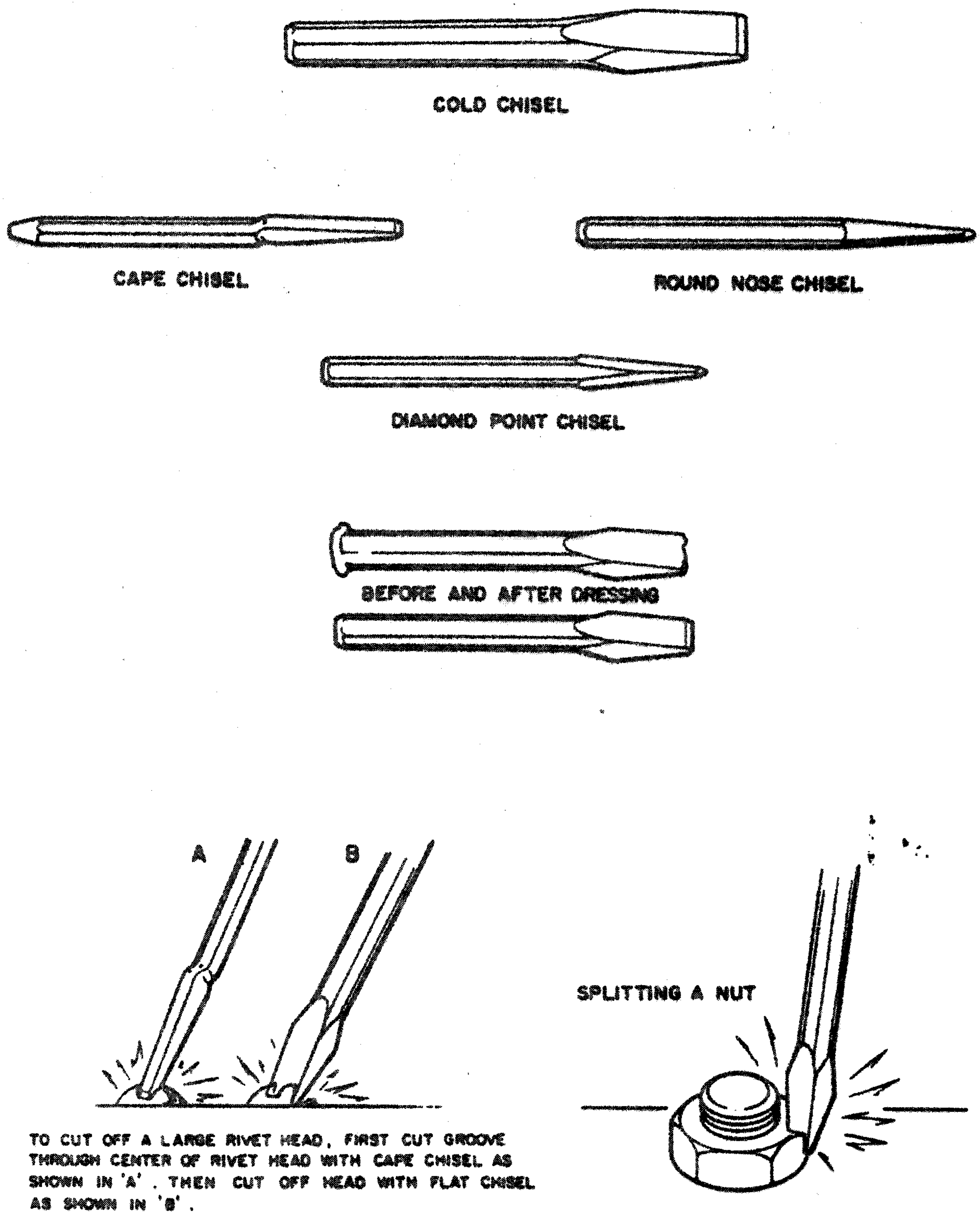


Figure 10.20. Chisels

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 10.21.)

CLASSIFICATIONS

1. The common (ball-peen) hammer 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.

2. The soft hammers 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.

3. Sledges are used for heavy work, where great force is needed, such as: slug wrench applications, driving stakes or breaking up rock. (See Figure 10.27.)

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.

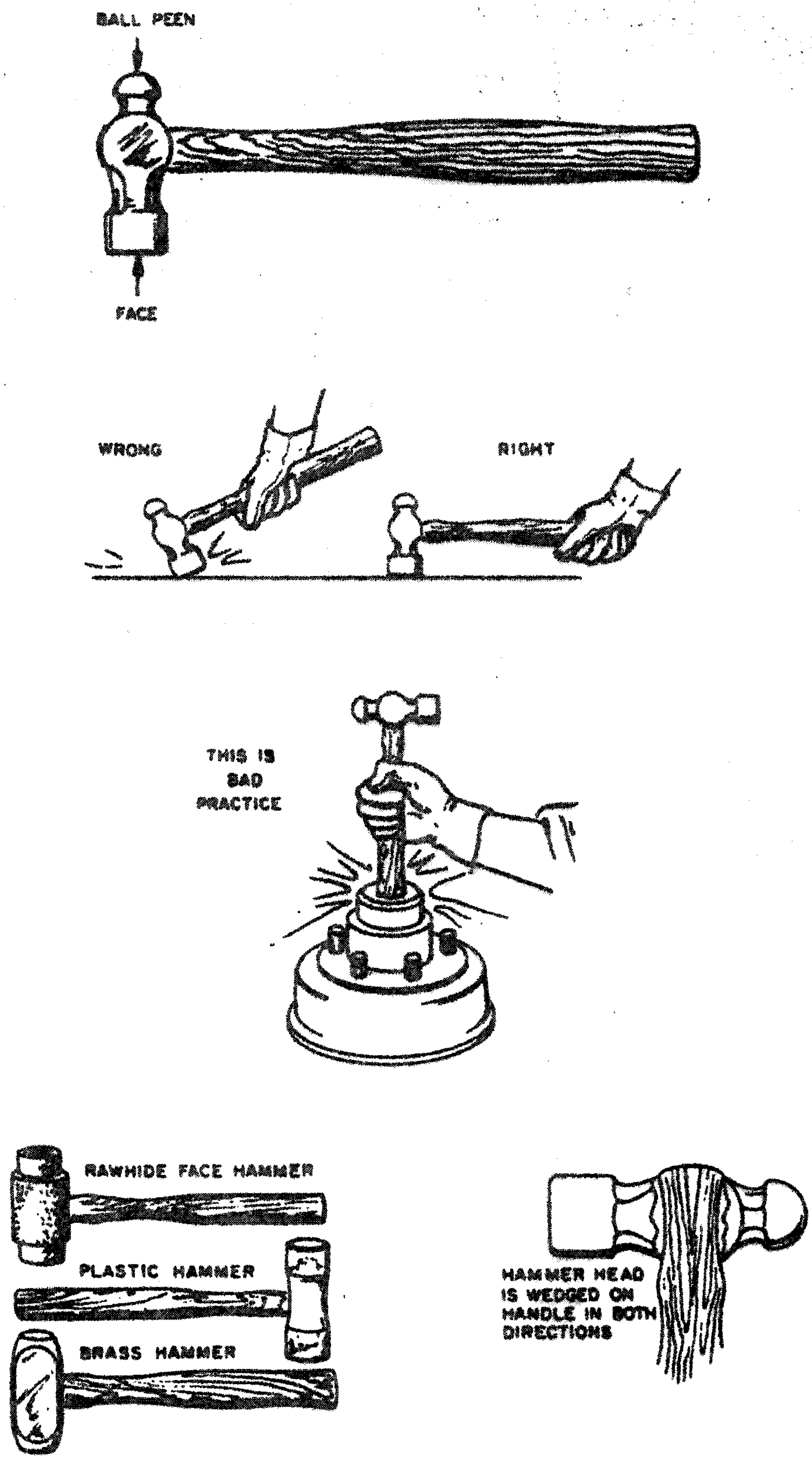


Figure 10.21. Hammers

SHEARS AND PLIERS

Shears, pliers and nippers are tools used to hold, turn, cut, shape or bend light work by hand. (See Figure 10.22).

PLIERS

A. Slip joint (5" to 10")
B. Duck bill
C. Needle nose
D. Water pump (channel type)
E. Vise clamp

SHEARS

A. Right and left cutting snips
B. Tin snips
C. Dikes (diagonal cutters)

1. Shears are used for cutting sheet metal of various materials and thickness.
2. Pliers are used principally for holding or bending thin material, or cutting electrical wire.
3. Diagonal cutters are used for cutting off small stock, such as cotter keys and electrical wire.
4. Avoid using pliers on a hardened surface as this dulls the teeth and will cause loss of grip.
5. 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.
6. Mechanics sometimes use pliers for loosening or tightening nuts. Always use wrenches on nuts, <u>NEVER PLIERS</u>. In fact, don't use pliers when any other tool will work.
7. Pliers like all other tools, should be kept clean.

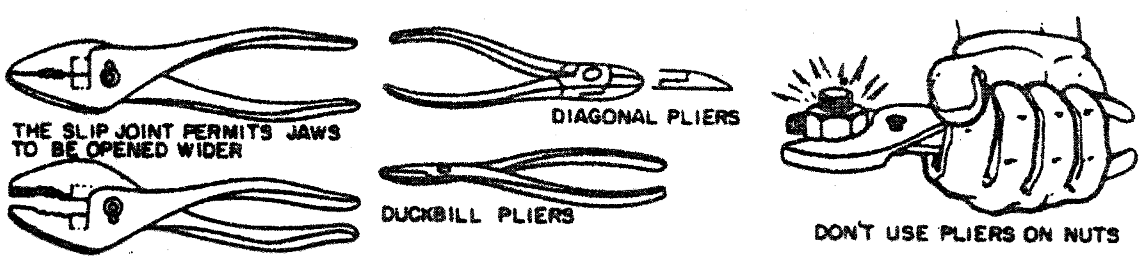


Figure 10.22. Pliers

SCREWDRIVERS

A screwdriver is intended for one principal purpose------to loosen or tighten screws.

COMMON (General Purpose) (Figure 10.23)

1. 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.

   A. Select the right size screwdriver for the screw slot. This not only prevents the screw slot from becoming burred and the blade tip from being damaged, but reduces the force required to keep the screwdriver in the slot.

   B. Screwdrivers are not designed to be 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.

   C. Don't 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.

      If one has to remove a rusty screw and the slot is full of rust; tap gently on the handle of the screwdriver, holding it at an angle to the slot of the screw. After the slot is cleared sufficiently one can tap on the screwdriver with a hammer to seat it well into the slot before trying to loosen the screw.

   D. Don't use pliers on a screwdriver.

   E. If a screwdriver blade becomes damaged through misuse it can be made serviceable again by grinding it on an emery wheel.

      1. First grind the tip straight and at a right angle to the shank.

         Note: Never hold the screwdriver against the emery wheel more than several seconds at a time. Keep dipping the blade in water to keep it cool.

      2. After the tip is ground square, dress off a little at a time from each face. Be careful to keep the blade thick enough to make a fairly tight fit in the slot of the screw for which the screwdriver is intended.

      3. Keep the faces parallel for a short distance or have them taper in a slight amount. Never grind the faces so they taper to a sharp edge at the tip. (See Figure 10.23)

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.

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 eah requires a special and different type of screwdriver. The sizes most commonly seen are: 1/4", 3/16", 5/16", and 3/8".

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.

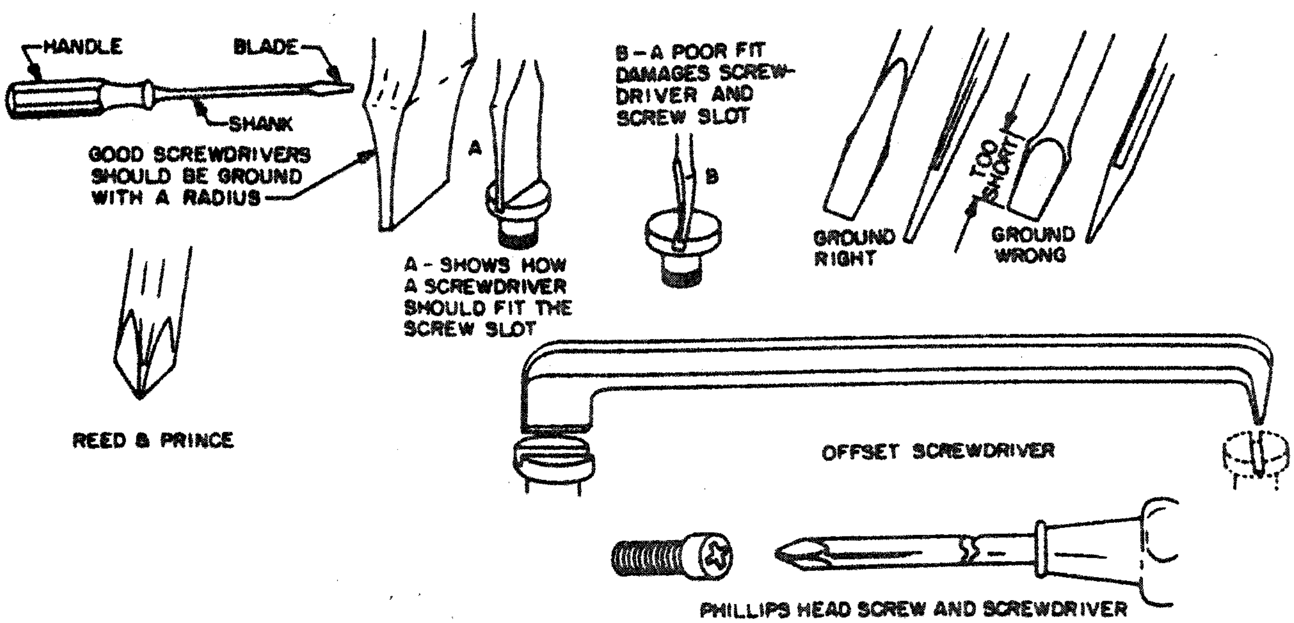


Figure 10.23. Screwdrivers

WRENCHES

OPEN-END WRENCHES

1. 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. (Figure 10.24)

2. 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.

3. The smaller the openings in the wrench, the shorter its overall length. The larger the opening 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.

4. 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 mechanic to know whether a nut or cap-screw is tightened the right amount.

5. There are a few simple rules for the correct use of open-end wrenches:

   A. Be sure that the wrench fits the nut or bolt head.

   B. When one has to put a hard pull on a wrench, make sure the wrench seats squarely on the sides of the nut.

   C. 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. (Figure 10.24)

   D. If one must push on the wrench, use the base of the palm and hold your hand open. This will avoid injury to your knuckles.

   E. When the jaws on an open-end wrench become spread, replace the wrench.

   F. Do not use a cheater (extension) on a wrench.

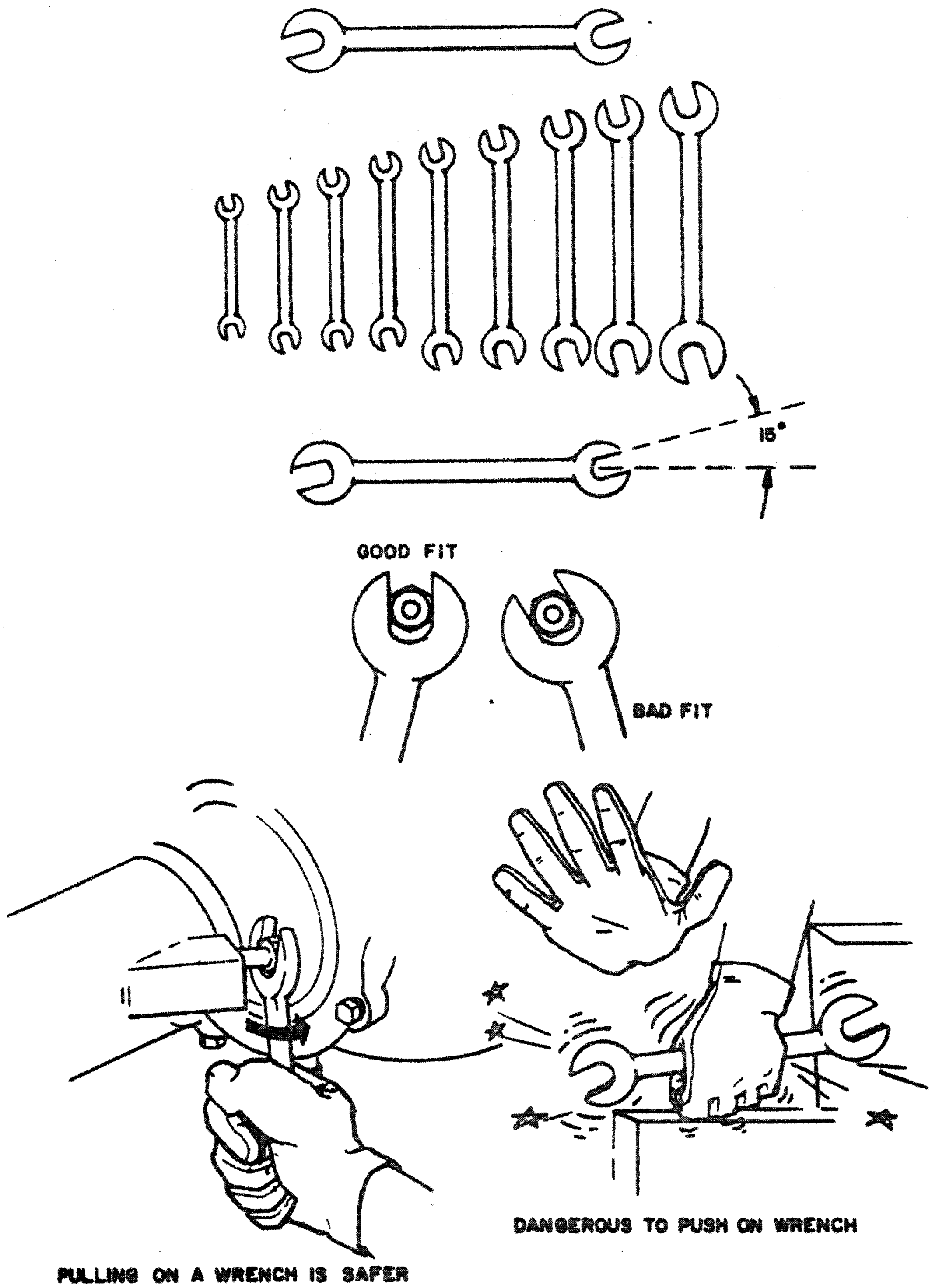


Figure 10.24. Open End Wrenches

BOX WRENCHES

1. Box wrenches are very popular with mechanics. One reason for this is that they can be operated in very close quarters. They are called "box" wrenches because they box or completely surround the nut or bolt head. (Figure 10.25)
2. Box 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.
3. 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.
4. The sides of the opening in a box wrench are thin and it is ideally suited for nuts which are hard to get at with an open-end wrench.
5. Some box 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.
6. The same rules for use shown for open-end wrenches hold true for box wrenches.

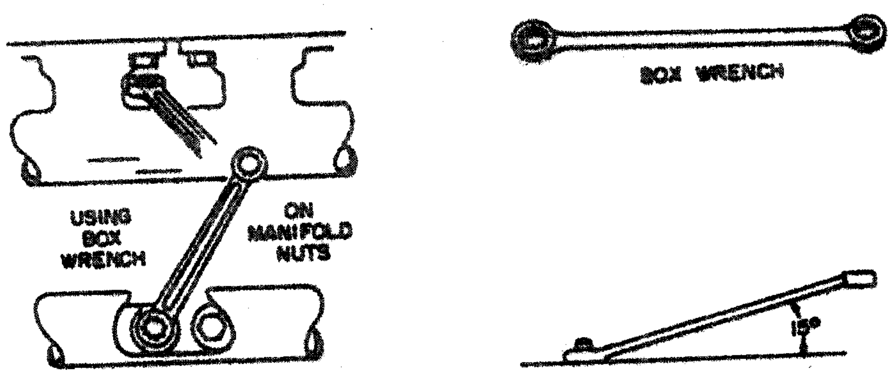


Figure 10.25. Box Wrenches

COMBINATION BOX AND OPEN-END WRENCH

1. Many mechanics prefer combination wrenches. A box wrench on one end and an open-end wrench on the other. They use the box end for "breaking-loose" or "snugging down" nuts and use the open-end the rest of the time. (Figure 10.26)

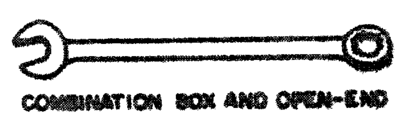


Figure 10.26. Combination Box and Open-End Wrench

STRIKING WRENCH

1. You never should hammer a wrench, but there is one exception. There is a 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 "slugging" or "striking" wrenches. These wrenches are especially useful on large size nuts.

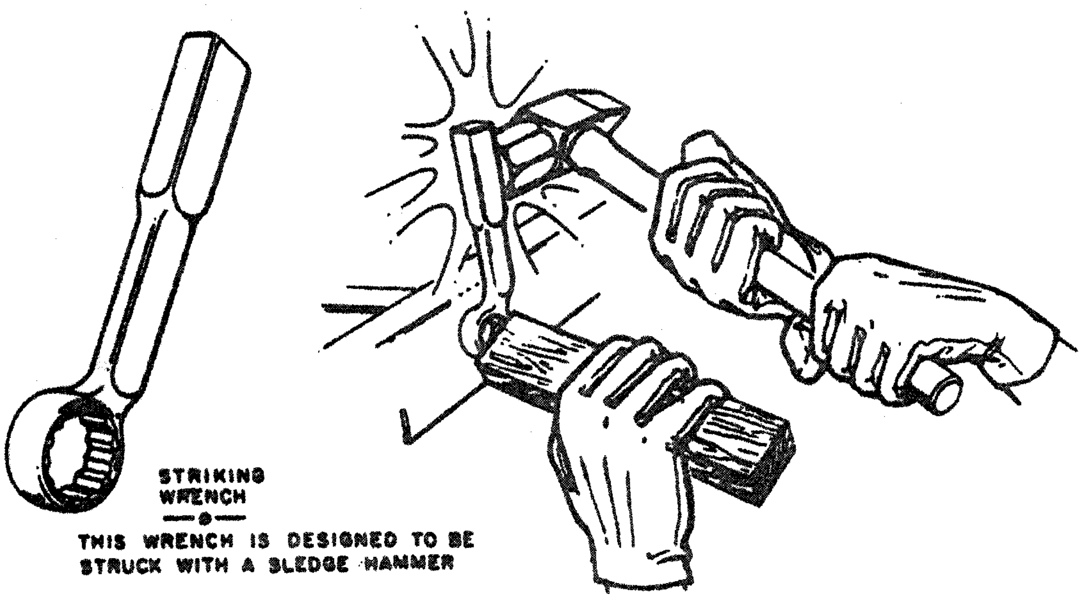


Figure 10.27. Sledging Wrench

SET-SCREW WRENCHES

1. 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.

2. 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.

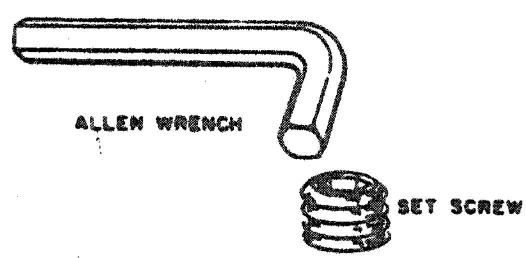


Figure 10.28. Set-Screw Wrench

SOCKET WRENCHES

1. The type of wrench which has done most to make the mechanic's work easier and save time is the socket wrench.
2. The socket is detachable and may be attached to several different types of handles for many different applications. (See Figure 10.29, 30, 31, 32, and 33)
3. The handle most commonly used is the ratchet. (Figure 10.29)
4. 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 10.30)

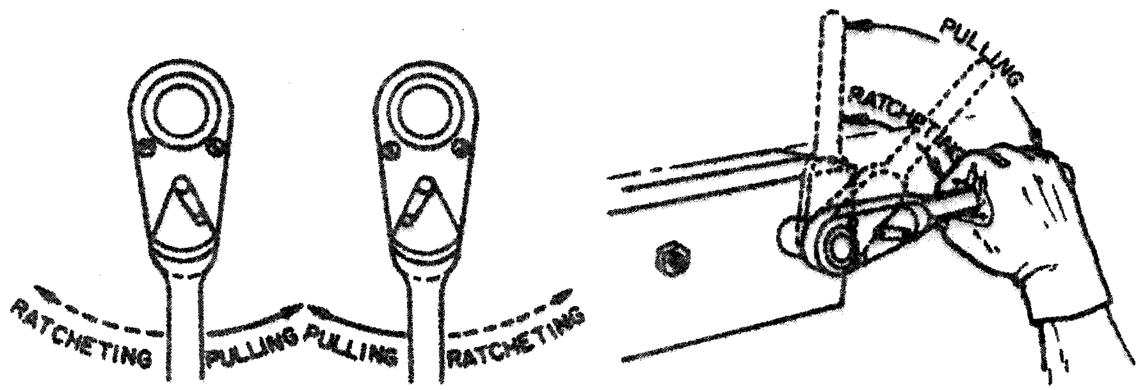


Figure 10.29. Ratchet Handle

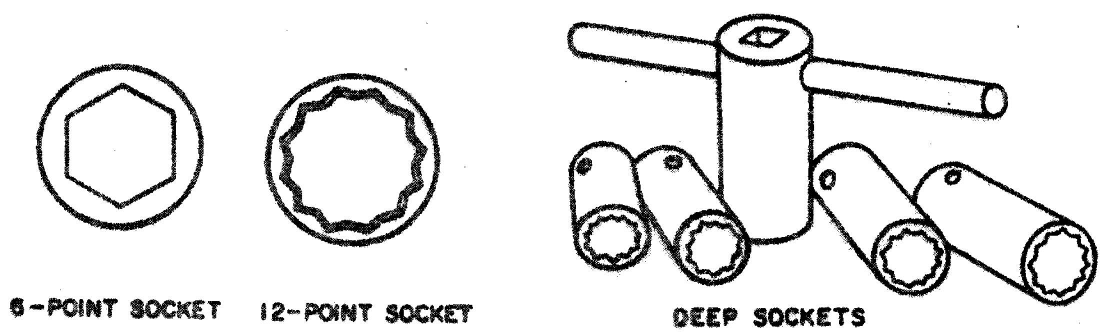


Figure 10.30. Ratchet Handle and Deep Sockets

HINGED OFFSET HANDLE

1. 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 10.31)

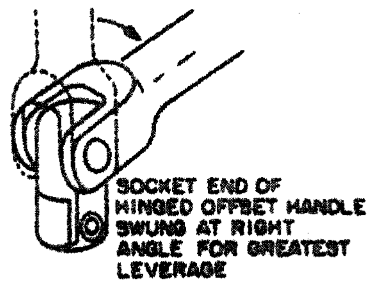
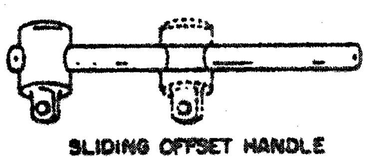


Figure 10.31. Hinged Offset Handle

SLIDING OFFSET HANDLE

1. 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 10.32)



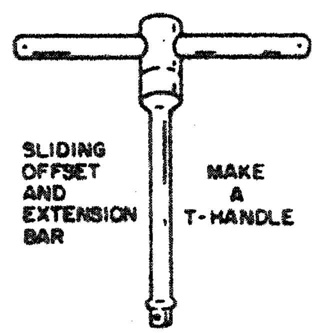


Figure 10.32. Sliding Offset Handle

SPEED HANDLE

1. 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 10.33)

Figure 10.33. Speed Handle

ADJUSTABLE WRENCHES (Not to be used unless approved by supervisor.)

1. Adjustable wrenches are shaped somewhat similar to open-end wrenches but have one jaw adjustable. (Figure 10.34)
2. The angle of the opening to the handle on an adjustable wrench is 22-1/2 degrees.
3. Although adjustable wrenches are convenient, they are not intended to take the place of standard open-end wrenches, box wrenches, or socket wrenches.
4. Adjustable wrenches aren't intended for hard service, treat them gently.
5. 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 10.34)
   B. After placing the wrench on the nut, tighten the adjusting knurl so that the wrench fits the nut snugly. (Figure 10.34)
6. 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.
7. Inspect them for cracked knurls or jaws which may result in failures.

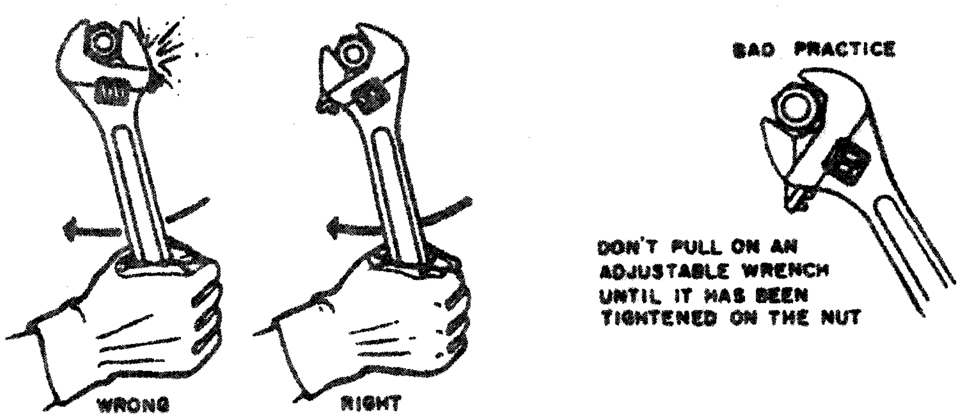


Figure 10.34. Adjustable Wrench

PIPE WRENCHES

1. 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 10.35)

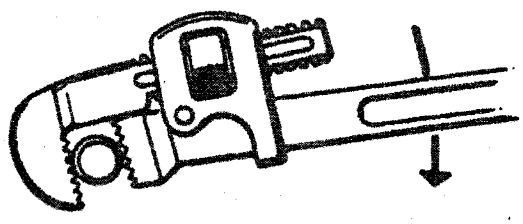


Figure 10.35. Pipe Wrench

THREADS, TAPS AND DIES

GENERAL INFORMATION

1. 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.

2. 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.

3. 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.

4. Use of Taps:

   A. 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.

   B. There are three forms of taps:

      1. 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.

      2. Plug tap----(2nd one used)
         The plug tap is used when one end of the hole is closed.

      3. 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.

5. Use of Dies:
   Dies are used for cutting male or external threads.

   A. Clean die before use.

   B. Die adjustment screw started loosely and then adjusted tighter, in steps, while making threads.

   C. Die inserted in handle (stock) with tapered thread side down or towards the work.

D. Set screw in handle inserted in recess hold in die and securely tightened.

E. Die started perpendicular to center line of part.

F. Use proper cutting fluid.

G. Back off die after every 1/2 to 1 turn to remove chips.

COMBINATION SQUARE

1. A combination square combines in handy form the equivalent of several tools; inside try square, outside try square, mitre square, plumb, level, depth gage, marking gage, straight edge, etc.
2. 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.
3. Graduations on the blade are in 8ths, 16ths, and 32nds. Handle can be locked to the blade at any position by a knurled knob.
4. Common uses for the combination square are shown in Figure 10.37.

PROTRACTOR

1. Common uses for the protractor are shown in Figure 10.36.

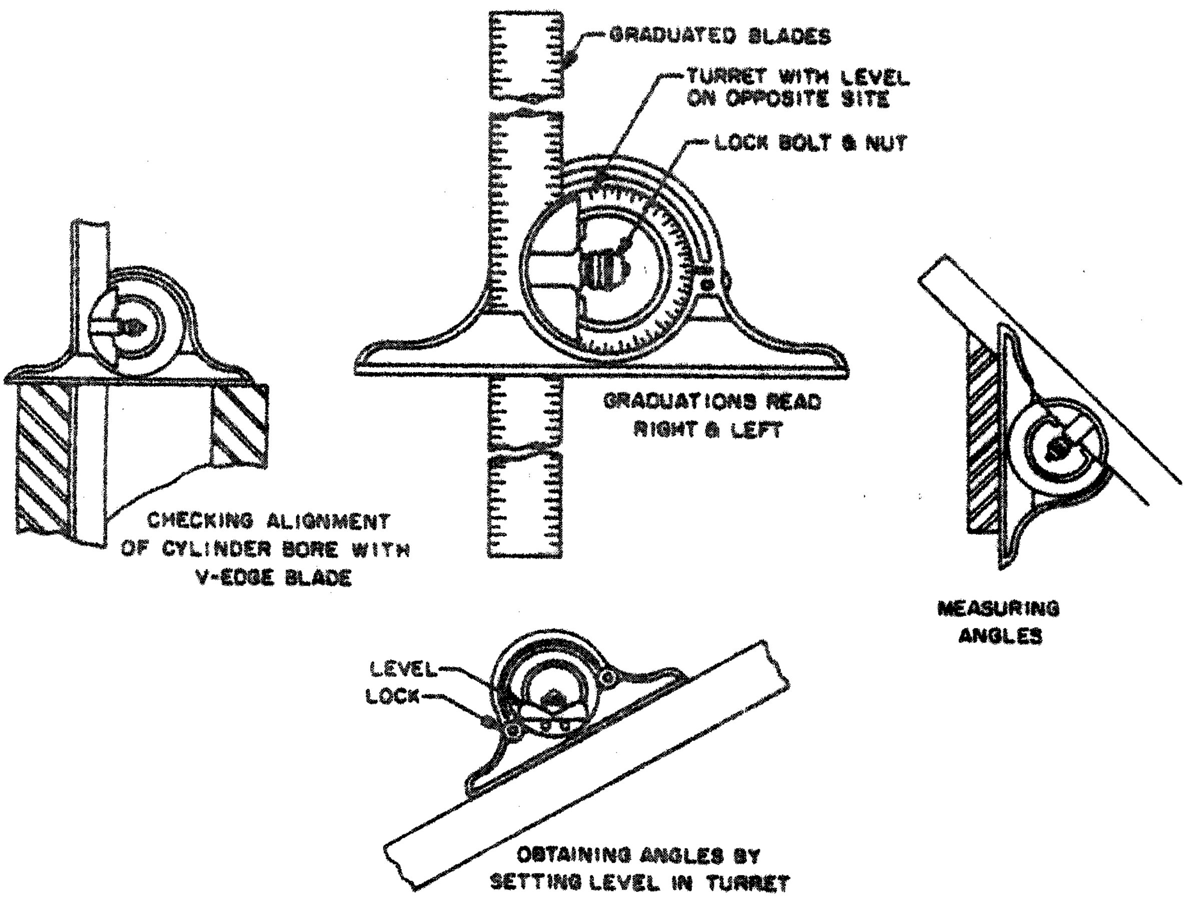


Figure 10.36. Uses for Protractor

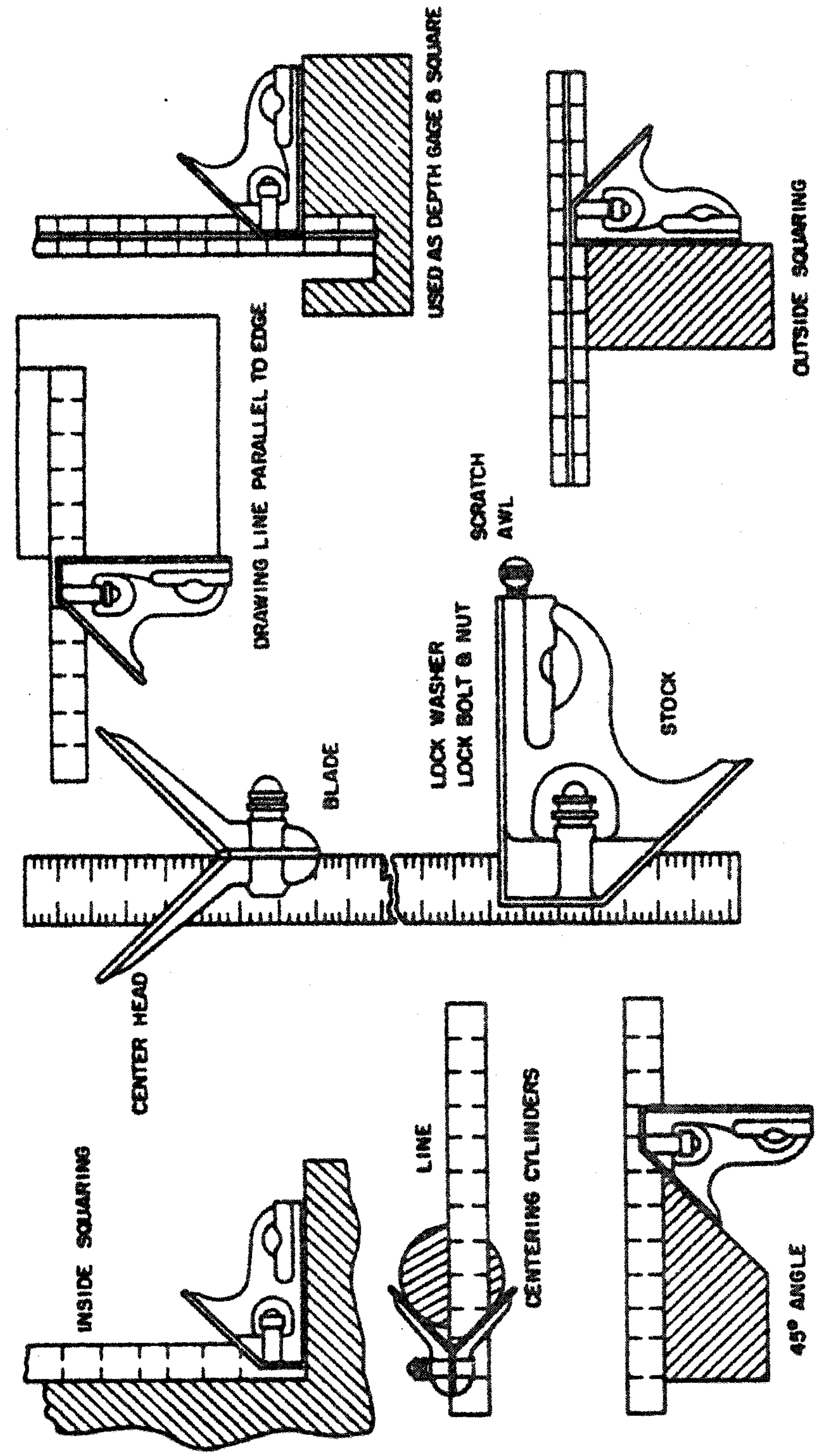


Figure 10.37. Uses for Combination Squares

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 10.38. 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.

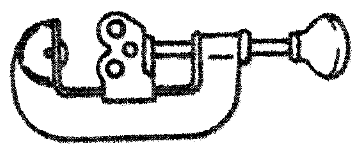


Figure 10.38. Tube Cutter

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 10.39. See Operating Instructions for the Hand Tube Bender starting on page 48. A bench installed tube bender is shown in Figure 10.40.

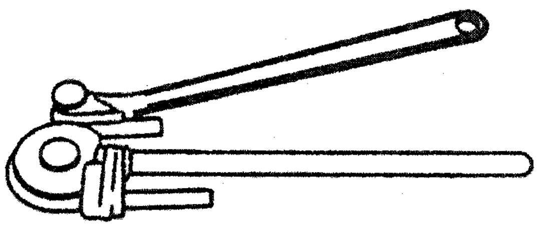


Figure 10.39. Hand Tube Bender

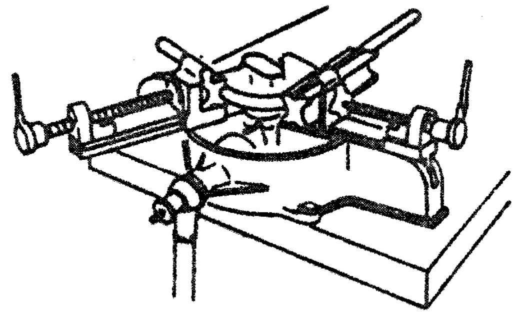


Figure 10.40. Bench Tube Bender

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

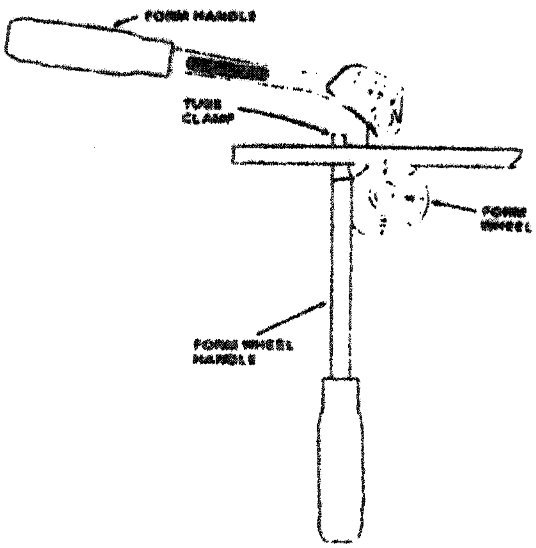


Figure 10.41

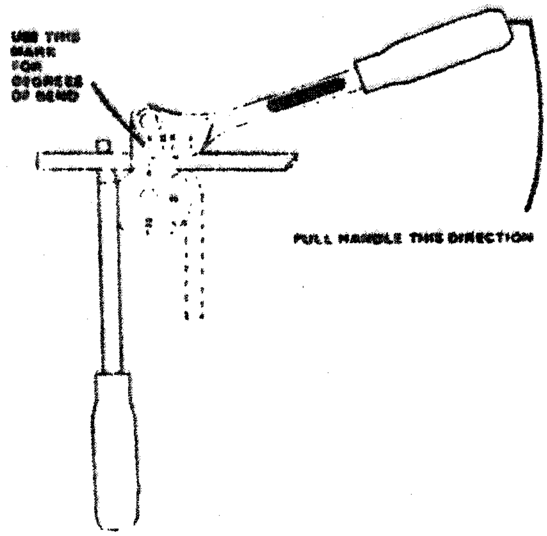


Figure 10.42.

1. Raise form handle. (Figure 10.41)

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 10.42)

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 10.42. 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 10.43. 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 10.43.

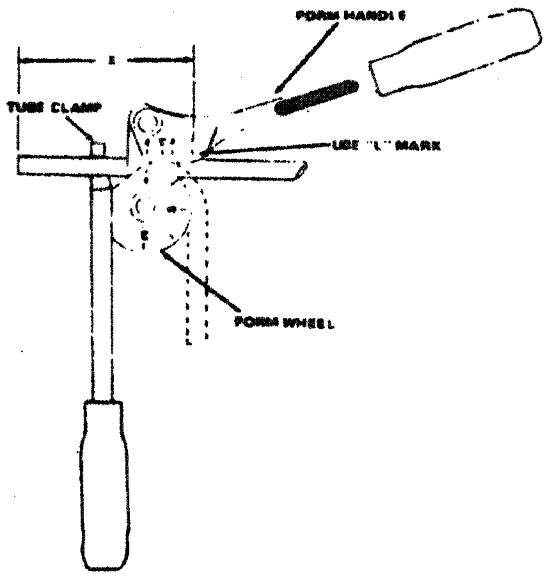


Figure 10.43.

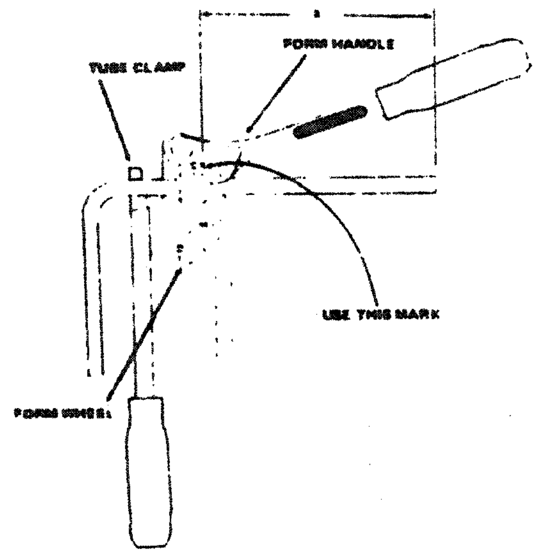


Figure 10.44.

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 10.44. 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.

4. If more than one bend is required (Figure 10.45), measure from the center line of the first bend leg and mark per drawing dimension. Proceed with bend as described in Step 2.

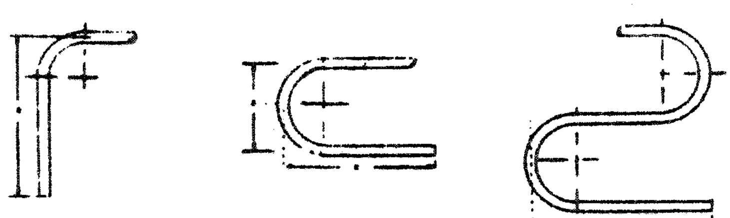


Figure 10.45.

SINGLE 45 DEGREE BENDS

A single 45 degree bend 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 on tube is located directly in line with the "45" graduation on form handle shown in Figure 10.46.

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".

4 EASY STEPS FOR FIGURING OFFSET BENDS

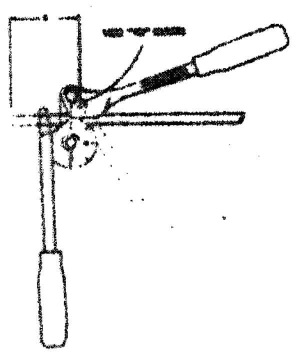


Figure 10.46.

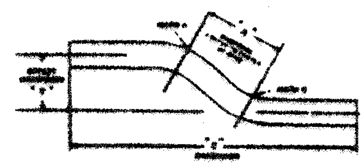


Figure 10.47.

STEP 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 application as explained in section on How to Figure Length of Tubing Required For 45 Degree Offset Applications.

STEP 2 - Figure the length of tube which is needed to meet your offset requirements (X in dimension diagram) 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".

STEP 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.

STEP 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 on the table 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".

OFFSET BEND CALCULATOR

ANGLE OF OFFSET 30°		ANGLE OF OFFSET 45°	
AMOUNT OF OFFSET		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	3	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

ANGLE OF OFFSET 30°		ANGLE OF OFFSET 45°	
AMOUNT OF OFFSET		AMOUNT OF OFFSET	
(Y Dimension)	(X Dimension)	(Y Dimension)	(X Dimension)
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	11-1/4	-5/8	7-31/32
-3/4	11-1/2	-3/4	8-1/8
-7/8	11-3/4	-7/8	8-5/16
6	12	6	8-15/32

NOTE: Keep bender bearings and form handle grooves lubricated. Keep oil away from form wheel grooves.

GUIDE FOR MAKING DIMENSIONAL BENDS

WITH IMPERIAL BLUE DOT TUBE BENDERS 3/16, 1/4, 5/16, 3/8 O.D.

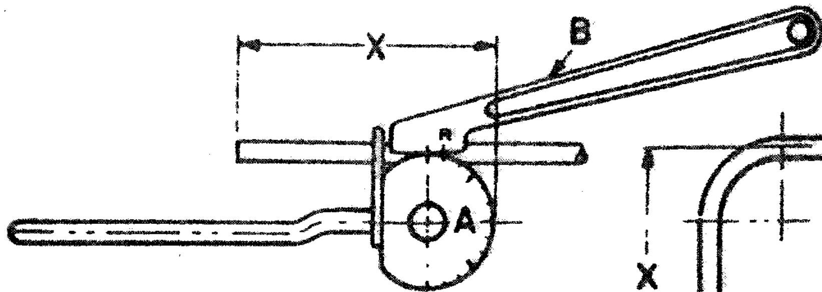
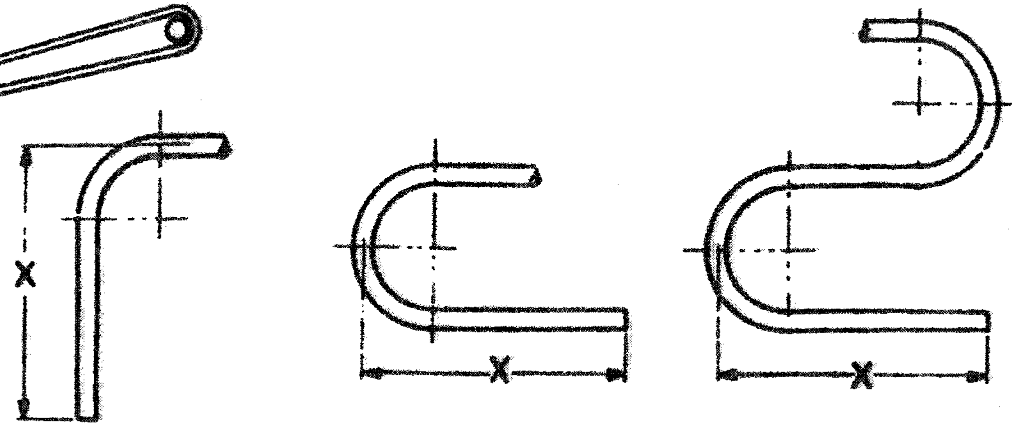


FIG. 10.49

A–MANDREL

B–HANDLE



TO OBTAIN "X" DIMENSION, TUBE SHOULD BE PLACED IN BENDER AS ILLUSTRATED IN FIGURES 10.49 AND 10.50

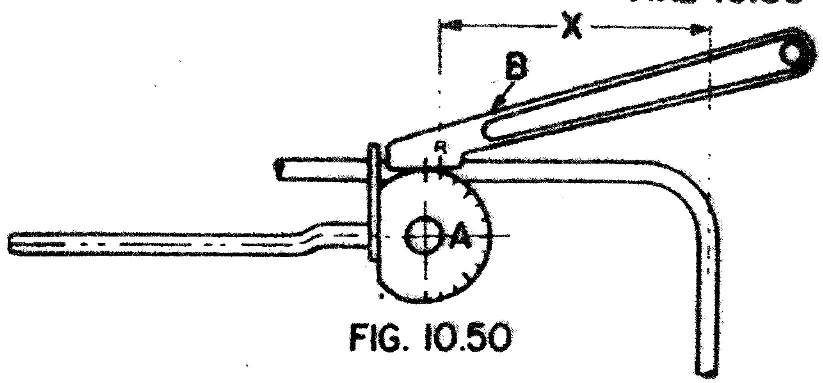
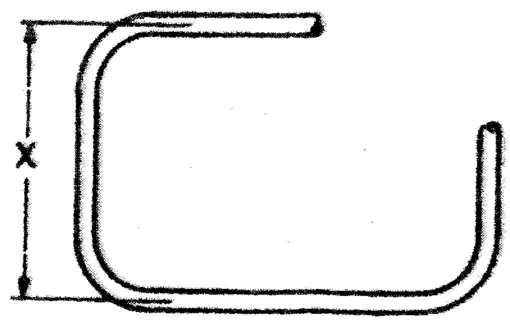


FIG. 10.50



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 jaws. (See Figure 10.52)

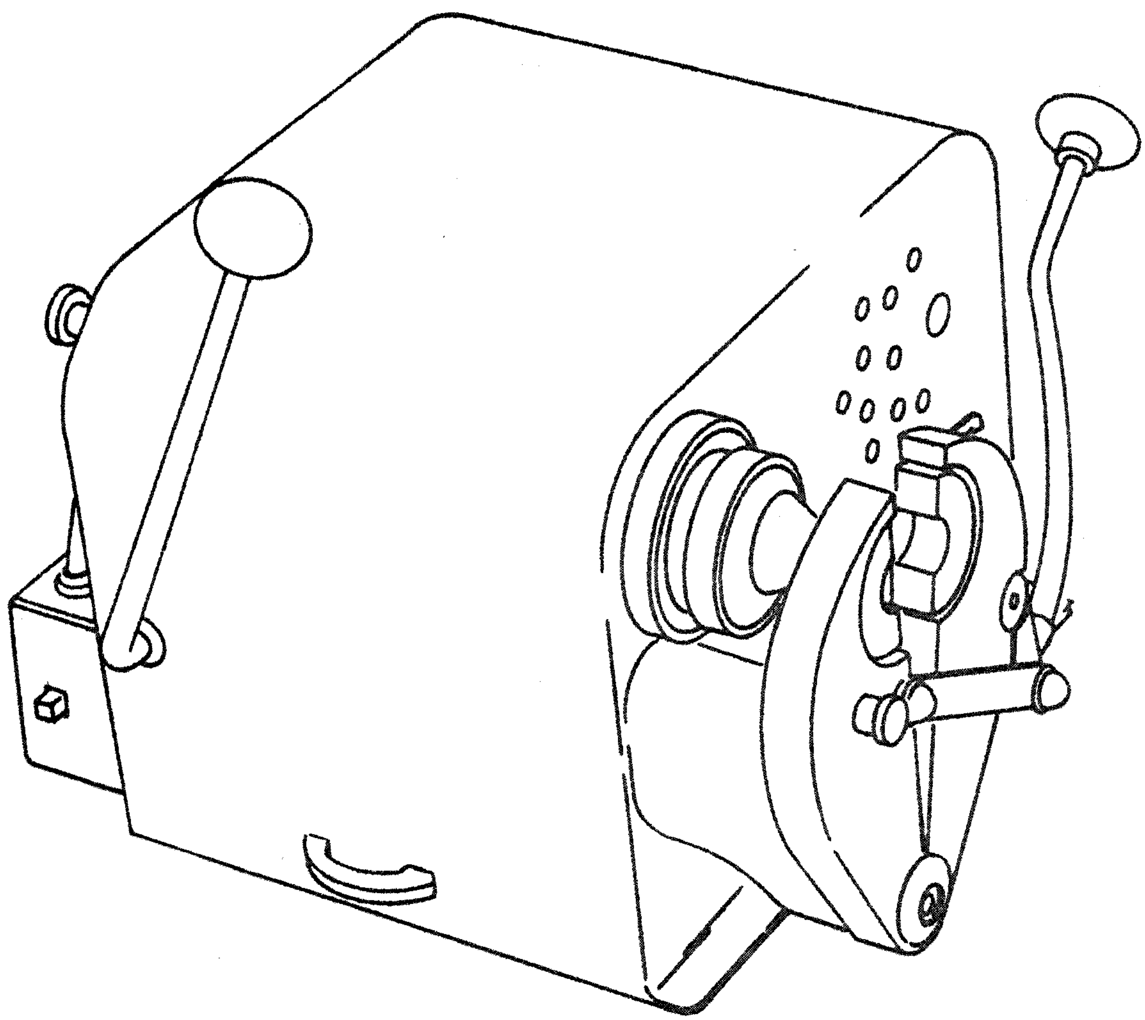


Figure 10.52. Tube Flaring Machine

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 align 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 fixed 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 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.

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 - 9/16-inch size). Preparation of tubing consists of coning and threading operations.

Cone superpressure tubing as follows:

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 10.53.

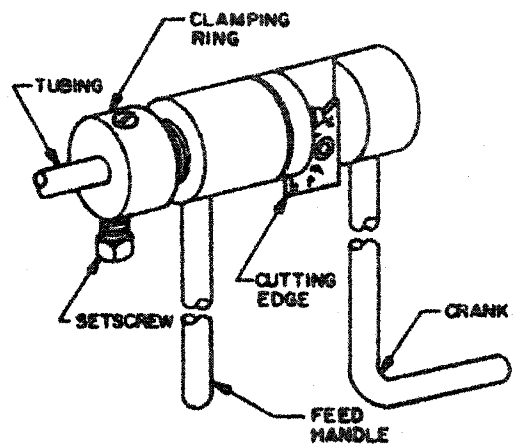


Figure 10.53. Forming Tool for Superpressure Tubing

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 (Figure 10.54).

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.

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

Figure 10.54. Superpressure Tubing Threads

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 foming tool from tubing.

Assemble threading tool (Figure 10.55) as follows:

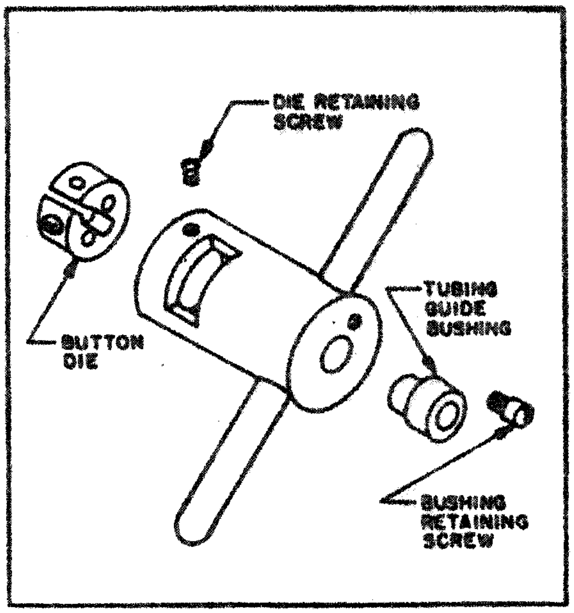


Figure 10.55. Threading Tool for Superpressure Tubing

1. Select proper size tubing guide bushing for tubing to be threaded, and insert it into threading tool, aligning curved slot with retaining screw hole.

2. Secure tubing guide bushing with bushing retaining screw.

3. 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.

4. Align button die until two conical recesses and slot of die line up with three die retaining screws.

5. Tighten die retaining screws.

Thread superpressure tubing as follows:

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 (Figure 10.54) 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.

SECTION 11

MISCELLANEOUS

CONTENTS

COMPRESSED GAS BOTTLES

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 3000 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:

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.

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.)

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.

APPENDIX A

MATERIAL SELECTION AND COMPATIBILITY

METALS, O-RINGS, HOSE LINERS, GASKETS, AND PACKINGS										
SERVICE	NICKEL	ALUMINUM	CARBON STEEL	COPPER	18-8 STAINLESS	O-RINGS		HOSE LINERS	GASKETS	PACKINGS
						DYNAMIC	STATIC			
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

METALS, O-RINGS, HOSE LINERS, GASKETS, AND PACKINGS										
SERVICE	NICKEL	ALUMINUM	CARBON STEEL	COPPER	18-8 STAINLESS	O-RINGS		HOSE LINERS	GASKETS	PACKINGS
						DYNAMIC	STATIC			
Hydraulic (Cont.)										
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

* Ratings based on 100° 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	PACKINGS
Others (Cont)										
Nitric Acid Solution	U	U	U	U	S	24	4,10	1,4,10	4,7,10	4,10
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
Alkylboranes	S	S	S	U	S	4	4,10	4,10		

LUBRICANTS AND SEALS

SERVICE	LUBRICANTS: O-RINGS AND GASKETS (STATIC AND DYNAMIC)	LUBRICANTS: SLIDING SURFACES	LUBRICANTS, SEALS, AND ANTISEIZE: STRAIGHT THREADS STATIC	LUBRICANTS, SEALS, AND ANTISEIZE: STRAIGHT THREADS DYNAMIC	LUBRICANTS, SEALS, AND ANTISEIZE: 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	17,26	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

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
Cryogenic (Cont)					
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
Trichloroethylene	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

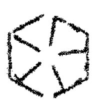
1 - BUNA N	15 - SPECIFICATION MIL-H-5606
2 - BUTYL RUBBER (SR613-75)	16 - SPECIFICATION MIL-G-3278
3 - NEOPRENE	17 - NAZ-20502
4 - TEFLON	18 - MOLYKOTE TYPE Z POWDER
5 - VITON-A (SR270-70)	19 - FLUOROLUBE GREASE (GR 362)
6 - FLURO SILICONE (TH 1081)	20 - TEFLON TAPE, SPECIFICATION MIL-T-27730
7 - FLEXITALLIC WITH TEFLON FILLER	21 - ALUMINUM 2S
8 - JM-76	22 - SOFT COPPER
9 - FLEXITALLIC WITH TEFLON OR ASBESTOS FILLER	23 - STAINLESS STEEL
10 - KEL-F	24 - VITON-A (SR275-70)
11 - ASBESTOS (NO LONGER IN USE)	25 - DC-11
12 - MIL-G-4343	26 - HOKE SLIC SEAL
13 - DC-55	27 - PERMATEX NO. 2
14 - FLUOROLUBE (LG-160)	28 - HIGH-DENSITY POLYETHYLENE (SPECIFICATION MIL-H-26666 AND MIL-H-27462)

ASTM, SAE, AND ISO GRADE MARKINGS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in)	Mechanical Properties: Proof Load (psi)	Mechanical Properties: Yield Strength Min (psi)	Mechanical Properties: 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
No Grade Mark	ASTM A307 Grades A&B	Bolts, Screws, Studs	Low Carbon Steel	1/4 thru 4	-	-	60,000
No Grade Mark	SAE J429 Grade 2	Bolts, Screws, Studs	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
B 5	ASTM A193 Grade B5	Bolts, Screws, Studs for High Temperature Service	AISI 501	1/4 thru 4	-	80,000	100,000
B 6	ASTM A193 Grade B6	Bolts, Screws, Studs for High Temperature Service	AISI 410	1/4 thru 4	-	85,000	110,000
B 7	ASTM A193 Grade B7	Bolts, Screws, Studs for High Temperature Service	AISI 4140, 4142 or 4145	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
B 16	ASTM A193 Grade B16	Bolts, Screws, Studs for High Temperature Service	CrMoV Alloy Steel	1/4 thru 2-1/2 Over 2 1/2 thru 4 Over 4 thru 7	- - -	105,000 95,000 85,000	125,000 110,000 100,000
B 8	ASTM A193 Grade B8	Bolts, Screws, Studs for High Temperature Service	AISI 304	1/4 and larger		30,000	75,000
B 8 C	ASTM A193 Grade B8C	Bolts, Screws, Studs for High Temperature Service	AISI 347	1/4 and larger		30,000	75,000
B 8 M	ASTM A193 Grade B8M	Bolts, Screws, Studs for High Temperature Service	AISI 316	1/4 and larger		30,000	75,000

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	Mechanical Properties		
					Proof Load (psi)	Yield Strength Min (psi)	Tensile Strength Min (psi)
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	125,000 115,000 105,000 100,000
B8C	ASTM A320 Grade B8C		AISI 347				
B8F	ASTM A320 Grade B8F		AISI 303 or 303Se				
B8M	ASTM A320 Grade B8M		AISI 316				
B8T	ASTM A320 Grade B8T		AISI 321				

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 thru 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
	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
	ASTM A325 Type 2		Low Carbon Martensitic Steel, Quenched and Tempered	1/2 thru 1	85,000	92,000	120,000
	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
	ASTM A354 Grade BB,	Bolts, Studs	Alloy Steel, Quenched and Tempered	1/4 thru 2-1/2 2 3/4 thru 4	80,000 75,000	83,000 78,000	105,000 100,000
	ASTM A354 Grade BC				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[a]	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				

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		Low or Medium Carbon Steel		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	Bolts, Screws, Studs	Medium Carbon Steel, Quenched and Tempered	All Sizes thru 1-1/2	85,000	92,000	120,000
10.9 or 109	ISO R898 Class 10.9		Alloy Steel, Quenched and Tempered		120,000	130,000	150,000

NOTES: 1 ASTM Specifications

A 193 – Alloy Steel Bolting Materials for High-Temperature Service

A 307 – Low-Carbon Steel Externally and Internally Threaded Standard Fasteners

A 320 – Alloy Steel Bolting Materials for Low-Temperature Service

A 325 – High-Strength Bolts for Structural Steel Joints, including Suitable Nuts and Plain Hardened Washers

A 354 – Quenched and Tempered Alloy Steel Bolts and Studs with Suitable Nuts

A 449 – Quenched and Tempered Steel Bolts and Studs

A 490 – Quenched and Tempered Alloy Bolts for Structural Steel Joints

2. SAE Specification

J429 – Mechanical and Quality Requirements for Externally Threaded Fasteners

3 ISO Recommendations

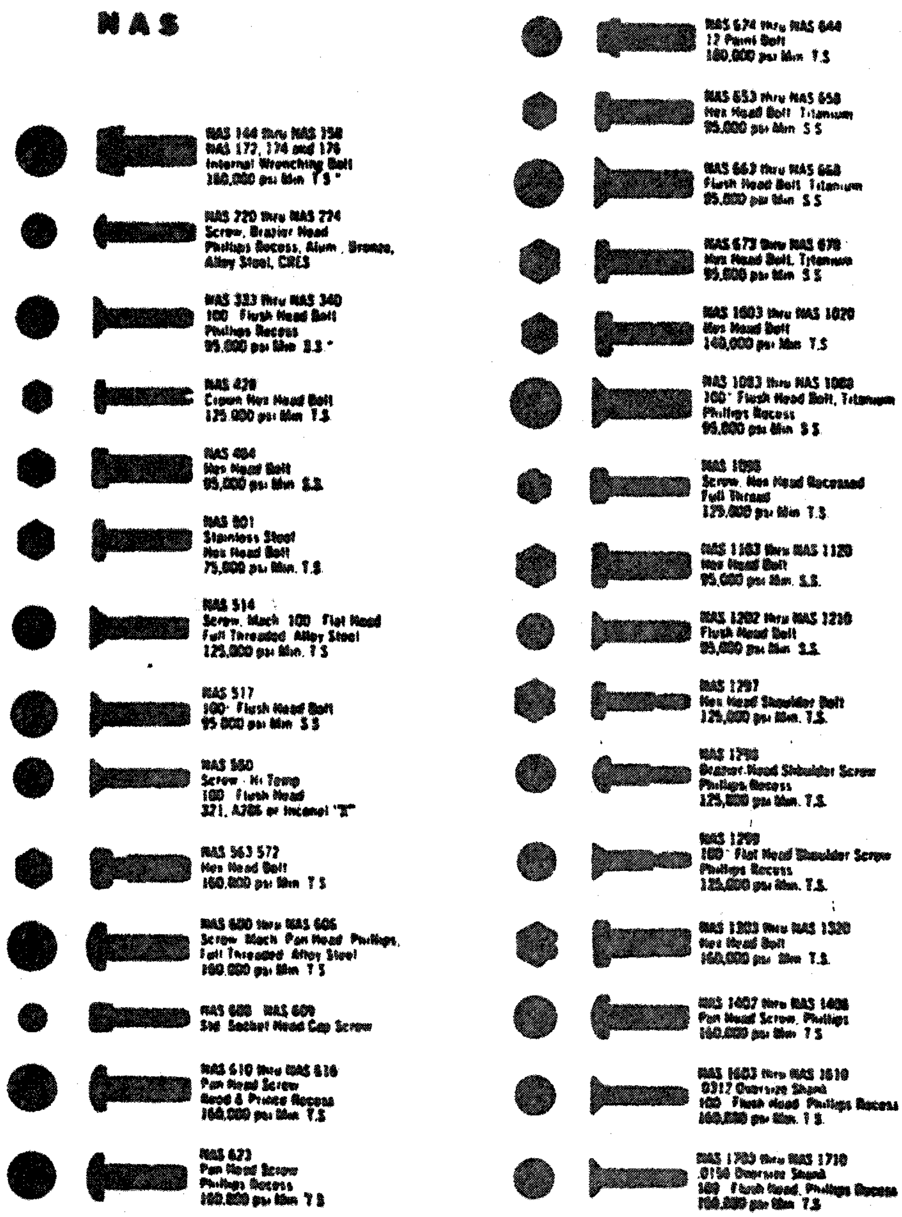
No R898 – Mechanical Properties of Fasteners – Part I – Bolts, Screws and Studs

4. Grade 7 bolts and screws are roll threaded after heat treatment.

(Courtesy Industrial Fasteners Institute)

APPENDIX C

SIMPLIFIED GUIDE TO NAS, AN, AND MS SCREWS AND BOLTS



NAS 2903 thru NAS 2920
0156 Oversize Shank
Hex Head Bolt
160,000 psi Min. T.S.

NAS 3003 thru NAS 3020
0312 Oversize Shank
Hex Head Bolt
160,000 psi Min. T.S.

A N

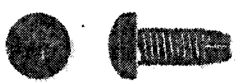
AN 3 thru AN 20
Hex Head Bolt
Steel & Stainless Steel
125,000 psi Min. T.S.
Aluminum
62,000 psi Min. T.S.

AN 73 thru AN 81
Hex Head Bolt
125,000 psi Min. T.S.

AN 173 thru AN 186
Hex Head Bolt, Close Tol. Shank
Alloy & Stainless Steel & Aluminum

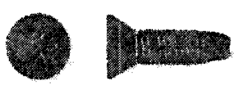
AN 500 thru AN 501
Screw, Mach. Fillister Head, Slotted
Carbon Steel, CRES, Brass

AN 502 thru AN 503
Screw, Mach. Drilled Fillister, Slotted
Alloy Steel
125,000 psi Min. T.S.



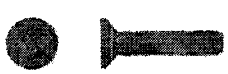
AN 504
Screw, Mach. Tapping, Thread Cutting,
Round Head, Carbon Steel and CRES;
Slotted and Recessed

AN 505
Screw, Mach. Flat Head 82°
Carbon Steel, Brass, CRES Alum.



AN 506
Screw, Mach. Tapping, Thread Cutting
Flat Head 82°
Carbon Steel, CRES; Slotted & Recessed

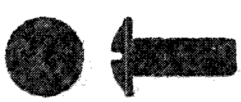
AN 507
Screw, Mach. Flat Head 100°
Carbon Steel, CRES, Brass, Alum.;
Slotted & Recessed



AN 509
Screw, Mach. Flat Head 100°
Alloy Steel, Alum., CRES; Recessed

AN 510
Screw, Mach. Flat Head 82°
Carbon Steel, CRES, Brass, Alum.;
Recessed

AN 515 and AN 520
Screw, Mach. Round Head
Carbon Steel, Brass, CRES, Alum.;
Recessed



AN 525
Screw, Mach. Washer Head
Steel, Alum.; Slotted & Recessed

AN 526
Screw, Mach. Truss Head
Carbon Steel, CRES, Alum.;
Recessed

AN 530
Screw, Tapping, Thread Forming or
Thread Cutting, Round Head, Spaced Thd.,
Recessed, Carbon or CRES Steel

AN 531
Screw, Tapping, Thread Forming or
Thread Cutting, 82° Flat Head, Spaced Thd.,
Recessed, Carbon or CRES Steel

AN 101001 thru AN 108200
Hex Head Bolt
Alloy & CRES Steel
125,000 psi Min. T.S.

AN 148551 thru AN 149350
Internal Wrenching Bolt
140,000 psi Min. T.S.

M S

MS 9033 thru MS 9039
MS 9060 thru MS 9066
12 Point Bolt - A286 - 1200°
130,000 psi Min. T.S.

MS 9088 thru MS 9094
12 Point Bolt - Steel
125,000 psi Min. T.S.

MS 9122 thru MS 9123
Slotted Hex Head Mach. Screw
125,000 psi Min. T.S.

MS 9146 thru MS 9152
MS 9157 thru MS 9163
MS 9169 thru MS 9175
12 Point Bolt
125,000 psi Min. T.S.

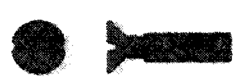
MS 9177 thru MS 9178
12 Point Bolt, A286 - 1200°
130,000 psi Min. T.S.

MS 9183 thru MS 9186
MS 9189 thrus MS 9192
12 Point Bolt - Steel
125,000 psi Min. T.S.

MS 9187 thru MS 9188
12 Point Bolt - A286 - 1200°
130,000 psi Min. T.S.

MS 9224
12 Point Bolt - A286 - 1200°
130,000 psi Min. T.S.

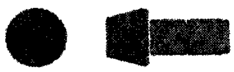
MS 9316 thru MS 9317
Slotted Hex Head Mach. Screw
140,000 psi Min. T.S.



MS 18219
Flat Countersunk Head, Slotted,
Nonmagnetic, CRES Mach. Screw


MS 16200
Pan Head Slotted CRES
Mach. Screw


MS 16637 thru MS 16838
Screw Shoulder, Socket Head, Hex
Alloy Steel, uncoated, Cad. or Zinc


MS 20004 thru MS 20024
Internal Wrenching Bolt
160,000 psi Min. T.S.


MS 20033 thru MS 20046
Hex Head Bolt - 1200°
110,000 psi Min. T.S.

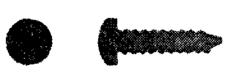

MS 20073 thru MS 20074
Hex Head Bolt
125,000 psi Min. T.S


MS 21250
12 Point Bolt
180,000 psi Min. T.S.


MS 24583
Screw, Mach. Flat Countersunk Cross
Recessed, Carbon Steel, Cadmium


MS 24584
Screw Mach. Pan Head
Cross Recessed, Carbon Steel, Cadmium


MS 24615 thru MS 24616
Screw, Tapping, Thread Forming, Type A,
Flat Countersunk, Cross Recessed, Carbon
Steel, Cad. Plated or CRES

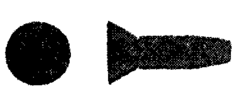

MS 24617 thru MS 24618
Screw, Tapping, Thread Forming, Type A,
Pan Head, Cross Recessed, Carbon Steel,
Cad. Plated or CRES

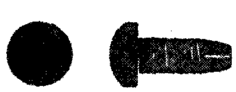

MS 24619 thru MS 24620
Screw, Tapping, Thread Forming, Type B,
Flat Countersunk, Cross Recessed, Carbon
Steel, Cad. Plated or CRES


MS 24621 thru MS 24622
Pan Head, Self Tapping, Thread Forming,
Cross Recess, Type B, Carbon Steel,
Cad. Plated or CRES


MS 24623 thru MS 24624
Flat Head, Self Tapping, Thread Cutting,
Cross Recess, Type BF, BG or BT;
Carbon Steel, Cad. Plated or CRES


MS 24625 thru MS 24626
Pan Head, Self Tapping, Thread Cutting,
Cross Recess, Type BF, BG or BT;
Carbon Steel, Cad. Plated or CRES


MS 24627 thru MS 24628
Flat Head, Self Tapping, Thread Cutting,
Cross Recess, Type D, F, G or T;
Carbon Steel, Cad. Plated or CRES


MS 24629 thru MS 24630
Pan Head, Self Tapping, Thread Cutting,
Cross Recess, Type D, F, G or T,
Carbon Steel, Cad. Plated or CRES

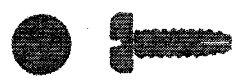

MS 24635 thru MS 24636
Flat Head, Self Tapping, Thread Forming,
Slotted, Type A, Carbon Steel,
Cad. Plated or CRES


MS 24637 thru MS 24638
Pan Head, Self Tapping, Thread Forming,
Slotted, Type A, Carbon Steel,
Cad. Plated or CRES

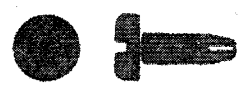

MS 24639 thru MS 24640
Flat Head, Self Tapping, Thread Forming,
Slotted, Type B, Carbon Steel,
Cad. Plated or CRES


MS 24641 thru MS 24642
Pan Head, Self Tapping, Thread Forming,
Slotted, Type B, Carbon Steel,
Cad. Plated or CRES

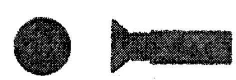

MS 24643 thru MS 24644
Flat Head, Self Tapping, Thread Cutting,
Spaced Threads, Slotted, Type BF, BG or BT;
Carbon Steel, Cad. Plated or CRES


MS 24645 thru MS 24646
Pan Head, Self Tapping, Thread Cutting,
Spaced Threads, Slotted, Type BF, BG or BT;
Carbon Steel, Cad. Plated or CRES


MS 24647 thru MS 24648
Flat Head, Self Tapping, Thread Cutting,
Slotted, Type D, F, G, or T;
Carbon Steel, Cad. Plated or CRES

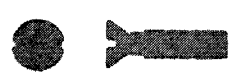

MS 24649 thru MS 24650
Pan Head, Self Tapping, Thread Cutting,
Slotted, Type D, F, G or T;
Carbon Steel, Cad. Plated or CRES


MS 25087 A
Screw, Externally Relieved Body


MS 35188 thru MS 35203
Flat Head Machine Screw, Cross Recess;
Steel, Brass, Alum., CRES; Plain, Cadmium
or Zinc Plated, Phosphate, Black Oxide,
Anodized or Passivated


MS 35204 thru MS 35219
Pan Head Machine Screw, Cross Recess;
Steel, Brass, Alum., CRES; Plain, Cadmium
or Zinc Plated, Phosphate, Black Oxide,
Anodized or Passivated


MS 35221 thru MS 35236
Pan Head Machine Screw, Slotted; Steel,
Brass, Alum., CRES; Plain, Cadmium or
Zinc Plated; Phosphate, Black Oxide,
Anodized or Passivated


MS 35237 thru MS 35251
and MS 35262
Flat Head Machine Screw, Slotted; Steel,
Brass, Alum., CRES; Plain, Cadmium or
Zinc Plated; Phosphate, Black Oxide,
Anodized or Passivated


MS 35263 thru MS 35278
Fillister Head Machine Screw, Drilled,
Slotted, Steel, Brass, Alum., CRES; Plain,
Cadmium or Zinc Plated; Phosphate,
Black Oxide, Anodized or Passivated


MS 35455 thru MS 35458 and
MS 35459 thru MS 35461
Socket Head Cap Screws, Alloy Steel and
CRES, uncoated, Cadmium or Zinc Plated;
Phosphate Treated or Passivated, etc.

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