

CHAPTER 13

WAVEGUIDES

13.1 GENERAL

A waveguide is a transmission line that consists of a hollow tube which propagates electromagnetic waves. The electrical characteristics of a waveguide are determined by its inside dimensions.

The mode of propagation of the electromagnetic waves through the waveguide is described by the various configurations of electric (E) and magnetic (H) fields existing in a plane perpendicular to the waveguide axis. These modes are further identified by double subscripts that indicate the electric- or magnetic-field distribution in half cycles along the x- and the y-axis, respectively, of the waveguide.

The different modes are TE (transverse-electric) waves; TM (transverse-magnetic) waves; and TEM (transverse-electromagnetic) waves. A typical mode-designation might be $TE_{1,0}$, which indicates a transverse-electric mode with one half-cycle of E-field along the x-axis, and zero half-cycles along the y-axis.

Enclosed waveguides may be classified as rectangular, circular, or elliptic. Rectangular waveguide, the most common, is manufactured from metal or metal alloys, and has a hollow, rectangular inner cross-section. This type is primarily used for special applications such as rotating joints. Elliptic waveguide, also manufactured from metal, has a hollow elliptic inner cross-section; this is a newer commercial type and is not widely used at present.

Tables 13-1 and 13-2 list the electrical and physical characteristics of preferred rigid rectangular waveguides.

Ridged waveguide is a variation of rectangular waveguide. This waveguide has a single or double ridge protruding into the waveguide from the broad faces of the rectangular waveguide. Because of its construction, ridged waveguide has a very broad operating frequency range. Table 13-3 lists the characteristics of common single-ridged waveguides; table 13-4 covers double ridged waveguides.

13.2 COUPLINGS

Waveguide couplings can be grouped into three general classes: contact couplings, cover flanges with waveguide seals, and choke couplings, as shown in figure 13-1. Table 13-5 is a list of preferred waveguide flanges.

a. Contact Coupling. A contact coupling consists of two flanges, each soldered, welded, or brazed to the end of the waveguide, and bolted together. The waveguide tubing generally extends through the flange and is machined flush with it after assembly.

b. Waveguide Seals. Waveguide seals were devised to fit between two covers, or flat face flanges as an alternate method for providing good RF and pressure sealing without requiring precise care in machining, or cleaning surfaces prior to assembly.

c. Choke Coupling. A choke coupling is relatively simple to assemble as it is not necessary for the flange faces to make contact at the waveguide ends. A choke coupling has a choke flange and a cover flange. The choke flange has a groove so constructed that it minimizes the possibility of reflections caused by discontinuities in the inner surface of the coupling.

13.3 ASSEMBLIES

Waveguide assemblies include bends, corners, straight twists, and tees, as illustrated in figure 13-2.

Bends and corners in a waveguide system are used to change the direction of transmission. The change of direction may be in the plane of the electric (E), or magnetic (H) fields, and is correspondingly called an E- or H-plane bend or corner. The E-plane bend (called an EASY bend) is a flat (large-dimension) bend; the H-plane bend (called a HARD bend) is an edgewise (small-dimension) bend.

A waveguide twist is used to change the polarization of a rectangular waveguide. The E-plane (series) and H-plane (shunt) tees are generally used for joining three transmission lines at one point. Energy may be divided from one input into two output lines, or may combine energy from two inputs into one output. The magic tee functions in a manner that is similar to a hybrid transformer; an input at A or B will result in equal outputs at C or D branches. An input at C or D will result in equal outputs at A or B.

Section 8 of MIL-HDBK 216 contains a complete listing of both rigid and flexible waveguide assemblies together with a brief functional description and pertinent engineering data.

13.4 FLEXIBLE WAVEGUIDE

Flexible waveguide is used where it is necessary to form bends or to provide flexible connection to equipment subject to vibration. Flexible waveguides have the same dimensions as corresponding rigid waveguides, and use the same fittings, but generally rigid waveguide is preferred. If a choice is possible, rigid waveguide should be used because of its lower power loss.

Five basic types of construction are used for flexible waveguides:

o Interlocked. A thin metal strip is spirally-wound and interlocked to form a flexible, rectangular tube.

- o Soldered-Convolutd. A thin metal strip is spirally-wound, convoluted, and soldered to form a rectangular tube.
- o Seamless. A thin-walled, seamless metal tube is corrugated to form a rectangular tube.
- o Vertebrae. Individual choke sections are inserted into, and held in place by, a synthetic-rubber jacket.
- o Null-Point Seam. A corrugated sheet is folded to form a rectangular tube that has annular cavities or bellows. The lapped seam is located in the center of the larger cross-sectional dimension and is offset to provide a smooth inside contour.

Waveguides are available in various lengths, and most types are obtained from the factory with flanges already attached. If field assembly is required, manufacturers' instructions should be followed. The procedure for assembling a fitting to one type of flexible waveguide is as follows:

- STEP 1. Cut waveguide to required length; make sure ends are cut square.
- STEP 2. Scrape inside and outside of ends with a metal object to remove burrs.
- STEP 3. Clean out filings and chips.
- STEP 4. Using a blowtorch to heat fitting and to apply solder, tin the inside surface of the fitting.
- STEP 5. Apply rosin-core solder to ends of the waveguide to tin it uniformly.
- STEP 6. Insert tinned end of waveguide into fitting; be sure to keep edges and surfaces square.
- STEP 7. If a number of fittings are to be assembled, fabricate a tapered block. Seat the fitting over the block, allow sufficient clearance on taper to slide into waveguide.
- STEP 8. Wrap a wet rag around the tubing, above the fitting, to prevent opening of turns of the waveguide.
- STEP 9. Use a blowtorch to heat joint. Direct flame onto the fitting only.
- STEP 10. Apply a small amount of flux to the joint.
- STEP 11. Solder the fitting to flexible waveguide; make sure that solder flows smoothly into the first two convolutions.
- STEP 12. Clean fitting with an approved solvent and allow to dry before installation.

The following precautions shall be observed when installing flexible waveguide:

- o Do not bend too sharply. Figure 13-3 shows satisfactory and unsatisfactory bends.
- o Do not permit a vertical flexible-waveguide run to support the weight of the waveguide below it.

13.5 ADAPTERS

Waveguide adapters are used to provide a transition from a rigid rectangular waveguide to a coaxial line, using appropriate connectors at each end.

Adapters preferred by the Armed Services are covered by MIL-A-22641. MIL-HDBK-216, Section 9, contains a list of waveguide adapters and a list showing those preferred for military electronic systems.

13.6 DUMMY LOADS

Dummy (artificial) loads are available for use in waveguides in the frequency range from 1.2 to 40 GHz. Each has a limited frequency range over which it provides a satisfactory match to the transmission line. Figure 13-4 shows a typical waveguide dummy load.

The load usually consists of a resistance element in a shorted section which appears to the transmission line as an infinite line. When in use, the specified average power, and the peak power should not be exceeded. Table 13-6 lists the dummy loads available with applicable engineering data.

13.7 ATTACHMENT OF FLANGES

To install flanges on waveguides, it is necessary to become familiar with hard-soldering and brazing procedures.

13.7.1 Hard Soldering

Hard soldering (silver soldering) is the process of bonding two metals with a metal alloy. Hard soldering is accomplished at 399°C (750°F) or higher. Hard soldering is a form of brazing, but because it is performed at lower temperatures than brazing, it requires a slightly different technique. Use an air-acetylene or an oxy-acetylene torch for the process, and proceed as follows:

STEP 1. Clean parts to be soldered.

STEP 2. Apply suitable flux to solder area.

STEP 3. Clamp parts together tightly.

STEP 4. Adjust the flame of the air-acetylene torch so that it is as large as possible; if using an oxy-acetylene torch, adjust flame so that it has a sharply-defined inner core.

STEP 5. Heat the clamped parts by passing the torch flame over them; use a circular pattern. If the oxy-acetylene torch is used, keep the inner core a few inches from the work; do not apply torch flame to the joint.

STEP 6. Remove flame from the parts when the metal becomes dull red; do not overheat metal, apply only enough heat to melt the hard-solder wire.

STEP 7. Dip wire into suitable flux.

STEP 8. Touch wire to joint; capillary action will cause the melted wire to flow into joint.

STEP 9. After parts have cooled, remove all traces of flux.

13.7.2 Brazing

Brazing is the process of joining two metals with a filler metal of a different composition and a lower melting point. The filler metal is distributed, by capillary action, between the surfaces of the parts to be joined. Brazing requires less heat than welding and, therefore, may be used to join metals which would be damaged by intense heat. One alloy of filler metal used for brazing melt at 426.7°C (800°F). Hard-soldering filler metals melt at a lower temperature.

a. Brazing Materials. The two materials required for brazing are filler metal and flux. The filler metal may be in the form of clips, rings, washers, fillings, powder, or wire. Torch brazing, the method to be covered herein, is normally accomplished with wire filler.

Various filler metals require various fluxes. The correct flux must be chosen for each specific brazing application. Fluxes are available in the form of powders, pastes, vapor gases, and coatings on filler wires. They are used to remove oxides and other impurities during brazing.

b. Procedure for Torch Brazing. Use an air-acetylene or oxy-acetylene torch. The metal to be brazed and the filler wire used will determine the flame level. The reducing flame is obtained by decreasing the amount of oxygen supplied to the torch tip; the oxidizing flame is obtained by increasing the oxygen supplied to the torch tip. The procedure for torch brazing is as follows:

STEP 1. Clean parts to be brazed.

STEP 2. Apply flux of a type suitable for the filler and the base metals to the brazing area.

STEP 3. Clamp parts together tightly.

STEP 4. Adjust torch flame.

STEP 5. Heat clamped parts by passing the torch flame back and forth over them in a constant circular pattern.

STEP 6. Place the filler wire along the joint to be brazed.

STEP 7. Play the torch flame along the filler wire. The lower the melting point of the filler wire, the greater must be the distance between the torch tip and the wire.

STEP 8. Add filler wire until the joint is completely filled. Do not allow the flame to concentrate on one spot, otherwise the flux will burn or the base metal will melt.

STEP 9. Allow joint to cool.

STEP 10. Remove all traces of flux.

13.7.3 Flange Installation

Flanges shall be installed by the appropriate following procedures:

a. Brass and Copper Waveguide.

STEP 1. Cut waveguide to required length; make sure it is cut square.

STEP 2. Clean contact surface to be brazed with fine emery or crocus cloth.

STEP 3. Clean out flange and end of waveguide.

STEP 4. Insert waveguide into flange; leave 0.002 to 0.008 inch of guide outside of coupling. (Use an alignment jig similar to the one shown in figure 13-5 to ensure positioning of the flange with respect to waveguide. A mandrel should be used to prevent deformation of waveguide.

STEP 5. Secure the flange to the waveguide by use of two C-clamps and strips of steel.

STEP 6. Apply suitable flux to outside of flange and to area of waveguide to be brazed.

STEP 7. Apply heat, holding flame a distance from joint area and move in a circular pattern to prevent localized overheating.

STEP 8. When flux has liquified, braze the waveguide to flange.

STEP 9. Silver-solder the gas escape vents located in the wide side of the flange.

STEP 10. Remove all traces of flux by flushing the end in boiling water, or with flux remover.

b. Aluminum Waveguide.

STEP 1. Preclean waveguide end by submerging it into a hot solution of caustic soda (one-half pound caustic soda to two gallons of boiling water) for 10 to 15 seconds.

STEP 2. Remove from solution and rinse in clean, cold water.

STEP 3. Submerge waveguide end in a heavy glass, stainless-steel, or stone receptacle filled with concentrated nitric acid for approximately 10 seconds to restore the natural color of the aluminum.

STEP 4. Remove from nitric-acid bath and rinse well in clear, cool water.

STEP 5. Install flange on waveguide so waveguide protrudes 1/32-inch beyond the flange face. (Use an alignment jig and a mandrel, if required, and secure the flange to the waveguide as described in the procedure for brass and copper waveguide.)

STEP 6. Apply suitable flux mixed with a small amount of water or alcohol to areas of aluminum to be brazed and to several inches of brazing rod.

STEP 7. Use a No. 3 torch tip and adjust for a slightly carbonizing (oxygen-starved) flame.

STEP 8. Apply heat to parts to be brazed; keep in constant motion so that all areas will receive an even distribution of heat (flame should be from one to three inches from the metal).

STEP 9. Apply suitable filler to area to be brazed when flux has melted.

STEP 10. Remove all traces of flux.

STEP 11. Clean completed assembly in same manner as described in Steps 1 through 4.

c. Cleaning Waveguide. Each waveguide section must be carefully cleaned prior to installing. Any dirt in the waveguide that forms a discontinuity on the inner surface will affect its performance. It is necessary to clean different types of metals with different processes.

(1) Brass Waveguide. A brass waveguide shall be cleaned as follows:

STEP 1. Remove oil and grease from waveguide by washing in a hot solution, 82°C (180°F) of Oakite No. 23.

STEP 2. Rinse waveguide in hot water.

CAUTION

Avoid contact with pickling or neutralizing solution; if skin is exposed to these solutions, wash immediately with cold water and then with warm water and soap. Avoid inhaling fumes.

STEP 3. Immerse waveguide into an acid-pickle solution of one gallon of sulphuric acid and nine gallons of water; temperature of the solution shall be between room temperature and 66°C (150°F). (A heavy oxide scale may need a hotter and more concentrated solution.)

STEP 4. Remove red stain (cuprous oxide) with a solution of sodium-bichromate and sulphuric acid. A typical proportion for the solution is 12 ounces of sulphuric acid, 4 ounces of sodium-bichromate, and 1 gallon of water. This solution should be maintained from room temperature to 49°C (120°F). Cleaning time depends on the condition of the waveguide.

STEP 5. Submerge waveguide in a 55°C (67°F) bright-dip solution of two gallons of sulphuric acid, one gallon of nitric acid, one-half fluid ounce of hydrochloric acid and one to two quarts of water.

STEP 6. Immerse waveguide into hot water.

STEP 7. Neutralize the acid solution by immersing the waveguide into one of the following baths:

- o One and one-half pounds of potash; one and one-half gallons of water.
- o One pound of soda ash; seven gallons of water.

STEP 8. Wash waveguide in hot water to remove all traces of neutralizing solution.

(2) Aluminum Waveguide. An aluminum waveguide shall be cleaned by the methods given in Steps 1 through 4 of the aluminum-waveguide-flange installation procedures.

The outside surfaces of most brass and aluminum waveguides may be cleaned by sandblasting. Use a light sandblast and apply evenly. Do not sandblast waveguides that have 0.04-inch thick walls.

d. Painting Waveguide. After the waveguide is cleaned, the exterior surfaces shall be painted.

e. Exterior. Paint the exterior surface of the waveguide as follows:

STEP 1. Apply a coat of air-dry, zinc-chromate primer.

STEP 2. Allow to dry for 12 to 16 hours.

STEP 3. Apply a coat of air-dry, gray enamel (FSN 8010-285-8298, five-gallon can).

STEP 4. Allow to dry for 12 to 16 hours.

STEP 5. Apply a second coat of gray enamel.

STEP 6. Allow to air-dry.

13.8 LAYOUT AND INSTALLATION OF RUN

The first step in fabricating a waveguide run is to make a full-scale template. This template will provide accurate information about the shape, radius, and angle of all bends and twists in the waveguide run, as well as the overall length of the run and positions of bulkhead connections and flange holes. The template is usually made from 1/2-inch mild steel wire or wood. If wood is used, it shall be about the same size as the waveguide to be installed. The advantages of using wood are its rigidity, its ability to more nearly approximate the size of the waveguide, and the ease of marking data on it. A disadvantage is that a gradual bend cannot be easily shown.

Figure 13-6A shows a template made from metal wire; figure 13-6B shows a template made from wood. Figure 13-6C shows a template for measuring the twist of a waveguide; the adjustable plates (of a size to match flanges) are rotated to approximate the required twist and positioned on the rod to simulate the waveguide length. The plates are locked into position by set-screws. The degree of twist may then be determined by measurement of the template.

Installation practices to be observed are as follows:

- o Ensure that the waveguide is clean before installation by performing the following steps:

- STEP 1. Pull a clean, lint-free rag, saturated with an approved solvent, through the waveguide. The rag may be suspended between two lengths of plumber's tapes, steel fish tapes, or lintless strings.

- STEP 2. Repeat process until a clean rag does not pick up any dirt.

- o Use a minimum number of couplings in any run.
- o Use prefabricated bend assemblies if proper bending equipment is not available.
- o Start waveguide run from antenna and work down to building; then start at transmitter and work toward joining point.
- o Slope horizontal runs toward transmitter.

- o Use drain holes at all low points.
- o Make as direct a run as possible (maximum run length for 6-1/2- x 3-1/4- and 3- x 1-1/2-inch waveguide is 100 feet; maximum run length for smaller sizes shall be 50 feet).
- o Support waveguide at least every five feet with a hanger (first hanger must be as close as possible to antenna).
- o Use as few bends and twists as possible; never make more than 10 changes of direction in any one waveguide run.
- o Do not allow the weight of any part of a vertical waveguide run to be supported by an elbow or by a horizontal waveguide run.
- o Protect exposed sections of waveguides with a removable shield.
- o Waterproof all points where waveguide passes through a bulkhead. Figure 13-7 illustrates a method of waterproofing a run that passes through a metal bulkhead.

13.9 PRESSURIZER SYSTEMS

Air dielectric RF cables and waveguides are usually maintained under dry air or nitrogen gas pressure to prevent entrance of moisture into the transmission lines, which would degrade the performance of the lines.

13.9.1 Types of Pressure Systems

a. Periodic Charge. A periodic charge system (sometimes referred to as a static system) is one where the cable sheaths are maintained nearly gas tight. The cables involved are filled with nitrogen gas from cylinders, connected at various charge points. An established pressure is permitted to equalize and is maintained by frequent recharging and by repairing both large and small leaks.

b. Continuous Pressure. A continuous feed pressure system is one where the cable is supplied dry air or nitrogen continuously, from a fixed and permanently located source, or sources, to maintain a minimum established pressure. In this system small leaks need not be repaired if the minimum established pressure can be maintained. An air compressor-dryer unit is the commonly used supply source for this type of system. The continuous feed pressure system has certain advantages over the periodic charge system in that the continuous supply of dry air delivered to the cables provides greater protection. In small installations nitrogen gas cylinders may be used in a continuous feed pressure system. The continuous pressure system is the one primarily in use at Naval shore stations.

13.9.2 Nitrogen Gas

The gas used as a pressurization agent is dry nitrogen. It is supplied in steel cylinders containing about 15 pounds of gas at a pressure of 2000 pounds per square inch.

This is equivalent to about 200 cubic feet of gas at normal atmospheric pressure and temperature. Manifolds may be required at a central point to transfer nitrogen gas from 200 cubic foot nitrogen cylinders to 24 cubic foot containers.

A two stage pressure-testing regulator is required to control the flow of gas from cylinders to cables. It consists of an internal assembly of reducing valves, a safety valve, and two gauges. The high pressure gauge indicates the pressure of gas in the cylinder(s) and the volume of gas remaining in the cylinders at atmospheric pressure. The low pressure gauge indicates the pressure of the gas delivered to the regulator outlet.

13.9.3 Air Dehydrator

Dry air provided by a compressor dehydrator is the agent normally used for cable pressurization. The dehydrator removes moisture from the air by compressing it and passing it through a desiccant drying agent such as silica-gel crystals which are blue in color when dry. When they become saturated, the crystals turn pink and should be replaced or heated in an oven to remove the moisture and to regain their original blue color. The dehydrator provides dry air under the required pressure to the cables or waveguides.

A manifold assembly is used to provide a number of pressure outlets for various transmission line requirements. The outlets branch out from a single pressure inlet using only one dehydrator for the system. Each outlet has a valve and gauge to provide individual pressure readings.

13.9.4 Cable Pressurization

After the cable has been installed and connected to the pressurization system, the cable must be purged to remove any moist air which may have accumulated. Changes in temperature can cause moisture from any outside air that enters the cable to condense and seriously impair the efficiency.

To purge air in the cable, remove the gas port plug located on the connector at the antenna end of the cable permitting the air in the cable to escape. After the air is released, replace the plug and repressurize the cable with dry air applied at the transmitter end. Repeat this procedure three times. Another method is to adjust the line pressure regulator until indicated pressure is 10 PSI, then allow a volume of air three times the air volume of the cable to escape at the antenna end. An alternative method is to pressurize to 10 PSI and let the air escape at the transmitter end of the cable. Repeat this procedure three times, allowing an hour each time for the air to mix.

Pressurization can be accomplished manually or automatically, depending on the amount of cable in use at the station and whether or not the site is attended. A dry air hand pump is satisfactory for attended sites using a relatively small amount of cable or waveguide. Automatic electric dehydrators are recommended for unattended sites or those where larger amounts of cable are employed. A cylinder of compressed air can also be used. Gauge pressures of 5 to 10 PSI are adequate for most installations.

When pressurizing equipment is connected to the gas port on the cable connector, or whenever pipe fittings are reassembled, the threads must be covered with pipe thread compound to ensure a leak-proof connection. Replace the valve caps securely. After installation, the waveguides should be checked for leaks. Use a commercial leak detector or brush on a full strength liquid detergent over all joints and check for bubbles. Maintain an unbroken soap film over the entire joint for several minutes to detect very small leaks.

Table 13-1. Rigid Rectangular Waveguides Electrical Characteristics

Type designation	Recommended operating range for TE ₁₀ mode		Cut-off for TE ₁₀ mode		Range in $\frac{2\lambda}{\lambda_c}$	Range in $\frac{\lambda_g}{\lambda}$	Theoretical attenuation lowest to highest frequency 1/ (db/100 ft.)		Theoretical CW power rating lowest to highest frequency 2/ (megawatts)		Type of material
	Frequency (GHz)	Wavelength (cm)	Frequency (GHz)	Wavelength (cm)							
RG-290/U	0.32 - 0.49	93.68 - 61.18	0.256	116.84	1.60-1.05	1.68-1.17	0.040-0.026	528.3	-753.8	AL 1100	
RG-291/U	0.35 - 0.53	85.65 - 56.56	0.281	106.68	1.62-1.06	1.68-1.18	0.046-0.031	439.3	-625.4	AL 1100	
RG-201/U	0.410 - 0.625	73.2 - 48.8	0.328	91.44	1.60-1.05	1.67-1.18	0.057-0.038	325.1	-461.4	AL 1100	
RG-202/U	0.490 - 0.750	60.0 - 40.0	0.393	76.20	1.57-1.05	1.62-1.17	0.076-0.051	224.1	-320.4	AL 1100	
RG-203/U	0.64 - 0.96	48.8 - 31.2	0.513	58.42	1.67-1.07	1.82-1.18	0.113-0.076	132.0	-186.9	AL 1100	
RG-204/U	0.75 - 1.12	40.0 - 26.7	0.605	49.53	1.62-1.06	1.70-1.19	0.147-0.098	93.81	-133.7	AL 1100	
RG-205/U	0.96 - 1.45	31.2 - 20.7	0.766	39.12	1.60-1.06	1.66-1.18	0.205-0.139	59.67	-84.18	AL 1100	
RG-69/U	1.12 - 1.70	28.79 - 17.65	0.908	33.04	1.62-1.07	1.70-1.18	0.316-0.209	41.34	-59.74	Copper Alloy	
RG-108/U	1.12 - 1.70	28.79 - 17.65	0.908	33.04	1.62-1.07	1.70-1.18	0.273-0.180	41.34	-59.74	AL 1100	
RG-206/U	1.12 - 1.70	28.79 - 17.65	0.908	33.04	1.62-1.07	1.70-1.18	0.484-0.320	41.34	-59.74	Mag AZ31B	
RG-337/U	1.45 - 2.20	20.67 - 13.68	1.154	26.00	1.60-1.05	1.67-1.18	0.440-0.299	26.19	-37.00	Copper Alloy	
RG-339/U	1.45 - 2.20	20.67 - 13.68	1.154	26.00	1.60-1.05	1.67-1.18	0.674-0.458	26.19	-37.00	Mag AZ31B	
RG-338/U	1.45 - 2.20	20.67 - 13.68	1.154	26.00	1.60-1.05	1.67-1.18	0.380-0.258	26.19	-37.00	AL 1100	
RG-104/U	1.70 - 2.60	17.65 - 11.54	1.375	21.82	1.62-1.06	1.70-1.18	0.583-0.387	18.23	-26.26	Copper Alloy	
RG-105/U	1.70 - 2.60	17.65 - 11.54	1.375	21.82	1.62-1.06	1.70-1.18	0.502-0.334	18.23	-26.26	AL 1100	
RG-207/U	1.70 - 2.60	17.65 - 11.54	1.375	21.82	1.62-1.06	1.70-1.18	0.892-0.592	18.23	-26.26	Mag AZ31B	
RG-112/U	2.20 - 3.30	14.3 - 10.0	1.737	17.27	1.65-1.15	1.78-1.22	0.791-0.550	11.87	-16.44	Copper Alloy	
RG-113/U	2.20 - 3.30	14.3 - 10.0	1.737	17.27	1.65-1.15	1.78-1.22	0.682-0.474	11.87	-16.44	AL 1100	
RG-208/U	2.20 - 3.30	14.3 - 10.0	1.737	17.27	1.65-1.15	1.78-1.22	1.211-0.842	11.87	-16.44	Mag AZ31B	
RG-48/U	2.60 - 3.95	11.54 - 7.6	2.080	14.42	1.60-1.05	1.67-1.17	1.102-0.754	7.645	-10.85	Copper Alloy	
RG-75/U	2.60 - 3.95	11.54 - 7.6	2.080	14.42	1.60-1.05	1.67-1.17	0.950-0.651	7.645	-10.85	AL 1100	
RG-167/U	2.60 - 3.95	11.54 - 7.6	2.080	14.42	1.60-1.05	1.67-1.17	1.687-1.155	7.645	-10.85	Mag AZ31B	
RG-340/U	3.30 - 4.90	9.09 - 6.12	2.577	11.64	1.56-1.05	1.60-1.18	1.404-0.996	5.475	-7.549	Copper Alloy	
RG-341/U	3.30 - 4.90	9.09 - 6.12	2.577	11.64	1.56-1.05	1.60-1.18	1.211-0.858	5.475	-7.549	AL 1100	
RG-342/U	3.30 - 4.90	9.09 - 6.12	2.577	11.64	1.56-1.05	1.60-1.18	2.149-1.523	5.475	-7.549	Mag AZ31B	
RG-49/U	3.95 - 5.85	7.60 - 5.13	3.155	9.51	1.60-1.06	1.67-1.19	2.071-1.436	3.296	-4.697	Copper Alloy	
RG-95/U	3.95 - 5.85	7.60 - 5.13	3.155	9.51	1.60-1.06	1.67-1.19	1.785-1.238	3.296	-4.697	AL 1100	
RG-168/U	3.95 - 5.85	7.60 - 5.13	3.155	9.51	1.60-1.06	1.67-1.19	3.168-2.197	3.296	-4.697	Mag AZ31B	
RG-343/U	4.90 - 7.05	6.12 - 4.26	3.705	8.10	1.51-1.04	1.52-1.17	2.305-1.722	2.792	-3.719	Copper Alloy	
RG-344/U	4.90 - 7.05	6.12 - 4.26	3.705	8.10	1.51-1.04	1.52-1.17	1.988-1.485	2.792	-3.719	AL 1100	
RG-345/U	4.90 - 7.05	6.12 - 4.26	3.705	8.10	1.51-1.04	1.52-1.17	3.527-2.634	2.792	-3.719	Mag AZ31B	
RG-50/U	5.85 - 8.20	5.13 - 3.66	4.285	7.00	1.47-1.05	1.48-1.17	2.936-2.319	1.975	-2.531	Copper Alloy	
RG-106/U	5.85 - 8.20	5.13 - 3.66	4.285	7.00	1.47-1.05	1.48-1.17	2.532-1.999	1.975	-2.531	AL 1100	
RG-169/U	5.85 - 8.20	5.13 - 3.66	4.285	7.00	1.47-1.05	1.48-1.17	4.492-3.548	1.975	-2.531	Mag AZ31B	
RG-51/U	7.05 - 10.00	4.25 - 3.00	5.260	5.70	1.49-1.05	1.51-1.17	4.114-3.197	1.284	-1.702	Copper Alloy	
RG-68/U	7.05 - 10.00	4.25 - 3.00	5.260	5.70	1.49-1.05	1.51-1.17	3.548-2.756	1.284	-1.702	AL 1100	
RG-170/U	7.05 - 10.00	4.25 - 3.00	5.260	5.70	1.49-1.05	1.51-1.17	6.275-4.891	1.284	-1.702	Mag AZ31B	
RG-52/U	8.20 - 12.40	3.66 - 3.42	6.560	4.57	1.60-1.06	1.68-1.18	6.424-4.445	0.758	-1.124	Copper Alloy	
RG-67/U	8.20 - 12.40	3.66 - 3.42	6.560	4.57	1.60-1.06	1.68-1.18	5.540-3.833	0.758	-1.124	AL 1100	
RG-171/U	8.20 - 12.40	3.66 - 3.42	6.560	4.57	1.60-1.06	1.68-1.18	9.830-6.801	0.758	-1.124	Mag AZ31B	
RG-346/U	10.00 - 15.00	3.00 - 2.00	7.847	3.82	1.57-1.05	1.61-1.18	7.601-5.309	0.622	-0.903	Copper Alloy	
RG-347/U	10.00 - 15.00	3.00 - 2.00	7.847	3.82	1.57-1.05	1.61-1.18	6.554-4.758	0.622	-0.903	AL 1100	
RG-348/U	10.00 - 15.00	3.00 - 2.00	7.847	3.82	1.57-1.05	1.61-1.18	11.631-8.124	0.622	-0.903	Mag AZ31B	
RG-91/U	12.40 - 18.00	2.42 - 1.67	9.490	3.16	1.53-1.05	1.55-1.18	9.578-7.041	0.457	-0.633	Copper Alloy	
RG-349/U	12.40 - 18.00	2.42 - 1.67	9.490	3.16	1.53-1.05	1.55-1.18	8.259-6.071	0.457	-0.633	AL 1100	
RG-172/U	12.40 - 18.00	2.42 - 1.67	9.490	3.16	1.53-1.05	1.55-1.18	14.655-10.773	0.457	-0.633	Mag AZ31B	
RG-352/U	15.00 - 22.00	2.00 - 1.36	11.54	2.60	1.54-1.05	1.57-1.18	6.910-5.079	0.457	-0.633	Silver Grade C	
RG-353/U	15.00 - 22.00	2.00 - 1.36	11.54	2.60	1.54-1.05	1.57-1.18	8.836-6.402	0.312	-0.433	Copper Alloy	
RG-351/U	15.00 - 22.00	2.00 - 1.36	11.54	2.60	1.54-1.05	1.57-1.18	13.08-9.477	0.312	-0.433	AL 1100	
RG-350/U	15.00 - 22.00	2.00 - 1.36	11.54	2.60	1.54-1.05	1.57-1.18	20.01-14.57	0.312	-0.433	Mag AZ31B	
RG-53/U	18.00 - 26.50	1.67 - 1.13	14.080	2.13	1.57-1.06	1.60-1.18	20.48-15.04	0.171	-0.246	Copper Alloy	
RG-121/U	18.00 - 26.50	1.67 - 1.13	14.080	2.13	1.57-1.06	1.60-1.18	17.66-12.97	0.171	-0.246	AL 1100	
RG-173/U	18.00 - 26.50	1.67 - 1.13	14.080	2.13	1.57-1.06	1.60-1.18	31.34-23.02	0.171	-0.246	Mag AZ31B	
RG-66/U	18.00 - 26.50	1.67 - 1.13	14.080	2.13	1.57-1.06	1.60-1.18	14.77-10.85	0.171	-0.246	Silver Grade C	
RG-354/U	22.00 - 33.00	1.36 - 0.91	17.28	1.74	1.56-1.05	1.60-1.18	25.03-17.41	0.139	-0.209	Copper Alloy	
RG-355/U	22.00 - 33.00	1.36 - 0.91	17.28	1.74	1.56-1.05	1.60-1.18	21.58-15.01	0.139	-0.209	AL 1100	
RG-356/U	22.00 - 33.00	1.36 - 0.91	17.28	1.74	1.56-1.05	1.60-1.18	38.29-26.63	0.139	-0.209	Mag AZ31B	
RG-357/U	22.00 - 33.00	1.36 - 0.91	17.28	1.74	1.56-1.05	1.60-1.18	16.18-11.25	0.139	-0.209	Silver Grade A	
RG-96/U	26.50 - 40.00	1.13 - 0.750	21.100	1.423	1.59-1.05	1.65-1.17	24.55-16.80	0.096	-0.146	Silver Grade C	
RG-271/U	26.50 - 40.00	1.13 - 0.750	21.100	1.423	1.59-1.05	1.65-1.17	21.99-15.06	0.096	-0.146	Silver Grade A	
RG-97/U	33.00 - 50.00	0.909 - 0.600	26.350	1.138	1.60-1.05	1.67-1.17	34.57-23.50	0.0644	-0.097	Silver Grade C	
RG-272/U	33.00 - 50.00	0.909 - 0.600	26.350	1.138	1.60-1.05	1.67-1.17	30.98-21.06	0.0644	-0.097	Silver Grade A	
RG-358/U	40.00 - 60.00	0.75 - 0.500	30.69	0.978	1.53-1.02	1.56-1.16	38.92-27.32	0.048	-0.070	Silver Grade C	
RG-98/U	50.00 - 75.00	0.600 - 0.400	39.900	0.752	1.60-1.06	1.67-1.17	64.23-43.89	0.030	-0.044	Silver Grade A	
RG-273/U	50.00 - 75.00	0.600 - 0.400	39.900	0.752	1.60-1.06	1.67-1.17	57.55-39.32	0.030	-0.044	Silver Grade C	
RG-99/U	60.00 - 90.00	0.500 - 0.330	48.400	0.620	1.61-1.06	1.68-1.18	87.79-58.86	0.020	-0.030	Silver Grade A	
RG-274/U	60.00 - 90.00	0.500 - 0.330	48.400	0.620	1.61-1.06	1.68-1.18	78.67-52.74	0.020	-0.030	Silver Grade C	
RG-359/U	75.00 - 110.00	0.400 - 0.270	58.85	0.510	1.57-1.06	1.61-1.18	100.9-71.03	0.014	-0.020	Silver Grade A	
RG-278/U	90.00 - 140.00	0.330 - 0.214	73.840	0.406	1.63-1.05	1.72-1.17	153.7-98.67	0.0088	-0.013	Silver Grade A	
RG-276/U	110.00 - 170.00	0.273 - 0.177	90.845	0.330	1.65-1.07	1.76-1.18	213.5-135.3	0.0059	-0.0093	Silver Grade A	
RG-275/U	140.00 - 220.00	0.214 - 0.136	115.750	0.259	1.65-1.05	1.76-1.17	308.2-193.7	0.0037	-0.0061	Silver Grade A	
RG-277/U	170.00 - 260.00	0.177 - 0.115	137.52	0.218	1.62-1.06	1.70-1.18	377.0-250.5	0.0028	-0.0045	Silver Grade A	

1/ Resistivity of copper (OF - DLP) = 1.78 microhm-cm, Aluminum 1100 = 2.90 microhm-cm, Aluminum 6061 = 4.31 microhm-cm, Copper Alloy = 3.9 microhm-cm, Magnesium = 9.13 microhm-cm, Silver, Grade A = 1.63 microhm-cm, Silver, Grade C = 2.03 microhm-cm.
 2/ Based on considerations of breakdown varying with frequency and waveguide size as outlined in Gould and Gliden's "Handbook on High Power Capabilities of Waveguide Systems" for practical applications these values should be reduced by a factor of 5.

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Table 13-2. Rigid Rectangular Waveguides,
Physical Characteristics (Sheet 1 of 4)

Type designation (see figure)	Dimensions (inches)									ASTM type material
	Inside			Outside			Wall		Max ^{2/} inner corner radius	
	Width (a)	Height (b)	Tolerance	Width (c)	Height (d)	Tolerance	Thickness (nominal)	Max allow eccent ^{1/}		
RG-53/U RG-121/U RG-173/U RG-66/U	0.420	0.170	±0.002	0.500	0.250	±0.003	0.040	0.003	0.0156	OF-DLP Copper alloy 1100 6061 AZ31B MIL-S- 13282
RG-354/U RG-355/U RG-356/U RG-357/U	0.340	0.170	±0.0020	0.420	0.250	±0.003	0.040	0.003	0.0156	OF-DLP Copper alloy 1100 6061 AZ31B Copper alloy & MIL-S- 13282
RG-96/U RG-271/U	0.2800	0.1400	±0.0015	0.360	0.220	±0.002	0.040	0.002	0.0156	MIL-S- 13282 OF-DPL & MIL-S- 13282 Copper alloy & MIL-S- 13282
RG-97/U RG-272/U	0.2240	0.1120	±0.0010	0.304	0.192	±0.002	0.040	0.002	0.010	MIL-S- 13282 OF-DLP & MIL-S- 13282 Copper alloy & MIL-S- 13282
RG-358/U	0.1880	0.094	±0.0010	0.268	0.174	±0.002	0.040	0.002	0.010	OF-DLP & MIL-S- 13282 Copper alloy & MIL-S- 13282
RG-98/U RG-273/U	0.1480	0.0740	±0.0010	0.228	0.154	±0.002	0.040	0.002	0.008	MIL-S- 13282 OF-DLP & MIL-S- 13282 Copper alloy & MIL-S- 13282

See footnotes at end of table.

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Table 13-2. Rigid Rectangular Waveguide,
Physical Characteristics (Sheet 2 of 4)

Type designation (see figure)	Dimensions (inches)									AS TM type material
	Inside			Outside			Wall		Max ^{2/} inner corner radius	
	Width (a)	Height (b)	Toler- ance	Width (c)	Height (d)	Toler- ance	Thick- ness (nominal)	Max allow eccent ^{1/}		
RG-290/U	23.000	11.500	±0.020	23.376	11.876	±0.020	0.188	0.010	0.125	1100 6061
RG-291/U	21.000	10.500	±0.020	21.376	10.876	±0.020	0.188	0.010	0.125	1100 6061
RG-201/U	18.000	9.000	±0.020	18.250	9.250	±0.020	0.125	0.010	0.125	1100 6061
RG-202/U	15.000	7.500	±0.015	15.250	7.750	±0.015	0.125	0.010	0.0937	1100 6061
RG-203/U	11.500	5.750	±0.015	11.750	6.000	±0.015	0.125	0.010	0.0937	1100 6061
RG-204/U	9.750	4.875	±0.010	10.000	5.125	±0.010	0.125	0.010	0.0625	1100 6061
RG-205/U	7.700	3.850	±0.010	7.950	4.100	±0.010	0.125	0.010	0.0625	1100 6061
RG-69/U RG-103/U RG-206/U	6.500	3.250	±0.008	6.660	3.410	±0.008	0.080	0.008	0.0468	OF-DLP Copper alloy 1100 6061 AZ31B
RG-337/U RG-339/U RG-338/U	5.100	2.550	±0.008	5.260	2.710	±0.008	0.080	0.008	0.0468	OF-DLP Copper alloy AZ31B 1100 6061
RG-105/U RG-104/U RG-207/U	4.300	2.150	±0.008	4.460	2.310	±0.008	0.080	0.008	0.0468	OF-DLP 1100 6061 Copper alloy AZ31B
RG-113/U RG-112/U RG-208/U	3.400	1.700	±0.006	3.560	1.860	±0.006	0.080	0.007	0.0468	OF-DLP 1100 6061 Copper alloy AZ31B
RG-75/U RG-48/U RG-167/U	2.840	1.340	±0.006	3.000	1.500	±0.006	0.080	0.006	0.0468	OF-DLP 1100 6061 Copper alloy AZ31B
RG-341/U RG-340/U RG-342/U	2.290	1.145	±0.006	2.418	1.273	±0.006	0.064	0.005	0.0468	OF-DLP 1100 6061 Copper alloy AX31B

See footnotes at end of table.

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Table 13-2. Rigid Rectangular Waveguides.
Physical Characteristics (Sheet 3 of 4)

Type designation (see figure)	Dimensions (inches)									ASTM type material
	Inside			Outside			Wall		Max ^{2/} inner corner radius	
	Width (a)	Height (b)	Toler- ance	Width (c)	Height (d)	Toler- ance	Thick- ness (nominal)	Max allow eccent ^{1/}		
RG-95/U RG-49/U RG-168/U	1.872	0.872	±0.005	2.000	1.000	±0.005	0.064	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-344/U RG-343/U RG-345/U	1.590	0.795	±0.005	1.718	0.923	±0.005	0.064	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-106/U RG-50/U RG-169/U	1.372	0.622	±0.004	1.500	0.750	±0.004	0.064	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-68/U RG-51/U RG-170/U	1.122	0.497	±0.004	1.250	0.625	±0.004	0.064	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-67/U RG-52/U RG-171/U	0.900	0.400	±0.004	1.000	0.500	±0.004	0.050	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-347/U RG-346/U RG-348/U	0.750	0.375	±0.003	0.850	0.475	±0.003	0.050	0.004	0.0312	OF-DLP 1100 6061 Copper alloy AZ31B
RG-91/U RG-349/U RG-172/U RG-107/U	0.622	0.311	±0.0025	0.702	0.391	±0.003	0.040	0.003	0.0156	OF-DLP Copper alloy 1100 6061 AZ31B MIL-S- 13282
RG-352/U RG-353/U RG-351/U RG-350/U	0.510	0.255	±0.0025	0.590	0.335	±0.003	0.040	0.003	0.0156	OF-DLP Copper alloy 1100 6061 AZ31B MIL-S- 13282

See footnotes at end of table

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Table 13-2. Rigid Rectangular Waveguides,
Physical Characteristics (Sheet 4 of 4)

Type designation (s figure)	Dimensions (inches)									ASTM type material
	Inside			Outside			Wall		Max ^{2/} inner corner radius	
	Width (a)	Height (b)	Tolerance	Width (c)	Height (d)	Tolerance	Thick-ness (nominal)	Max allow eccentric ^{1/}		
RG-99/U RG-274/U	0.1220	0.0610	±0.0005	0.202	0.141	±0.002	0.040	0.002	0.006	MIL-S-13282 OF - DLP & MIL-S-13282 Copper alloy & MIL-S-13282
RG-359/U	0.100	0.050	±0.0005	0.180	0.130	±0.002	0.040	0.002	0.006	OF - DLP & MIL-S-13282 Copper alloy & MIL-S-13282
RG-278/U	0.0800	0.0400	±0.0003	1.120	0.080	±0.001	0.020	0.001	0.0031	MIL-S-13282 OF - DLP & Copper alloy & MIL-S-13282
RG-276/U	0.0650	0.03250	±0.00025	0.105	0.073	±0.001	0.020	0.001	0.0015	OF - DLP & MIL-S-13282 Copper alloy & MIL-S-13282
RG-275/U	0.05100	0.02550	±0.00025	0.091	0.066	±0.001	0.020	0.001	0.0015	OF - DLP & MIL-S-13282 Copper alloy & MIL-S-13282
RG-277/U	0.04300	0.02150	±0.00020	0.083	0.062	±0.001	0.020	0.001	0.0015	OF - DLP & MIL-S-13282 Copper alloy & MIL-S-13282

^{1/} The eccentricity of a waveguide is defined as one-half the difference between opposite wall thicknesses as measured at any cross section perpendicular to the longitudinal axis.

^{2/} Maximum outer corner radius, 1/32-inch; minimum outer corner radius, 1/64-inch.

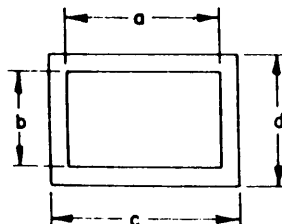


Table 13-3. Single Ridged Waveguides

Type/ designation	Frequency range (GHz)	C1G (GHz)	C1O (inches)	C2O (GHz)	a	Dimension in inches						C1O		
						b	d	s	t	R1 (max)	R2	Att db/ft ³	Power handl/ Cap. (kw)	
Bandwidth 2.4:1														
WRS175U24-	0.175-0.42	0.148	79.803	0.431	28.129	12.658	5.278	4.360				1.056	0.00024	32,870
WRS267U24-	0.267-0.64	0.226	52.260	0.658	18.421	8.289	3.457	2.855				0.691	0.00045	14,100
WRS420U24-	0.42-1.0	0.356	33.177	1.036	11.695	5.263	2.195	1.813	0.125	0.047		0.439	0.00087	5,682
WRS640U24-	0.64-1.53	0.542	21.792	1.577	7.682	3.457	1.442	1.191	0.125	0.047		0.288	0.00164	2,451
WRS840U24-	0.84-2.0	0.712	16.588	2.072	5.847	2.631	1.097	0.906	0.080	0.047		0.219	0.00248	1,421
WRS150D24-	1.5-3.6	1.271	9.293	3.699	3.276	1.474	0.615	0.508	0.080	0.047		0.123	0.00591	445.8
WRS200D24-	2.0-4.8	1.695	6.968	4.933	2.456	1.105	0.461	0.381	0.080	0.047		0.092	0.00908	250.6
WRS350D24-	3.5-8.2	2.966	3.982	8.632	1.404	0.632	0.264	0.218	0.064	0.031		0.053	0.0212	81.87
WRS475D24-	4.75-11.0	4.025	2.934	11.714	1.034	0.465	0.194	0.160	0.050	0.031		0.039	0.0333	44.43
WRS750D24-	² /7.5-18.0	6.356	1.858	18.498	0.655	0.295	0.123	0.1015	0.050	0.015		0.025	0.0661	17.82
WRS110C24-	² /11.0-26.5	9.322	1.267	27.130	0.4466	0.2010	0.0838	0.0692	0.040	0.015		0.017	0.117	8.285
WRS190C24-	² /18.0-40.0	15.254	0.7743	44.393	0.2729	0.1228	0.0512	0.0423	0.040	0.015		0.010	0.245	3.035
Bandwidth 3.6:1														
WRS108U36-	0.108-0.39	0.092	128.37	0.404	31.218	14.048	2.402	5.307				0.480	0.0016	14,550
WRS270U36-	0.27-0.97	0.229	51.572	1.006	12.542	5.644	0.965	2.132				0.193	0.0065	2,348
WRS390U36-	0.39-1.4	0.331	35.680	1.454	8.677	3.905	0.668	1.475	0.125	0.047		0.134	0.0112	1,124
WRS970U36-	0.97-3.5	0.822	14.367	3.611	3.494	1.572	0.269	0.594	0.080	0.047		0.054	0.0438	182.2
WRS140D36-	1.4-5.0	1.186	9.958	5.210	2.422	1.090	0.186	0.412	0.080	0.047		0.037	0.0759	87.56
WRS350D36-	3.5-12.4	2.966	3.982	13.030	0.968	0.436	0.075	0.165	0.050	0.031		0.015	0.300	13.99
WRS500D36-	² /5.0-18.0	4.237	2.787	18.613	0.678	0.305	0.052	0.115	0.050	0.015		0.010	0.513	6.857
WRS124C36-	² /12.4-40.0	10.508	1.124	46.162	0.273	0.123	0.021	0.046	0.040	0.015		0.004	2.008	1.115

¹/ Complete type designation shall include an additional symbol to indicate material:
A = Aluminum alloy B = Brass M = Magnesium alloy.
(For further information refer to MIL-H-23351.)
²/ Figure 2 in these frequency ranges only.
³/ Copper.
⁴/ Based on breakdown of air - 15,000 volts per cm (safety factor of approximately 2 at sea level). Corner radii considered.

FIGURE 1

FIGURE 2

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Table 13-4. Double Ridged Waveguides

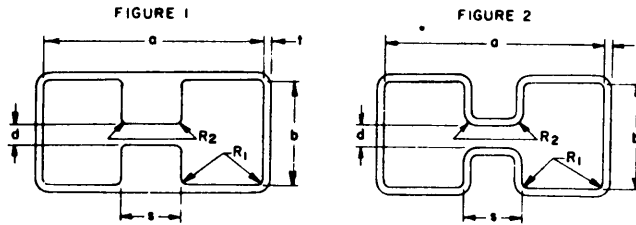
Type/ designation	Frequency range (GHz)	C10 (GHz)	C10 (inches)	C20 (GHz)	Dimension in inches							C10		
					a	b	d	s	t	R1 (max)	R2	Att db/ft ³	Power handl- Cap. (kw)	
Bandwidth: 2.4:1														
WRD175U24-	0.175-0.42	0.148	79.81	0.435	29.667	13.795	5.863	7.417				1.173	0.00023	
WRD267U24-	0.267-0.64	0.226	52.26	0.664	19.428	9.034	3.839	4.857				0.768	0.00043	
WRD420U24-	0.42-1.0	0.356	33.18	1.047	12.333	5.737	2.437	3.003	0.125	0.050	0.487	0.00025		
WRD640U24-	0.64-1.53	0.542	21.79	1.593	8.100	3.767	1.601	2.025	0.125	0.050	0.320	0.0016		
WRD840U24-	0.84-2.0	0.712	16.59	2.093	6.167	2.868	1.219	1.542	0.125	0.050	0.244	0.0024		
WRD150D24-	1.5-3.6	1.271	9.29	3.736	3.455	1.607	0.683	0.864	0.080	0.050	0.137	0.0058		
WRD200D24-	2.0-4.8	1.695	6.97	4.984	2.590	1.205	0.512	0.648	0.080	0.050	0.102	0.0089		
WRD350D24-	3.5-8.2	2.966	3.98	8.722	1.480	0.688	0.292	0.370	0.064	0.030	0.058	0.020		
WRD475D24-	4.75-11.0	4.025	2.93	11.842	1.090	0.506	0.215	0.272	0.050	0.030	0.043	0.032		
WRD750D24-	7.5-18.0	6.356	1.86	18.680	0.691	0.321	0.136	0.173	0.050	0.020	0.027	0.064		
WRD110C24-	^{2/} 11.0-26.5	9.322	1.28	27.406	0.471	0.219	0.093	0.118	0.040	0.015	0.019	0.11		
WRD180C24-	^{2/} 18.0-40.0	15.254	0.77	44.820	0.288	0.134	0.057	0.072	0.040	0.015	0.011	0.24		
Bandwidth: 3.6:1														
WRD10R36-	0.108-0.39	0.092	128.37	0.401	34.638	14.894	2.904	8.660			0.581	0.0014	28,830	
WRD270U36-	0.27-0.97	0.229	51.572	0.999	13.916	5.984	1.167	3.479			0.233	0.0055	4653	
WRD390U36-	0.39-1.4	0.331	35.680	1.444	9.628	4.140	0.807	2.407	0.125	0.050	0.161	0.0097	2227	
WRD970U36-	0.97-3.5	0.822	14.367	3.587	3.877	1.667	0.325	0.969	0.080	0.050	0.065	0.0378	361.2	
WRD140D36-	1.4-5.0	1.186	9.958	5.176	2.687	1.155	0.225	0.672	0.080	0.050	0.045	0.0656	173.5	
WRD350D36-	3.5-12.4	2.966	3.982	12.944	1.074	0.462	0.090	0.269	0.050	0.030	0.018	0.259	27.74	
WRD500D36-	5.0-18.0	4.237	2.787	18.490	0.752	0.323	0.063	0.188	0.050	0.020	0.013	0.443	13.59	
WRD124C36-	^{2/} 12.4-40.0	10.508	1.124	45.857	0.303	0.130	0.025	0.076	0.040	0.015	0.005	1.730	2.210	

^{1/}Complete type designation shall include an additional symbol to indicate material:
 A = Aluminum alloy B = Brass M = Magnesium alloy.

^{2/}Figure 2 in these frequency ranges only.

^{3/}Copper.

^{4/}Based on breakdown of air 15,000 volts per cm (safety factor of approximately 2 at sea level). Corner radii considered.



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Table 13-5. Flanges (Sheet 1 of 5)

Type	Functional description	Figure number	Material	For use with waveguide types	Engineering data
UG-39/U	Cover flange	7.2A	Copper alloy	RG-52/U (WR90)	Mates with UG-40B/U.
UG-41/U	Choke flange	7.2A	Copper alloy	RG-52/U (WR90)	Mates with UG-39/U.
UG-51/U	Cover flange	7.2B	Copper alloy	RG-51/U (WR112)	Mates with UG-52B/U.
UG-52B/U	Choke flange	7.2B	Copper alloy	RG-51/U (WR112)	Mates with UG-51/U. Replaces UG-42/U.
UG-53/U	Cover flange	7.2C	Copper alloy	RG-48/U (WR284)	Mates with UG-54B/U.
UG-54B/U	Choke flange	7.2C	Copper alloy	RG-48/U (WR284)	Mates with UG-53/U. Replaces UG-54, 200, 200A/U.
UG-55/U	Cover flange (expansion)		Copper alloy	RG-48/U (WR284)	Mates with UG-56/U.
UG-56/U	Choke flange (expansion)		Copper alloy	RG-48/U (WR284)	Mates with UG-55/U.
UG-65/U	Contact flange		Copper alloy	RG-48/U (WR284)	Mates with UG-66/U.
UG-66/U	Contact flange		Copper alloy	RG-48/U (WR284)	Mates with UG-65/U.
UG-116/U	Cover flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-117/U.
UG-117/U	Choke flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-116/U.
UG-135/U	Cover flange	7.2A	Aluminum	RG-67/U (WR90)	Mates with UG-136B/U.
UG-136B/U	Choke flange	7.2A	Aluminum	RG-67/U (WR90)	Mates with UG-135/U. Replaces UG-136/U.
UG-137B/U	Choke flange	7.2B	Aluminum	RG-68/U (WR112)	Mates with UG-138/U.
UG-138/U	Cover flange	7.2B	Aluminum	RG-68/U (WR112)	Mates with UG-137B/U.
UG-148C/U	Choke flange	7.2F	Copper alloy	RG-49/U (WR187)	Mates with UG-149A/U. Replaces UG-148B/U.
UG-149A/U	Cover flange	7.2F	Copper alloy	RG-49/U (WR187)	Mates with UG-148C/U.
UG-150/U	Contact flange		Copper alloy	RG-50/U (WR137)	Mates with UG-150/U.
UG-164/U	Cover flange		Copper alloy	RG-48/U (WR284)	Mates with UG-165/U.
UG-165/U	Choke flange		Copper alloy	RG-48/U (WR284)	Mates with UG-164/U.
UG-210/U	Choke flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-211/U.
UG-211/U	Cover flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-210/U.
UG-214/U	Cover flange		Copper alloy	RG-48/U (WR284)	Mates with UG-54A/U.
UG-247/U	Cover flange		Copper alloy	RG-50/U (WR137)	Mates with UG-248/U.
UG-248/U	Choke flange		Copper alloy	RG-50/U (WR137)	Mates with UG-247/U.
UG-319/U	Contact flange (male)		Copper alloy	RG-69/U (WR650)	Mates with UG-320/U.
UG-320/U	Contact flange (female)		Copper alloy	RG-69/U (WR650)	Mates with UG-319/U.
UG-322/U	Choke flange		Copper alloy	RG-69/U (WR650)	Mates with UG-323/U.
UG-323/U	Cover flange		Copper alloy	RG-69/U (WR650)	Mates with UG-322/U.

Note: Figure number refers to Figures of MIL-HDBK-216, 7 April 1967.

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Table 13-5. Flanges (Sheet 2 of 5)

Type	Functional description	Figure number	Material	For use with waveguide types	Engineering data
UG-343B/U	Choke flange	7.2D	Copper alloy	RG-50/U (WR137)	Mates with UG-344/U.
UG-344/U	Cover flange	7.2D	Copper alloy	RG-50/U (WR137)	Mates with UG-343B/U.
UG-381/U	Contact flange	7.2E	Copper alloy	RG-96 (WR28)	Mates with UG-381/U.
UG-383/U	Contact flange	7.2E	Copper alloy	RG-97/U (WR22)	Mates with UG-383/U.
UG-385/U	Contact flange	7.2E	Copper alloy	RG-98/U (WR15)	Mates with UG-385/U.
UG-387/U	Contact flange	7.2E	Copper alloy	RG-99/U (WR12)	Mates with UG-387/U.
UG-406B/U	Choke flange	7.2F	Aluminum	RG-95/U (WR187)	Mates with UG-407/U.
UG-407/U	Cover flange	7.2F	Aluminum	RG-95/U (WR187)	Mates with UG-406B/U.
UG-417A/U	Contact flange	7.2G	Copper alloy	RG-69/U (WR650)	Mates with UG-417A/U. Replaces UG-417/U.
UG-418A/U	Contact flange	7.2G	Aluminum	RG-103/U (WR650)	Mates with UG-418A/U. Replaces UG-418/U.
UG-419/U	Cover flange	7.2H	Copper alloy	RG-91,107/U (WR62)	Mates with UG-541A/U. Replaces UG-420/U. Use gasket M24211/1-003 when two cover flanges are used.
UG-435A/U	Contact flange	7.2G	Copper alloy	RG-104/U (WR430)	Mates with UG-435A/U. Replaces UG-435/U.
UG-437A/U	Contact flange	7.2G	Aluminum	RG-105/U (WR430)	Mates with UG-437A/U. Replaces UG-437/U.
UG-440B/U	Choke flange	7.2D	Aluminum	RG-106/U (WR137)	Mates with UG-441/U.
UG-441/U	Cover flange	7.2D	Aluminum	RG-106/U (WR137)	Mates with UG-440B/U.
UG-509/U	Contact flange		Copper alloy	RG-109/U	Mates with UG-510/U.
UG-510/U	Contact flange		Copper alloy	RG-109/U	Mates with UG-509/U.
UG-511/U	Contact flange		Copper alloy	RG-110/U	Mates with UG-512/U.
UG-512/U	Contact flange		Copper alloy	RG-110/U	Mates with UG-511/U.
UG-541A/U	Choke flange		Copper alloy	RG-91,107/U (WR62)	Mates with UG-419/U.
UG-553/U	Contact flange	7.2G	Copper alloy	RG-112/U (WR340)	Mates with UG-553/U.
UG-554/U	Contact flange	7.2G	Aluminum	RG-113/U (WR340)	Mates with UG-554/U.
UG-584/U	Cover flange	7.2C	Aluminum	RG-75/U (WR284)	Mates with UG-585A/U. Replaces UG-439/U.
UG-585A/U	Choke flange	7.2C	Aluminum	RG-75/U (WR284)	Mates with UG-584/U. Replaces UG-438, 438A/U.
UG-595/U	Cover flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-596A/U.
UG-596A/U	Choke flange		Copper alloy	RG-53,66/U (WR42)	Mates with UG-595/U.
UG-597/U	Cover flange	7.2H	Aluminum	RG-121/U (WR42)	Mates with UG-598A/U. Use gasket M2421/1-005 when two cover flanges are used.
UG-598A/U	Choke flange		Aluminum	RG-121/U (WR42)	Mates with UG-597/U.

Note: Figure number refers to Figures of MIL-HDBK-216, 7 April 1967.

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Table 13-5. Flanges (Sheet 3 of 5)

Type	Functional description	Figure number	Material	For use with waveguide types	Engineering data
UG-599/U	Cover flange	7.2H	Copper alloy	RG-96/U (WR28)	Mates with UG-600A/U. Use gasket M24211/1-006 when two cover flanges are used.
UG-600A/U	Choke flange		Copper alloy	RG-96/U (WR28)	Mates with UG-599/U.
UG-933/U	Contact flange		Copper alloy	RG-127/U (WR650)	Mates with UG-933/U.
UG-954/U	Cover flange		Copper alloy	Navy type 14 ACM	
UG-979/U	Choke flange		Copper alloy	RG-132/U (WR650)	Similar to UG-322/U.
UG-1008A/U GPX-13	Contact flange		Copper alloy		Replaces UG-1008/ GPX-13 Mates with UG-1007A/GPX-13.
UG-1027/U	Contact flange		Stainless steel	Navy type 14 ACM	Similar to UG-417A/U.
UG-1087/U	Contact flange		Copper alloy		Special flange.
UG-1140/U	Choke flange		Aluminum	RG-103/U	Mates with UG-323/U.
UG-1165/U	Cover flange	7.2B	Aluminum alloy	RG-349 (WR62)	Mates with UG-1166/U. Aluminum type UG-419.
UG-1166/U	Choke flange	7.2A	Aluminum alloy	RG-349 (WR62)	Mates with UG-1165/U. Aluminum type UG-541A/U.
UG-1196/U	Cover flange		Magnesium alloy	RG-167/U	Mates with UG-1197/U.
UG-1197/U	Choke flange		Magnesium alloy	RG-167/U	Mates with UG-1196/U.
UG-1198/U	Cover flange		Magnesium alloy	RG-168/U	Mates with UG-1199/U.
UG-1199/U	Choke flange		Magnesium alloy	RG-168/U	Mates with UG-1198/U.
UG-1200/U	Cover flange		Magnesium alloy	RG-169/U	Mates with UG-1201/U.
UG-1201/U	Choke flange		Magnesium alloy	RG-169/U	Mates with UG-1200/U.
UG-1202/U	Cover flange		Magnesium alloy	RG-170/U	Mates with UG-1203/U.
UG-1203/U	Choke flange		Magnesium alloy	RG-170/U	Mates with UG-1202/U.
UG-1204/U	Cover flange		Magnesium alloy	RG-171/U	Mates with UG-1205/U.
UG-1205/U	Choke flange		Magnesium alloy	RG-171/U	Mates with UG-1204/U.
UG-1206/U	Cover flange		Magnesium alloy	RG-172/U	Mates with UG-1207/U.
UG-1207/U	Choke flange		Magnesium alloy	RG-172/U	Mates with UG-1206/U.

Note: Figure number refers to Figures of MIL-HDBK-216, 7 April 1967.

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Table 13-5. Flanges (Sheet 4 of 5)

Type	Functional description	Figure number	Material	For use with waveguide types	Engineering data
UG-1208/U	Cover flange		Magnesium alloy	RG-173/U	Mates with UG-1209/U.
UG-1209/U	Choke flange		Magnesium alloy	RG-173/U	Mates with UG-1208/U.
UG-1475/U	Miniature, unpressurized, contact		Copper alloy	RG-49/U (WR187)	Mates with self.
UG-1476/U	Miniature, unpressurized, contact		Copper alloy	RG-50/U (WR137)	Mates with self.
UG-1477/U	Miniature, unpressurized, contact		Copper alloy	RG-51/U (WR112)	Mates with self.
UG-1478/U	Miniature, unpressurized, contact		Copper alloy	RG-52/U (WR90)	Mates with self.
UG-1479/U	Miniature, unpressurized, contact		Copper alloy	RG-48/U (WR284)	Mates with self.
UG-1480/U	Miniature, unpressurized, contact		Aluminum alloy	RG-95/U (WR187)	Mates with self.
UG-1481/U	Miniature, unpressurized, contact		Aluminum alloy	RG-106/U (WR137)	Mates with self.
UG-1482/U	Miniature, unpressurized, contact		Aluminum alloy	RG-68/U (WR112)	Mates with self.
UG-1483/U	Miniature, unpressurized, contact		Aluminum alloy	RG-67/U (WR90)	Mates with self.
UG-1484/U	Miniature, unpressurized, contact		Aluminum alloy	RG-75/U (WR284)	Mates with self.
UG-1521/U	Subminiature contact		Copper alloy	RG-97/U (WR22)	Mates with self.
UG-1522/U	Subminiature contact		Copper alloy	RG-99/U (WR12)	Mates with self.
UG-1523/U	Subminiature contact		Copper alloy	RG-98/U (WR15)	Mates with self.
UG-1524/U	Subminiature contact		Copper alloy	RG-275/U	Mates with self.
UG-1525/U	Subminiature contact		Copper alloy	RG-276/U	Mates with self.
UG-1526/U	Subminiature contact		Copper alloy	RG-277/U	Mates with self.
UG-1527/U	Subminiature contact		Copper alloy	RG-278/U	Mates with self.
UG-1528/U	Subminiature contact		Copper alloy	RG-359 (WR10)	Mates with self.
UG-1529/U	Subminiature contact		Copper alloy	RG-358 (WR19)	Mates with self.
UG-1530/U	Subminiature contact		Copper alloy	RG-354 (WR34)	Mates with self.

Note: Figure number refers to Figures of MIL-HDBK-216, 7 April 1967.

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Table 13-5. Flanges (Sheet 5 of 5)

Type	Functional description	Figure number	Material	For use with waveguide types	Engineering data
UG-1711/U	Cover flange	7.2H	Aluminum alloy	RG-105/U (WR430)	Mates with self. Use gasket M24211/2-003.
UG-1712/U	Cover flange	7.2H	Copper alloy	RG-112/U (WR340)	Mates with self. Use gasket M24211/2-004.
UG-1713/U	Cover flange	7.2H	Aluminum alloy	RG-113/U (WR340)	Mates with self. Use gasket M24211/2-004.
UG-1714/U	Cover flange	7.2H	Copper alloy	RG-69/U (WR-650)	Mates with self. Use gasket M24211/2-001.
UG-1715/U	Cover flange	7.2H	Copper alloy	RG-337/U (WR510)	Mates with self. Use gasket M24211/2-002.
UG-1716/U	Cover flange	7.2H	Copper alloy	RG-104/U (WR430)	Mates with self. Use gasket M24211/2-003.
UG-1717/U	Cover flange	7.2H	Aluminum alloy	RG-338/U (WR510)	Mates with self. Use gasket M24211/2-002.
UG-1720/U	Cover flange	7.2H	Aluminum alloy	RG-103/U (WR-650)	Mates with self. Use gasket M24211/2-001.
UG-1724/U	Cover flange	7.2H	Copper alloy	RG-48/U (WR284)	Mates with self. Use gasket M24211/2-005.
UG-1725/U	Cover flange	7.2H	Aluminum alloy	RG-75/U (WR284)	Mates with self. Use gasket M24211/2-005.
UG-1726/U	Cover flange	7.2H	Copper alloy	RG-340/U (WR229)	Mates with self. Use gasket M24211/2-006.
UG-1727/U	Cover flange	7.2H	Aluminum alloy	RG-341/U (WR229)	Mates with self. Use gasket M24211/2-006.
UG-1728/U	Cover flange	7.2H	Copper alloy	RG-49/U (WR187)	Mates with self. Use gasket M24211/2-007.
UG-1729/U	Cover flange	7.2H	Aluminum alloy	RG-95/U (WR187)	Mates with self. Use gasket M24211/2-007.
UG-1730/U	Cover flange	7.2H	Copper alloy	RG-343/U (WR159)	Mates with self. Use gasket M24211/2-008.
UG-1731/U	Cover flange	7.2H	Aluminum alloy	RG-344/U (WR159)	Mates with self. Use gasket M24211/2-008.
UG-1732/U	Cover flange	7.2H	Aluminum alloy	RG-50/U (WR137)	Mates with self. Use gasket M24211/2-009.
UG-1733/U	Cover flange	7.2H	Aluminum alloy	RG-106/U (WR137)	Mates with self. Use gasket M24211/2-009.
UG-1734/U	Cover flange	7.2H	Aluminum alloy	RG-51/U (WR112)	Mates with self. Use gasket M24211/2-010.
UG-1735/U	Cover flange	7.2H	Aluminum alloy	RG-68/U (WR112)	Mates with self. Use gasket M24211/2-010.
UG-1736/U	Cover flange	7.2H	Copper alloy	RG-52/U (WR90)	Mates with self. Use gasket M24211/2-011.
UG-1737/U	Cover flange	7.2H	Aluminum alloy	RG-67/U (WR90)	Mates with self. Use gasket M24211/2-011.

Note: Figure number refers to Figures of MIL-HDBK-216, 7 April 1967.

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Table 13-6. Dummy Loads

TYPE	FRE- QUEN- CY kHz	FOR USE WITH	TERMINA- TION	AVER- AGE POWER (Watts)	PEAK POWER (lowest to high- est frequency)	ENGINEERING DATA
DA-6/U	8.50-9.60	RG-52/U	UG-40/U	200	300 kw	See note
DA-7/UP	7.05-10.00	3/8 coax	UG-23B/U	1	1 kw	Max. VSWR 1.1
DA-8/UP	5.65-7.05	3/8 coax	UG-23B/U	1	1 kw	Max. VSWR 1.1
DA-9/UP	4.00-5.65	7/8 coax	UG-23B/U	1	1 kw	Max. VSWR 1.1
DA-10/UP	5.65-7.05	RG-76/U	UG-141/U	1	1 kw	Max. VSWR 1.1
DA-11/UP	4.00-5.65	RG-76/U	UG-141/U	1	1 kw	Max. VSWR 1.1
DA-45/UP	20-440	3/8 coax	N Male	1	1 kw	
DA-55/U	12.4-18.0	RG-69/U	UG-419/U	100	.28 megawatt	VSWR 1.10:1
DA-77/U	1.70-2.60	RG-104/U	UG-435A/U	1	1 kw	
DA-81/U	.925-3.95	7/8 coax	UG-46/U	1	1 kw	
DA-82/U	.1-1.7	1-5/8 coax	UG-50/U	1	1 kw	
DA-99/SLT	.015-2.70	RG-128/U	UG-677/U		1 kw	Max. VSWR 1.2
DA-102/UPM-63	15.7-17.0	RG-91/U	UG-419/U	1	1 kw	VSWR < 5.0:1
DA-111/UPM-12	8.50-9.60	RG-52/U	UG-39/U			Calibrated mismatch
DA-141/U	2.60-3.95	RG-48/U	UG-53/U	1	1 kw	VSWR < 1.01:1
DA-142/U	3.95-5.85	RG-49/U	UG-149A/U	1	1 kw	VSWR < 1.01:1
DA-143/U	8.20-12.0	RG-52/U	UG-39/U	1	1 kw	VSWR < 1.01:1
DA-144/U ¹	3.85-8.20	RG-106/U	UG-440A/U	800	.710 megawatt	VSWR < 1.10:1
DA-145/U ¹	2.60-3.95	RG-75/U	UG-584/U	4500	3.20 megawatt	VSWR < 1.10:1
DA-146/U ¹	8.30-12.4	RG-67/U	UG-136A/U	500	.290 megawatt	VSWR < 1.10:1
DA-147/U ¹	1.12-1.70	RG-103/U	UG-418A/U	4500	17.2 megawatt	VSWR < 1.10:1
DA-148/U ¹	7.08-10.0	RG-68/U	UG-137A/U	600	.460 megawatt	VSWR < 1.10:1
DA-149/U ¹	3.95-5.85	RG-95/U	UG-406A/U	2000	2.00 megawatt	VSWR < 1.10:1
DA-154/U	1.00-4.00	Rigid guide		1	1 kw	
DA-158/U ¹	26.5-40.0	RG-96/U	UG-599/U	75	.100 megawatt	VSWR < 1.15:1
DA-159/U ¹	12.4-18.0	RG-107/U	UG-419/U	250	.160 megawatt	VSWR < 1.15:1
DA-160/U ¹	18.0-26.5	RG-121/U	UG-597/U	150	.125 megawatt	VSWR < 1.15:1
CG-97/AP	1.55-5.20	RG-155/U	UG-46/U			Used in eqpt. AN/AP A-22
TS-74A/UPM	1.55-5.20	7/8 coax	UG-45 and -46/U	200	250 kw	Similar to TS-105/ TPM-1. Terminates in 50 & 72 ohm lin s
TS-105/TPM-1	0.39-1.65	1-5/8 coax		200	250 kw	Used in eqpt. AN/TPM-1

¹ Requirements in accordance with Specification MIL-D-3954.

Note: This component is not recommended for use over the entire frequency range of the associated waveguide due to the dummy load termination.

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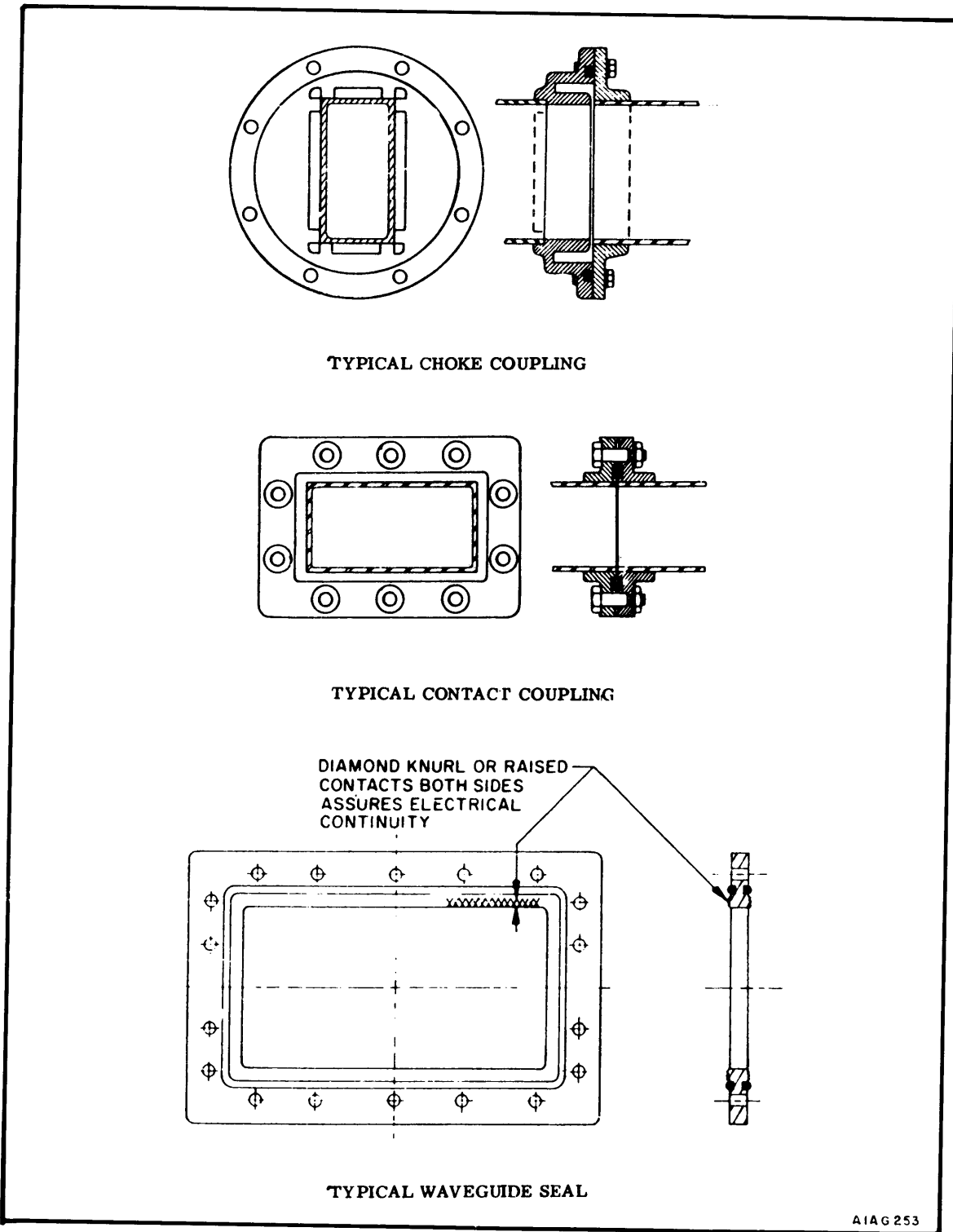


Figure 13-1. Waveguide Couplings

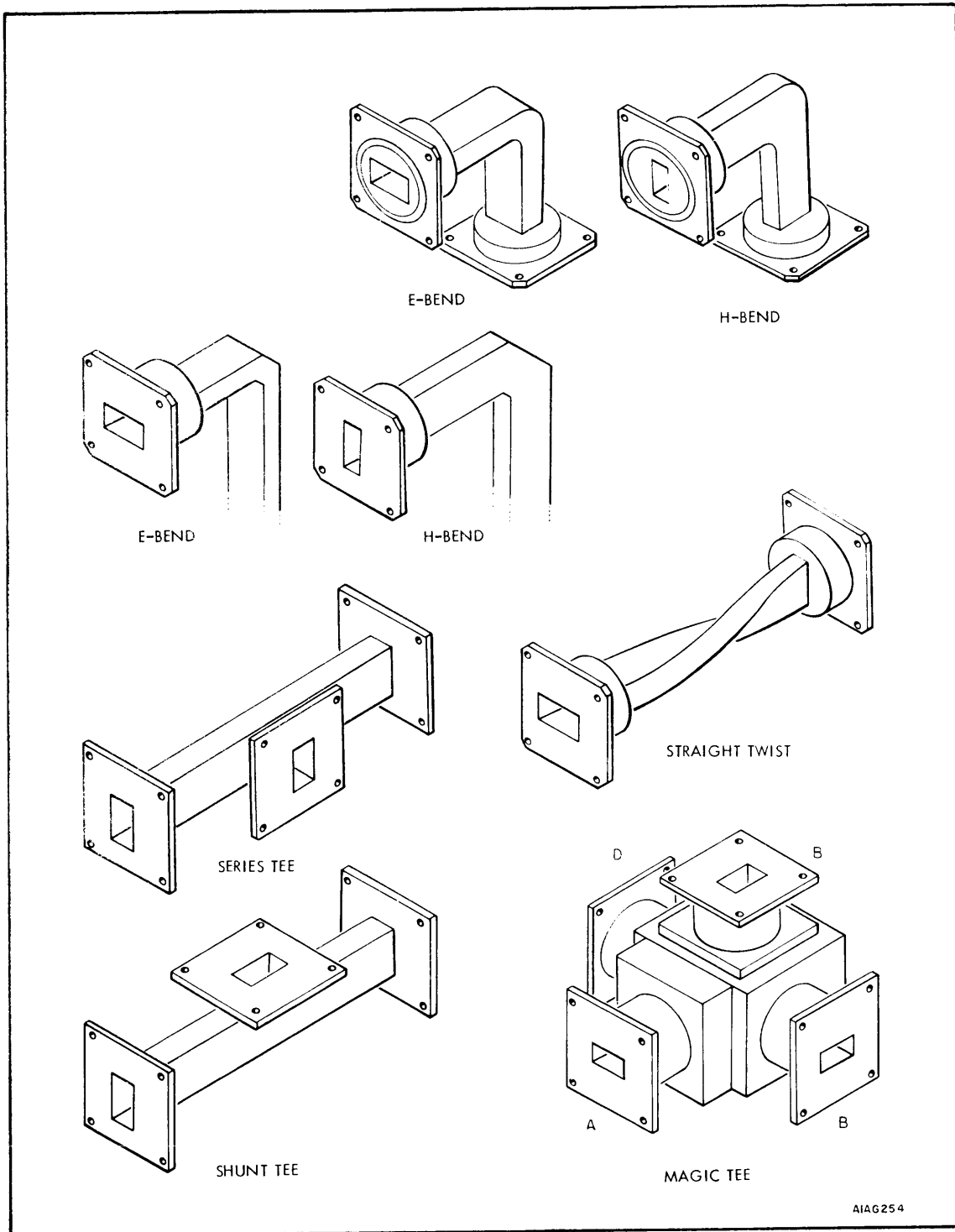


Figure 13-2. Rigid Waveguide Assemblies

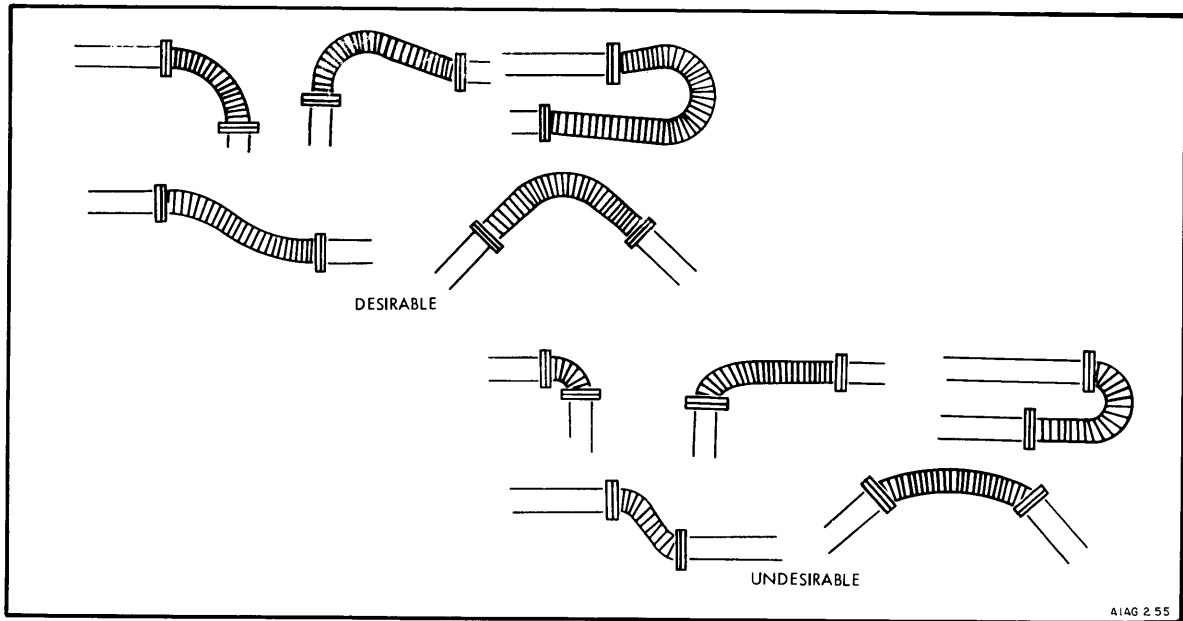


Figure 13-3. Flexible Waveguide Bends

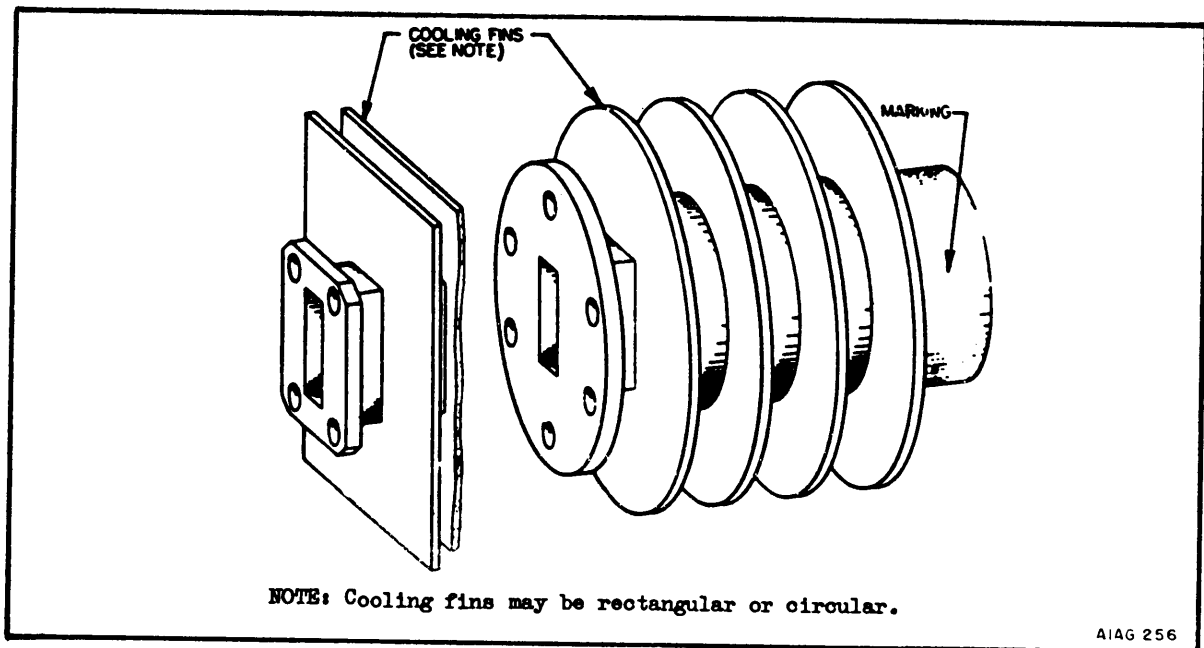


Figure 13-4. Typical Waveguide Dummy Load

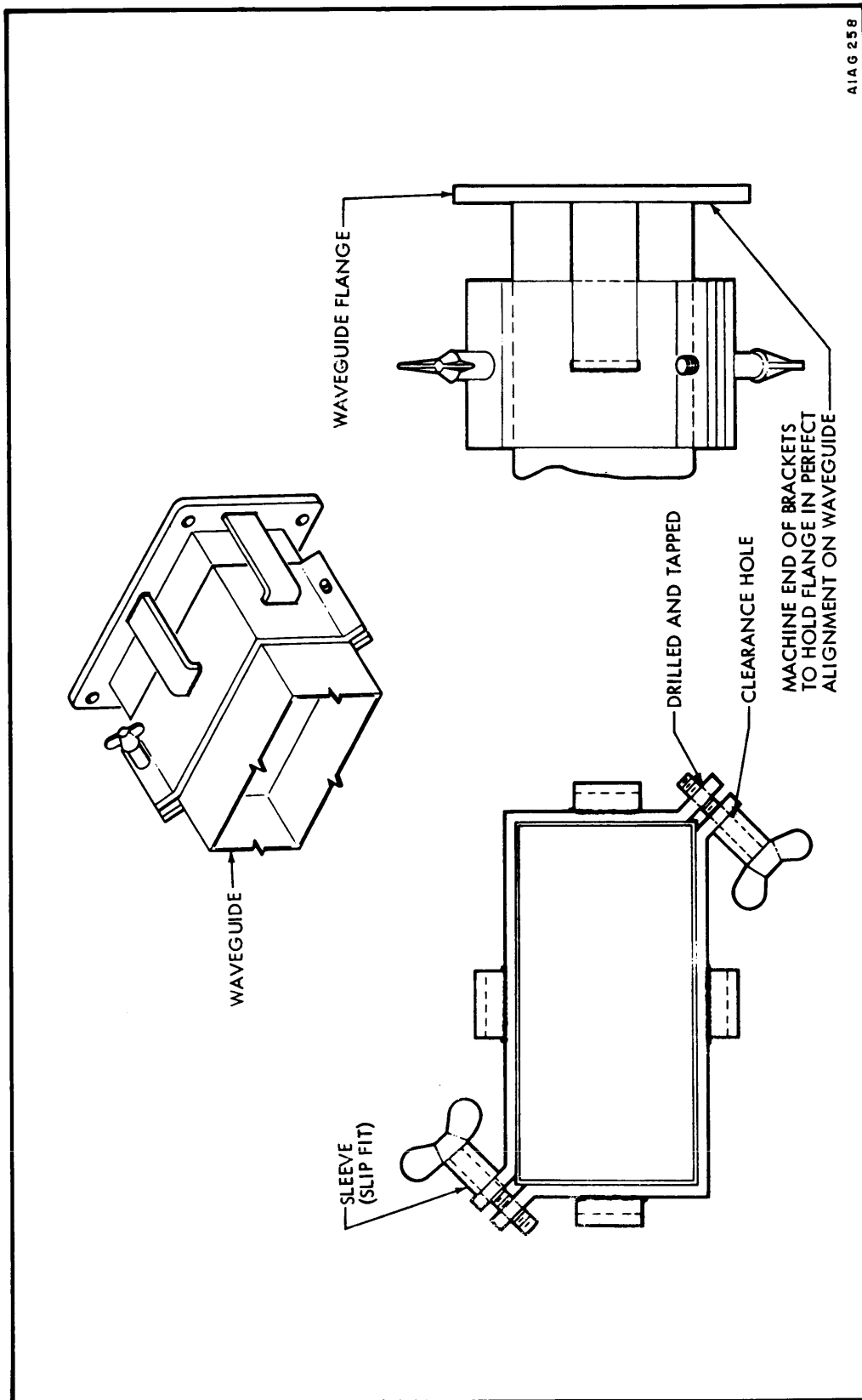


Figure 13-5. Alignment Jig for Waveguide Flange Installation

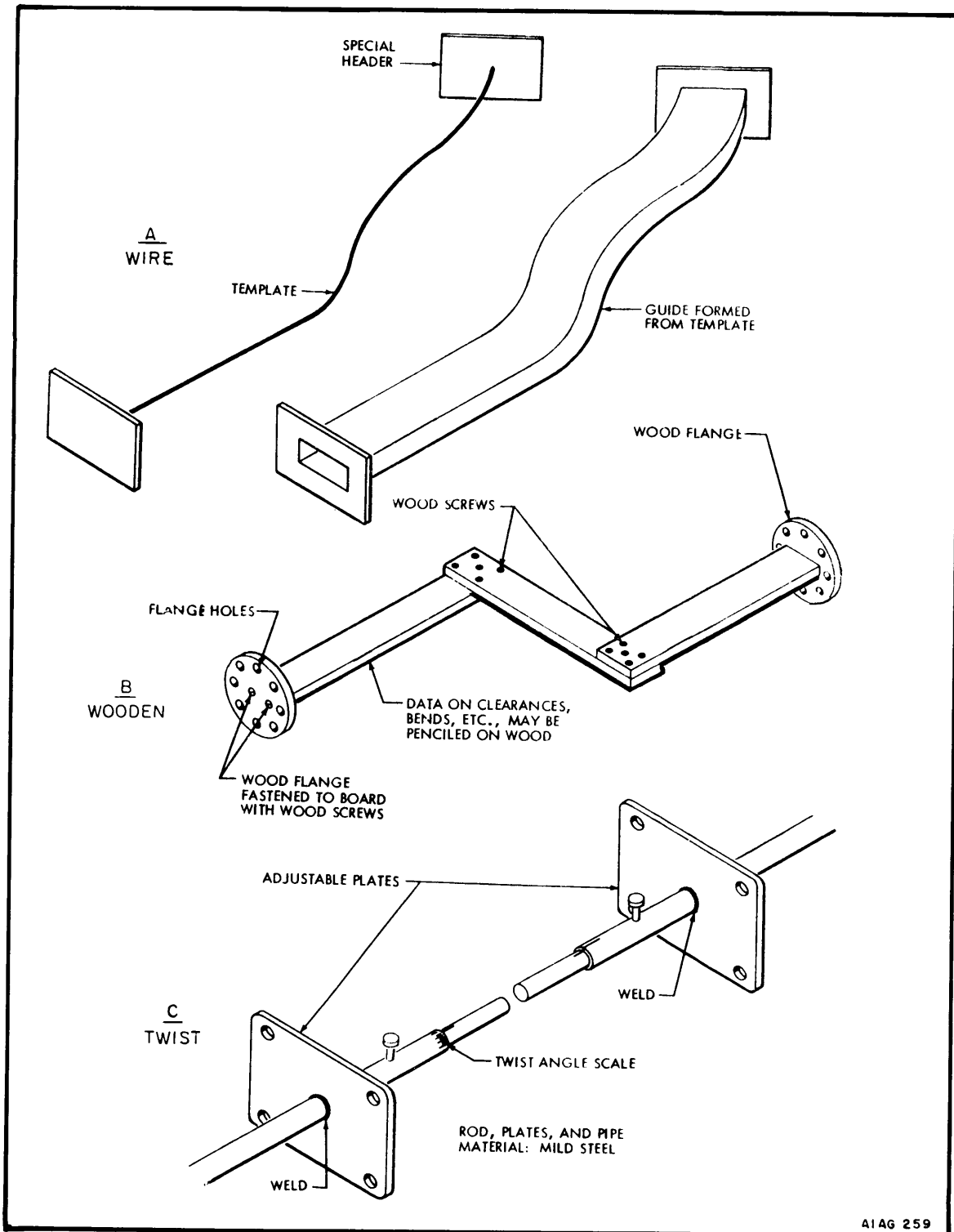


Figure 13-6. Waveguide Template

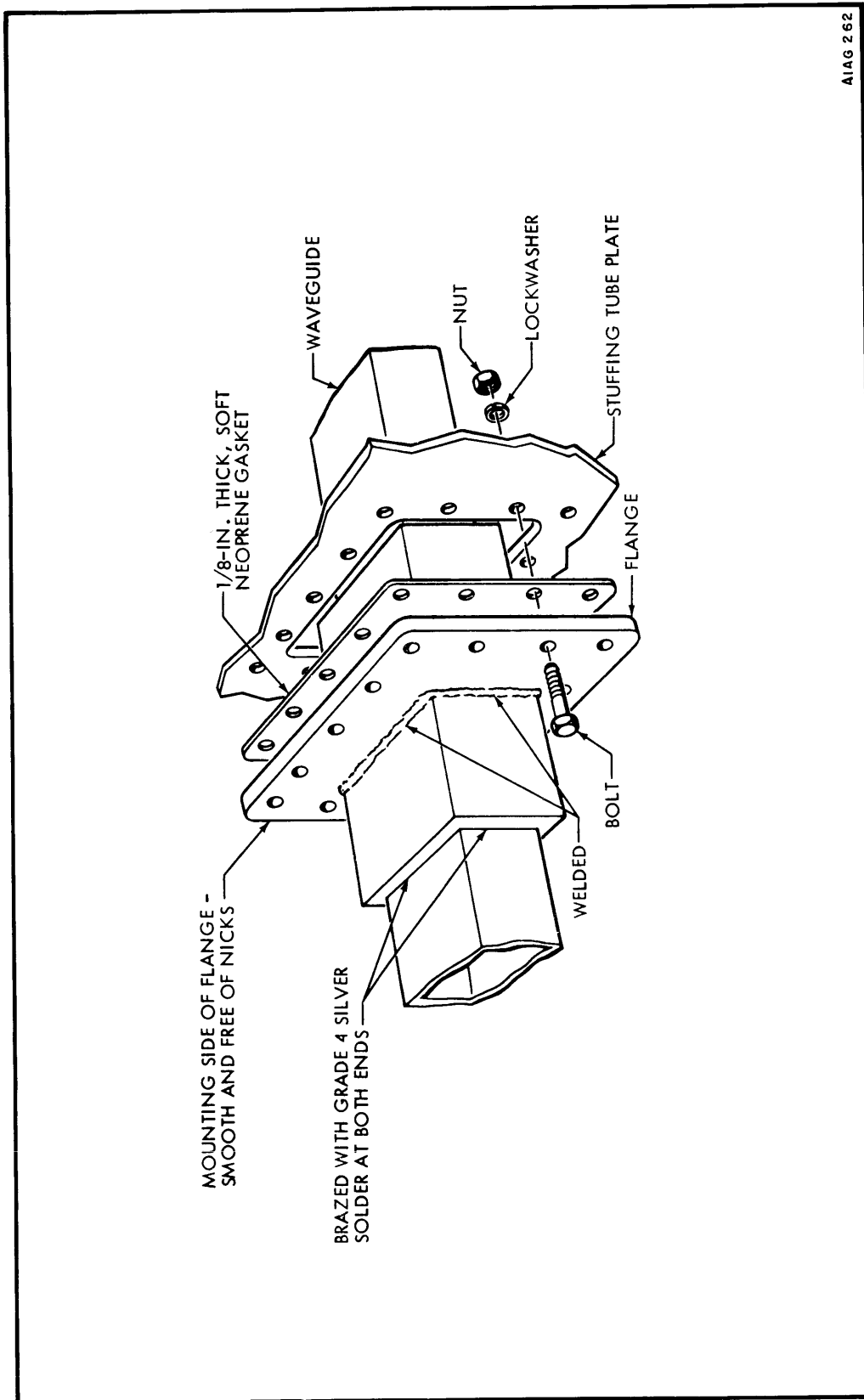


Figure 13-7. Weatherproofed Penetration of Bulkhead

