July 28, 1959 F. E. ASHBAUGH ET AL 2,897,461

WAVE GUIDE CONSTRUCTION

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Fig. 2.

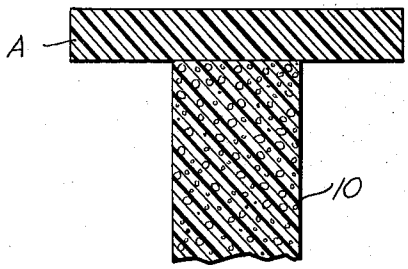
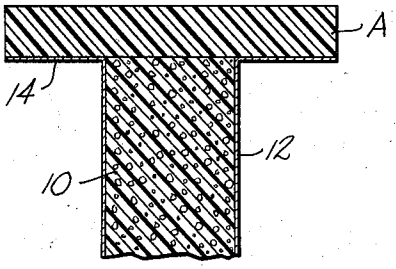


Fig. 3.



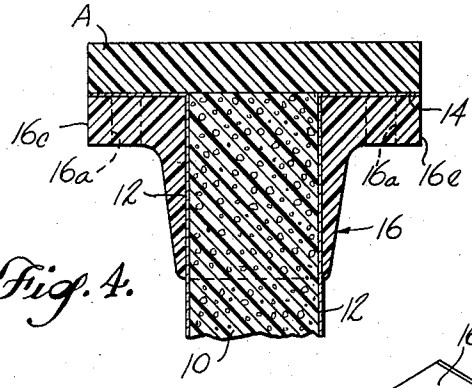


Fig. 4.

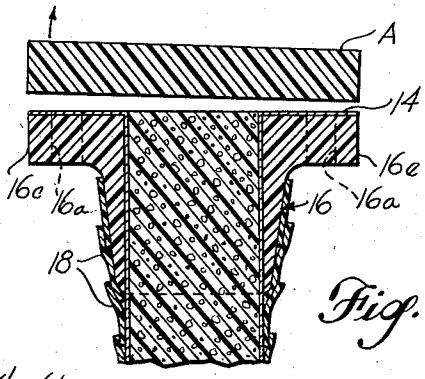


Fig. 5.

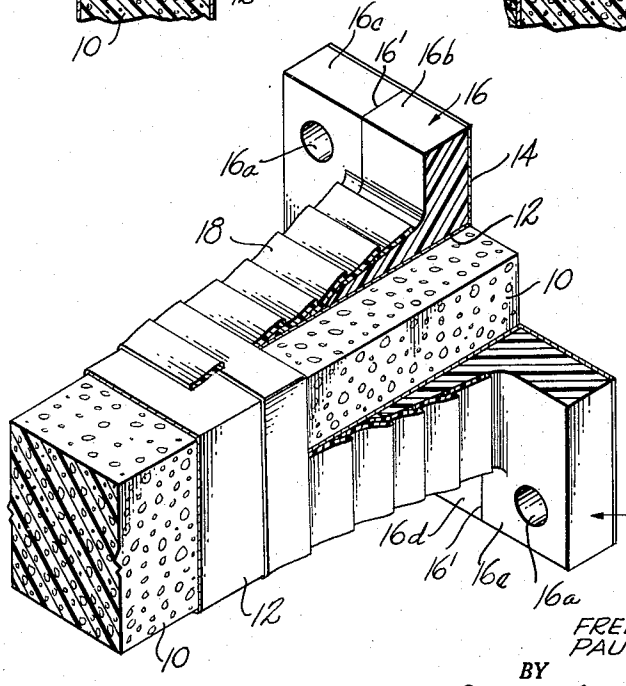


Fig. 1.

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WAVE GUIDE CONSTRUCTION

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4 Claims. (Cl. 333—95)

This invention relates to improvements in the construction of electromagnetic wave guides generally of the tubular conductor type used extensively in microwave apparatus. The invention is herein illustratively described by reference to its presently preferred form as applied to the construction of a rectangular wave guide with an integral end flange; however it will be readily appreciated by those skilled in the art that certain modifications and changes therein may be made without departing from the essential and characterizing features involved and that the novel teachings of the invention may be applied to wave guides of various configurations as well as to associated microwave components in or through which electromagnetic wave energy is propagated or sustained. The term "wave guide" as used hereinafter is intended to embrace all such wave guide and associated microwave components to which the novel aspects of the invention may be applied.

An object of the invention is a wave guide of lightweight construction.

Another object is a wave guide construction simplifying the manufacture of complexly shaped wave guides and wave guide components.

Still another object is such a wave guide which is sealed against penetration of moisture into the wave guide and associated apparatus connected thereto.

A further object is such a wave guide which will permanently retain a given effective internal pressurization insuring constancy of operation in widely varied ambient pressure, thereby eliminating the need for pressurizing equipment commonly used with conventional microwave apparatus, especially in aircraft applications.

A general object is an improved wave guide construction particularly suited for aircraft and similar microwave applications.

Conventional wave guides comprise hollow metal tubes and cavities deriving their structural strength and rigidity from a substantial metal wall thickness. Difficult molding procedures are involved in producing accurate internal dimensioning and these procedures became very complex when special forms are required such as bends and fittings of various types. These procedures to be economical usually involved the preliminary step of producing a disposable mold core of the desired wave guide internal form and ultimately dissolving or otherwise removing the core material from the hollow metal wave guide molded around it. Often, however, complex bends cannot be made in a unitary form but must be assembled from sections of wave guide secured together by flanged couplings.

The present invention achieving the above objects provides a wave guide construction wherein the preshaped core upon which a conductive shell is formed advantageously becomes a permanent part of the completed wave guide. In accordance with the improved wave guide construction the desired wave guide internal configuration is molded, cut or assembled from a solidified

low density foam dielectric substance having a relatively low dielectric loss tangent, high strength and low specific weight. The form, strength and rigidity of the completed wave guide are imparted chiefly by this permanent foam plastic core. The wave guide conductor is then formed by applying a thin continuous layer of conductive metal to all longitudinal surfaces of the core. This layer need be sufficiently thick only for electrical purposes as it is not required to add appreciable strength nor rigidity to the completed wave guide. At very high frequencies the "skin effect" of electrical currents required to flow in the wave guide wall for unattenuated propagation of energy in the guide permits the metal layer thickness to be less than a few hundredths of an inch. In the preferred form of construction this conductive layer or shell is protectively encased in a lightweight overlayer which is preferably formed by a resin impregnated Fiberglas laminate.

These and other features, objects and advantages of the invention will become more fully evident from the following description by reference to the accompanying drawings.

Figure 1 is a perspective view of a section of rectangular wave guide with a coupling flange thereon and with portions broken away sectionally to illustrate internal construction.

Figures 2 to 5, inclusive, are longitudinal sectional views showing successive stages in the manufacture of the wave guide construction appearing in Figure 1 according to the presently preferred technique.

With reference to Figure 1 the completed wave guide structure illustrated by way of example comprises a solidified foam dielectric core **10** of desired rectangular cross-sectional dimensions and of any desired length and longitudinal configuration. Upon the longitudinal walls of this rigid core the thin conductive metal layer **12** is applied, and forms a continuous shell constituting a wave guide conductor for propagation of microwave energy through the length of its interior.

A metal layer flange conductor **14** is formed integrally with the end of the tubular metal shell **12**. Normally the plane of this end flange conductor will be perpendicular to the longitudinal axis of the shell immediately adjoining it. The end flange conductor **14** is maintained in this relationship with the conductively coated core by backing elements preferably formed of a suitable solid plastic substance and together constituting a flange collar **16** surrounding and adhesively bonded to the end of the metal layer **12**. This flange collar has bolt holes **16*a*** in each of its four corners by which the flanged end of the completed wave guide may be secured in conductive relationship to the flanged end of another similar wave guide or to a different microwave component such as a cavity resonator, high-frequency oscillator tube or the like. The flanged collar **16** may be moulded in one piece or as illustrated, in four separate pieces **16*b***, **16*c***, **16*d*** and **16*e*** adhesively bonded together at interfaces **16'** coincident with opposite longitudinal walls of the wave guide.

A protective over-layer **18** surrounding the thin conductive shell is applied in the example by wrapping the same with overlapping turns of resin impregnated Fiberglas fabric tape. The wrapping is caused to overlap the base of the collar **16** which is tapered in thickness to receive the wrapping smothly. After the wrapping is complete the resin is cured resulting in a tough and durable shield for the relatively soft conductive metal layer **12**. Depending upon its thickness and make-up this laminated shield lends strength and rigidity to the completed wave guide, although as mentioned above the permanent foam dielectric core **10** constitutes the principal structural member of the wave guide.

The various different types of low density dielectric substances which lend themselves to manufacture of the permanent core **10** in this construction are virtually too numerous to mention. Examples of different types of dielectrics which may be used include alkyd-isocyanate, polyesters, polystyrenes, cellulose acetate, polyvinyl chloride, styrene-butadiene copolymers, phenolic resins, urea resins, melamine, silicones, certain ceramics and others. Of course some of these are better than others for the purposes at hand since they vary in their capability of being molded or cut into desired shapes when foamed into a lightweight cellular state having a low dielectric loss factor, a high degree of toughness, strength and rigidity, non-absorbency to moisture and the capacity to retain pocketed gas or air at constant internal pressures despite ambient pressure changes to which the completed wave guide is subjected. It will be appreciated, therefore, that any dielectric substance meeting these requirements for a practicable wave guide core may be employed. The term "foam dielectric" is intended to embrace all suitable core substances meeting the requirements as above indicated.

Preferably the foamed dielectric core **10** is molded, since its exterior surface is then smooth and the conductive metal layer **10** subsequently deposited thereon will also be smooth, hence most efficient for its purpose as a conductor of microwave currents.

The preferred method of molding a foamed core piece having an exceptionally smooth exterior is to transfer the mixture of dielectric powder and foaming agent used to a mold which has been coated with a special parting film. This film is produced by brushing or spraying a suitable silicone resin on the mold surfaces and baking the same at the necessary temperature for producing a cure and for bonding the cured resin film to the mold surfaces. One or more coats of lacquer or resin are then sprayed or brushed on this cured basic film before the foam mixture is injected into the mold. It is found that the solidified foam cured in such a mold adheres to the lacquer or resin coatings applied to the basic film, but that these coatings do not adhere to the basic film. In this manner the molded core is easily broken from the mold and possesses very smooth surfaces as desired. Moreover the basic silicone resin film is unimpaired and may be used over and over again.

However, instead of one-piece molding the core may be machine-cut if desired or assembled from molded or cut pieces bonded together to build up the desired core configuration. This latter expedient is particularly useful in forming complex wave guide components and fittings and enables eliminating many of the coupling flanges now being used in hollow metal wave guides many sections of which cannot readily be molded in unitary form. Furthermore the improved construction involving a permanent foam dielectric core permits fixing the position of a core insert component by its embedment in the core during molding or assembling operations. Metal elements producing reactance effects and the like are often incorporated inside wave guides and the improved construction greatly simplifies their installation in most instances.

The density of the dielectric core substance will depend of course upon the degree to which it is expanded by the particular foaming technique employed and upon the density of the unfoamed dielectric substance. It is found that good results are achieved with any of the above enumerated dielectrics if their density in solidified foamed condition approximates ten pounds per cubic foot. By "good results" is meant a favorable balance between the factors of strength and rigidity (fostered by higher densities) on the one hand, and a light-weight, low dielectric loss core, on the other hand. The attributes of moisture resistance and pressurization are not affected by density of the completed core since they derive from the self-sealing properties of the core material filling

out the entire interior of the microwave conductor shell **12** wherein intense electrical fields may exist tending to produce arcing and electrical losses in unpressurized, unsealed wave guides of conventional form.

In practical wave guide assemblies produced according to the above, weight savings ranging in the order of 50 to 70 percent and more are achieved on the basis of the weight of conventional hollow brass tube wave guide construction. The importance of this in aircraft and similar microwave apparatus is manifest.

A thin conductive metal coating **12** may be successfully applied to the core **10** by any of various different techniques. Those presently favored are electroplating, "vacuum metalizing," and spraying, the latter being preferred. A third method is to wrap the core in metal foil and spray the wrapping joints or edges with the same or a similar metal for electrical continuity. Copper, brass, aluminum, zinc or other conductive metals or alloys may be used for the conductive layer.

Figures 2 to 5 inclusive illustrate the preferred method of forming the end flange. As in Figure 2, a mandrel plate A is temporarily bonded to the end face of the core **10** and is of a size and shape corresponding to the desired flange dimensions. As in Figure 3, the metal coating **12, 14** is applied in a single operation to all sides of the core and to the back side of the mandrel plate A projecting therebeyond. The flange collar elements **16***b*, **16***c*, **16***d* and **16***e* are then assembled around the coated core adjacent the coated mandrel plate (Figure 4) with adhesive substance applied to all surfaces of contact so as to bond these elements to each other and to the shell conductor **12** and flange conductor **14**. The wrapping **18** is then applied and the wrapping impregnant cured. Thereupon the mandrel plate A is removed, as shown in Figure 5, leaving the metal flange conductor **14** exposed for purposes of electrical contact in a wave guide joint.

The foregoing detailed explanation of the preferred mode of practicing the invention is intended to convey an understanding of the essentials involved therein but the details of illustration are not to be construed as limiting the scope thereof.

We claim as our invention:

1. A wave guide for electromagnetic wave propagation comprising an elongated continuous low-density foam dielectric core of substantially rigid predetermined wave guide form and a relatively thin conductive metal layer adhered to the sides of said core and forming a continuous shell surrounding the same insufficiently thick to impart appreciable stiffness and rigidity of itself to the wave guide, said core imparting stiffness and rigidity to the completed wave guide, said wave guide additionally comprising an end connecting flange formed by a conductive metal flange electrically contiguous to an end of the conductive metal shell, and a backing element adhered to the metal flange and to the shell at the base of said flange.

2. The wave guide defined in claim 1, and a protective overlayer surrounding and adhered to the conductive metal shell comprising a resin-impregnated fabric wrapping.

3. The method of manufacturing flanged wave guides for electromagnetic waves comprising the initial step of forming a wave guide core of low-density foamed dielectric substance having an end face to be connected to other electromagnetic wave guide means, temporarily adhering a mandrel plate to said end face to project beyond all edges thereof, applying a conductive metal coating to all sides of said core and to the exposed portions of the side of said plate adhered to said core to form a flanged continuous conductive shell surrounding said core, adhering a backing collar to the flange of said conductive shell and to the shell itself surrounding said core at the base of such flange, and thereafter removing said mandrel plate to expose said core end face and said flange.

4. The method defined in claim 3, comprising the further step of protectively encasing the conductively coated core by applying a wrapping of resin impregnated fabric thereto, and curing the resin in said wrapping.

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