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NOTICE OF CHANGE

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MIL-HDBK-660A
NOTICE 1
5 September 2002

MILITARY STANDARDIZATION HANDBOOK

FABRICATION OF RIGID WAVEGUIDE ASSEMBLIES (SWEEP BENDS AND TWISTS)

TO ALL HOLDERS OF MIL-HDBK-660A:

1. THE FOLLOWING PAGES OF MIL-HDBK-660A HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
3		3	7 July 1972
4		4	7 July 1972
5		5	7 July 1972
5a			NEW PAGE
6		6	Reprinted without change
27		27	Reprinted without change
28		28	7 July 1972
31		31	Reprinted without change
32		32	7 July 1972
37		37	Reprinted without change
38		38	7 July 1972
39		39	Reprinted without change
40		40	7 July 1972
41		41	Reprinted without change
42		42	7 July 1972

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-HDBK-660A will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the handbook is completely revised or canceled.

Custodians:
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Navy - EC
Air Force - 11

Preparing activity:
DLA - CC

(Project 5985-1225)

AMSC N/A

FSC 5985

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TABLE I. Waveguide bend values - Continued.

Waveguides	Bending Radius	Dimension
3/4 x 1-1/2 inches M85/1-067-XXX (RG 50/U) M85/1-065-XXX (RG 106/U)	Minimum bending radius, "E" No "H" bends, use manufactured elbows Minimum length for 90-degree twist Maximum inside wall variance	12 inches 15 inches ± 1/32 inch
5/8 x 1-1/4 inches	Minimum bending radius, "E" Minimum bending radius, "H" Minimum length for 90-degree twist Maximum inside wall variance	6 inches 12 inches 18 inches ± 1/32 inch
1-1/2 x 1/2 inches RG 110/U	Minimum bending radius, "E" Minimum length for 90-degree twist Maximum inside wall variance	6 inches 15 inches ± 1/32 inch

1.2.6 Never make a bend or twist sharper than the specified minimum unless conditions make it absolutely necessary. Under no conditions should the radius of a bend or twist be less than one full wavelength of the center frequency for any waveguide. The reflections caused by poorly matched bends can result in a high standing wave ratio.

$$\text{Wavelength in cm} = \frac{30{,}000}{f \text{ in MHz}}$$

$$\text{Wavelength in inches} = \frac{11{,}808}{f \text{ in MHz}}$$

EXAMPLE A: The radii of preformed bends for M85/1-043-XXX (RG 48/U) is 7.5 inches (191 mm), whereas, the radii of bends formed for M85/1-043-XXX (RG 48/U) TE_{10} mode wavelength range (lowest to highest recommended operating frequency) is from 4.539 to 2.987 inches (115.29 to 75.87 mm). The mean wavelength is 3.763 inches (96 mm) and a waveguide half wavelength is 1.8815 inches (47.790 mm). Any multiple of 1.8815 inches (47.790 mm) that generates a radius greater than 7.5 inches (191 mm) shall be used as the mean electrical length of a formed bend for M85/1-043-XXX (RG 48/U) waveguide.

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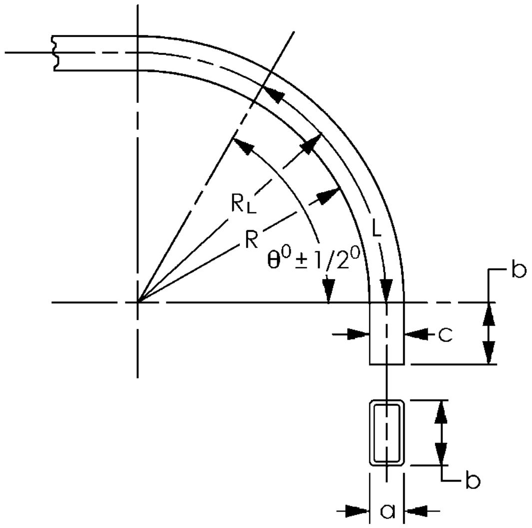

$$R_L = 57.32° \; x \; \frac{L}{\Theta°}, \; R = R_L - \frac{c}{2}$$

L = mean electrical length
c = height or width of outer dimension of waveguide depending on plane of bend.
b = larger dimension of waveguide

FIGURE 2. Electrical length of bend.

To determine the radius of a 90-degree bend, the following calculations are made.

From the above formula in Example A: $R_L = \frac{57.32° \bullet L}{90°} \; \theta = 90°$

$R_L = 0.637L$

Referring to M85/1-043-XXX (RG 48/U), operating in the TE_{10} mode where R_L is greater than 7.5 + $\frac{a}{2}$ inches, where R = 7.5 inches and L is a multiple of $\frac{\lambda}{2}$. $\lambda = 3.763$ inches, $\frac{\lambda}{2} = 1.8815$ inches, a = 1.34 inches, b = 2.84 inches, c = 1.5 inches for an "E" bend.

Then let L = 6 x $\frac{\lambda}{2}$ = 11.289 inches, then R_L = 0.637 x 11.289 = 7.2 inches and R = 6.44 inches.

Since the resultant value is less than 7.5 inches, the radius cannot be used. Based on similar computations,

when: L = 7 x $\frac{\lambda}{2}$ = 13.170, R_L = 8.39, R = 7.64 inches

L = 8 x $\frac{\lambda}{2}$ = 15.05, R_L = 9.588, R = 8.838 inches and so forth; hence, the radii computed for a value of L which is a multiple of $\frac{\lambda}{2}$ of 7 or greater may be used.

For an "H" bend, c = 3.0 inches

when: L = 7 x $\frac{\lambda}{2}$ = 13.170, R_L = 8.39, R = 6.89 inches

L = 8 x $\frac{\lambda}{2}$ = 15.05, R_L = 9.588, R = 8.09 inches and so forth; hence a value of L which is a multiple of $\frac{\lambda}{2}$ of 8 or greater may be used.

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2. APPLICABLE DOCUMENTS

2.1 General. The documents below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

FEDERAL

O-F-499 - Flux, Brazing (Silver Brazing Filler Metal, Low Melting Point).
QQ-B-654 - Brazing, Alloys, Silver.

DEPARTMENT OF DEFENSE

MIL-DTL-3970 - Waveguide Assemblies, Rigid, General Specification for.

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Defense Automation and Production Service, Building 4D (DPM-DODSSP), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DEPARTMENT OF DEFENSE

NAVSHIPS S9086-CH-STM-010/CH-074R4 - Welding and Allied Processes.

(Copies of Government publications are available from Defense Automation and Production Service, Building 4D (DPM-DODSSP), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

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2.3 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B46.1 - Surface Roughness, Waviness, and Lay.

(Application for copies should be addressed to: American Society of Mechanical Engineers (ASME), 3 Park Avenue, M/S 10D, New York, NY 10016.)

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8 - Filler Metals for Brazing and Braze Welding.

(Application for copies should be addressed to: American Welding Society (AWS), 550 N. W. LeJeune Road, Miami FL 33126.)

3. PREPARATION FOR BENDING AND TWISTING

3.1 Fabrication of template. The first step in fabricating waveguide bends is to make a full-scale template (see figures 3 and 4). The purpose of the template is to provide the shop with accurate information as to the shape, radius, and angle of all bends and twists in the waveguide as well as the position of the connection, flange holes, and overall length of the run.

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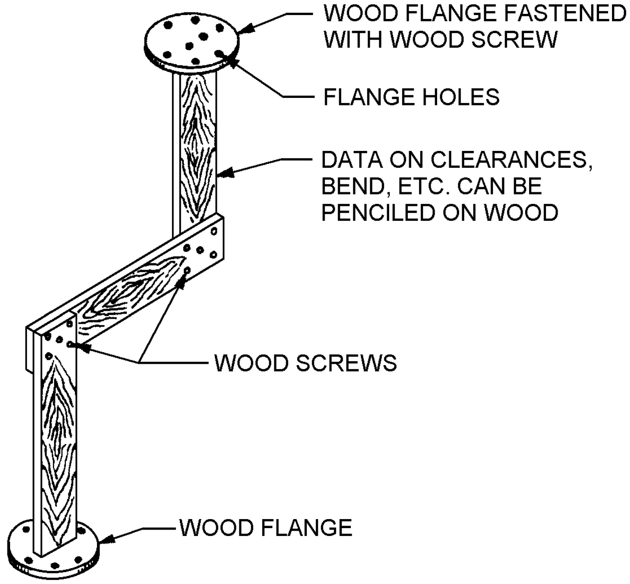

FIGURE 3. Wooden waveguide template.

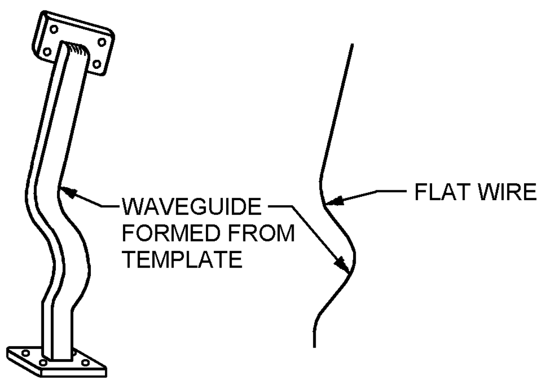

FIGURE 4. Wire template.

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5. PRE-ASSEMBLY OPERATIONS

5.1 Removal of filling. If rosin is used for filling, dents and wrinkles should be removed while the filler is in the guide, but not otherwise. Use a flatting hammer with curvature corresponding to the shape being formed.

5.1.1 Alloy method. After bending and twisting, immerse the guide in a tank of hot water at 82°C to 93°C (180°F to 200°F), (corrosion-resisting steel tank preferred), and allow the alloy to run out. Do not use a torch. Tilt and shake the guide to remove the alloy as completely as possible. Plunge the emptied guide (while still hot) into cold water for 2 minutes to solidify any small drops of alloy retained in the oil film. To remove the oil film and remaining solid particles of alloy, flush the guide with a cold grease solvent (such as Oakite No. 23, or equivalent), then use a tight-fitting material and pull it through the guide.

5.1.2 Rosin method. Remove both plugs and tilt the guide, using a chain hoist if desired.

CAUTION

ALWAYS REMOVE BOTH PLUGS BEFORE MELTING OUT THE ROSIN

Using a torch adjusted for moderate heat, apply heat to the bottom end of the guide until the rosin begins to flow, then gradually raise the torch along the guide. After the guide is clear, direct the flame through the interior to remove remaining particles of rosin. It is not necessary to melt all the rosin. The tendency is for the surface of the rosin to melt, permitting chunks to slide out of the guide.

WARNING

NEVER APPLY HEAT TO THE MIDDLE OF A GUIDE THAT
IS FILLED WITH ROSIN. AN EXPLOSION WILL RESULT.

5.2 Removal of dents and wrinkles from waveguide. Dents and wrinkles should be removed from the waveguide after the filler has been removed (if the filler is rosin, imperfections may be removed from the waveguide while the rosin is in place). Dents are removed from an empty guide as follows:

a. Seal the guide in the usual way at both ends and fit one end with a valve.

b. Fill the guide with air pressure of about 28 pounds per square inch (p.s.i.)

CAUTION

THE AIR PRESSURE MUST BE CLOSELY WATCHED AS PRES-
SURE EXCEEDING 30 P. S. I. WILL BULGE THE GUIDE.

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c. Heat the area around the dent with a torch and remove the dent by means of a flatter. A blow torch should not be used on magnesium waveguide as magnesium material will support combustion after the ignition temperature has been reached.

5.3 Cutting. Cut the waveguide with a hacksaw or a powered metal cutting saw.

5.3.1 Hacksaw. For soft metal waveguides, use a fine tooth blade (10 to 14 teeth per inch). For copper or copper alloy, the guide can be cut with a blade having 20 to 24 teeth per inch.

5.3.2 Power saw. A recommended blade for cutting brass waveguide is the Simmonds T-11 steel blade, or equivalent. It is to be driven at approximately 1,200 revolutions per minute (r.p.m.).

5.3.3 Squareness of cut. The cut should be square and at right angles to the length of the guide. The edges must be filed or ground smooth so that the ends do not deviate from squareness by more than .031 (0.79 mm) of an inch. All fillings, chips, and other bits of metal must be removed from the guide before inserting the waveguide into the flange.

5.3.4 Modification of flanges and heavy wall waveguides for proper fit. There are two ways of modifying the pieces to assure proper fit.

5.3.4.1 Cover flange. Machine the heavy wall waveguide down to the size of the standard waveguide so that it will fit into a standard choke flange (see figure 28).

5.3.4.2 Choke flange. Machine the alignment cutout of the choke flange to accept the heavy wall waveguide (see figure 29).

5.4 Cleaning. Prior to brazing, cleaning is required to remove surface contaminants, such as grease, oil, oxide film, dust, and metal particles from the filler and the parts to be brazed. Best business practices should be used.

6. ASSEMBLY

6.1 Attachment of flanges. The parts to be assembled shall be thoroughly clean. Avoid the use of emery paper or crocus cloth to clean contact surface of the guide and the flange. Best business practices should be used. The flanges are then torch-brazed, silver-soldered, or dip brazed. A contact flange shall not be used as a cover flange in a choke coupling; see MIL-DTL-3970 for the correct mating cover flange. Alignment of the waveguide and flange is important to minimize mismatch and reflection losses.

6.1.1 Assembly of contact or cover flange to waveguide. When installing contact or cover flanges to a waveguide, the following method should be used:

a. The surfaces to be brazed must be thoroughly clean (see 5.4).

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b. For brazing brass flange to brass waveguide, apply silver solder flux over the surface areas to be joined (Handy and Harmon, or equal, flux thinned with water to the consistency of paste, free from lumps or type B brazing flux conforming to O-F-499). For brazing aluminum flange to aluminum waveguide, a flux that will produce maximum flow of filler metal is Alcoa No. 33, or equivalent.

WARNING

THE FLUX IS POISONOUS. AVOID INHALING.

c. Slide contact or cover flange over the guide to extend beyond the flat of the flange, allowing approximately 1/32 inch of waveguide to extend beyond the flat of the flange on all sides. See figure 30 for attachment of through flange on waveguide.

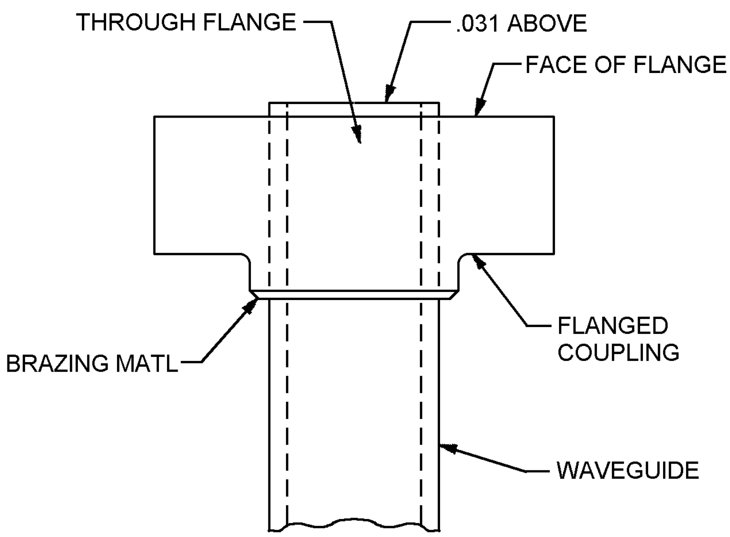

FIGURE 30. Through flange on waveguide.

d. The bore of the flange shall be concentric with the waveguide bore to within .005 inch (see figure 31). The flange face shall be perpendicular ± 1/2 degree to the edge and side planes of the internal surfaces of the waveguide (see figure 32).

6.1.2 Assembly of choke or socket flanges to waveguide. When installing choke or socket flanges to the waveguide, the following method should be used (see figure 33):

a. The surface to be brazed must be thoroughly clean (see 5.4).

b. Repeat 6.1.1b.

c. The waveguide must be square in all three planes to within ± 1/2 degree before assembly (see figure 34).

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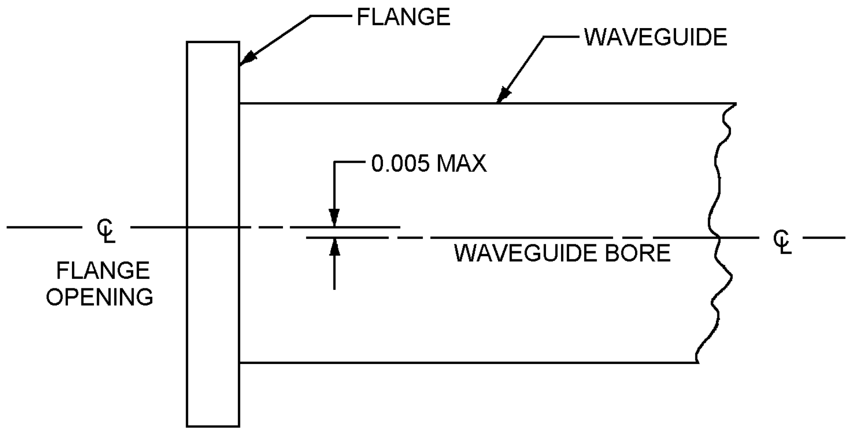

FIGURE 31. Concentricity of waveguide and flange.

d. The bore of the flange shall be concentric with the waveguide bore to within .005 inch (see figure 31).

6.1.3 Clamps and jigs. (See figures 35 and 36).

6.2 Silver brazing brass waveguide. Brass waveguide assemblies shall be brazed with a silver base alloy in accordance with QQ-B-654, grade IV or VI. After the parts to be brazed are properly clamped and fluxed, start preheating. A soft brush type flame (torch tip No. 6) should be used. Spread the flames of the air-acetylene torch as large as possible for heating evenly. However, if oxyacetylene is used, there should be a sharply defined inner cone. Exercise extreme care in handling the waveguide while soldering to prevent buckling.

CAUTION

DO NOT USE SOFT SOLDER ON THE FACE OF THE FLANGE. SOFT SOLDER OXIDIZES WITH AGE AND MAY CAUSE A HIGH RESISTANCE JOINT.

WARNING

CONTAINS CADMIUM. BRAZING HEAT CAN PRODUCE TOXIC FUMES. USE IN ACCORDANCE WITH VENTILATION AND HEALTH REQUIREMENTS OF NAVSHIPS S9086-CH-STM-010/CH-074R4

Apply heat to the flat surface of the flange as shown in figures 37 and 38. If oxyacetylene is used, the flame must be applied with the inner cone a few inches off the work. Heat the assembly sufficiently to melt the silver solder. Apply the silver solder to the surfaces to be brazed (refer to figures 36 and 37). For a good joint, the liquefied solder must flow thoroughly and evenly between the guide and flange. Maintain adequate heat to melt the silver solder without applying the torch to the joint or solder. Insufficient heat results in a weak joint and overheating burns the flux, warps the flange and causes

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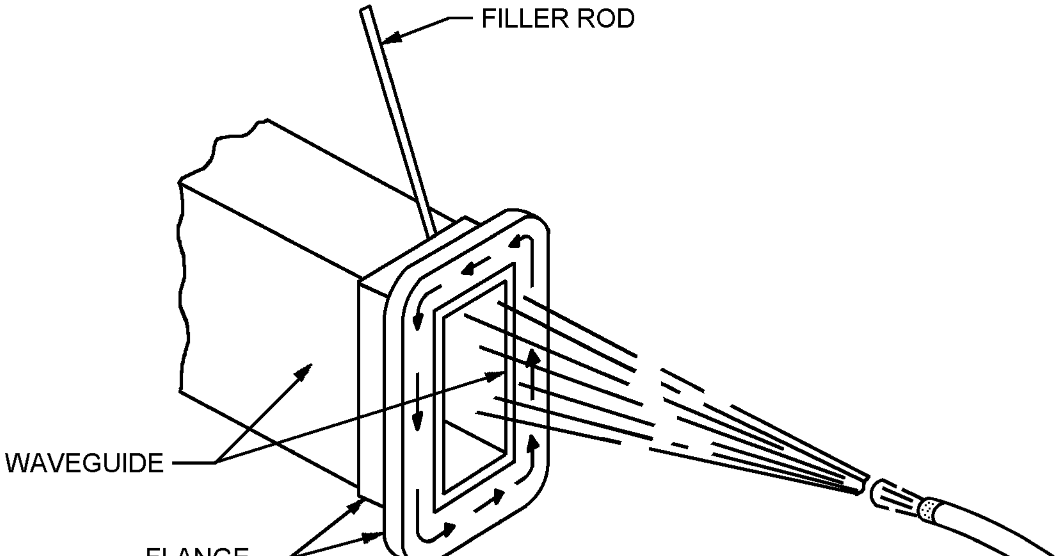

FIGURE 37. Silver soldering waveguide and flange-sleeve design.

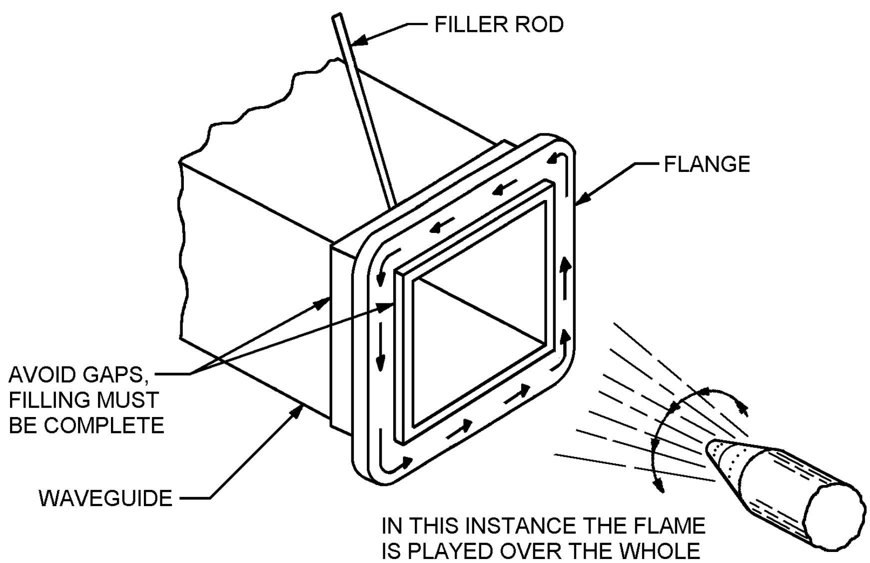

FIGURE 38. Directing flame on contact or cover flange.

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oxidation. The guide and flange should be cooled in air without the use of forced cooling. Very carefully grind, file, or sandpaper flat flange and waveguide ends to a smooth surface approximately 63 microinches root mean square (rms).

6.3 Brazing flanges on aluminum waveguide. The basic equipment and methods required for brazing aluminum flanges on aluminum waveguide are described below.

6.3.1 Torch tips (numbers 1 to 5). The use of various size torch tips are determined by the thickness and size of the area to be brazed. The tips vary according to the size of their openings. The No. 3 tip is suggested for waveguide brazing.

6.3.2 Brazing rod. The main requirement for a good brazing alloy is that it melts at a low temperature to provide a practicable brazing range. Specifically recommended is BAlSi-4 as specified in AWS-A5.8 or Alcoa No. 716, or equal brazing rod, .0625 inch (1.5875 mm) thick - brazing range 512°C to 595°C (970°F to 1085°F).

6.3.3 Brazing. Place the guide upright with the prepared end to be soldered on the bottom. Insert the waveguide through the flange so that .031 inch (0.79 mm) of guide extends beyond the face of the flange, preventing the solder from entering the guide. A suitable jig, such as four bolts threaded into the flange (see figure 36), can be used to keep the flange from its flat surface. After the parts to be brazed are properly damped or supported, apply the flux to the areas to be brazed and to several inches of the brazing rod. Use a No. 3 torch tip and adjust for "reducing" flame (oxygen starved flux). Apply heat to the parts to be brazed, keeping the torch in constant motion at all times for an even distribution of heat for proper fusion. When the flux dissolves into a liquid and becomes transparent, apply the brazing rod to the area to be brazed. The rod applied at one point only will flow around and seal the joint if the heat is properly distributed (see figure 39). Do not allow the flame to concentrate on one spot as it may burn the flux or melt the bare metal. Once the filled metal has started to flow into the joint, the heat should not be increased. After the joint has cooled, all traces of the flux should be removed to prevent corrosion of the parts.

6.4 Dip brazing of aluminum waveguide.

6.4.1 Brazing flux. A recommended dip brazing flux is Aluminum Brazing Salt Pack Type "D", produced by Park Chemical Co., or equivalent.

6.4.2 Preparation of parts.

6.4.2.1 Cleaning. The cleaning directions given in 5.4 are to be used.

6.4.2.2 Chemical dipping. Parts shall be dipped and rinsed as follows:

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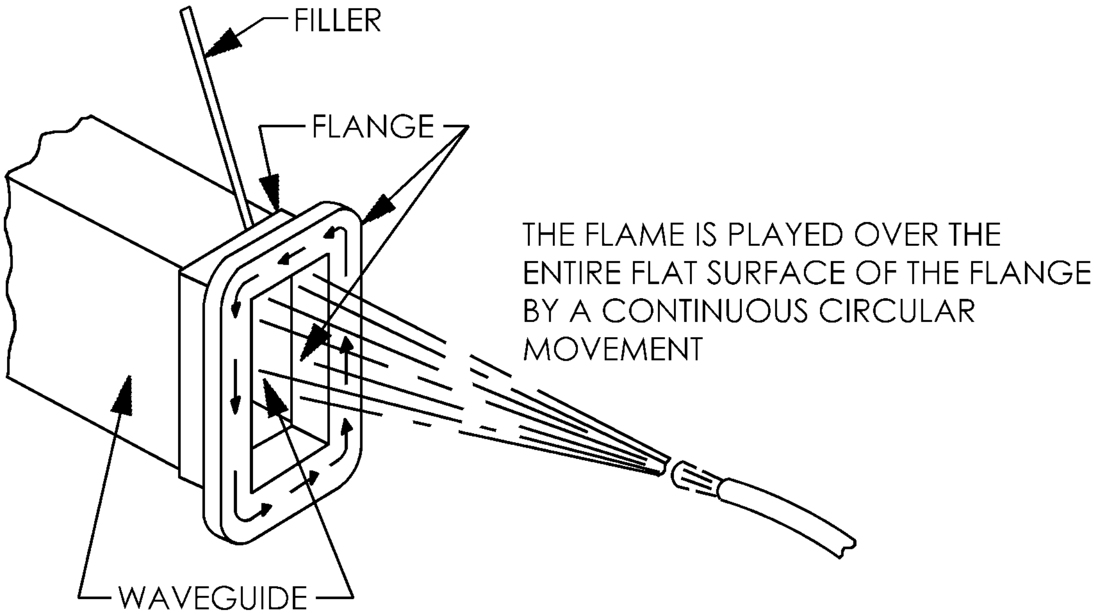

FIGURE 39. Brazing waveguide and flange-butt design.

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a. Immerse parts in a nitric hydrofluoric acid solution maintained at room temperature for 30 to 60 seconds. The solution shall be prepared as follows:

Quantity	Composition
1 gallon	58-62 percent HNO_3(39'5'Be')
half pint	48 percent HF (1 15 specific gravity)
9 gallons	water (room temperature)

b. Rinse in two cascade cold-water rinse tanks with running water and constant overflow. Fresh water supply to tank two with overflow to tank one. Rinse for 30 seconds min. in tank one and then tank two in that order. Do not rinse in hot water.

6.4.2.3 Assembly. Parts shall be assembled and a mandrel, of sufficient size to ensure precise alignment of waveguide to flange, shall be inserted to the joint area and the flange inert gas-tack welded on two opposing corners of the waveguide prior to dip brazing. Heat resistant alloy wire, rod shims, jigs, clamps, or perforated baskets shall be used to assemble the transmission line components for dip brazing.

6.4.2.3.1 Final cleaning. Parts shall be cleaned with an additional soak for approximately 1 minute in a nitric hydrofluoric acid solution maintained at room temperature to remove all traces of flux particles (see 6.4.2.2a) and rinsed (see 6.4.2.2b).

6.5 Dry air piping connection. For waveguide sections requiring the addition of fittings for dry air pressurization and purging, see figure 40 for details of construction and location. The inside of the waveguide shall be inspected following completion of fitting assembly; the surface shall be smooth, free of burrs, and distortion.

6.5.1 Air connection completion. These air connections shall be completed before final assembly of waveguide.

7. FINISHING OPERATION

7.1 Finishing operation. The finishing operation as required will be performed in the following order: machining, smoothing, cleaning and sealing/painting.

7.1.1 Machining. Following brazing, machining, such as broaching may be necessary to obtain desired configuration.

7.1.2 Smoothing. The surface finish of the inside of the waveguide shall be sanded smooth, if necessary, by carefully using fine emery paper or crocus cloth. The average interior surface roughness shall be measured in accordance with ASME B46.1 and shall conform to the specified requirement. Flaws shall not be included in the surface roughness. When measured, as specified above, the average interior surface roughness of the waveguide shall not exceed the values shown in table II, except the corner radius need not be included in the measurement.

7.1.3 Cleaning waveguide. When fabrication is completed, each waveguide section must be carefully cleaned (see 5.4).

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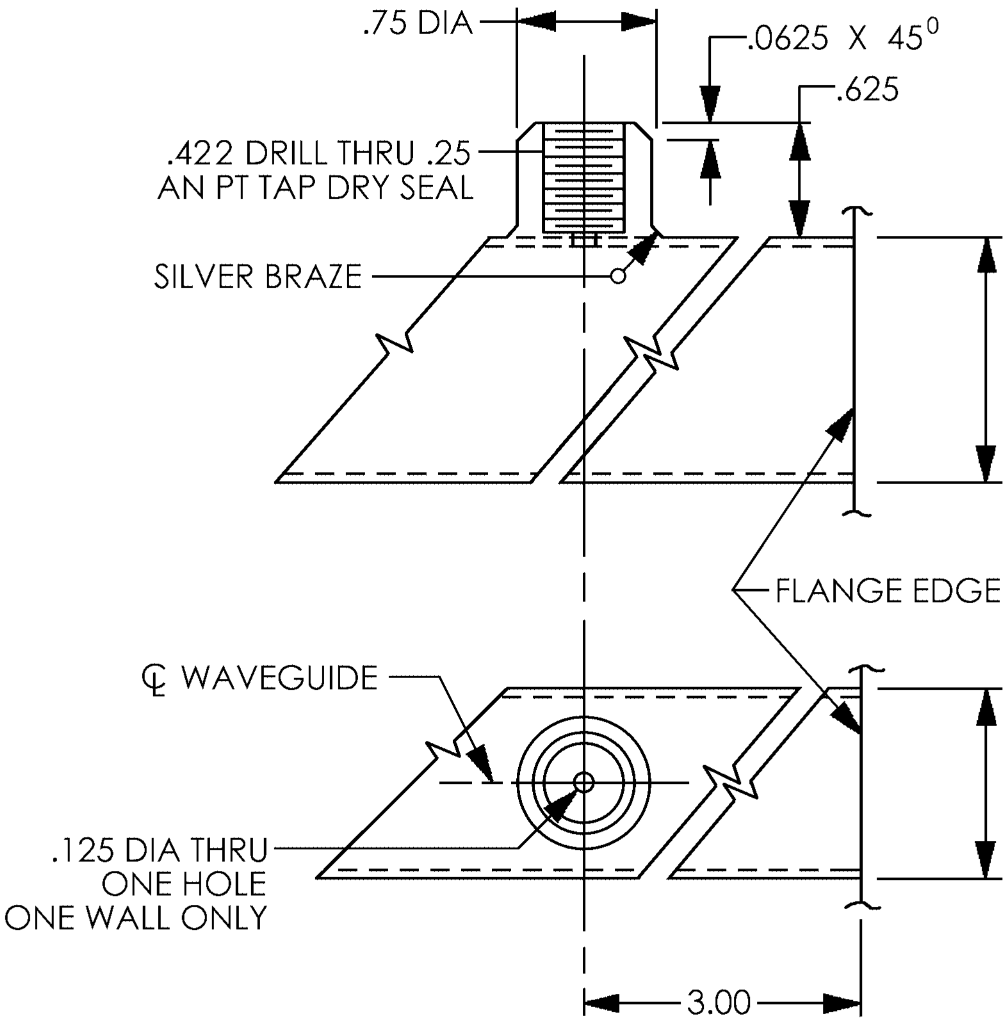

FIGURE 40. Fitting for air connection.

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TABLE II. Surface roughness tolerances of waveguides.

Specified major inner dimensions (inches)	Allowable surface roughness, maximum arithmetic average (A. A.)	
	Aluminum, aluminum alloy, and magnesium alloy	Copper, copper alloy, silver alloy, silver lined copper, and silver lined copper alloy
Up to 4, exclusive - - - - - - - - - -	63	32
4 and over - - - - - - - - - - - - - - -	125	63

The flatness and surface finish on the flange surfaces at and near the junction with the interior of the waveguide wall shall be the following:

a. The flatness shall not deviate more than .002 inches per inch.

b. Surface finish shall be as specified in table II.

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Preparing activity:
DLA - CC

(Project 5985-1225)