

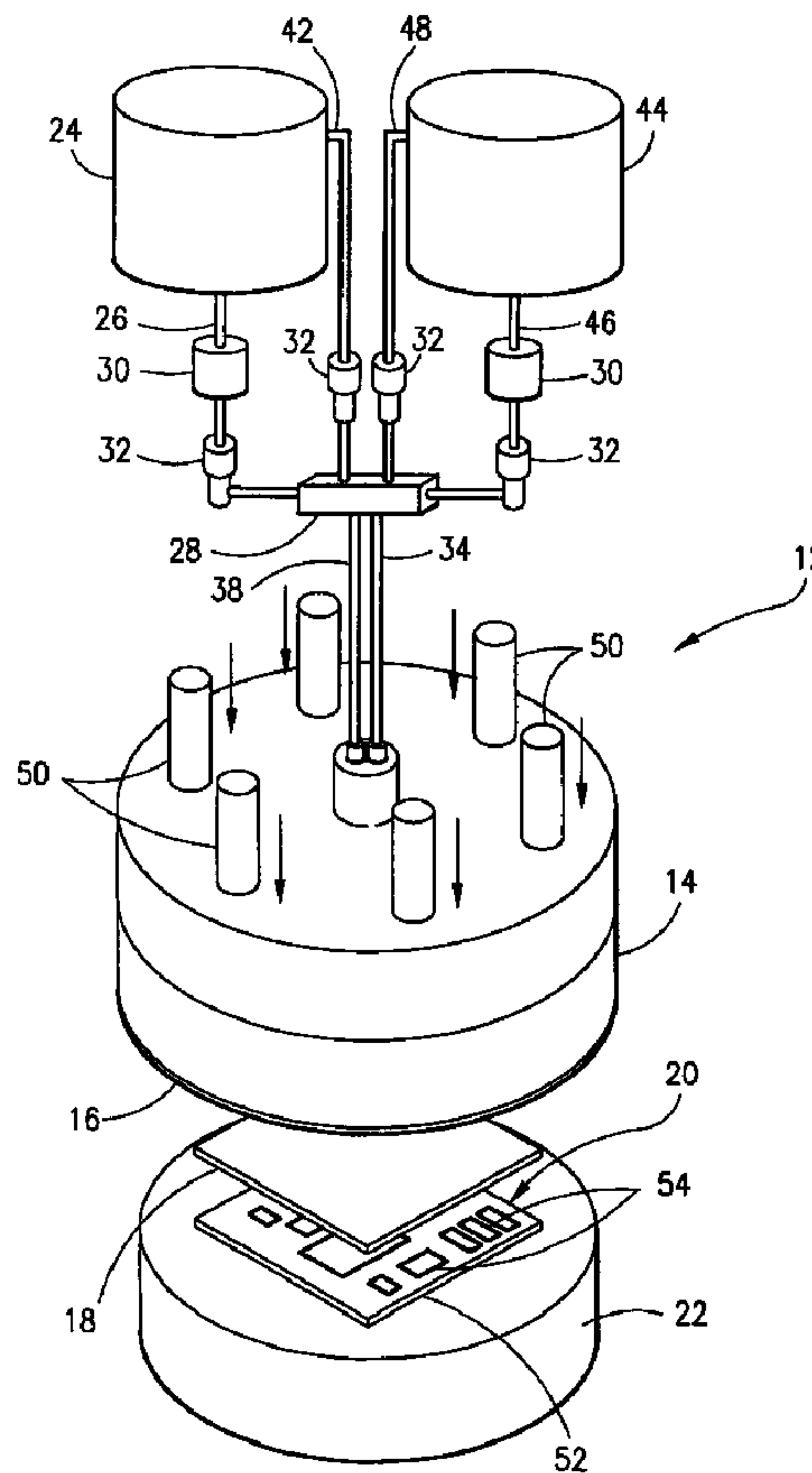


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(54) Titre : PROCÉDE ET APPAREIL PERMETTANT DE SCELLER DES CIRCUITS IMPRIMÉS SOUPLES CONCUS AU MOYEN D'UN SUBSTRAT LCP

(54) Title: METHOD AND APPARATUS FOR SEALING FLEX CIRCUITS MADE WITH AN LCP SUBSTRATE



(57) **Abrégé/Abstract:**

A method and apparatus is disclosed for affixing a cover layer formed of liquid crystal polymer to a flex circuit consisting of circuit elements mounted to a liquid crystal polymer substrate in order to encapsulate the circuit elements between the cover layer and substrate to protect them from exposure to moisture and contaminants.

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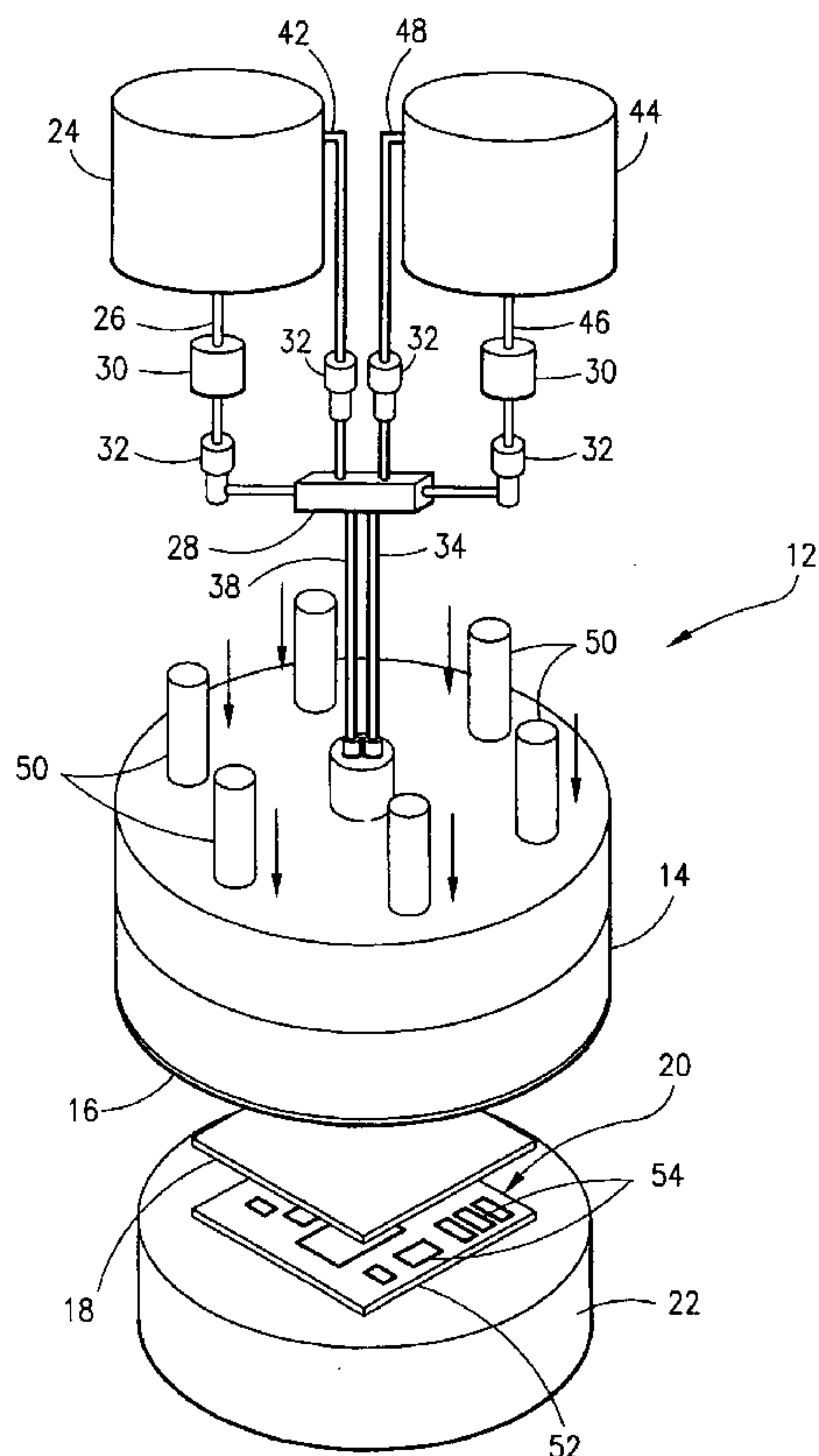
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**METHOD AND APPARATUS FOR SEALING FLEX CIRCUITS MADE WITH AN  
LCP SUBSTRATE**

BACKGROUND OF THE INVENTION

5 Flexible or "flex" circuits are used in a wide variety of applications where an electrical circuit must bend around corners or be flexed during operation. Flex circuits are thin, light weight, flexible and exhibit high routability. Traditionally, polyimide films have been used as substrates in  
10 the manufacture of flex circuits due to their good thermal stability and mechanical strength. Other properties of polyimide films, however, limit the speed or frequency at which electric components mounted thereto can operate.

Liquid crystal polymer ("LCP") has been developed in  
15 recent years as a replacement for polyimide films in flex circuits. LCP is a thermoplastic aromatic polyester which is thermally stable, with an upper use temperature in excess of 250°C and good inherent flame retardant properties. LCP films, in comparison to polyimide films, have about one-tenth  
20 of the moisture uptake and a lower coefficient of humidity expansion. Lower moisture absorption leads to higher frequency signal and data processing. Additionally, LCP films have a lower dielectric constant and a lower loss or  
25 dissipation factor over the functional frequency range of 1kHz to 45 GHz, with negligible moisture effects, compared to polyimide films.

The fabrication of flex circuits with LCP films is expected to lead to their use in more demanding environments where moisture and other contaminants are prevalent.  
30 Particularly in such types of applications, the circuit elements applied to the LCP substrate of the flex circuit must be protected from damage. Soldermask coatings, which have been employed to provide protection from moisture and contaminants in polyimide films, have been considered for use

with LCP substrates. Additionally, due to the thermoplastic nature of LCP, the application of an LCP film cover layer to an LCP substrate has been proposed as a means of effectively encapsulating circuit elements. There is a need, however, for  
5 an efficient and dependable method and apparatus to perform such an encapsulation operation.

#### SUMMARY OF THE INVENTION

This invention is directed to a method and apparatus  
10 for affixing an LCP cover layer to a flex circuit consisting of circuit elements mounted to an LCP substrate in order to protect the circuit elements from damage and/or reduced operational efficiency due to the presence of moisture and contaminants.

15 In the presently preferred embodiment, the apparatus includes an iso-static press having a hollow interior connected to a source of oil or other liquid whose temperature can be accurately controlled and maintained. The oil is heated to a temperature in the range of approximately 283°C to  
20 320°C and transferred from a tank into the interior of the press. The base of the press has a plate or membrane formed of a flexible material covered with a non-stick surface which does not adhere to LCP.

The flex circuit is placed on a support such that  
25 the circuit elements are exposed. An LCP cover layer is then placed atop the flex circuit, after which time the press is activated to move into contact with the cover layer. The flexible membrane at the base of the press is capable of substantially conforming to the shape of the circuit elements,  
30 thus urging the LCP cover layer around them to the underlying LCP substrate of the flex circuit. The temperature and pressure applied by the press is sufficient to cause the LCP cover layer and substrate to "flow" or melt to a limited extent and thus adhere together forming a secure bond so that

the circuit elements between the two are substantially encapsulated.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5           The structure, operation and advantages of the presently preferred embodiment of this invention will become further apparent upon consideration of the following description, taken in conjunction with the accompanying drawings, wherein:

10           FIG. 1 is a schematic, perspective view of the apparatus of this invention; and

            FIG. 2 is a block diagram illustrating the operation of the apparatus shown in Fig. 1.

#### 15   DETAILED DESCRIPTION OF THE INVENTION

            Referring now to the Figs., the apparatus 10 of this invention is schematically illustrated. The apparatus 10 includes an iso-static press 12 having a housing 14 formed with a hollow interior. The base of the housing 14 mounts a  
20 flexible membrane 16 having an exposed surface coated with Teflon® or other release agent which will not stick to LCP, and an inside surface coated with a hydrophobic film. Preferably, the flexible membrane 16 is formed of high density polyethylene, butyl rubber, ethylene propylene diene monomer  
25 rubber or a similar material.

            As discussed in more detail below, the press 12 is operative to apply heat and pressure against a cover layer 18 which overlies a flex circuit 20 placed upon a support 22. In the presently preferred embodiment, the press 12 is heated by  
30 the introduction into its hollow interior of heated oil or a similar fluid whose temperature can be relatively accurately controlled and maintained within the range of about 283°C to 325°C. A first reservoir 24 having heating elements (not shown) containing a valve 32, is connected by a supply line 26

to a manifold 28. A pump 30 and valve 32 are located in the supply line 26, between the first reservoir 24 and manifold 28, as shown. The manifold 28, in turn, is connected by an input line 34 to one port at the top of the press 12, and by an output line 38 to a second port. A recirculation line 42, containing a valve 32, is connected between the manifold 28 and the top of the first reservoir 24.

In view of the relatively high temperature obtained by the press 12 during operation, it is advantageous to provide a cooling capability to step the temperature down. To that end, a second reservoir 44 is provided which contains the same fluid as first reservoir 24 except at ambient temperature. The bottom of second reservoir 44 is connected by a line 46 to the manifold 28, and a recirculation line 48 connects the manifold 28 to the top of the second reservoir 44. A pump 30 and valve 32 are located in the line 46 between the second reservoir 44 and manifold 28, and a valve 32 is mounted in the recirculation line 48.

The press 12 is moved with respect to the support 22 by a number of pneumatic or hydraulic pistons 50 which are mounted at equal intervals along the top surface of the press 12. Conventionally, the pistons 50 are independently actuated by a source of air or fluid (not shown) to ensure that the press 12 applies uniform pressure to the cover layer 18 and flex circuit 20 over the entire surface area of the flexible membrane 16. The detailed construction of the press 12 forms no part of this invention, and is therefore not discussed further herein.

### 30 System Operation

As discussed above, the method and apparatus 10 of this invention are designed to provide a means for encapsulating circuit elements to protect them from moisture and contaminants. The flex circuit 20 consists of a substrate

52 formed of LCP upon which a number of circuit elements 54 are mounted. The cover layer 18 is also formed of LCP, which, because of its thermoplastic nature, will "flow" or begin to melt at a temperature of about 283°C. By placing the cover  
5 layer 18 over the flex circuit 20 and applying heat and pressure, the cover layer 18 and substrate 52 adhere to one another with a secure bond and entirely enclose the circuit elements 54 between them.

The apparatus 10 is operated by a commercially  
10 available controller 56 as schematically depicted in the flow diagram of Fig. 2. Initially, oil or other fluid within the first reservoir 24 is brought up to a temperature in the range of 283°C to 325°C by activating heating elements (not shown) therein. The controller 56 is operative to activate the  
15 heating elements via a signal input through lead 58, or they may be independently activated by a switch (not shown) located at the first reservoir 24. The controller 56 then inputs signals through leads 60 and 62 to start the pump 30 and open valve 32, respectively, thus initiating the flow of heated oil  
20 out of the first reservoir 24. When it is desired to heat the press 12 in preparation for circuit encapsulation, the controller 56 deactivates the pump 30 and valve 32 in line 46 from second reservoir 44 by signals input through leads 64 and 66, respectively. The heated oil flows into the press 12  
25 through the manifold 28 and into the input line 34 leading into the interior of the press 12. Preferably, the temperature of the heated oil within the press 12 is controlled and maintained by continuously recirculating it from the first reservoir 24 through the manifold 28 and input  
30 line 34 into the press 12, and then out of the press 12 through the output line 38 and manifold 28 to the recirculation line 42 connecting the manifold 28 to the first reservoir 24. The controller 56 opens the valve 32 within recirculation line 42 via a signal input through line 68 to

allow the heated oil to pass from the manifold 28 into the first reservoir 24.

With the press 12 at the appropriate temperature, the encapsulation process can proceed. The flex circuit 16 is positioned on the support 22 so that the circuit elements 54 on the LCP substrate 52 are exposed. The LCP cover layer 18 is then placed atop the substrate 52 and circuit elements 54. The controller 56 operates the pistons 50 causing the press 12 to move toward the support 22. Upon engagement of the flexible membrane 16 at the bottom of the press 12 with the cover layer 18, at a uniform pressure on the order of 200 psi, the flexible plate 16 substantially conforms to the shape of the circuit elements 54 beneath. In turn, the cover layer 18 is forced around the circuit elements 54 into contact with substrate 52. The press 12 is maintained in this position for a period of time sufficient to heat both the LCP cover layer 18 and LCP substrate 52 to a melt temperature of at least 283°C, but not more than about 320°C, causing them to bond to one another and thus encapsulate the circuit elements 54 between the two.

After completing one or more encapsulation procedures, the temperature of the press 12 may be stepped down by circulating comparatively cool, ambient temperature oil into the press 12 from the second reservoir 44. The controller 56 is operative to deactivate the pump 30 and close valve 32 within line 26 connected to the first reservoir 24, while activating pump 30 and opening valve 32 within the line 46 connected to the second reservoir 44. The controller 56 closes the valve 32 within the recirculation line 42, and then opens the valve 32 within the recirculation line 48 extending from the manifold 28 to the second reservoir 44 by inputting a signal to such valve 32 through a line 70. As a result, ambient temperature oil is recirculated within the press 12 to reduce its temperature.

**CLAIMS**

1. Apparatus for sealing circuit elements of an electrical circuit between a substrate upon which the circuit elements are mounted and a cover sheet overlying the substrate and circuit elements, each of the substrate and cover sheet being formed of liquid crystal polymer, said apparatus comprising:

an iso-static press having a hollow interior, said hollow interior being connected to a first source of heated fluid and a second source of cooling fluid;

a flexible membrane mounted to said iso-static press in position to contact the cover sheet;

a support for carrying the substrate and cover sheet;

whereby said iso-static press when at least partially filled with heating fluid is directed toward said support so that said flexible membrane contacts said cover sheet and substantially conforms to the shape of the circuit elements on the substrate, said iso-static press and flexible membrane exerting sufficient force and heat to cause the liquid crystal polymer forming both the cover sheet and the substrate to adhere together thus sealing the circuit elements between the two.

2. The apparatus of claim 1 in which said flexible membrane is formed of a material chosen from the group consisting of high density polyethylene, butyl rubber and ethylene propylene diene monomer rubber.

3. The apparatus of claim 1 in which said flexible membrane is formed with a non-stick surface for contact with the cover sheet.

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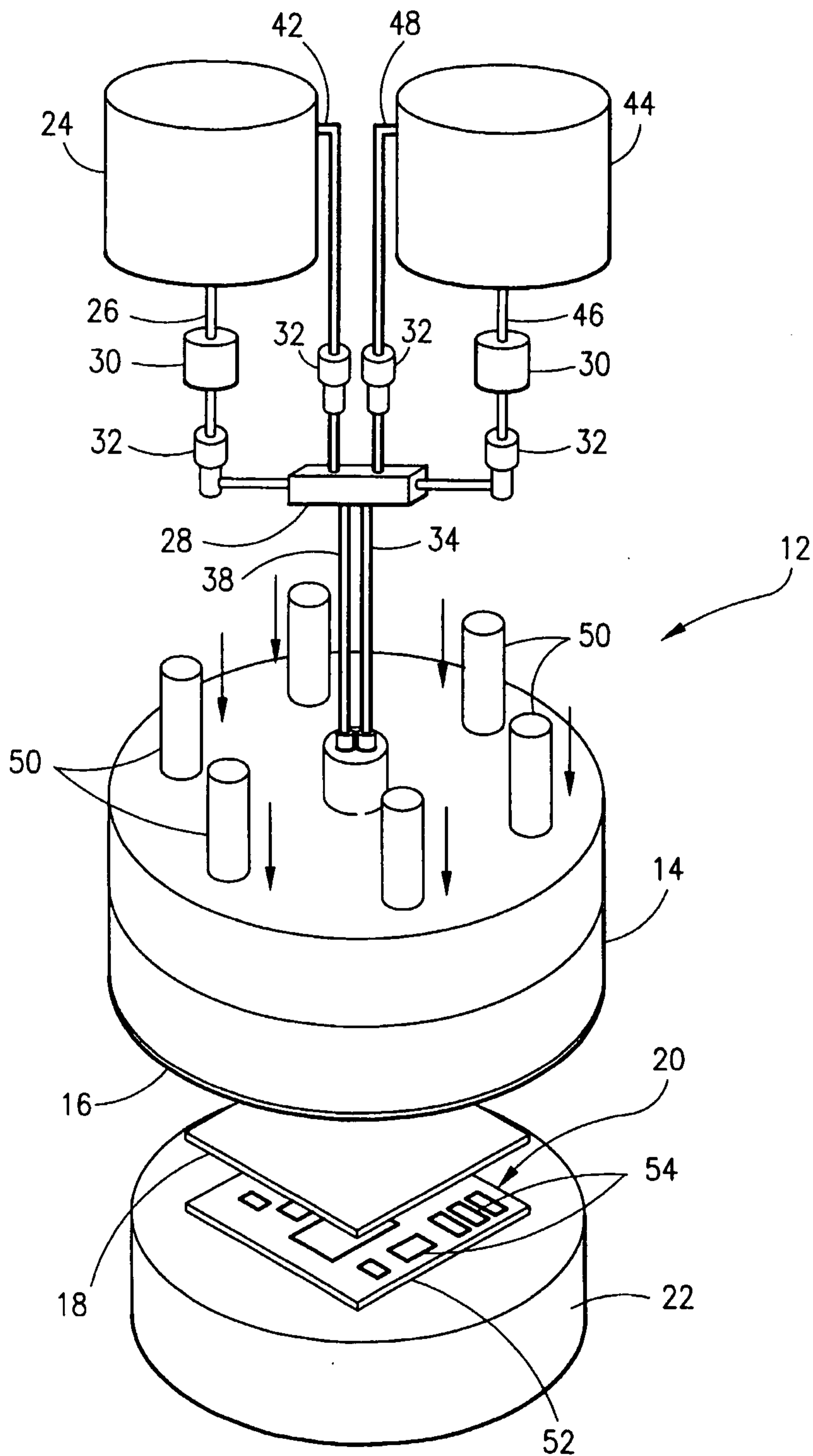


FIG. 1

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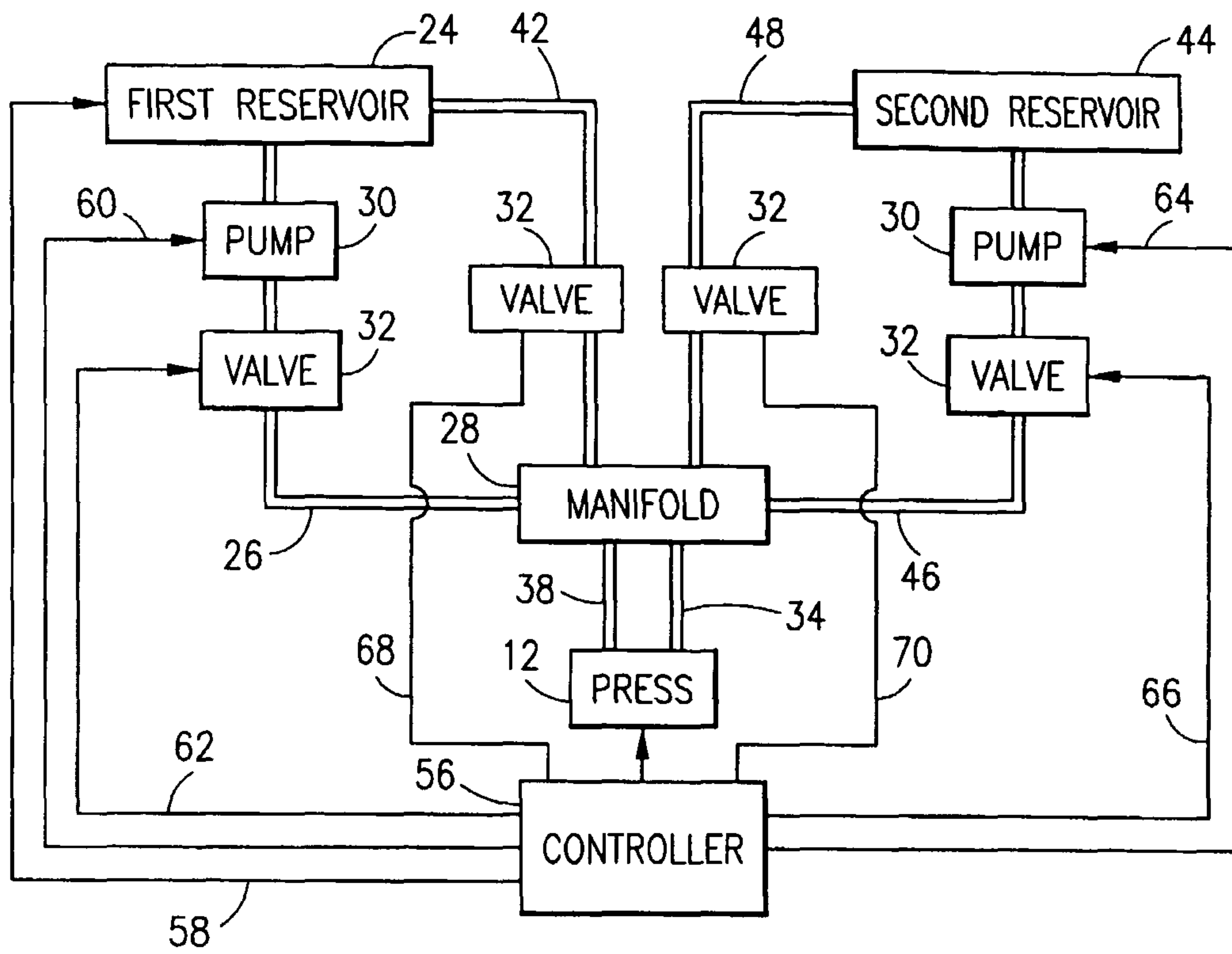


FIG. 2

