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COAXIAL CONNECTOR FOR HIGH-FREQUENCY TRANSMISSION LINES

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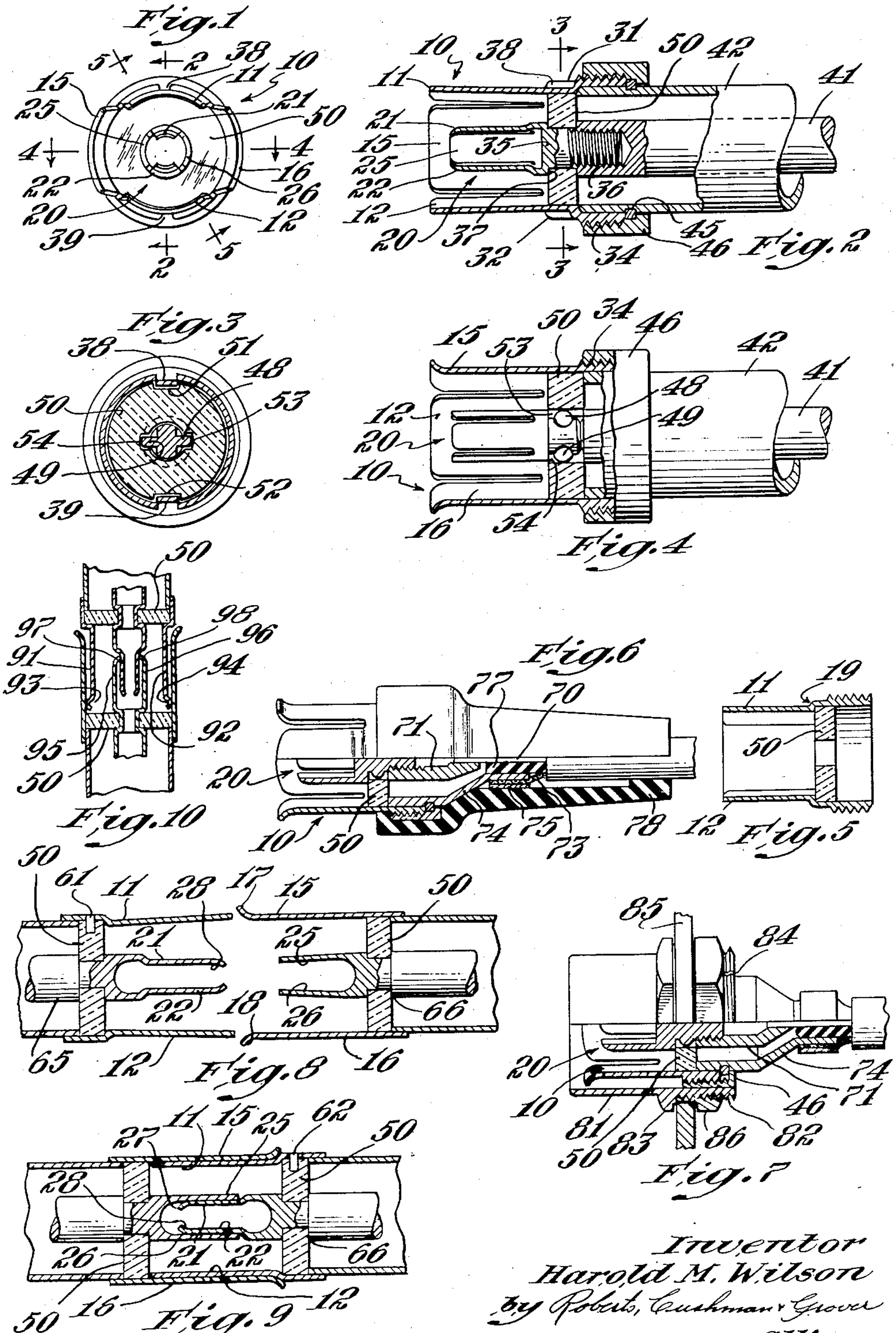

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COAXIAL CONNECTOR FOR HIGH-FREQUENCY TRANSMISSION LINES

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1

It is desirable to associate for energy transmission, and again to disassociate components of apparatus carrying electrical and magnetic waves of high frequency, if at all possible with practically the same facility with which connections of low frequency apparatus can be established. Due to the nature of short wave energy flow, the problem of providing satisfactory connections of this type encounters difficulties which are quite foreign to those encountered in low frequency transmission, particularly also if the connections are to be of the nature of coaxial conductors.

It is one of the principal objects of the present invention to provide a connector system of the above mentioned type which permits joining of two apparatus components in direct and simple manner not requiring skill or particular attention, and which can be relied upon to pass ultra high frequency power without objectionable reflections and micro wave radiations.

Other objects of the invention are to provide such a connector assembly one end conductor or connector proper of which can be readily engaged with the identical element of any other connector to form a continuous transmission line of impedance characteristics suitable for efficiently passing high frequency energy of the above mentioned type; to provide such a connector assembly which inherently assures, for purposes of ultra high frequency energy transmission, continuity of conductor surface; to provide such a connector assembly which can be easily attached to wave guide transmission lines especially also coaxial lines, of the most commonly used types, permitting proper matching and shielding to prevent the above mentioned detrimental reflection and radiation; to provide a coaxial connector which may be readily engaged with any other connector of the same type and dimensions to form a uniform concentric transmission line; to provide a connector assembly which facilitates the mechanical engagement of a pair of connectors without affecting its electrical continuity; to provide such a connector which is electrically compensated for discontinuities due to mechanical construction; to provide a coaxial connector which permits mechanically secure engagement of both inner and outer conductors; and to provide a connector of the type referred to which is easily adaptable for a large variety of uses, to join flexible lines or rigid lines, or to connect such lines to panel apparatus, and generally speaking to provide an electrical connector system

2

for ultra high frequency transmission purposes which is simple, dependable and inexpensive and permits secure and easy joining of the conduits to be connected while fully insuring electrical continuity of the type necessary for such transmission.

In one of its principal aspects the invention employs an electrical connector composed of two coaxial conductors each of which has an inner and an outer set of contact fingers for engagement with the outer and inner sets of fingers of a substantially identical connector, these conductors being positively inter-connected to fixate them in such mechanical as well as electrical relationship that the secure engagement with an identical connector is with certainty assured while a high frequency power conduit of substantially uniform impedance condition throughout the connector is established through electrical compensation of mechanically required discontinuities.

In another aspect, individual conductors are according to the invention made from single pieces of tubing, each with a plurality of contact fingers for engagement with the fingers of a substantially identical connector, these fingers defining when thus engaged, together with an insulator for separating the conductors, two concentric cylinders, one for each of two coaxial conductors and each cylinder having fingers radially offset alternately to the inside and outside thereof.

In a further important aspect of the invention, continuity of the effective wave guiding surfaces of the connector is insured by outwardly tapering or otherwise deforming the conductor fingers lying on the inside of the above mentioned outer cylinder and, in the case of coaxial connectors, by inwardly tapering or otherwise deforming the contact fingers on the outside of the inner cylinder while easy and convenient joining of substantially identical conductors is provided by flaring the conduit fingers on the outside of the outer cylinder outwardly at their ends and forming the ends of the conduit fingers lying on the inside of the inner cylinder inwardly; in a preferred embodiment the fingers are flared as well as tapered in the above indicated manner.

It will be understood that the above mentioned cylinders are susbtantially defined by the fingers of a connector when it is engaged with another identical connector, whereas certain fingers may depart slightly from this defining shape when disengaged.

An additional feature of a practical embodiment of the invention is the arrangement of the above mentioned sets of conduit fingers in such a manner that one of the sets of the outer conductor is radially displaced inwardly to form a step at the root of the set, the above mentioned insulating and separating body contacting the conductor against this step, the dielectric constant and dimensions of the insulator and the depth of the step being so correlated that they compensate each other to maintain substantially uniform impedance conditions through the connector; the inner conductor of the coaxial connector may be stepped in analogous manner, the impedance change due to the change of shape of the metallic conductor being again compensated by correlating dielectric constant and dimensions of the separator so as to compensate for the mechanically required discontinuity, to provide uniform impedance conditions throughout the connector. In accordance with the invention, the separating insulators are preferably so arranged that their distance in a connector assembly is appreciably different from one half of the wave length or a multiple thereof, of the high frequency energy transmitted through the assembly.

In some of the more specific aspects of the invention, the coaxial conductors of the connector are provided with keys which engage corresponding recesses of the above mentioned insulator disk, which permits easy assembly and establishes secure angular as well as axial alignment of the conductors, the insulator providing this mechanical function together with the above mentioned electrical compensation for impedance change if the conductor shape should be discontinuous as above mentioned; instead of providing rotational alignment by means of keys and key ways of conductors and insulating separator respectively, set pins, flats, or analogous provisions may be used.

These and other objects, aspects and features will appear from the following description of several typical practical embodiments illustrating the novel characteristics of my invention.

In the drawing:

Fig. 1 is a front elevation of a coaxial connector according to the invention;

Fig. 2 is a section on 2—2 of Fig. 1 with parts of the conductors of a coaxial line shown in elevation;

Fig. 3 is a section on line 3—3 of Fig. 2;

Fig. 4 is a section on lines 4—4 of Fig. 1 with the coaxial line conductors and part of the coupling nut shown in elevation;

Fig. 5 is a section on lines 5—5 of Fig. 1, with the inner conductor and coupling nut omitted;

Fig. 6 is an elevation and longitudinal section of a connector similar to that shown in Figs. 1 to 5 but particularly suited for connecting a flexible coaxial cable conductor instead of a rigid coaxial conductor;

Fig. 7 is an elevation and section similar to those of Fig. 6, but of a connector particularly suited for mounting on a panel;

Fig. 8 is a schematical longitudinal section through a pair of matching connectors according to the invention in position to be joined, with the tapers exaggerated in order more plainly to illustrate this feature of the invention;

Fig. 9 is a schematical longitudinal section in a plane normal to the section plane of Fig. 8, through a connector assembly with two mutually engaged identical connectors; Figures 8 and 9 also show modifications of the provisions for rotational correlation of the inner and outer conductors; and

Fig. 10 is a schematical longitudinal section similar to Fig. 9, showing a modification with formed contact ridges instead of tapered fingers, the height of the formed ridges being exaggerated in order to illustrate this feature more clearly.

All figures show an outer conductor 10, preferably pressed from a single piece of tubing, with inner fingers 11 and 12, and outer fingers 15 and 16. As particularly shown in Figs. 8 and 9, the inner fingers 11 and 12 are tapered outwardly, whereas the ends of the outer fingers 15 and 16 are flared outwardly as indicated by numerals 17 and 18.

All figures also show the inner conductor 20 which has inner fingers 21 and 22 and outer fingers 25, 26. As indicated in Figs. 8 and 9, the outer fingers of the inner conductor are tapered inwardly, whereas the ends of the inner fingers are flared inwardly at 27, 28.

As particularly shown in Figs. 2, 3 and 5, the outer and inner surfaces of outer fingers 15 and 16 are flushed throughout, whereas the inner fingers 11 and 12 are set back inwardly so that their outer surface is in the cylinder containing the inner surface of the outer fingers, at the same time forming the step particularly shown in Fig. 5 at 19.

Formed at the roots 31, 32 of the inner fingers 11, 12 are keys 38, 39 whose outer surface is flush with the outer surface of the inner, and the inner surface of the outer fingers, whereas the inner surface of these keys is flush with the inner surface of the fingers at whose roots they are formed, as indicated in Figs. 1 and 3.

The attached side of the outer conductor tube 10 is provided with a thread 34. It should be noted that in Fig. 2 the section is taken through the keys of the inner fingers 11 and 12 and the key ways of the insulator disk to be described hereinbelow, so that the roots 31, 32 of the inner fingers 11, 12 do not appear in section.

The above described inner conductor tube 20 has a shank 35 provided with an inner thread 36 (Fig. 2), and joins the roots of the conductor fingers proper with a shoulder 37. The shank 35 of the inner conductor 20 has, formed thereon by pressing, two keys or ears 48, 49.

As shown in Figs. 2 and 3, the inner conductor 20 may be screwed to a solid inner coaxial conductor 41, whereas the outer conductor 10 is connected to an outer coaxial conduit 42 by means of a square retaining ring 45 (Fig. 2) resting in a recess of conductor 42, and a coupling nut 46 whose thread matches the above mentioned thread 34 of the outer conductor tube 10.

The insulating ring 50 has two outer key ways 51, 52 and two inner key ways 53, 54, which are shaped to engage the keys 38, 39 of the outer conductor and the ears 48, 49, respectively, of the inner conductor, as clearly shown in Fig. 3.

When assembled, the nut 46 presses shoulder 19 of the outer conductor against one face of the insulator 50, which face also engages shoulder 37 of the inner conductor, whereas the other face of the insulator 50 rests against the end faces of the coaxial conductors 41 and 42. This pressurable surface contact and the keys and key ways above described provide a very rigid assembly which firmly secures the axial and rotational correlation of the effective conductor members 10 and 20.

In order to provide for convenient and easy joining of two connectors and to maintain electrical continuity, the fingers may be flared and tapered as mentioned above and indicated in Fig. 8 which shows the taper exaggerated. It will be noted that the inner fingers of the outer conductors are tapered outwardly whereas the outer fingers of the inner conductors are tapered inwardly which provides, through the slight spring action of this construction, secure mechanical juncture but primarily also firm electrical contact at regions where the continuity of the wave guiding surfaces is least disturbed.

Instead of tapering selected sets of fingers as above described, the same result may be accomplished by forming the tips of the inner fingers of the outer conductor outwardly and by forming the tips of the outer fingers of the inner conductor inwardly, as will be described with reference to Fig. 10.

In order to join components of high frequency apparatus by means of a device according to the invention, it is merely necessary to juxtapose two individual identical connectors in approximate alignment as for example indicated in Fig. 8, and gently slide them together until resistance indicating full juncture is encountered. Due to the above described correlation of the mechanical and electrical factors involved, this juncture establishes a conduit providing for all practical purposes undisturbed high frequency transmission.

Figs. 8 and 9 also show two other possibilities of rotationally securing the conductors relatively to each other, namely pins **61**, **62** made from insulating material for example a polystyrene, and pressurably driven through a hole of the outer conductor into a corresponding bore of the insulator disk. Or, instead of providing the insulator disk **50** with one or two sets of key ways, it may be flattened at one or several points, as indicated at **65**, **66** of Figs. 8 and 9 respectively, these flats corresponding to similarly flattened portions of the inner conductor members.

The change in the ratio of diameter of the outer and inner conductors occurring at the above discussed shoulders constitute discontinuities of the effective wave guiding surfaces, in the case of a coaxial conductor the inner surface of the outer conductor and the outer surface of the inner conductor. These discontinuities would disturb the smooth wave progress, and according to the present invention they are compensated by correlating them with the dimensions of the insulating disk **50** whose diameters and dielectric constant are so chosen that characteristic impedance is maintained constant throughout the conduit. For any conductor diameters and insulating material the characteristic impedance of a coaxial transmission line is given by the formula

$$Z_0=(138/\sqrt{\epsilon})\ \mathrm{Log}_{10} D/d$$

where ϵ is the dielectric constant of the insulating material, D is the inside diameter of the outer conductor and d is the outside diameter of the inner conductor.

It will be evident that the dielectric constant and diameters of the insulator **50** will depend upon the configuration of the conduits and will vary according to requirements at hand. In a satisfactory practical embodiment, the air insulated portions ($\epsilon=1$) of the conduits and connectors have an inside diameter of 0.562'' of the outer conductor, and an outside diameter of 0.244'' of the inner conductor, while the compensating disk, made of polystyrene with a dielectric constant of approximately 2.6 has a diameter of .625'', with a central hole of .165'' diameter, thereby maintaining a characteristic impedance of substantially 50 ohms throughout. As mentioned above, the tapers and flares of the end conduits **10** and **20** are so chosen that they promote undisturbed transmission. The outermost fingers **15** and **16** also shield the points of pressurable electrical contact with the contacting fingers **11** and **12** of any other mating connector thus preventing objectionable wave radiation.

In designing connectors of this type for a given frequency it is also desirable to choose the length of the fingers so that the distance of the insulator disks is not near a half wave length or a multiple thereof, because any configuration providing less than full compensation, such as due to mechanical imperfection, tends to be additively detrimental between two disks separated by one-half electrical wave length of the transmitted energy flow.

As indicated by similar numerals, the connecting or end conductor elements of the connectors shown in Figs. 6 and 7 are similar to those above described with reference to Figs. 1 to 5, 8 and 9.

The construction according to Fig. 6, particularly suitable for connecting flexible coaxial lines, differs from the previously described embodiment as follows.

In order to attach the connector according to Fig. 6 to a flexible coaxial conductor, the inner conductor **20** is attached to the flexible inner conductor **70** by means of an inner transition piece **71**, which conforms at its connector end to the rigid conductor **41** shown in Fig. 2 but which is tapered at its cable end and drilled to accommodate the flexible inner coaxial conductor to which it is attached for example by soldering. The outer conductor **10** is connected to the flexible outer coaxial conductor **73**, which may be a braided metal hose, by means of an outer transition piece **74** which conforms with its connector end to the rigid outer conductor **42** of Fig. 2 but which is tapered at its cable end to an outer diameter accommodating that of the flexible outer conductor **73** to which it is attached for example by means of a crimp ring **75**. Outer and inner flexible conductors are separated by a layer of flexible insulation **77** and protected by a neoprene or plastic sheath. The entire connector assembly is housed within a cable guard **78** made for example of soft black rubber or neoprene.

The embodiment according to Fig. 7 is again so far as the inner and outer conductors **10** and **20** are concerned, similar to the embodiments described above with reference to Figs. 1 to 5, and it incorporates transition pieces **71** and **74** which are essentially similar to those described above with reference to Fig. 6. In addition to the above described elements, this embodiment incorporates a panel adapter **81** with saw cut slits **84**, an outer thread **82**, and a rim **83**. This assembly is attached to a panel **85** by means of nut **86**, which presses adapter **81** against nut **46** and at the same time secures the entire assembly to the panel **85**.

It will be evident that the above described elements of the connector according to the invention may vary as to their configuration, if not as to their function, according to requirements at hand; on the other hand it will be understood that the above described preferred embodiment permits ready and easy adaptation to a variety of uses, with a maximum number of parts usable for all modifications, which are those ordinarily required in apparatus of the present type.

It will be understood that the manner of relatively positioning the outer and inner conductors by means of an insulator body may vary according to requirements, but that one of the basic concepts of the invention, namely the electrical compensation of a conductor configuration required by mechanical considerations, by way of correlating mechanical and electrical patterns, is in the above described embodiment carried out by means of elements which together fulfill both mechanical and electrical requirements with a minimum of parts or complexity of structural configuration.

The modification shown in Fig. 10 provides proper electrical contact and essential conduit continuity by means of a construction which may sometimes be preferable to the incorporation of the above described slight taper of fingers such as **11**, **12** and **25**, **26**. In this modification, all fingers are always substantially cylindrical surfaces, but the tips of the inner fingers of the outer conductor and those of the outer fingers of the inner conductor are formed slightly to protrude outwardly, and inwardly, respectively. Thus, fingers **91** and **92** of Fig. 10 are provided with outwardly protruding formed rims **93**, **94**, and fingers **95** and **96** with inwardly protruding rims **97**, **98**. These formed rims can be very small, just high enough to insure pressurable electric content at the roots of the corresponding opposite fingers, while avoiding any possibly detrimental deformation.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. A coaxial electrical connector comprising an inner conductor and an outer conductor each having a plurality of contact fingers for engagement with the fingers of a substantially identical connector, said fingers defining cylinders with each cylinder having fingers radially offset alternately to the inside and outside thereof, said outer conductor having an inwardly projecting key, and said inner conductor having an outwardly extending key; and an insulator disk having an outer recess fitting said first and an inner recess fitting said second key to provide rotational orientation so that the contact fingers of each conductor will registeringly engage the contact fingers of said identical connector.

2. A coaxial electrical connector comprising an inner electrical conductor attached to a metallic core, an outer electrical conductor attached to a metallic conduit surrounding said core, and an annular insulator body separating said conductors, said conductors each having several contact fingers formed and arranged to define two respective concentric cylinders with alternate contact fingers radially offset to the inside and outside of said cylinders, the fingers lying inside the cylinder of said outer conductor and the fingers lying outside the cylinder of said inner conductor having well defined steps at the attached ends of the fingers to provide mutual axial localization of said insulator body, said outer conductor having a key projecting inwardly beyond said step as an extension of the inner surface of one of said inside fingers of the outer conductor, said inner conductor having a key projecting outwardly within the outer surface of one of said outer fingers of the inner conductor, and said insulator body having inner and outer concentric rims fitting said inner and outer steps of said conductors, respectively, and having recesses fitting said keys, to provide axial and angular relative localization of said conductors.

3. A coaxial electrical connector comprising an inner conductor and an outer conductor each having a plurality of contact fingers for engagement with the fingers of the inner and outer conductors of a substantially identical connector, said fingers defining cylinders with each cylinder having fingers radially offset alternately to the inside and outside thereof, said outer conductor having a surface deformation element and said inner conductor likewise having a surface deformation element; and an insulator body having a surface deformation element corresponding to and engaging said deformation element of said outer conductor and also having a surface deformation element corresponding to and engaging said deformation element of said inner conductor; said deformation elements providing rotational registration of inner and outer conductors of the connector so that the contact fingers of each conductor will registeringly engage the contact fingers of said identical connector.

4. Connector according to claim 3 wherein said surface deformation element of one of said conductors includes a projecting key and the corresponding surface deformation element of said insulator body includes a recess fitting said key.

5. Connector according to claim 3 wherein said surface deformation element of one of said conductors includes a pin pressurably driven through a hole of said conductor and the corresponding surface deformation element of said insulator body is a bore which fits said pin.

6. Connector according to claim 3 wherein said surface deformation element of one of said conductors includes a flattened portion and the corresponding deformation of said insulator body includes a flat surface fitting said flattened portion.

7. Connector according to claim 3 for short wave length transmission lines, wherein the distance of said insulator body from the tips of said fingers is such that, upon engagement of two identical connectors, the two bodies are at a distance substantially differing from one half of said wave length or a multiple thereof.

8. Connector according to claim 3 wherein the contact fingers lying on the inside of the cylinder defined by the fingers of the outer conductor are tapered outwardly and the contact fingers lying on the outside of the cylinder defined by the fingers of the inner conductor are tapered inwardly, thereby to insure continuity of the inner surface of the outer conductor and the outer surface of the inner conductor, through pressurable contact of the tips of the tapered fingers with the roots of the corresponding fingers of said substantially identical connector.

9. Connector according to claim 3 wherein the fingers lying on the inside of the cylinder defined by the fingers of the outer conductor have an outwardly embossed tip and the fingers lying on the outside of the cylinder defined by the fingers of the inner conductor have an inwardly embossed tip, thereby to insure continuity of the inner surface of the outer conductor and the outer surface of the inner conductor, through pressurable contact of said tips with the roots of the corresponding fingers of a substantially identical connector.

10. Connector according to claim 3 wherein the tips of the outer contact fingers of the out-

side conductor are flared outwardly, the tips of the inner contact fingers of the inside conductor are flared inwardly, and the tips of the remaining fingers terminate in circles within said flared tips, so as to be forced into pressurable contact upon engagement with the respective flared fingers of a substantially identical connector.

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