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T. J. KILDUFF ET AL

3,539,429

METHOD OF FABRICATING A FLUID HANDLING ELEMENT

Filed Nov. 14, 1967

2 Sheets-Sheet 1

FIG. 1

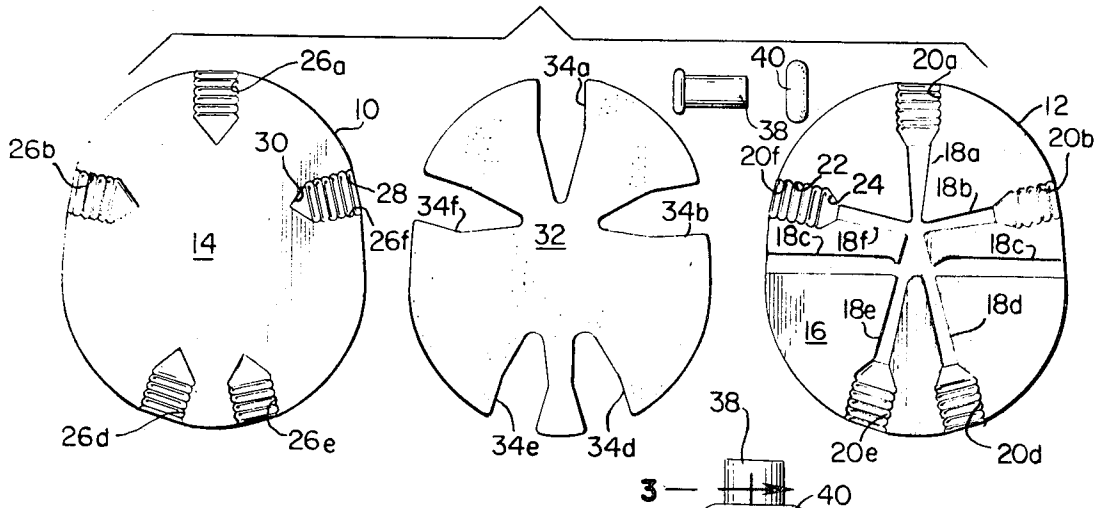


FIG. 3

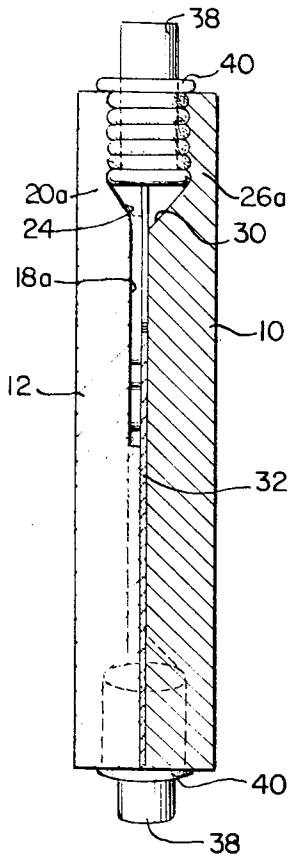
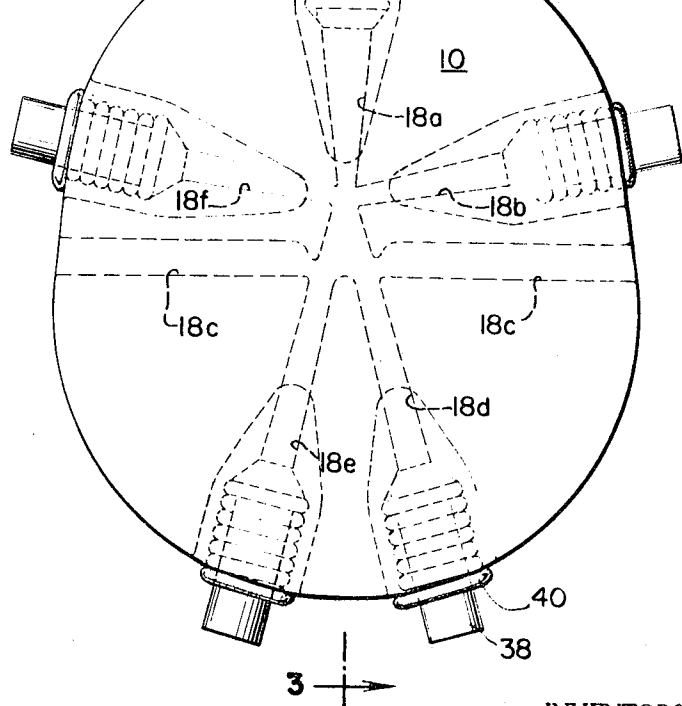


FIG. 2



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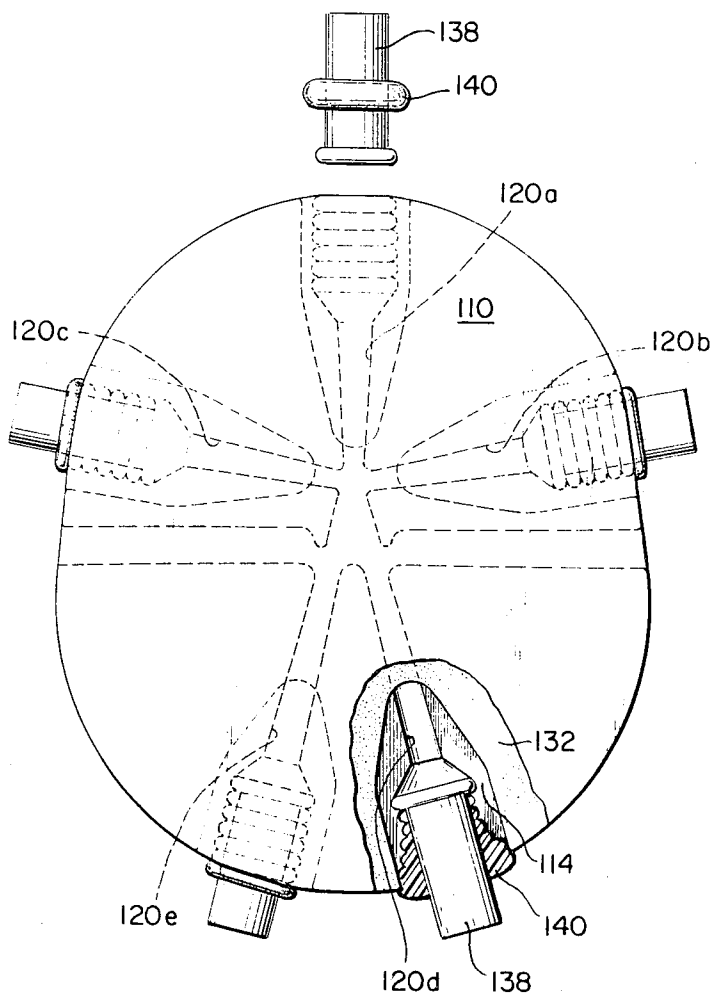


FIG. 4

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METHOD OF FABRICATING A FLUID HANDLING ELEMENT

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Int. Cl. F15c 1/08

U.S. Cl. 156—292

5 Claims

ABSTRACT OF THE DISCLOSURE

A method of fabricating a fluid handling element consisting of a relatively solid housing having fluid conduits formed therethrough. Channels are formed in the mating surface of one of a pair of mating blocks and enlarged, connector-receiving bores are formed at the intersection of the channels with the periphery of the blocks. Connector tubes having heat-activated adhesive therearound are disposed in the enlarged bores and a sheet of heat-activated adhesive, cut out in the areas of the enlarged bores, is disposed between the mating surfaces of the blocks. The assembly is united by applying heat and pressure thereto to activate the adhesive.

BACKGROUND OF THE INVENTION

This invention relates generally to fabrication of fluid handling elements of the type having a relatively solid housing with fluid transmitting conduits disposed therethrough. Although the following description is specifically directed to fluid amplifiers, it should be understood that the teachings of this invention may be applied, with equal facility, to other fluid handling structures if desired.

Fluid amplifiers comprise fluid-operated systems which amplify the momentum, pressure, or mass flow of a fluid input signal supplied to the system. A description of the structure and operation of fluid amplifiers in general is contained in U.S. Pat. No. 3,282,280, issued Nov. 1, 1966, to Horton.

The operation of fluid amplifiers generally requires that the body be fabricated in mating sections or blocks with the internal conduiting and chambering thereof being formed from channels cut or routed in the mating surface of one of the blocks. Due to the complex configuration of the internal channeling required in the amplifier, it is generally not feasible to form the channels by external drilling a solid block as is more conventional in simpler fluid handling elements. Once the channeling is suitably formed in the mating surface of one of the blocks, it has been conventional in the prior art, to assemble the blocks by applying a liquid adhesive to the mating surfaces and then bonding the blocks to form the resultant amplifier body.

Once the body has been formed as described above, it has been conventional to insert connector tubes for subsequent bonding at the intersection of the fluid conduits with the periphery of the fluid amplifier housing.

Prior art methods of fabricating fluid amplifiers present several problems in that, first, since a complete seal must be made at all points of contact around the channels, application of the adhesive is particularly critical. The degree of reliability achieved with liquid adhesives and/or solvents has been found to be no more than about 60%. Furthermore, because of the squeeze-out characteristic of wet adhesive, extreme care must be exercised in order to ensure that the channels be kept free of excessive adhesive. This requires further effort in the form of care in application of the adhesive, clean out the excessive adhesive where possible, or rejection of the element where squeeze-out occurs and cleanout is not possible. Due to

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the above, the cost of fluid amplifiers fabricated by the prior art processes has been excessively high.

SUMMARY OF THE INVENTION

This invention provides a new method of fabricating fluid handling elements and particularly fluid amplifiers, which avoids the disadvantages of the prior art by providing means to bond the components of the elements while avoiding the likelihood of contamination of the fluid conduits of the elements by excess adhesive squeezed out during the bonding procedure. This is achieved by providing a dry, heat-activated adhesive between the components to be bonded, thereby eliminating the danger of contaminating the fluid conduits.

The invention also provides a method of simplifying the assembly of fluid handling elements by attaching connector tubes to a fluid handling element simultaneous with the bonding of the components thereof, thereby eliminating an additional step of the prior art methods of fabrication. This is achieved in one embodiment by providing a sleeve of dry adhesive around the connector tubes which sleeve and tubes are inserted in the element prior to bonding of the components thereof, and are bonded simultaneously with the bonding of the components. In another embodiment the connector tube is surrounded by a ring-shaped sleeve of foam adhesive.

In a preferred embodiment, a pair of housing blocks are formed with mating surfaces. Fluid channels are formed in the mating surface of one of the blocks. Enlarged portions are formed in the mating surfaces of the blocks proximate the intersection of at least one of the channels with the periphery of the housing and dry adhesive sleeve-encapsulated connector tubes being disposed in the enlarged portions. A sheet of dry adhesive, cut to the configuration of the housing and provided with cut-outs which accept the adhesive sleeve or foam adhesive encapsulated connector tube, is disposed between the mating surfaces of the blocks and the assembly is bonded by application of heat and pressure to form a laminate. In the foam adhesive embodiment the foam is actuated by heat expanding the adhesive to fully seal the void between the tubes and enlarged portions.

Other advantages and attendant objects of the invention will become better understood to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawing wherein like numerals throughout the figures thereof indicate like components and wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of the components of a fluid amplifier in accordance with the invention prior to assembly thereof;

FIG. 2 is an enlarged elevational view of the components of FIG. 1 after assembly;

FIG. 3 is a sectional view of the amplifier of FIG. 2 taken along the line 3—3 thereof; and

FIG. 4 is a view similar to FIG. 2 illustrating another embodiment in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a fluid amplifier according to the invention comprises a pair of housing blocks 10 and 12 having flat, smooth mating surfaces 14 and 16 formed thereon. In prior art construction, when blocks 10 and 12 were made of thermoplastic resins, it has been necessary to provide lapped flat surfaces on the mating surfaces of the blocks, since when blocks 10 and 12 are molded thermoplastics, shrinkage and irregular surfaces are produced during the mold operation. In this invention, however, machine finishing of the surfaces 14

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and 16 has been found to be adequate to obtain sufficient bonding with the method taught by this invention.

The block 12 is provided with a plurality of intersecting channels 18a through 18f in the surface 16. The channels 18a, 18b and 18d through 18f have enlarged portions 20a, 20b, and 20d through 20f thereto at the intersection thereof with the periphery of the block 12. The enlarged portions are formed with transversely disposed serrations or ferrules 22 in the walls thereof for purposes to be described in greater detail below. A tapered segment 24 provides smooth transition between the channels and their respective enlarged portions. The block is provided with recesses 26a, 26b, and 26d through 26f in the mating surface 14 at points corresponding to the corresponding post-scripted enlarged portions in the block 12. The recesses in the block 10 are substantially identical to the enlarged portions in the block 12, having ferrules 28 and terminating in a conical segment 30 substantially identical to the corresponding structure of the enlarged portions 20a, 20b and 20d through 20f so that, upon proper alignment of the mating surfaces 14 and 16, an enlarged opening, substantially cylindrical in cross-section and in communication with the corresponding channel, is formed.

A sheet of dry, heat-activated adhesive 32, configured to conform to the blocks 10 and 12 and having cutouts 34a, 34b and 34d through 34f formed therein at points corresponding to like post-scripted enlarged portions 20a, 20b and 20d through 20f in the block 12, provide the means to join the mating surfaces of the blocks 10 and 12. The cutouts are preferably shaped to taper inwardly from the periphery of the sheet 32 as shown.

A connector tube 38 and an annular, dry, heat-activated adhesive sleeve 40, formed to fit over the tube 38 and configured to fit into the enlarged portions 20a, 20b and 20d through 20f in the block 12 and the corresponding recesses in the block 10, provide means to connect an external fluid source or sink to the amplifier. The major diameter of the sleeve 40 is substantially equal to the major or root diameter of the ferrules 22 and 28 so that, upon assembly of the blocks 10 and 12, the ferrules 22 and 28 bite into the external surface of the sleeve 40 to provide positive retention thereof. The minor diameter of the sleeve 40 preferably provides a slip fit with the tube so that compression of the sleeve under the forces imposed thereon by the assembly of blocks 10 and 12 will provide engagement between the interior surface of the sleeve 40 and the external surface of the tube 38 to afford a seal between the components.

The adhesive in the sheet 32 and the sleeves 40 must be free of volatiles that can cause outgassing and subsequent flaws in the bonds effected thereby, when cured at 100° C. The adhesive furthermore must, between the non-activated and activated states, have no significant dimensional changes which could cause stresses and subsequent failures in the bond achieved thereby. Furthermore, the strength of the adhesive must be sufficient to withstand the normal pressures encountered in the specific fluid application for which the amplifier is to be used. It is furthermore desired that the adhesive should be capable of storage at room temperature for periods of weeks without refrigeration. As an example, an adhesive system that has been found to have desirable properties for the purposes of this invention is composed of the following (parts by weight):

Solid epoxy resin (WPE=200-220)	1.95
Solid epoxy resin (WPE=330-380)	12.60
2-ethyl-4-methyl imidazole	0.45
Acetone	85

The composition of epoxy adhesives and methods for their preparation are described in the Kirk-Othmer "Encyclopedia of Chemical Technology," vol. 8, page 294 et seq., Interscience Publishers, Second Edition (1965).

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In forming the adhesive sheet 32, an adhesive solution is compounded and applied to a very thin web or film carrier material. Such application may be accomplished by dripping the carrier into the solution, by brushing or spraying the solution onto the carrier, or by any other similar means. The impregnated carrier is then air dried to remove the solvent from the solution. The solids content of the solution is preferably chosen to deposit a thickness of approximately 0.0002 inch of resin on the carrier upon removal of the solvent. The dried adhesive sheet is then cut, by die-cutting or the like, to the configuration of the adhesive sheet 32 as shown in FIG. 1.

The carrier can comprise any material suitable for the purpose such, for example, as glass cloth, paper, or plastic films approximately 0.001 inch in thickness. Materials that have shown great promise for this purpose are glassine paper and polyimide film. As in the case of the adhesive, the carrier material should be selected from one which will maintain its dimensional stability during curing of the adhesive.

The adhesive sleeves 40 may be fabricated by substantially the same process as set forth above, with the exception that the carrier comprises a sleeve or tube made from paper or the like.

If the amplifier is to be exposed to elevated temperatures, carriers, such as glass or polyimide film and adhesives made from heat-resistant novolak-epoxy type resins, may be substituted for the above-described materials. If a certain degree of flexibility is required in the bond, it is contemplated that a urethane resin or a polysulfide rubber may be incorporated into the adhesives to give them a greater elastomeric property.

Referring now to FIGS. 2 and 3 of the drawing, the fluid amplifier is shown in its assembled form. The blocks 10 and 12 with the sheet 32 sandwiched therebetween and assembled tube 38 and sleeve 40 inserted in the recesses 26a, 26b and 26d through 26f or the enlarged portions 20a, 20b and 20d through 20f, are brought together with their mating surfaces 14 and 16, in an adjacent relationship, and are pressed together to compress the sheet 32 therebetween. The blocks may be formed from any suitable material. In the present illustration, the blocks are polycarbonate thermoplastic. Pressure is applied by covering the blocks with pads of silicone rubber bonded to aluminum plates to distribute the pressure during cure. Heat is supplied to activate the adhesive in the sheet 32 and in the sleeves 40 to adhere the various components to one another.

As an example, with the aforesaid adhesive composition, the assembly was heated to moderate temperatures in the range of 70-100° C. and a pressure of 70-100 p.s.i. imposed on the blocks 10 and 12 and held at temperature for approximately one hour.

In FIG. 4 another embodiment of the invention is illustrated. Components of the embodiment of this figure corresponding to those of the preceding figures are indicated by like numerals of the next higher order. In this embodiment connector tubes 138 are provided with a ring 140 of foamable epoxy adhesive therearound. The ring 140 is preferably applied by pulling the material to string it out. The strung out material is then wrapped around the tube 138 to form the ring 140. The tubes are then inserted into the enlarged portions of the block 114 prior to application of the adhesive 132. The rings 140 are preferably of such thickness that, when the block 112 is matched with the block 114, the rings are deformed to conform with the interior of the enlarged portions 120a through 120f. With the units under pressure and with the application of heat as described above in the preceding embodiments, the epoxy ring 140 expands and fills the void surrounding the tube 138 and simultaneously bonds the tubes to the blocks.

In most instances, the embodiment of FIG. 4 is preferred since, after fabrication of the blocks 112 and 114,

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the enlarged portions 120d and 126a through 120e and 126e making up the bores seldom have identical interior diameter dimensions. Because of this, the openings formed thereby are not circular and some compensation must be made in order to provide consistent seals. In addition, the expanding adhesive satisfied a requirement to fill the space between the openings formed by the bores 120 and 126 and the edge of the adhesive 132.

It should be understood that the above-described methods, while suitable for bonding simple amplifier units, are especially adapted for bonding arrays of fluid amplifiers, i.e., fluid amplifier integrated circuits and the like. In such arrays, the prior art methods utilizing wet adhesive systems are particularly unsuited because of the potential squeeze-out.

The invention provides a completely prefabricatable assembly thereby reducing the time and cost involved in fabrication by eliminating mixing time and the time and cost involved in careful application of the adhesive.

What has been set forth above is intended primarily as exemplary of the teachings in accordance with the invention to enable those skilled in the art in the practice thereof. It should therefore be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is new and therefore desired to be protected by Letters Patent of the United States is:

What is claimed is:

1. A method of fabricating a fluid handling element comprising the steps of:

fabricating a pair of mating housing blocks;

forming channels in the mating surface of at least one of the blocks extending to the periphery of the block and forming an enlarged portion in each of the blocks at the intersection of at least one of the channels with the periphery thereof to define an enlarged bore when the blocks are united;

disposing a connector tube in each of the enlarged portions of one of the blocks;

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disposing a sheet of dry, dimensionally-stable, heat-activated adhesive having cutouts at the point of coincidence with the connector tubes between the mating surfaces of the blocks; and

uniting the blocks by applying pressure and heat thereto to activate the adhesive and bond the assembly.

2. A method in accordance with claim 1 further comprising disposing a sleeve of dry, dimensionally-stable, heat activated adhesive around the connector tubes prior to bonding the assembly.

3. A method in accordance with claim 1 further comprising disposing a ring of heat-activated expandable adhesive around the connector tubes prior to bonding the assembly.

4. A method in accordance with claim 1 further comprising forming the said sheet of dry adhesive by coating a carrier sheet with a solution of liquid adhesive and air drying said coating to produce a non-tacky resinous film.

5. A method in accordance with claim 4 wherein the liquid adhesive includes a solid epoxy resin, a curing agent and a solvent.

References Cited

UNITED STATES PATENTS

2,715,598	8/1955	Rees et al.	156—309 X
2,810,674	10/1957	Madden	156—330 X
2,992,954	7/1961	Nelson et al.	156—330 X
3,038,826	6/1962	Medl	156—330 X
3,283,768	11/1966	Manion	137—81.5
3,366,143	1/1968	Bauer	137—81.5 X
3,406,053	10/1968	Jaenicke	156—330 X

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137—81.5; 156—106, 309, 313, 330