

Feb. 4, 1947.

A. A. BURR

2,415,082

FINE WIRE STRAIN GAUGE

Filed June 30, 1944

2 Sheets-Sheet 1

FIG. 1

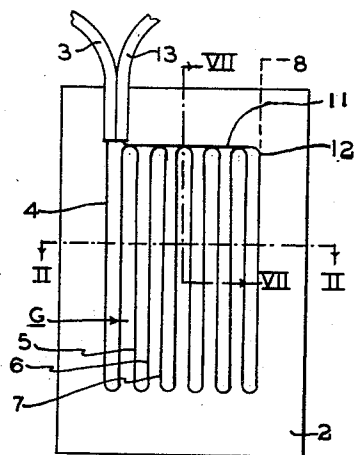


FIG. 2

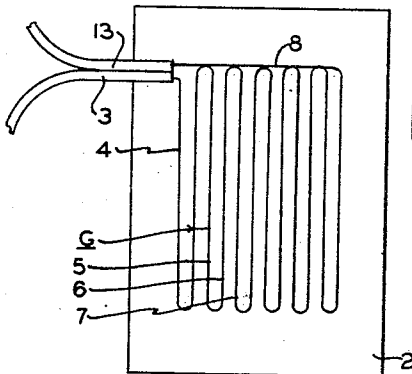
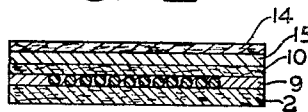


FIG. 3

FIG. 4

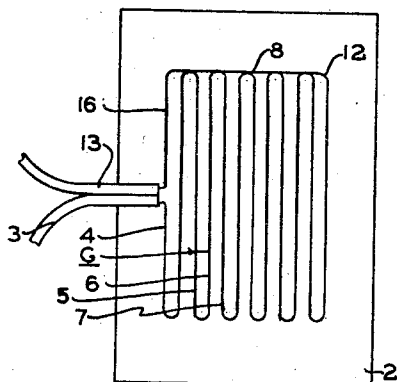


FIG. 5

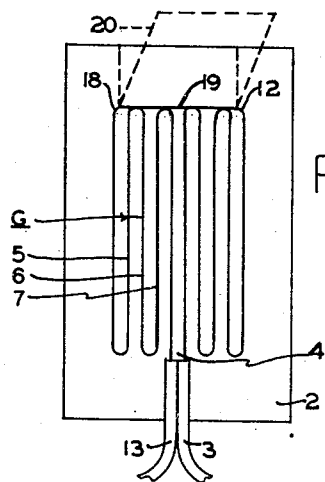
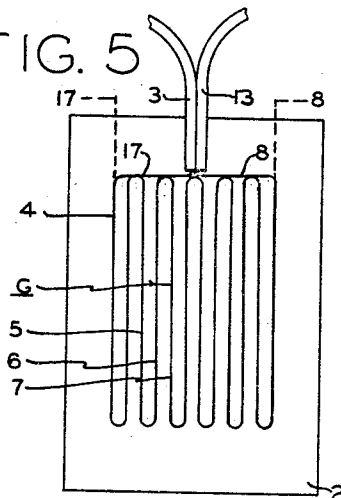


FIG. 6

Inventor  
Arthur Albert Burr  
by  
Walter F. Kaufman  
Attorney

**Feb. 4, 1947.**

A. A. BURR

**2,415,082**

FINE WIRE STRAIN GAUGE

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2 Sheets-Sheet 2

FIG. 7

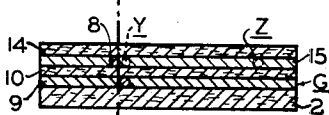


FIG. 8

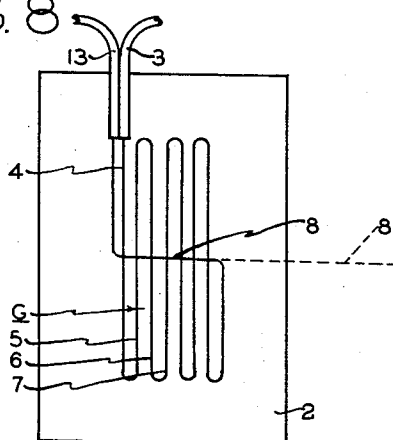


FIG. 9

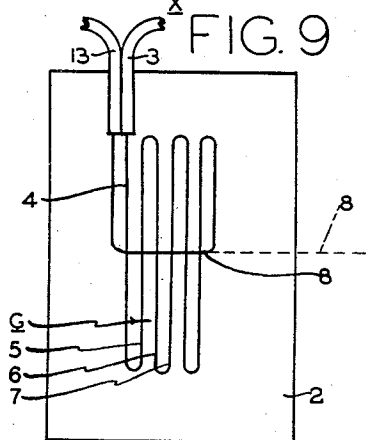


FIG. 10

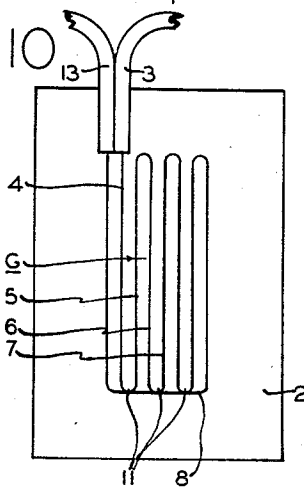


FIG. 11

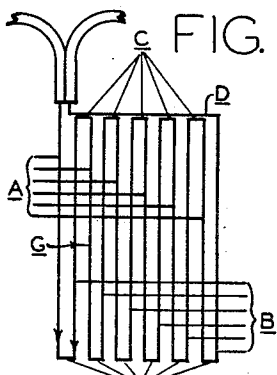


FIG. 12

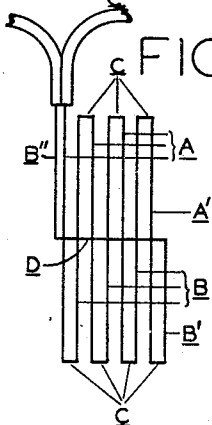
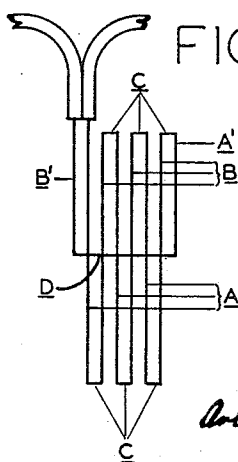


FIG. 13



Inventor  
Arthur Albert Burr  
by  
Walter F. Kaufman  
Attorney

## UNITED STATES PATENT OFFICE

2,415,082

## FINE WIRE STRAIN GAUGE

Arthur Albert Burr, Lancaster, Pa., assignor to  
Armstrong Cork Company, Lancaster, Pa., a  
corporation of Pennsylvania

Application June 30, 1944, Serial No. 542,847

7 Claims. (Cl. 201—63)

1

This invention relates to fine wire strain gauges of the general type disclosed in Simmons, Jr. Patent 2,292,549 of August 11, 1942.

My invention finds particular usefulness in installations where stray magnetic or high frequency fields are present which might induce a voltage in the strain gauge and result in false readings.

As an example, in equipment for the manufacture of plywood by dielectric heating to activate the adhesive which bonds the layers together, the press is provided with a pair of parallel, highly conductive plates of copper which are positioned on each side of the stack of layers to be bonded. These plates are connected to a source of high frequency current and the plies of wood and adhesive are heated dielectrically. Pressure is applied during heating to effect a firm bond and create a final product having the desired density.

The high frequency voltage which exists across the copper condenser plates causes high frequency electromagnetic radiation into the neighboring space and, to limit such radiation, common practice is to surround the consolidating press in the zone of the condenser plates with a grounded copper network effective to limit the extent of such radiation.

It is often desirable, for reasons of extreme sensitivity, to use a fine wire strain gauge to electrically record variations in total force exerted by the grounded press platen. This necessitates positioning of the gauge within the high frequency confining network. Any electrical apparatus which is subject to inductive pickup cannot be used in such area because of the false readings which would inevitably result from the inductive pickup. Thus, a non-inductive strain gauge must be used in such instances if accurate readings are to be obtained.

In electric spot welding equipment, it is desirable to determine the force exerted by the electrodes at various intervals during the course of the welding cycle and since relatively large currents are utilized and concomitantly large magnetic fields are present in such work, non-inductive gauges must be provided for best results.

The strain gauges now available are generally not of the non-inductive type and those which are intended to be substantially non-inductive will nevertheless be responsive to magnetic or high frequency fields to such extent that their use in connection with electrical equipment where such fields are encountered is impracticable. A real demand has existed for a non-inductive fine

2

wire strain gauge for such uses but all prior attempts to fabricate a commercially acceptable gauge have failed, primarily because of two factors. First, the non-inductive gauges heretofore proposed have required complicated windings and this is difficult to accomplish by hand and is practically impossible on automatic winding equipment. Second, with such gauges, great difficulty has been encountered in avoiding short circuiting, particularly under conditions of use. Actual practice with such gauges has resulted in repeated failure. The Simmons, Jr. patent suggests that a non-inductive gauge be formed of a doubled strand of wire, but this is difficult to fabricate and also likely to short circuit in use.

It is an object of my invention to provide a strain gauge which is substantially non-inductive and which is in the form of a simple winding which may be made without difficulty.

Another object of my invention is to provide a fine wire strain gauge which is non-inductive and which is not likely to short circuit under conditions of use, either in tension or under compression.

I have accomplished the foregoing objects by creating a fine wire strain gauge in which there is but a single multiple turn grid formed from a single unlooped strand of wire, with the various turns constituting the grid lying in a single plane and substantially parallel to each other, with the turns being in spaced pairs of equal length, and with a portion of the wire lying substantially at right angles to the parallel turns and contiguous thereto so as to eliminate all loops which are not balanced out. The strain gauge of my invention is therefore non-inductive. It may be used in the plywood fabricating equipment referred to above, in aluminum spot welding equipment, in other places where the strain gauges now available have failed because of inductive pickup, and in fact in any service where a fine wire gauge is useful.

In order that my invention may be more readily understood, I will describe the same in connection with the attached drawings in which all views are diagrammatic and not to scale, and in which:

Figure 1 is a view illustrating a strain gauge of my invention in its preferred form;

Figure 2 is an exaggerated sectional view of a completed gauge taken along the line II—II of Figure 1;

Figures 3, 4, 5, and 6 are views illustrating modifications of my invention;

Figure 7 is a longitudinal sectional view to an

exaggerated scale taken on the line VII—VII of Figure 1, showing a portion of a completed gauge; Figures 8, 9, and 10 are views illustrating other modified forms of my gauge; and

Figures 11, 12, and 13 are developed views indicating generally the balancing out of the various turns of the grid.

In the manufacture of my gauge, a jig is employed to assist in the proper positioning of the wire which forms the grid. The jig may be in the form of a backing board having spaced pins disposed in pairs along two parallel lines. The pins are .011" in diameter, and project above the backing board about .250". They are spaced .031" from center to center in a longitudinal direction.

The wire which forms the grid may be any of those wires available for that purpose. I have used a Nichrome alloy wire .001" in diameter with satisfactory results. The size of the wire, the diameter of the spacing pins and the distances between pins in directions both longitudinally and transversely of the gauge will vary depending upon the character of the object to which the gauge is to be applied for pressure or other determination as well as other variable factors.

The first step in the process of fabrication of my preferred gauge is the application of a backing or supporting layer 2 to the jig. The backing layer 2 is preferably about .002" thick and may be a so-called onion-skin paper the same as or similar to that commonly used for air-mail purposes. The backing 2 is pressed down firmly over the pins against the backing board of the jig, care being taken to insure that the paper lies flat and in good contact with the backing board.

The backing layer 2 is then stiffened by the application of a thin coating of nitrocellulose lacquer which strikes well through the thickness of the layer 2. This coating stiffens the paper and makes the formation of the gauge more convenient. It also functions to aid in securing the grid in proper position as will be clear from further description.

The grid has been generally indicated in the various views by the letter G. Prior to winding the grid, a lead 3 is soldered to the wire 4. The lead 3 is then cemented in place onto the backing 2 in the proper position. The wire 4 is then formed into grid G, being formed in turns. The positioning of the various turns is determined by the position and spacing of the pins on the backing board. It will be noted that a single wire 4 is employed in forming the grid G and that the grid is in the form of spaced turns, both portions of each turn being parallel throughout the distance between the longitudinally spaced pins. For example, section 5 is parallel to section 6 and section 6 is parallel to section 7 and so on throughout the grid. The number of turns constituting the grid may vary depending upon the requirements of use.

The return end 8 of the wire 4 is brought out parallel to the turns and temporarily held against the backing board as shown in dotted lines in Figure 1 and is under slight tension.

A coating of nitrocellulose lacquer 9 is applied over the entire surface of the backing 2, and the wire 4 that serves to firmly bond the wire 4 in position against the backing 2, with the turns of the grid in parallel relationship. The initial application of lacquer to the paper prior to winding of the grid assists in securing a firm bond because the solvent in the second coating will have at least a slight dissolution effect on the first coat-

ing resulting in a good bond between the two. The first coating serves to fill or impregnate the paper so that the second coating will lie above the backing 2 and serve more or less as a matrix surrounding the various turns of the wire 4, as shown in Figure 2. It will be borne in mind that the wire used in strain gauges is usually of less than hair thickness, generally in the order of one thousandth of an inch thick, and a thin coating of lacquer will, therefore, form a matrix. After the coating 9 has dried and hardened, the unit is removed from the jig. This should be done carefully to avoid any distortion of the turns or tearing of the paper. The unit will lie flat and may be handled for further fabrication.

A cover paper 10 is next applied over the ends 11 at least of the wire 4 to insulate the turns of the grid from the return 8 which is brought back to the point of beginning. I prefer to use a cover paper 10 the same size as the backing 2. The cover paper 10 may be .001" thick and is preferably a cigarette paper. The fabrication is accomplished in the following manner.

A perforation is provided in the paper 10 at the point 12 (diagrammatically illustrated in Figure 1). The paper is then coated with nitrocellulose lacquer and the return 8 drawn through the perforation. The paper 10 is pressed firmly into engagement with the previously assembled portion of the gauge and bonded thereto by setting or drying of the lacquer. After the layers have been bonded the return 8 is brought back to the point of beginning.

The positioning of the return 8 is important, for it must be so disposed that no loop is formed which is not balanced out. To accomplish this the return 8 must (a) lie at substantially right angles to the direction of the turns of the grid, (b) be contiguous to such turns but insulated therefrom, (c) should be parallel to the base, and (d) should lie a minimum distance above the grid.

As shown in Figure 7, the return 8 may lie contiguous to the ends 11 of the turns of the grid, so that a plane perpendicular to the base 2 and tangential to the return 8 will be tangential to the ends 11 of the turns which constitute the grid. This is indicated by the dotted line x in Figure 7. The return 8 may overlie the ends, as shown in dotted lines y in Figure 7, and, in fact, may be positioned anywhere along the length of the grid and overlie it; one such position being indicated in dotted lines z in Figure 7. Return 8 must not be positioned beyond the ends 11 (or the corresponding opposite ends), for this will create a loop which will result in inductive pickup. In other words, the portion of the wire which lies at right angles to the turns of the grid must be so disposed that it is possible to construct a plane perpendicular to the base and tangential to such portion which will be tangential to the turns of the grid or will intersect them. If this is not possible, then the portion at right angles is not contiguous to the turns and an objectionable loop will be present.

The return 8 will be spaced above the grid G a distance approximately equal to the thickness of the cover sheet 10. This distance should be as small as practicable. With the cover sheet 10 made of cigarette paper, the distance is about .001". Too great spacing must be avoided in order to eliminate all objectionable loops.

It should be remembered that Figure 7 is drawn to an exaggerated scale and is diagrammatic; the total thickness of the gauge is only about six

thousandths of an inch and not capable of convenient illustration to scale.

A lead 13 is secured to the return 8 and this lead 13 is adhesively secured to the cover paper 10. Leads 3 and 13 are preferably twisted and may be shielded, if necessary or desirable.

A facing sheet 14, which may be of the same material as the cover sheet 10, is adhesively secured to the unit by a layer of adhesive 15. This facing sheet 14 may cover only the exposed portion of the wire 4, constituting the return 8, or may, and preferably does, cover one face of the whole unit as shown in Figures 2 and 7. This layer may be eliminated and a coating of lacquer or other protective material applied in its stead.

The gauges shown in Figures 3, 4, and 5 are essentially the same as shown in Figure 1, except for the positioning of the leads. In Figure 3, the leads are positioned at the upper left-hand side of the gauge. The fabrication of this gauge will be the same as described above in connection with Figures 1, 2, and 7, except that the leads 3 and 13 will be cemented to the base paper 2 in a slightly different position.

The gauge shown in Figure 4 may be fabricated in a manner similar to the gauge of Figure 1 but when bringing the return 8 back to the point of beginning care will have to be exercised to be sure that run 16 is parallel to all the turns of the grid. This may be accomplished without difficulty, however.

In the gauge shown in Figure 5, the end 17 will be treated in the same manner as the return 8 of Figure 1. That is, the end 17 will be held under slight tension as shown in dotted lines in Figure 5. Two perforations will be provided in the cover paper 10 and both portions 8 and 17 will be brought together over the cover paper 10 and then adhesively secured in position.

The gauge shown in Figure 6 is somewhat different from those shown in the other views in that the leads 3 and 13 are brought out from the center. In making this gauge the lead 3 is adhesively secured in place and the right-hand turns are formed. The wire 4 is then brought around the point 12 (this may be one of the pins on the jig) and is then directed at right angles to the grid sections to the point 18. A sheet of cigarette paper may be folded over the portion 19 of the wire to enclose the same as shown at 20 in dotted lines. The left-hand turns are then formed and lead 13 attached and adhesively secured in place. A coating of lacquer may be then applied to the base layer 2 and the cigarette paper looped over the portion 19, brought into engagement with the lacquer, and adhesively secured in place. A facing sheet may then be applied over the whole upper surface of the gauge and secured in place.

In the embodiments shown in Figures 8 and 9 the return 8 is contiguous to the turns of the grid G and in overlying relationship, being separated by a thin layer of paper such as the cover sheet 10 of Figure 7. This serves to insulate the return 8 from the turns of the grid G. The position assumed by the return 8 is indicated by the dotted lines marked *z* in Figure 7. It will be noted that the paper layer 10 lies between the wire of grid G and the return *z*.

In the fabrication of the gauge shown in Figures 8 and 9, the return 8 will be placed in the position shown in dotted lines prior to the application of the cover sheet 10, in much the same manner as the return 8 is positioned in the fabrication of the gauge shown in Figure 1. An

opening will be provided in the cover sheet 10 to receive the return 8 and care will be used to bring this return across the grid G at right angles to the turns 5, 6, 7, etc., and then parallel to the turns to connect with lead 13 which is fixed in place by adhesive in the same manner as in the fabrication of the gauge of Figure 1. The adhesive matrix 15 and the facing sheet 14 will be applied to complete the gauge.

The gauge of Figure 10 is substantially the same as that shown in Figure 1 except that the return 8 is disposed contiguous to the bottom ends 11' of the grid G rather than the top ends 11 as shown in Figure 1. This gauge would be more difficult to fabricate than the gauge of Figure 1 since the problem of positioning the return 8 along the bottom of the grid, turning it at right angles and then bringing it parallel to the wire 4 coming from lead 3 would be encountered. Such a gauge can be constructed, however, and does perform satisfactorily.

In each of the embodiments, the turns which form the grid G lie in parallel relationship and each turn is constituted of a pair of wire sections of equal length. This is diagrammatically shown in Figures 11, 12, and 13 and will now be described. The diagram of Figure 11 represents the gauge of Figure 1. It will be noticed that there are six turns in the grid G, each turn consisting of a portion A and a portion B. The six portions A are of the same length as the six portions B. If there be any stray magnetic field in the vicinity of the gauge when in use, the induced voltage in portion A of one turn will be in one direction, as indicated by the arrow in Figure 11, whereas in the portion B of that turn it will be in the opposite direction, as indicated. This will be true for each turn. Thus, with all portions parallel and of equal length, the magnetic fields will have no effect whatsoever in the turns of the grid G. However, unless the wire 4 is wound back upon itself in the same or in a different plane as suggested by the prior art, it is not possible to bring the leads together without a portion of the wire lying in non-parallel relationship with respect to the turns. In each of the gauges shown in the attached drawings, there is a portion of the wire which is not parallel to the turns. However, in each case, such portion is disposed at right angles to the turns and contiguous to but insulated from the grid. The portions C which are directed substantially normal to the portions A and B when added together are equal to the length of the portion D constituting the return 8 and the portions C and D are parallel. Since the portion D lies contiguous to the various turns of the grid G there is no loop formed between the portion D and the grid and no inductive pickup results. Since the various portions each in effect cancels a corresponding portion, the whole gauge balances out and inductive pickup is eliminated.

The diagram of Figure 12 corresponds to the gauge of Figure 8. It will be noted that the portions A and B of this gauge each corresponds in length so that the adjacent pairs constituting a turn cancel each other. This leaves, however, a portion A' which has not been cancelled. This portion is cancelled out by portion B' on one edge of the gauge and portion B'' on the opposite edge, the portions B' and B'' being of a length equal when added together to the length of the portion A'. In this embodiment also, the portions C, when added together are equal to the portion D.

In the gauges diagrammatically illustrated in Figures 11 and 12, each of the turns is of the same length. This is not true of the gauge shown in Figure 13 but the same result is achieved and is explainable as follows: The three portions A cancel the three portions B and the portions C cancel the portion D. This leaves a portion A' which is of a length corresponding to about half of the length of the portions A and B. This portion A' is cancelled out by the portion B' which is likewise of a length about half the length of the portions A and B. The diagram of Figure 13 corresponds to the gauge shown in Figure 9 of the drawings.

The simplicity of the non-inductive gauge produced in accordance with this invention is apparent from the drawings, and from the description of the method of fabrication, it is clear that such gauges may be conveniently formed. The gauge is formed from a single strand of wire wound into a single plane grid and there is no problem of short circuiting in use.

In use, the gauge will be cemented to the surface under test, such as the electrode of a spot welding machine or the platen or ram of a press. A nitrocellulose cement, similar to the cement used in the fabrication of the gauge, may be used for this purpose. Thus, the filament which constitutes the grid of the gauge is bonded throughout its effective length to the member which is subjected to strain and which is to be gauged. The interposition of the base paper layer which supports the grid does not alter the effect for the filament is bonded to the base paper throughout (it is, in fact, encased within a matrix) and when the base paper is bonded to the member to be gauged, the effect is the same as though the filament were cemented directly to such member.

While I have illustrated and described certain preferred embodiments of my invention, it will be understood that the same is not so limited but may be otherwise embodied within the scope of the following claims:

I claim:

1. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as a multiple turn grid disposed in a single plane on said base layer, each turn of the grid being constituted of two portions of equal length, all of the turns being parallel to each other, and a portion of the filament lying at right angles to and contiguous with all of the turns of the grid but insulated therefrom and lying in a plane closely adjacent to the plane of the grid; and a cementing medium bonding said grid to said base layer throughout the effective length of the grid.
2. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as a multiple turn grid disposed in a single plane on said base layer, each turn of the grid being constituted of two portions of equal length and all of the turns being parallel to each other; a cementing medium bonding said grid to said base layer throughout the effective extent of said grid; a thin layer of insulation overlying at least a portion of the grid; and a portion of the filament lying at right angles to the turns of the grid and contiguous to all of the turns but insulated therefrom by said thin insulating layer and lying in

a plane closely adjacent to the plane of the grid.

3. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as a multiple turn grid disposed in a single plane on said base layer, each turn of the grid being constituted of two portions of equal length, and all of the turns being parallel to each other; a cementing medium bonding said grid to said base layer throughout the effective extent of said grid; a thin layer of insulation overlying at least a portion of the grid; and a portion of the filament lying at right angles to the turns of the grid and overlying them and insulated therefrom by said thin insulating layer and lying in a plane closely adjacent to the plane of the grid.

4. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as a multiple turn grid disposed in a single plane on said base layer, each turn of the grid being constituted of two portions of equal length, all of the turns being parallel to each other, and a portion of the filament lying at right angles to the turns of the grid and contiguous to one end of each turn thereof but insulated therefrom and lying in a plane closely adjacent to the plane of the grid; and a cementing medium bonding said grid to said base layer throughout the effective extent of the grid.

5. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as a multiple turn grid disposed in a single plane on said base layer, each of the turns of the grid being of equal length, all of the turns being parallel to each other, and a portion of the filament lying at right angles to the turns of the grid and contiguous to one end of each turn thereof but insulated therefrom and lying in a plane closely adjacent to the plane of the grid; and a cementing medium bonding said grid to said base layer throughout the effective length of the grid.

6. A non-inductive fine wire electrical strain gauge comprising a base layer; a single filament of electrically conductive material, the electrical resistance of which varies in accordance with changes in dimensions thereof, formed as a multiple turn grid disposed in a single plane on said base layer, each turn of the grid being constituted of two portions of equal length and all of the turns being parallel to each other; a matrix of cement encasing the turns of the grid and bonding the same to the base layer throughout the effective extent of the grid; a thin layer of insulation overlying at least a portion of the grid; an adhesive securing said insulation in place; a portion of the filament lying at right angles to the turns of the grid and contiguous to all of the turns but insulated therefrom by said insulation and lying in a plane closely adjacent to the plane of the grid; and an adhesive bonding said portion to said insulation.

7. A non-inductive fine wire electrical strain gauge comprising a thin paper base layer; a single filament of electrically conductive wire, the electrical resistance of which varies in accordance with changes in dimensions therein, formed as

a multiple turn balanced grid disposed in a single plane, a rigid matrix encasing the grid throughout the effective length thereof and securing the wire to the paper base layer, and a thin insulating layer covering the matrix encased wire of the grid, a portion of said filament overlying said insulating layer and disposed at right angles to the turns of the grid, said portion lying in a plane closely adjacent to the plane of the grid and contiguous to all of the portions of the grid and insulated therefrom by said insulating layer.

ARTHUR ALBERT BURR.

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## Certificate of Correction

Patent No. 2,415,082.

February 4, 1947.

ARTHUR ALBERT BURR

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 3, line 69, for the word "that" read *and*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of April, A. D. 1947.

[SEAL]

LESLIE FRAZER,

*First Assistant Commissioner of Patents.*