Nov. 3, 1959

N. B. WALES, JR

2,911,605

PRINTED CIRCUITRY

Filed Oct. 2, 1956

2 Sheets-Sheet 1

Fig. 1.

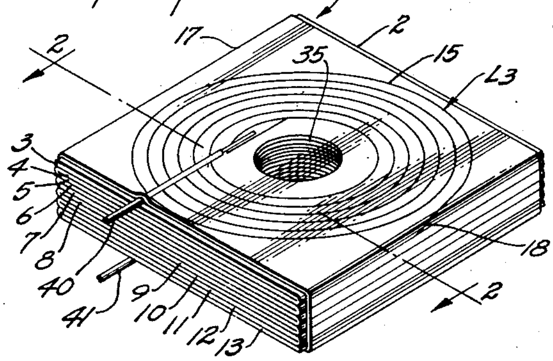


Fig. 2.

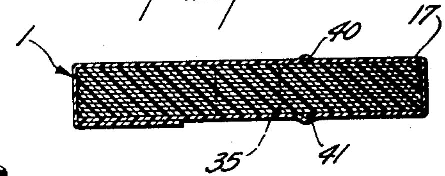


Fig. 3.

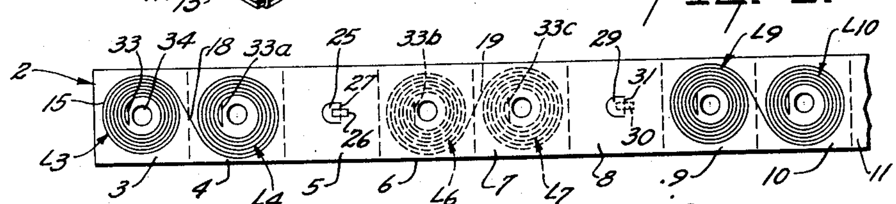
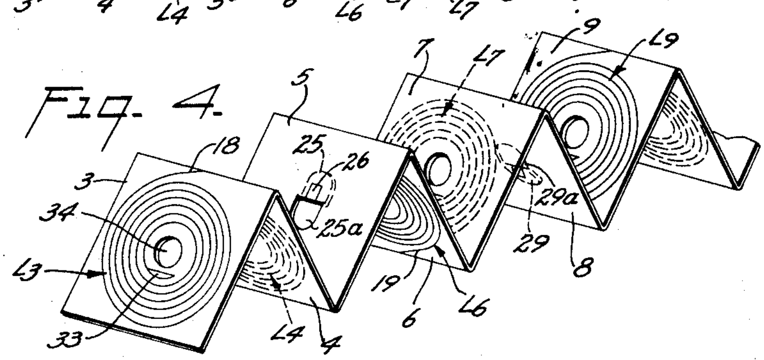


Fig. 4.



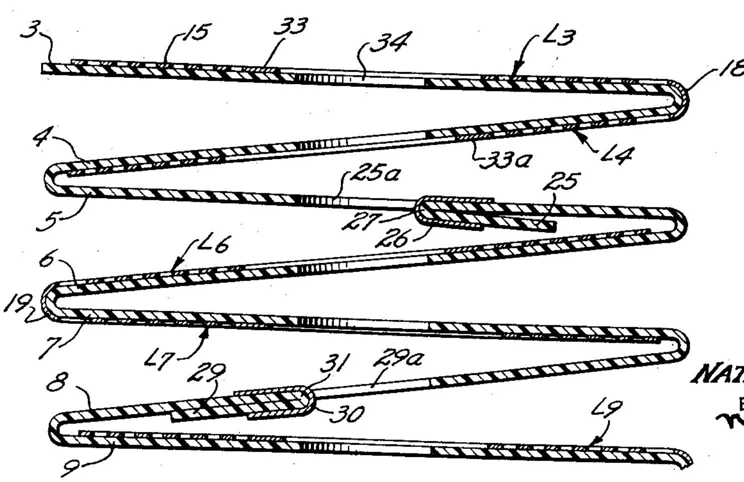


Fig. 5.

INVENTOR
NATHANIEL B. WALES, JR.
BY
Norman Friedman
ATTORNEY

Nov. 3, 1959 N. B. WALES, JR 2,911,605

PRINTED CIRCUITRY

Filed Oct. 2, 1956 2 Sheets-Sheet 2

Fig. 6.

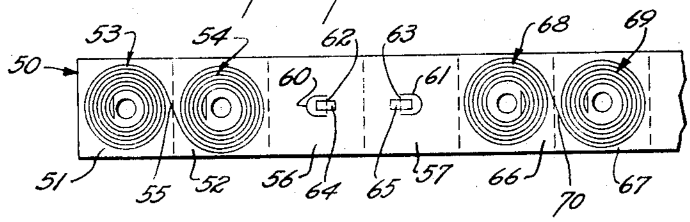
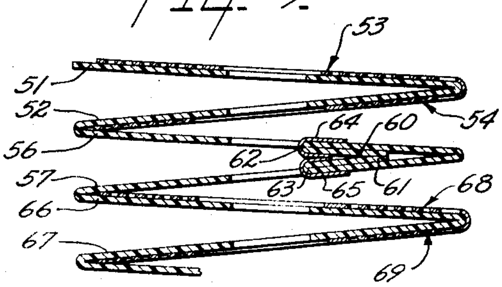


Fig. 7



INVENTOR
NATHANIEL B. WALES, JR.
BY Norman Friedman
ATTORNEY

United States Patent Office

2,911,605

Patented Nov. 3, 1959

1

2,911,605

PRINTED CIRCUITRY

Nathaniel B. Wales, Jr., New York, N.Y., assignor to Monroe Calculating Machine Company, Orange, N.J., a corporation of Delaware

Application October 2, 1956, Serial No. 613,582

14 Claims. (Cl. 336—200)

This invention pertains to printed circuit structures and deals with a novel concept in printed circuit structures which permits a substantial reduction in their size.

Electrical impedances, e.g. coils, have generally been of such a nature as to be relatively bulky. With the ever increasing trend towards miniaturization of electrical systems, there exists a corollary need for minimizing the volume of component impedances. It will be recognized, however, that the volume of the impedance must be reduced while maintaining as high as possible its desired electrical impedance value.

It is an object of the present invention to provide an impedance which is of greatly reduced volume as compared with prior art devices.

It is a further object of the invention to achieve such a reduction in volume in such a manner as to make the most efficient usage of the impedance volume in contributing to the impedance effect of the device.

It is a further object of the invention to provide such a device which fulfills the above stated objects and which readily lends itself to mass production manufacturing techniques employing automatic machinery.

As set forth in detail subsequently, the above objects are attained by providing a structure in the form of a plicated or fan-folded strip of electrically insulating sheet material on which is provided a printed circuit pattern defining a desired electric circuit arrangement in laminar or stacked form.

A feature of the invention resides in novel printed circuit arrangements for establishing localized electrical connection between two circuit portions separated by interposed insulating means.

This invention represents an improvement over devices of the nature of those disclosed in United States Patent 1,647,474 granted November 1, 1927 to F. W. Seymour.

For the purposes of the present disclosure, the invention is shown and described as embodied in an inductance. It will be understood, however, that the broader aspects of the invention and certain of its features can readily be applied to other circuit arrangements.

In the drawings:

Fig. 1 is a perspective view of a plicated printed circuit coil arrangement in accordance with the invention.

Fig. 2 is a sectional view taken on line 2—2 of Fig. 1.

Fig. 3 is a top plan view of a blank employed to make the article of Figs. 1 and 2.

Fig. 4 is a perspective view showing the manner in which the blank of Fig. 3 is fan-folded.

Fig. 5 is an enlarged elevational view in section showing the fan-folded blank just prior to bringing the various plications into their final intimate relation of Figs. 1 and 2.

Fig. 6 is a top plan view of a modified blank arrangement.

Fig. 7 is a view similar to Fig. 5 showing the manner of fan-folding the blank of Fig. 6.

Referring now to the drawings, there is shown in Figs. 1 and 2 a compact impedance 1 comprising a continuous sheet strip 2 of thin, pliable, electrically insulating backing material arranged in plicated (fan-folded) manner so as to provide a plurality of separate overlying layers numbered 3–13 inclusive. "Mylar" (polymeric ethylene terephthalate) has been found to be eminently well-suited as the material of which strip 2 is made.

2

Provided on and bonded to some of the layers is a thin coating of electrically conductive material 15, for example silver or aluminum, arranged in such a pattern as to form a coil. One of these coils L3 is shown in Fig. 1 provided on the outer surface of layer 3, and immediately underlying a transparent gummed tape member 17 which is wrapped around fan-folded strip 2 to maintain said strip in folded disposition.

As will be described subsequently in greater detail, certain spaced pairs of layers are each provided with serially connected coils, while the layer intermediate said pairs of layers is employed to establish electrical connection between the two coils lying on each side of said intermediate layer.

Referring to Fig. 5, the under face of layer 4 is provided with such a coil L4 serially connected to coil L3 of layer 3 by a line 18 of said electrically conductive material 15. Line 18 runs continuously at one end from the outermost turn of coil L3, over the common fold line at which layers 3 and 4 are interconnected, and to the outermost turn of coil L4.

Adjacent layers 6 and 7 are likewise provided with coils L6 and L7 on their upper and lower surfaces respectively. Coils L6 and L7 are serially connected electrically by a line 19 of said conductive material 15 extending between said coils and over the common fold line between layers 6 and 7.

Layer 5 intermediate layers 4 and 6 is not provided with a coil but is rather employed to establish electrical connection between coils L4 and L6 disposed on either side thereof as follows. As shown in Fig. 5, a tab 25 integral with layer 5 is folded back on the under surface of said layer. Tab 25 is provided with an electrically conductive coating 26 which extends continuously from the tab proper over the hinge line 27 of the tab and back along the upper surface of layer 5 so as to underlie the innermost turn of coil L4. It will be noted that the tab portion of coating 26 is of sufficient extent to overlie the innermost turn of coil L6. Accordingly, when the various layers 3, 4, 5, etc., are brought into intimate relationship as in Figs. 1 and 2, the coating 26 will contact the innermost portions of coils L4 and L6 and thereby serve to establish a serial electric connection between said coils, which are otherwise insulated from each other by layer 5.

A similar tab 29, integral with layer 8 and having an electrically conductive coating 30, establishes serial electrical connection between coils L7 of layer 7 and L9 of layer 9 in like fashion.

Fig. 3 illustrates a blank from which the afore-described impedance can economically be made. Said blank comprises an elongated strip 2 of the previously mentioned sheet material such as "Mylar" of one or one-half mil thickness.

Strip 2 may be considered as being subdivided along its length into a plurality of zones or portions 3, 4, 5, etc., corresponding to the previously described layers. Strip 2 is adapted to be fan-folded as in Fig. 4 along the transverse fold lines shown in broken lines in Fig. 3 to bring the various zones into consecutive stacked or laminar contacting relationship.

Applied and bonded to the various zones in the sequence set forth below is an arrangement of the electrically conductive material 15 forming the various coils and connector elements described previously.

Thus, zones **3** and **4** (Fig. 3) are each provided on their front faces with a coating of the electrically conductive material **15** defining respective clockwise spiral coils L3, L4 and their connecting lead **18**. Zones **6** and **7** are provided on their reverse faces with an electrically conductive coating defining coils L6, L7 and their connecting lead **19**. As viewed in Fig. 3, coils L6 and L7 are counterclockwise spiral configuration, and are shown in broken lines since they are disposed on the rear faces of their respective zones **6** and **7**.

The central portion of zone **5** is slit to form tab **25** adapted to be folded back along hinge line **27**. Applied to zone **5** is conductive coating **26** applied to the forward face of tab **25** and extending over hinge line **27** to the portion of zone **5** outside tab **25**.

Zones **9** and **10** are provided with a coating of electrically conductive material arranged in a pattern which is substantially identical with that applied to zones **3** and **4**.

Zone **8** is centrally slit in the manner of zone **5** to form tab **29** adapted to be folded upwardly along hinge line **31**. Conductive coating **30** applied to the rear face of zone **5** extends across said hinge line **31**.

The above-described pattern sequence as applied to the six zones numbered **3** through **8** inclusive, constitutes the basic repeating sequence applied to strip **2**. This basic repeating sequence consists of: two serially connected clockwise spiral coils L3 and L4 provided on one surface of the strip; tab **25** and its associated conductive coating **26** applied to the same side as said coils; two serially connected counterclockwise spiral coils L6 and L7 on the obverse face of the strip; and tab **29** and its associated conductive coating **30** also on the reverse strip face.

The above-described coil and connector six-zone sequence is repeated beginning with zones **9** and **10**. Coils L9 and L10 thus represent the first two elements of the repeated sequence. Zone **11**, a portion of which is shown in Fig. 3, will therefore be a duplicate of zone **5**. Similarly, the next three consecutive zones (not shown) will respectively be duplicates of zones **6–8** inclusive. In such fashion, the basic arrangement of the first six zones (**3–8**) will be repeatedly carried out along strip **2** for as great a length as desired.

The electrically conductive material **15** can be applied to backing strip **2** by any of the well-known printed circuit manufacturing techniques, as, for example, galvanic disposition, printing, stencilling, etching, fashioning metal foil to the appropriate shape and securing it to the nonconducting backing strip, etc.

The inner end of each of the various coils is somewhat widened as shown at **33** and **33***a* in Fig. 3 to provide an augmented contact area for establishing electrical connection to and from the coils.

Further, each of the coil zones, **3**, **4**, **6**, **7**, **9**, **10** etc. is provided with a central hole **34**, while the zones **5**, **8** will of course contain central apertures **25***a*, **29***a* after respective tabs **25** and **29** are folded back. When strip **2** is folded to bring the various zones into layered or laminar disposition as in Figs. 1, 2, and 5, the various holes and apertures will be substantially axially aligned to form a single central tubular bore **35** (Figs. 1, 2). This central bore **35** is adapted to receive a ferromagnetic core for use, if desired, in conjunction with the fan-folded coil structure. While holes **34**, **25***a*, and **29***a* have been shown as arcuate in the drawing, they may be square if desired.

The above-described blank of Fig. 3 is adapted to be cut transversely at any selected point to provide a desired impedance value. After having been so cut, and the connector tabs (e.g., **25**, **29**) folded back along a face of their appropriate zones, the strip **2** is folded in simple fan-fold or plicated manner as shown in Fig. 4. This last-mentioned step can readily be carried out by well-known automatic folding machinery.

Thereupon, the various folds or layers are brought into closely adjacent, intimate relationship (as in Fig. 2), and appropriate insulated lead-in wires **40** and **41** are respectively connected to the outermost coil at each end of the laminar stack as by soldering.

It will readily be seen that when the blank of Fig. 3 is fan-folded in the manner of Figs. 4 and 5 and the various plications brought to contacting relation as shown in Figs. 1 and 2, there is produced a highly compact article in which the various coils are serially connected and are so disposed that their respective flux fields are additive with regard to one another. It should be noted that "Mylar" strip **2** is magnetically permeable and will therefore not inhibit the formation of the flux field.

Thus, coils L3 and L4 are disposed on the remote outer faces of the adjoining pair of layers **3** and **4**, the coils thereby being insulated from one another by the insulating material of strip **2**. Lead **18**, extending over the common fold line between layers or plications **3**, **4**, serially interconnects the outer turns of coils L3 and L4.

In like fashion, coils L6 and L7 are provided on the remote outer faces of adjoining layers **6** and **7** and are serially connected by lead **19**.

The intermediate plicated portion or layer **5** serves to separate layer **4** from layer **6**, thereby providing insulating means between coils L4 and L6. The desired localized serial connection between said coils L4 and L6 is achieved by conductive coating **26** carried in part by tab **25** and extending through aperture **25***a* over the edge of said aperture.

Layer **8** similarly functions as a separating insulating means between layers **7** and **9**, serial connection being established between coils L7 and L9 by conductive coating **30** carried partly by tab **29** and extending through aperture **29***a* over the edge of said aperture.

To maintain the layers of the plicated article so formed in the intimate compressed relationship of Fig. 2, strip **17** of adhesive-coated insulating tape is wrapped around the fan-folded strip, adhesive side in, with the ends of said tape overlapped as shown in Fig. 2. The tape **17**, in addition to maintaining the fan-folded strip **2** in compressed condition also serves to insulate any exposed conductive portions of the stack from undesired contact with any electrical conductor which may be adjacent thereto in the environment in which the article of the invention is to be used. Tape **17**, which may be of the same "Mylar" material as strip **2**, further functions to hold lead-in wires **40** and **41** securely in place.

While tape **17** has been shown in Fig. 1 of the drawing as transparent for clarity of disclosure, it will be recognized that said tape may be made opaque or translucent, if desired.

Figs. 6 and 7 illustrate a modification of the invention in which the electrically conductive material **15** providing the electric circuitry of the device need be applied to only one side of a blank strip.

Referring to Fig. 6, strip **50**—which is of the same "Mylar" material as strip **2**—is provided on its first two zones **51**, **52** with substantially identical clockwise spiral printed circuit coils **53**, **54** connected by conductive lead **55**. Zones **56** and **57** are each centrally slit to provide respective tab members **60** and **61**, adapted to be folded under along the respective hinge lines **62**, **63**. Electrically conductive coatings **64**, **65** extend from each tab over the respective hinge lines **62**, **63** to the portions of said zones **56**, **57** on the opposite sides of said hinge lines. Zones **66** and **67** are provided with clockwise spiral coils **68**, **69** connected by lead **70**.

Fig. 7 illustrates the manner in which the blank of Fig. 6 is fan-folded after tabs **60** and **61** have been folded rearwardly along their respective hinge lines **62**, **63**. It will be seen that conductive coating **64** establishes electrical connection between coil **54** and coating **65**, while coating **65** establishes connection between coating **64** and coil **68**.

The modified form shown in Figs. 6 and 7 will thereafter be provided with lead-in wires and an exterior binding tape wrapping, corresponding respectively to elements **40**, **41** and **17** of the species of Figs. 1–5.

As stated previously, the device of Figs. 6 and 7 presents the advantage of providing all the necessary printed circuitry on only one side of the "Mylar" backing strip.

However, the Figs. 6 and 7 modification does not make as efficient use of the strip, since each alternate pair of adjacent zones is employed as a linking means for establishing electrical connection between coils. Thus, only 50% of the strip length comprises coil zones.

This is in contradistinction to the more efficient arrangement of Figs. 1–5, wherein only each third zone is used as a connector means between coils lying on each side of that zone. In the form of Figs. 1–5, therefore, 66⅔% of the strip length comprises coil zones contributing to the overall magnetic field produced.

I claim:

1. An electric circuit structure comprising a plicated strip of thin, flexible, sheet-like electrically insulating material, individual printed circuit coil means provided only on each plication of separated pairs of adjoining plications, said pairs being separated by an intervening plicated portion of said strip, the two coil means of each of said pairs being disposed on the respective remote outer faces of said adjoining plications, the adjacent confronting inner faces of said adjoining plications presenting only the insulating material of said strip to each other.

2. The invention set forth in claim 1, and further comprising means serially electrically connecting all said coil means.

3. The invention set forth in claim 2, said last named means including a printed circuit portion on said remote outer faces and extending over the common fold portion between said adjoining plications, said printed circuit portion serially connecting said two coil means at their outer portions.

4. Thte invention set forth in claim 2, said connecting means including conductive means provided on said intervening plicated portion of said strip, said conductive means serially connecting the coil means lying on opposite sides of said intervening plicated portion of said strip.

5. The invention set forth in claim 2, said intervening plicated portion being provided with an aperture and a folded-back tab adjacent thereto, said connecting means including a thin layer of conductive material on said intervening plicated portion, said conductive material extending through said aperture and being carried in part by said tab, said conductive material contacting the coil means lying on opposite sides of said intervening plicated portion.

6. In an electric circuit structure, a thin flexible sheet of electrically insulating material, a tab struck from said sheet and folded out of the plane of said sheet to one side thereof, thereby providing an aperture in said sheet, a thin layer of conductive material provided on the opposite side of said sheet and extending through said aperture over the fold line of said tab onto the outer face of said tab.

7. An electric circuit structure comprising a plicated strip of thin, flexible, sheet-like electrically insulating material, printed circuit impedance means provided only on each plication of separated pairs of adjoining plications, said pairs being separated by an intervening plicated portion of said strip, the impedance means of each of said pairs being disposed only on the respective remote outer faces of said adjoining plications, the adjacent confronting inner faces of said adjoining plications presenting only the insulating material of said strip to each other.

8. An electric circuit structure comprising a plicated strip of thin, flexible, sheet-like electrically insulating material, individual printed circuit coils provided on each plication of separated pairs of adjoining plications, said pairs being separated by an intervening plicated portion of said strip, the two coils of each of said pairs being disposed on the remote outer faces of said adjoining plications, a printed circuit lead provided on said remote faces and extending over the common fold portion between said adjoining plications, said lead serially connecting said two coils at their outer portions, and means for establishing serial electrical connection between coils disposed on opposite sides of said intervening plicated portion of said strip, said last named means comprising a thin layer of conductive material provided on both sides of said intervening portion, said intervening portion including a folded-back tab carrying a portion of said conductive material on one side of said intervening portion and further including an aperture through which said conductive material passes extends to the other side of said intervening portion.

9. An electric circuit structure comprising first electrical conductor means, second electrical conductor means, means interposed between and insulating said first and second conductor means from each other, said interposed insulating means being provided with an aperture and folded-back tab means, means for establishing localized electrical connection between said first and second conductor means, said connection means comprising a thin layer of conductive material provided on said interposed insulating means, said conductive material extending through said aperture and being carried at least in part by said tab means, said conductive material contacting a portion of said first and second conductor means.

10. The invention set forth in claim 9, said interposed insulating means comprising a thin pliable sheet, said tab means being integral with said sheet.

11. An electric circuit structure comprising first electrical conductor means, second electrical conductor means, means interposed between and insulating said first and second conductor means from each other, said interposed insulating means including an aperture and a tab adjacent to said aperture, said tab being folded back along a face of said insulating means, means for establishing localized electrical connection between said first and second conductor means, said last connection comprising a thin continuous layer of conductive material provided on the opposite face of said insulating means and the outer face of said tab and extending through said aperture over an edge thereof, said layer of conductive material contacting a portion of said respective first and second electrical conductor means.

12. An electric circuit structure comprising first electrical conductor means, second electrical conductor means, a thin pliable sheet-like member interposed between and electrically insulating said first and second conductor means from each other, a tab struck from and folded back along a face of said insulating member, thereby providing an aperture in said insulating member adjacent said tab, a layer of electrically conductive material provided on the opposite face of said member and extending over an edge portion of said aperture onto the outer face of said tab, the portion of said coating on said opposite face contacting one of said conductor means, and the portion of the coating on the outer face of said tab contacting the other conductor means, whereby electrical connection is established between said first and second conductor means.

13. In an electric circuit structure, a thin flexible sheet of electrically insulating material, a tab secured to said sheet and folded out of the plane thereof, a thin layer of conductive material provided on said sheet adjacent said tab and extending onto a face of said tab, an electrical conductor means lying out of the plane of the sheet, said folded tab contacting said conductor means, the conductive material provided on the tab engaging said conductor means and thereby establishing electrical com-

munication between the conductive material carried by the sheet and the conductor means.

14. The invention according to claim 13, said tab being substantially narrower than said sheet.

References Cited in the file of this patent

UNITED STATES PATENTS

1,647,474	Seymour	Nov. 1, 1927
2,014,524	Franz	Sept. 17, 1935

FOREIGN PATENTS

164,435	Australia	Aug. 3, 1955

OTHER REFERENCES

"Foldable Printed Circuits," Electronic Equipment, pages 15–17, August 1955.

"Etched Circuits," Wireless World, page 488, December 1952.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,911,605 November 3, 1959

Nathaniel B. Wales, Jr.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 24, after "line" for the indistinct numeral read -- 18 --; column 3, line 55, after "zones" strike out the comma; column 4, line 42, after "condition" insert a comma; column 5, line 40, for "Thte" read -- The --; column 6, line 17, after "material" strike out "passes"; column 6, line 43, for "said last connection" read -- said connection means --.

Signed and sealed this 10th day of May 1960.

(SEAL)
Attest:
KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,911,605 November 3, 1959

Nathaniel B. Wales, Jr.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 24, after "line" for the indistinct numeral read -- 18 --; column 3, line 55, after "zones" strike out the comma; column 4, line 42, after "condition" insert a comma; column 5, line 40, for "Thte" read -- The --; column 6, line 17, after "material" strike out "passes"; column 6, line 43, for "said last connection" read -- said connection means --.

Signed and sealed this 10th day of May 1960.

(SEAL)
Attest:
KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents