A FEASIBILITY STUDY OF PRESSURE SENSITIVE PAINT FOR HIGHWAY APPLICATIONS

APRIL 1983

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16. Abstract

A newly announced material, pressure sensitive paint (PSP), was investigated for potential in a large area weight sensitive transducer. Various geometries of sensors and paint types were analyzed. The results were that this material is neither sufficiently sensitive nor stable to provide a reliable indication of applied loading.

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A FEASIBILITY STUDY OF PRESSURE SENSITIVE PAINT FOR HIGHWAY APPLICATIONS

by

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University of Arkansas

FINAL REPORT

Transportation Research Committee Project No. 75

Conducted for

The Arkansas State Highway and Transportation Department

in cooperation with

The U. S. Department of Transportation

Federal Highway Administration

April 1983

ABSTRACT

A newly announced material, pressure sensitive paint (PSP), was investigated for potential in a large area weight sensitive transducer. Various geometries of sensors and paint types were analyzed. The results were that this material is neither sufficiently sensitive nor stable to provide a reliable indication of applied loading.

Implementation

No implementation of the results can be recommended.

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Chapter 1 Introduction

A recently concluded project (AHTD TRC-64) investigated and tested various types of transducers which might be useful in providing dynamic wheel load data. This data, once obtained, could then be used to realize weigh-in-motion systems for traffic classification and load enforcement purposes. At the conclusion of TRC-64, however, no low cost by effective weigh-in-motion transducer had been identified. Existing candidate transducers were either too expensive or of sufficiently large vertical dimension such that compression of vehicle suspension becomes a significant factor in analysis of the dynamic load signal. Subsequently a new material was announced which appeared to have characteristics applicable to dynamic load sensors. This project (TRC-75), concerns investigation of this material.

Appendix A contains the initial data regarding Pressure-sensitive Paint (PSP). According to the manufacturer, this material is sandwiched between two conducting surfaces to form the transducer. Pressure is then applied perpendicularly to the plane of the paint, so that the electrical resistance measured across the plates is then a function of the applied pressure. Such claims, if accurate, would suggest that a very thin, weight (pressure) sensitive element could be fabricated, since the conducting plates could be on the order of 0.062 inch thick each separated by a 0.015 inch thick layer of PSP. The manufacturer's literature states that transducers on the order of one square foot have been fabricated; no indication is given which suggests that a large area variable resistance transducer could not be produced. Thus PSP would appear to be ideally suited for realization of large area weigh-in-motion transducers.

Chapter 2 Data Acquisition and Analysis

Page A-5 indicates the various formulations of PSP available. Since the load ranges are given in pounds force, it is necessary to effect a conversion to pressure before making a selection. This is made possible by the inclusion of the transducer diameter for each of the resistance force curves shown on pages A-6 to A-8. For vehicle load measurements, the pressure range of interest is that approximating tire pressure, or in the range 40-100 psi. In this range, it is desirable to have a steep resistance change over pressure in order to provide the maximum signal with load variation. Thus the initial material selected for evaluation was EM-6.

PSP appears to be a dark gray conductive powder suspended in a rather volatile carrier. This viscous liquid must be stirred immediately before and during application since the powder tends to settle out quickly. After repeated trials, it was learned that PSP is best applied by dropping individual drops from a glass rod onto the surface in small circular areas approximately 0.5 in. in diameter. It is not suitable for brushing, as even very flexible brush fibers tend to leave areas with little or no paint coverage. At this writing, the cost of $87/oz. prohibits experimenting with spraying techniques. All sensors described below were thus fabricated using manual application of PSP.

Sensor Fabrication

Sensors for static testing of PSP were formed from 0.062 in. aluminum square plates 4 in. on a side. Each plate also had a small extension on one edge for electrical connection. A layer of PSP about 0.015 in. thick was applied between a pair of plates according to the geometries described below. The edges of the sensor were then sealed with silicone sealant for moisture protection and taped together.

PSP geometries utilized were:

Type 1: The inner surface of one plate was completely covered with paint. Since this was accomplished by spreading out individual drops, a consistantly uniform thickness layer could not be achieved. The greatest danger in fabricating a sensor is direct shorting between plates, thus considerable effort was expended in order to ensure that the entire surface was coated with the resistive paint. The consequence of this concern was overlapping of wet paint over dry, resulting in a somewhat non-uniform thickness.

Type 2: The inner surface of one plate had the paint applied in 0.5 in. diameter circles located in a square array on 0.75 in. centers. The remaining exposed surface between the painted circles was coated with a non-conducting paint. Silicone sealant was used again for moisture protection.

Type 3: Instead of rigid aluminum plates, a flexible plate was fabricated using 0.062 in. neoprene to which was glued a layer of heavy duty aluminum foil. The sensor was then constructed as described in 2, above. In this case the area between the circles was also covered with a spray adhesive to prevent foil separation during bending of the transducer.

Static Tests

A typical static test was performed by compressing the sensor and noting the force applied and corresponding DC resistance. Compression force was applied by a screw driven, manually operated plunger mounting a 3 in. diameter foot or probe. The opposite side of the sensor was held against a 3" foot also mounted to a proving ring with a dial indicator for displaying the force applied. DC resistance between the plates was noted on a digital voltmeter. Testing consisted of cycling the sensor up to 50 psi in about 1.5 psi increments and back down, recording the DC resistance at each increment. This was repeated several times for each type of sensor geometry.

Figure 1 illustrates the resistance characteristic of EM-6 with solid coverage. Note that in the vicinity of 50 psi the characteristic is very flat with little resistance change with pressure, which is not in accordance with the manufacturer's data. Not apparent on the graph is the considerable creep which accompanied each incremental increase in pressure, i.e., an immediate decrease in resistance, followed by a slow (30 sec. - 1 min.) sag to a lower value (shown). In addition, many (not all) of the resistance readings were not constant after this sag but fluctuated erratically with time.

Figures 2 and 3 depict the resistance characteristic for the 0.5 in paint circles on rigid and flexible backings, respectively. These are similar to Figure 1 in shape, with an increase in resistance due to a reduced area of paint between conducting backings. Note that the saturation behavior is preserved around 50 psi. The instability of many of the resistance readings was also observed for these samples also.

Since the EM-6 compound exhibited resistance saturation in the pressure region of interest, the manufacturer's data sheets were reviewed in order to determine if another more suitable compound might be found. Keeping in mind that a large area sensor would exhibit extremely low values of resistance due to the large area of paint required, a high resistance high pressure paint was considered to be most desirable. From the data sheets EMR-4 and EM-12 coupounds were selected and utilized to fabricate a type 2 geometry sensor.

Figures 4 and 5 illustrate the corresponding resistance behavior of these two compounds, respectively. Note that the resistance magnitudes are much

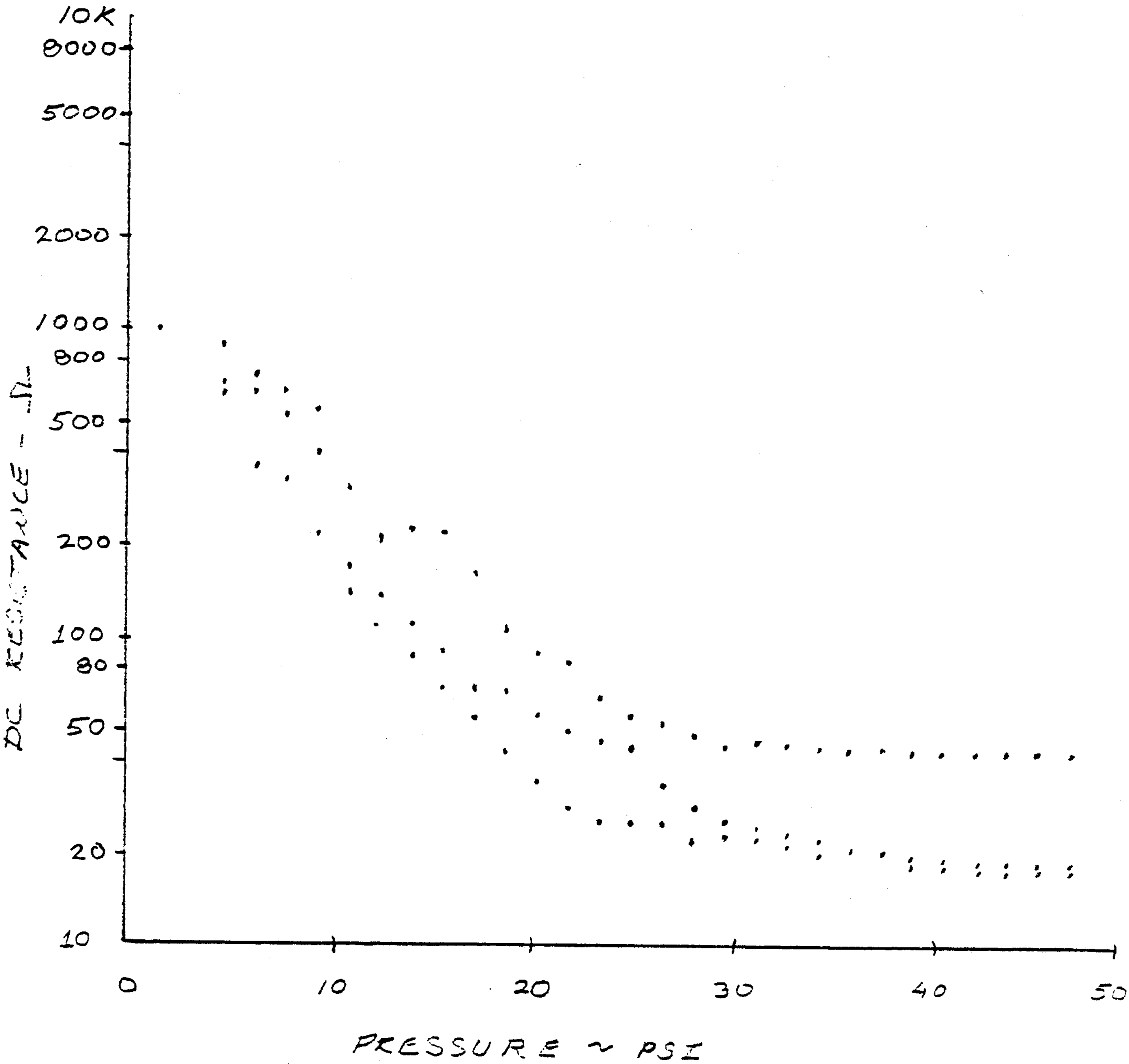


Figure 1. Resistance vs. applied pressure for PSP type EM-6.
Sensor consists of rigid plates totally coated with paint.

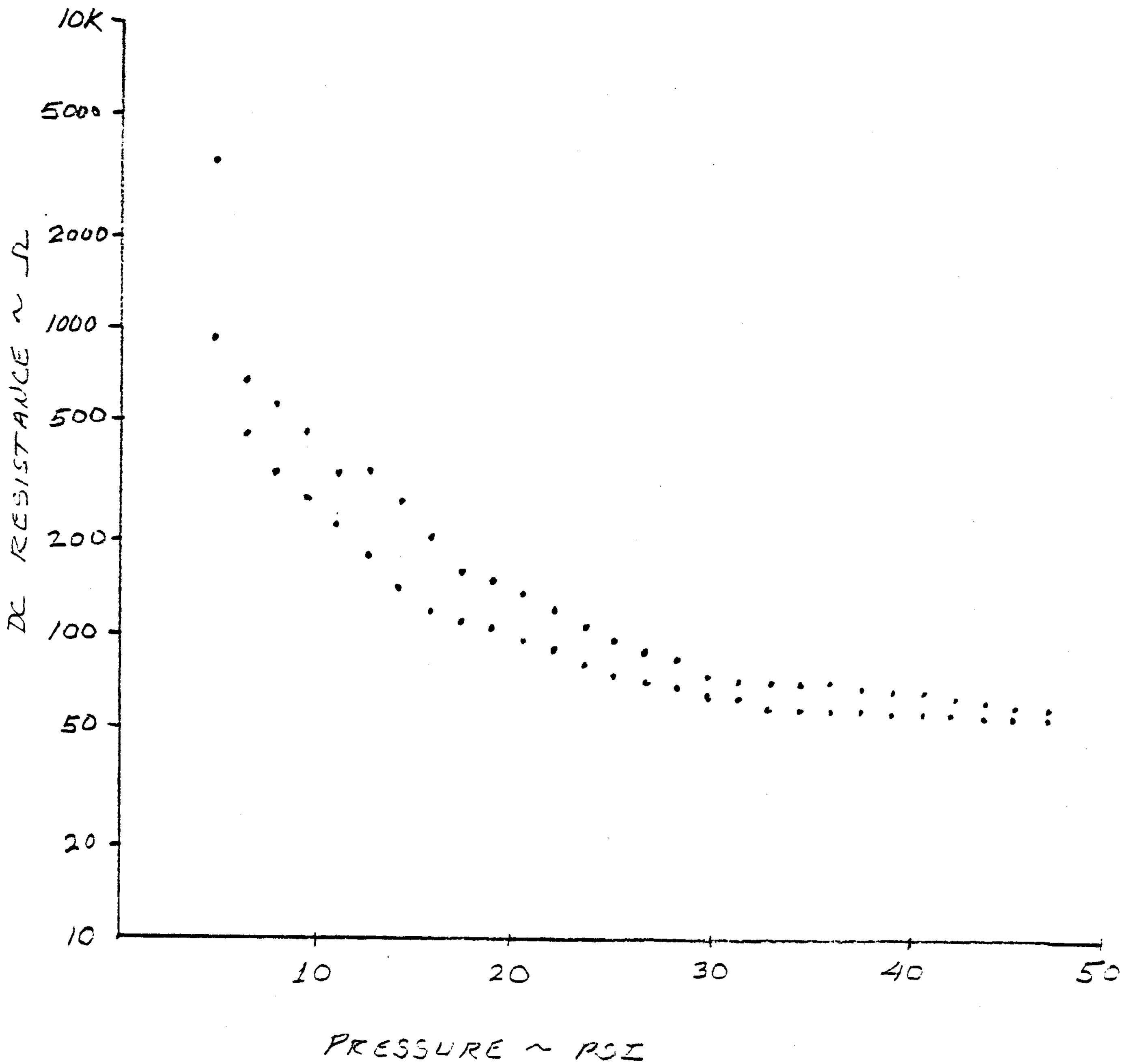


Figure 2. Sensor consists of rigid plates with paint deposited in 0.5 in. circles on 0.75 in. centers.

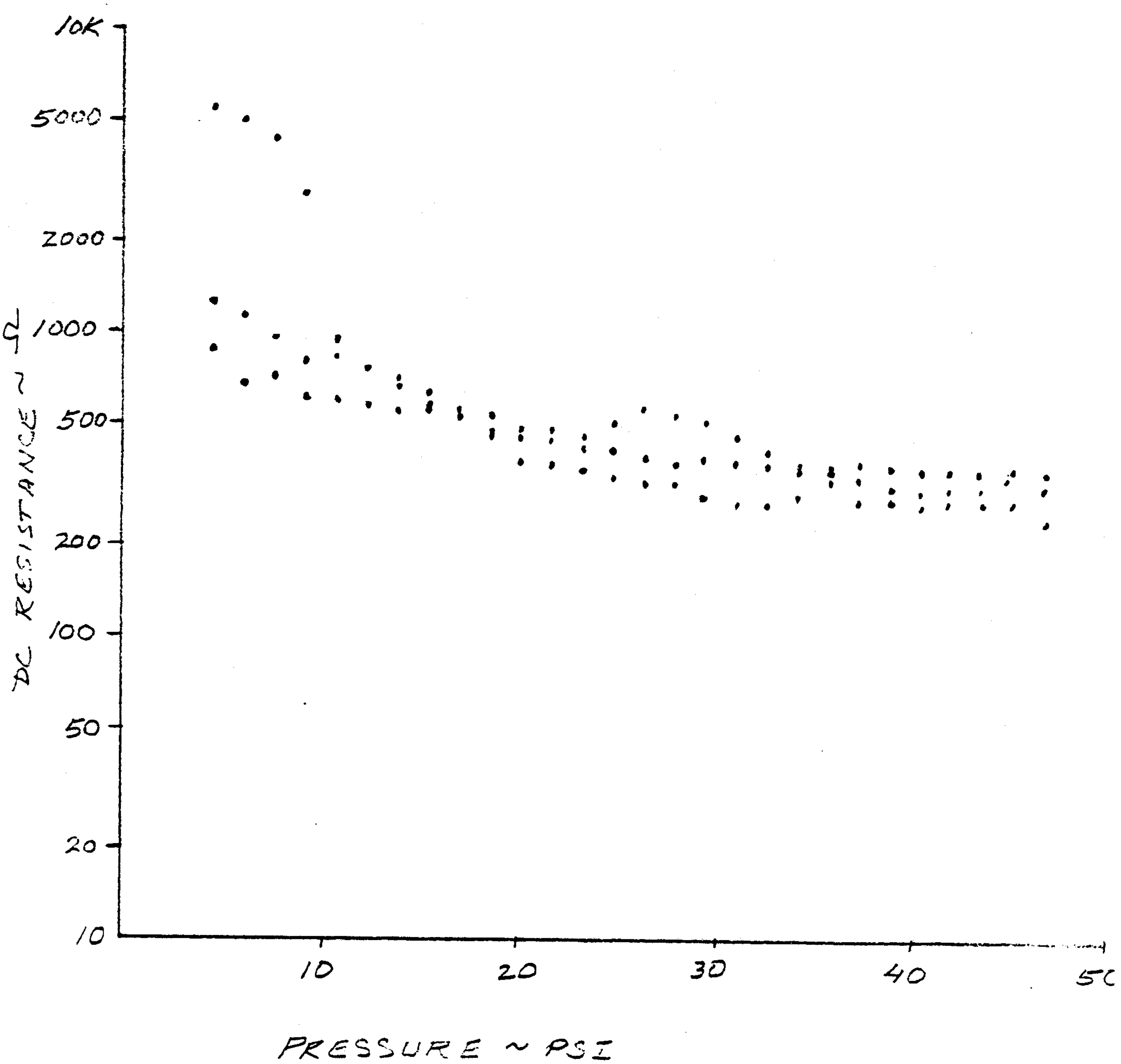


Figure 3. Resistance vs. applied pressure for PSP type EM-6. Sensor consists of flexible foil covered neoprene squares with paint deposited in 0.5 in. circles on on 0.75 in. centers.

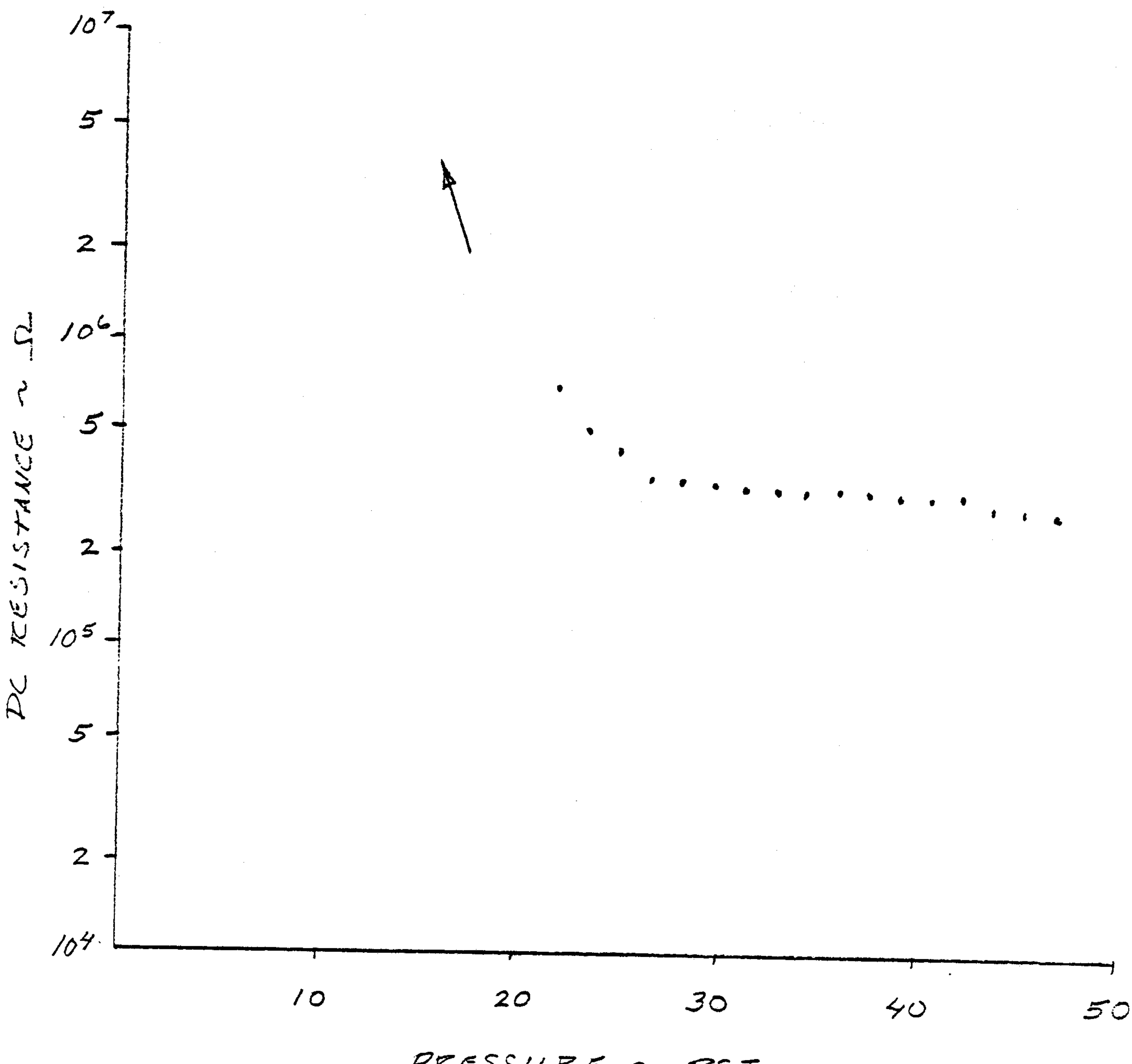


Figure 4. Resistance vs. applied pressure for PSP type EMR-4. Sensor consists of rigid plates with paint deposited in 0.5 in. circles on 0.75 in. centers.

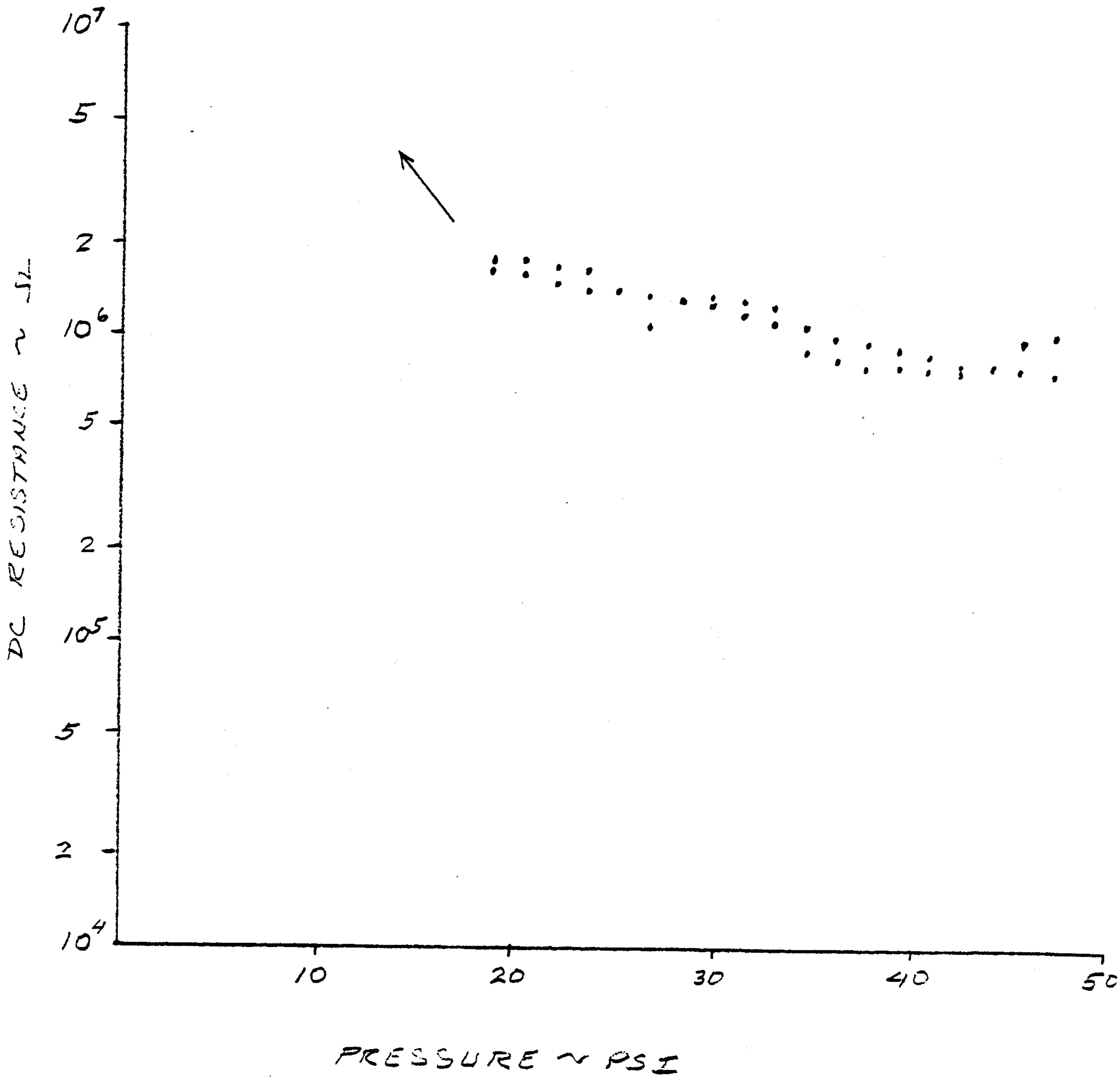


Figure 5. Resistance vs. applied pressure for PSP type EM-12. Sensor consists of rigid plates with paint deposited in 0.5 in. circles on 0.75 in. centers.

higher than those of EM-6. The saturation behavior is somewhat improved in that the characteristic is not quite so flat in the region of 50 psi. Unfortunately, erratic fluctuation in resistance values were observed as with EM-6.

Dynamic Tests

In order to record dynamic data from vehicles passing at highway speeds, it was proposed to utilize the Pavement Data Acquisition System (PDAS) developed previously for project HRP-51 and employed in TRC-61 and TRC-64. This would require interfacing the PSP sensor to the CD90 Carrier Demodulator (Validyne Engineering) installed in the PDAS vehicle. The CD90 is capable of driving and recording from two arm and four arm bridge configurations using variable resistance sensors such as strain gages, as well as transducers such as LVDTs using an AC signal source (20 KHZ in the PDAS).

To utilize the CD90, it is first necessary to null out the static resistance value and record only subsequent changes about that value. This is accomplished by means of two front panel controls. Although not generally a difficult procedure, the sensitivity of the CD90 does require that a stable impedance be presented by the bridge elements. Apparently due to the erratic fluctuations discussed previously in the resistance observations, null balancing of the 4 in. square transducers could not be achieved. Since the PSP manufacturer recommends preloading of the transducer if possible, null balancing was attempted with various loadings (up to 50 psi) to no avail.

At this point the CD90 manufacturer, Validyne Engineering, was contacted for assistance. They offered to study the interfacing problem for the University due to their considerable experience with the CD90. Thus preparations were made to ship several PSP sensors to Validyne for further analysis.

Large Area Sensor Fabrication

The 4 in. square sensors discussed above were to be utilized only for initial paint evaluation, since they are much too small for dynamic load studies. Rather than send Validyne these small units, it was decided to fabricate and deliver to Validyne sensors which would be large enough to employ in dynamic load tests. This would be particularly desirable because the null value of impedance for the small units would differ considerably from that for the large units, so that determination of balance conditions for the smaller units might not readily transfer to the larger sensors.

The following sensors were fabricated and delivered to Validyne Engineering. Each consisted of two rigid 0.062 in. thick aluminum plates approximately 2 ft. x 1 ft. in dimension.

Type 1: PSP type EMR-4 was deposited in 0.5 in. circles on 0.75 in. centers. The interior was coated with a non-conducting paint. Edges were sealed with silicone sealant and taped together.

Type 2: PSP type EM-12 was deposited in 0.75 in. circles on 1 in. centers. The remainder of the construction was identical to type 1.

Type 3: PSP type EM-12 was deposited in 0.5 in. circles on 0.75 in. centers. The remainder of the construction was identical to type 1 with the exception that the plates were riveted together in 10 places using non-conducting washers and pop rivets to provide a preload for the sensor.

Several subsequent discussions were held with Validyne Engineering after their testing program began. Essentially they encountered the same type of difficulties with CD90 interfacing that was described above with the smaller units, namely the unstable static impedance which precluded balancing of the carrier demodulator unit. This was in spite of the heavy loading placed upon each transducer under test. Contact was established between the PSP manufacturer and Validyne Engineering but no improvements were realized. Validyne's concise conclusions appear in Appendix B.

Chapter 3 Conclusions

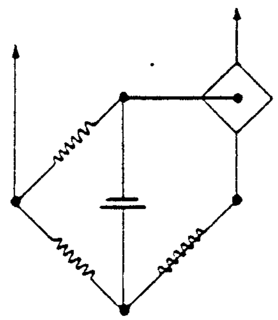
Pressure sensitive paint does not appear to be suitable for weigh-in-motion applications due to:

1) The apparent saturation of resistance when loaded to values corresponding to typical vehicle wheel loads.
2) The instability of static resistance (or impedance) which precludes interfacing with a high quality carrier demodulator unit such as the Validyne CD90.

APPENDIX A

Pressure Sensitive Paint Specifications and Related Applications Data

ELAB PRESSURE SENSITIVE PAINT



CHANGES FORCE OR PRESSURE INTO ELECTRICAL SIGNALS

One drop of MICRO-DUCER Pressure-Sensitive Paint makes a pressure transducer having almost no weight or volume. It is applicable to a surface of any shape, and will activate many difficult shapes such as wind tunnels, propellors, gear boxes and missile parts.

MICRO-DUCER PAINT is made available to the research engineer and experimenter, in ONE (1) OUNCE bottles, as an air drying liquid. Hundreds of transducers can be made from one ounce of this fluid, making fast results possible with great economy.

This type of MICRO-DUCER Pressure-Sensitive material can be applied to any metal or conducting surface, aluminum foil, printed circuitry, coated "Mylar", etc. It requires application between two conducting surfaces. When vacuum coated it forms a barometric pickup. If placed over a magnet or solenoid with a soft iron contactor on top, it can be a solid state relay without moving armature or contacts, magnetometer, amplifier, or indicate wind or water pressures.

Experiments with this material are unlimited in scope and completely fascinating. It is not necessary to have a large area to get results. A drop deposited on stainless steel about one-half inch in diameter is sufficient to operate relays, recorders, scopes, tube circuits, etc. No amplifier is required.

ELAB MICRODUCERS
3178 Pullman Street
Costa Mesa, CA 92626
Phone (714) 754-7841

Bulletin
EM-60

BACKGROUND

ELAB MICRO-DUCER pressure sensitive paint (and powder) is compounded from formulation of intermetallic resins. These intermetallic resins open the door to a versatile technique, both for measuring force and pressures, and for controlling them. The method is based on the electrical-conductivity variations possible in pressure cells incorporating these sensitive materials which undergo a large change in electrical resistance when they are compressed.

Cells are usually made of two electrical contact surfaces with pressure sensitive paint between them. The simple construction of these cells give almost unlimited flexibility in application. Cells also can be made using pressure sensitive powder which may be more suited for certain applications.

APPLICATION

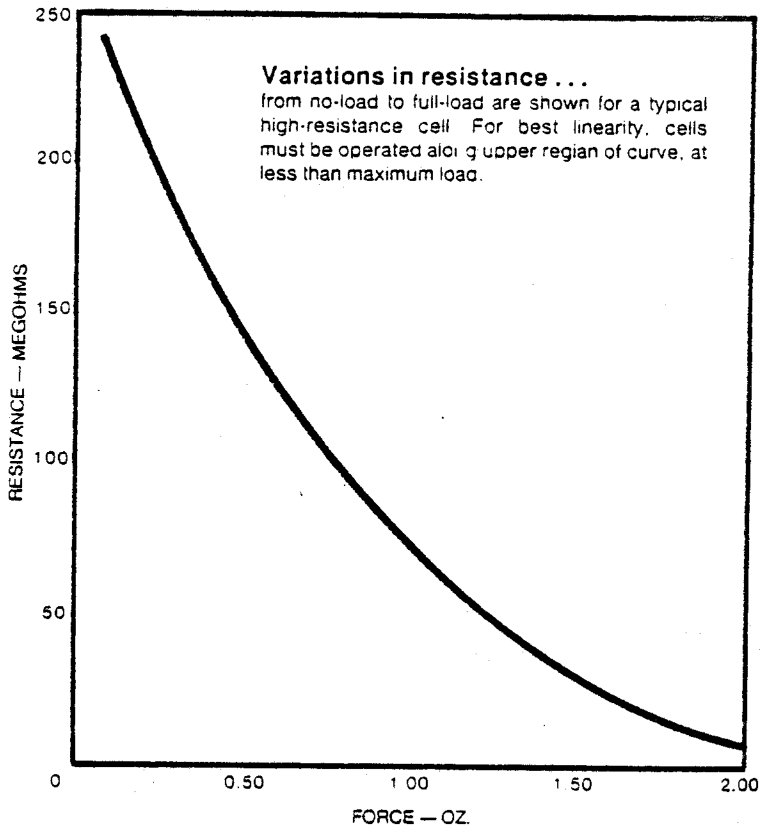
Cell versatility arises from both the ultra-wide range of forces they can measure and the areas they can cover. ELAB MICRO-DUCERS has developed many different compositions of this sensitive material for a wide variety of applications. For example, the sensitive material used in a small unit may have a resistance change of 500,000 ohms with an applied force of 1 lb., while a force of 15,000 lbs. on a large unit with a different type of sensitive material may have a resistance change of only 25 ohms.

There is basically no upper limit to size . . . cells a foot square have been fabricated. Cells as small as 0.003 square inches have recently been used for medical research.

This broad span — ability to measure an explosive force or the footfall of a housefly — is one advantage, but there are others. Along with high sensitivity, the cells have high output, eliminating the need for amplifiers when selecting them to operate relays, recording instruments, and other controls.

SENSITIVITY — OUTPUT

High sensitivity is the result of a considerable increase in relative resistance as no load pressure is approached. This ranges from about 15:1 for cells with a no-load resistance in ohms, and over 3,000,000:1 for cells with a maximum resistance of 100 meg ohms or more. High outputs are directly obtainable without amplification. For example, a cell rated at 30 ohms minimum change will, with 6V applied, pass less than 0.2 amp at no load, but 3 amp with full load force of 2 lbs. This is more than enough



current to operate standard relays or other control equipment requiring high current inputs, and also allows them to be used as contactless contacts.

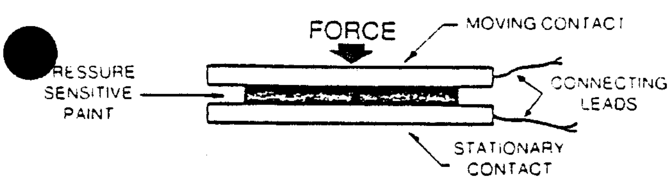
Where direct operation of relays or other control devices is not desired, high resistance cells are the answer. They will control high-impedance devices and can also supply input control signals for magnetic or transistor amplifiers.

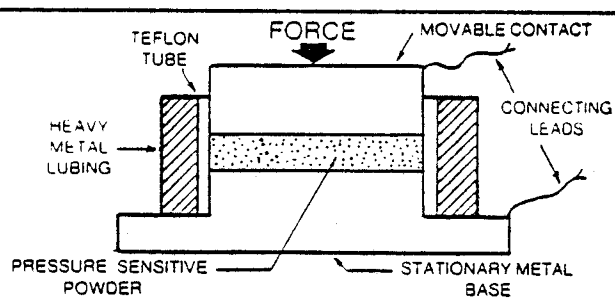
HYSTERESIS

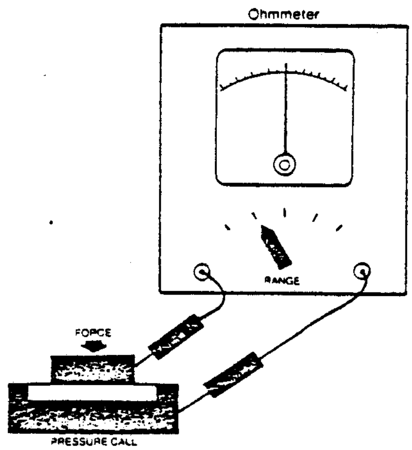
Hysteresis will vary. Generally, low pressure cells can withstand approximately 100% overload and high pressure units 2000 psi over their normal rating. Compression of cells made with pressure sensitive paint is negligible. Cells made from powder may compress as much as .007 inches at a 100,000 psi full load. Hysteresis for all units is normally less than 2%. To reduce hysteresis and increase stability in the region of zero pressure, the cells should be pre-loaded to about 5% of maximum force rating. Higher pre-loads can be used for certain applications.

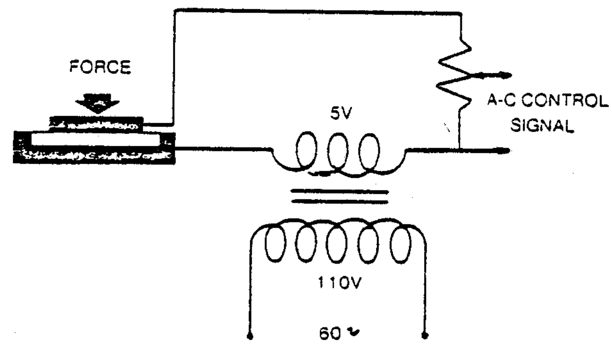
Because these cells have no moving parts, they can withstand high vibration and shock. In ambient atmospheres of high humidity the cells must be sealed against moisture.

Basic Forms.. Paint Sandwich, left Powder Cell, right









ELECTRICAL CONNECTIONS

The cells require only two electrical connections, one for each of the mating surfaces. In some cell designs insulation of the two contact areas may be required.

Either A-C or D-C voltages ranging from millivolts to 500V can be applied to these cells. The maximum is limited primarily by the maximum allowable cell temperature. Excessive current increases cell temperatures above rated limits and decreases cell sensitivity. The wattage of any cell can be increased by addition of a heat sink.

To boost both sensitivity and voltage rating, cells can be stacked and connected in series. This increases ratio of minimum to maximum current, but magnitude of current flow is decreased. Connecting stacked cells in parallel improves accuracy by averaging out differences, but also increases current flow.

TEMPERATURE RESPONSE

Temperature will cause some drift. Cells made from pressure sensitive paint can be used in temperatures of −100°F to + 250°F. However, if temperature ranges above or below 0°F to 150°F a temperature compensating bridge circuit can be incorporated.

Higher temperature cells can be made from pressure sensitive powder — up to 500°F. The powder can withstand temperatures in excess of 1000°F without damage.

DYNAMIC RESPONSE

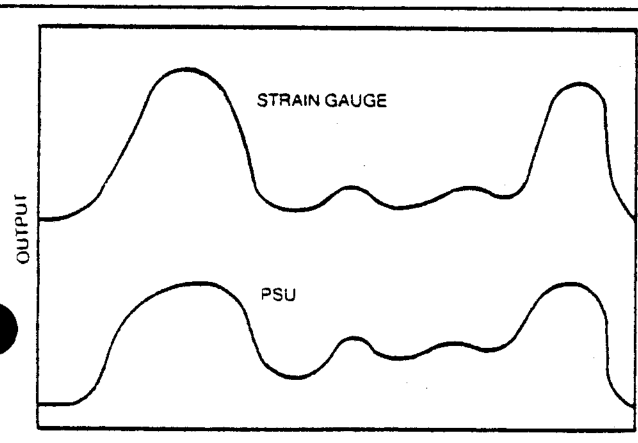
The pressure cells are essentially a pure resistance and have negligible inductance, allowing their use with voltages of carrier frequencies. However, as the frequency of applied voltage is increased, the electrical capacitance between the upper and lower contacts can become significant.

For calibration or tests of slow pressure or force variations, an ohmmeter, with ranges matching the cell resistance, is a simple and reliable indicator. To obtain a reading, the ohmmeter terminals are connected to the two cell contacts.

When pressure changes are faster than a few cycles per second, the cell output may be applied to a recording instrument or suitable oscilloscope without further amplification.

RELIABILITY

As far as it is known, there is no limit to the life of the paint (or powder) once it has been installed in a sensor and sealed to protect it from contamination and moisture. Millions of operating cycles have had no depreciating effect. More careful handling is required of cells made with pressure-sensitive powder instead of paint.

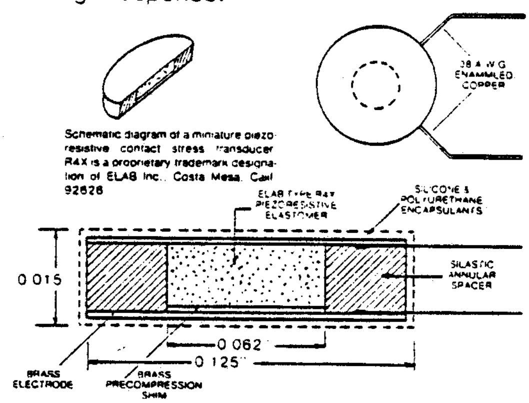


Comparison of performance of a pressure sensitive unit (PSU) comprising an ELAB transducer and a high performance strain-gauge type transducer done at the research laboratories of the University of Pittsburg.

EXAMPLES OF ACTUAL APPLICATIONS

MEDICAL RESEARCH

Following are some abstracts from medical papers issued as a result of research at the University of Pittsburgh.* "Assessment of contact stress distributions between irregular bodies of high compliance has often proven difficult because of the lack of suitable sensing elements. Miniature transducers using piezoresistive elastomers appear to provide a means for making such measurement." " . . . it has proven possible to fabricate transducers whose overall longitudinal elastic modulus (3000 lbs/in2) nominally matches that of the elastic component of articular cartilage response."



Schematic diagram of a miniature piezoresistive contact stress transducer R4X is a proprietary trademark designation of ELAB Inc., Costa Mesa, Calif 92626

*1. From "Experimental Mechanics" vol. 19, no. 6, 214, 219, June 1979" miniature piezoresistive transducers for transient soft body contact-stress problems."

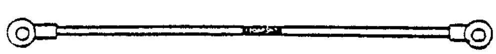
2. From paper presented at the ASME conference (June, 1981) — "Contact stress distribution measurements in the human hip joint" by Thomas D. Brown and Daniel Shaw — Dept. of Orthpaedic Surgery University of Pittsburgh, Pittsburgh, PA. 15261.

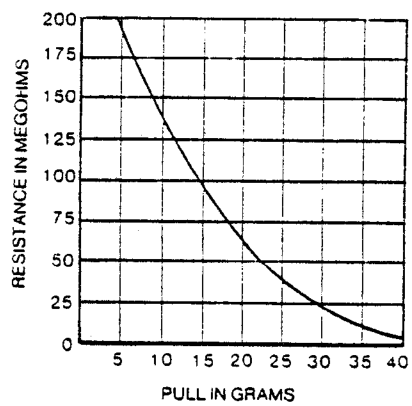
PRESSURE SENSITIVE CLOTHS

Flexible fibre glass fabric impregnated with micro-ducer paint will change resistance when compressed or subjected to change.

STRAIN CELLS

Sensitivities up to 1 megohm per gram of tension can be achieved. Construction can be the ultimate in simplicity; powdered material with binder is used like tape to separate stripped ends of stranded insulated hookup wire, positioned as for lap splice so that pull on wire is transmitted to material between ends to cause change in resistance. One model, shown below drops from 220 megohms to about 3 megohms for only 40-gram pull. Applications include wrapping around wrist for sensing pulse action.





ADJUSTABLE TRIMMER RESISTORS — POTENTIOMETERS

Most trimmers now on the market employ the principle of a resistance element being contacted by a wiping contact. This type of trimmer's power dissapation capabilities decrease exponentially with reduction of the area of the resistance element. A 1/2 watt trimmer set so that 1/10 of the element is active, would have a power rating of 0.067 watt. In a trimmer using micro-ducer pressure sensitive material, the *entire* resistance element is always active and the dissapation remains constant at any adjustable setting. Using the above describe principle, a variety of potentiometers and slide pots could be manufactured. Long life due to eliminating of sliding contacts and arcing are addition-benefits. Elimination of arcing would also be beneficial in explosive environments.

SOLID STATE MAGNETIC SWITCHES

This switch would be designed to activate circuits with no mechanical contact. A small, powerful, field-directed permanent magnet is mounted on the moving member. When this unit approaches close proximity to the small switching unit, the force generated is applied to micro-ducer pressure sensitive material which would drop the resistance from infinity to less than 100 ohms.

APPLICATIONS

1. Security systems
2. Force — pressure — vacuum measurement
3. Solid state explosion proof devices.
4. Limit and proximity switches.
5. Solid state key-boards.
6. Bin-level indicators
7. Traffic counters and/or regulators
8. Many and varied automated systems
9. Solid state slot car controls
10. Sump pump controls
11. Solid state sewing machine speet controls
12. Music ocillator controls
13. Solid state direct small motor controls
14. Excercisers
15. Project fade/dissolve controls
16. Solid state tunning strips-radios
17. Scales
18. Scuba safety devices
19. Dental drill speed controls
20. Bio-medical devices
21. Servo signaling devices
22. Structural sensing devices
23. Toys & Electronic games
24. Pin ball machines
25. Marine depth gauges
26. Phase angle gating of Triacs & SCRS
27. Offset control band (threshold) pressure controls
28. Many & varied automotive uses
29. Subminiature devices
30. Impact transducers
31. Differential transducers

ELAB FORCE — PRESSURE SENSING PRODUCTS

THE FOLLOWING TYPES OF PRESSURE SENSITIVE FORMULATIONS ARE AVAILABLE FROM STOCK. REFER TO GRAPHS ON PAGES 2-4 WHICH SHOW TYPICAL FORCE-RESISTANCE CURVES FOR EACH TYPE OF MATERIAL.

EMC-2
HIGH RESISTANCE — STABLE MATERIAL GENERALLY USED IN 0-250 LB RANGE.

EM3-AX
LOW HYSTERESIS — FAST RESPONSE GENERALLY USED IN 0-20 LB. RANGE.

EM-5
HIGH SENSITIVITY — GENERALLY USED IN 0-10 LB. RANGE.

EM-7
LOW FORCE — HIGH SENSITIVITY GENERALLY USED IN 0-5 LB. RANGE.

EM-9A
VERY HIGH SENSITIVITY — VERY LOW FORCE CAN BE USED IN 0-1 LB. RANGE.

EMC-10
GOOD SENSITIVITY — MEDIUM FORCE GENERALLY USED IN 0-300 LB. RANGE.

EM-3AW
VERY SENSITIVE — LOW FORCE LARGE RESISTANCE CHANGE WITH 1 LB. OF FORCE. (Recommend for powder only.)

EMR-4
FORMULATED FOR HIGH FORCE GENERALLY USED IN 0-30,000 LB. RANGE.

EM-6
HIGH STABILITY & SENSITIVITY GENERALLY USED IN 0-150 LB. RANGE.

EM-8
HIGH RESISTANCE & SENSITIVITY GENERALLY USED IN 0-20 LB. RANGE.

EM-9S
HIGH SENSITIVITY — LOW FORCE CAN BE USED AS SWITCHING MATERIAL.

EM-12
GOOD SENSITIVITY — HIGH FORCE GENERALLY USED IN 0-12,000 LB. RANGE.

PRICES: (F.O.B. COSTA MESA, CALIFORNIA)

PAINT . . . . $87.00/oz. (incl. 1 oz. EM472 Thinner & Applicator)

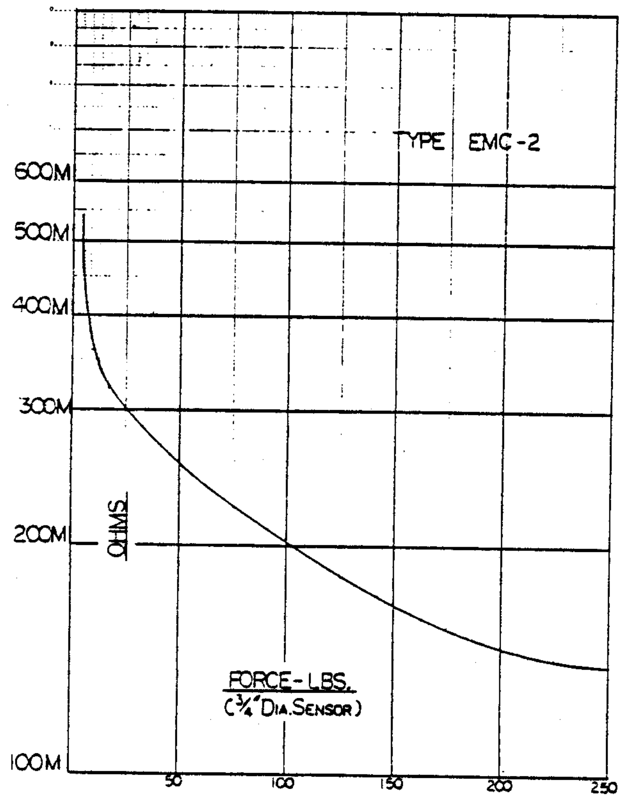
POWDER . . . . . 82.00/oz.

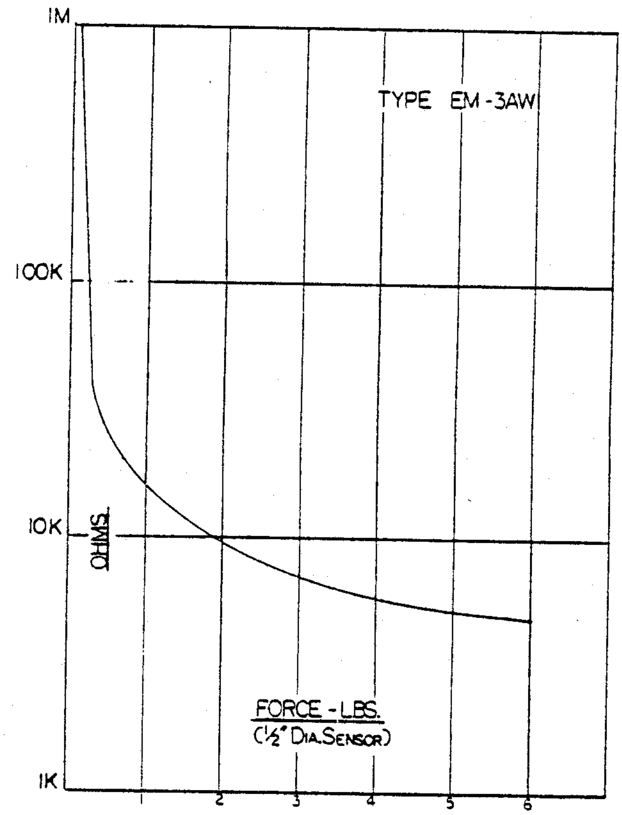
THESE PRODUCTS ARE CAREFULLY FORMULATED FROM ELAB INTERMETALLIC RESINS UNDER QUALITY CONTROLLED CONDITIONS. SUGGESTIONS FOR THEIR USE ARE BASED ON RELIABLE TESTS WHICH INDICATE UNIFORM PERFORMANCE, BUT BECAUSE SPECIFIC USE AND HANDLING ARE NOT CONTROLLED BY ELAB MICRO-DUCERS, NO WARRANTY EXPRESS OR IMPLIED, IS GIVEN AS TO THE PRODUCT USE, EFFECT OF SUCH USE, OR THE RESULTS OBTAINED.

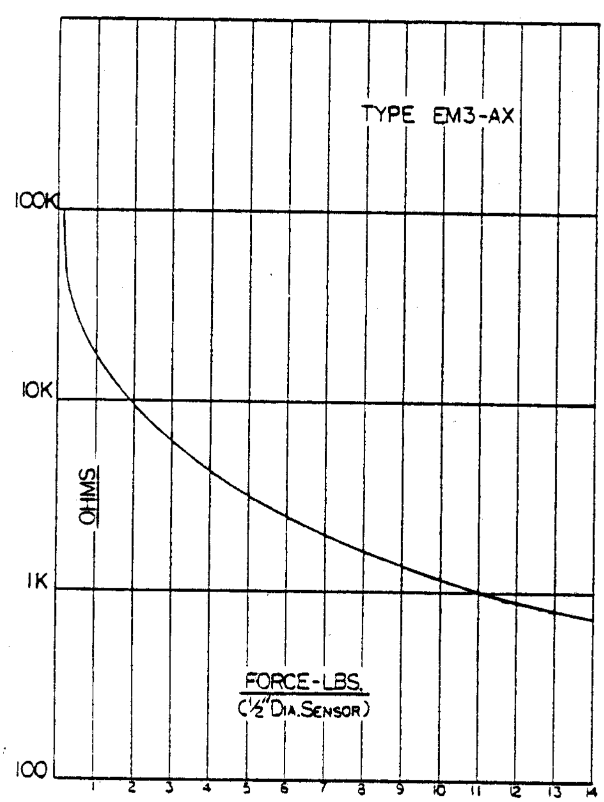
ELAB MICRODUCERS
3178 Pullman Street
Costa Mesa, CA 92626
Phone: (714) 754-7841

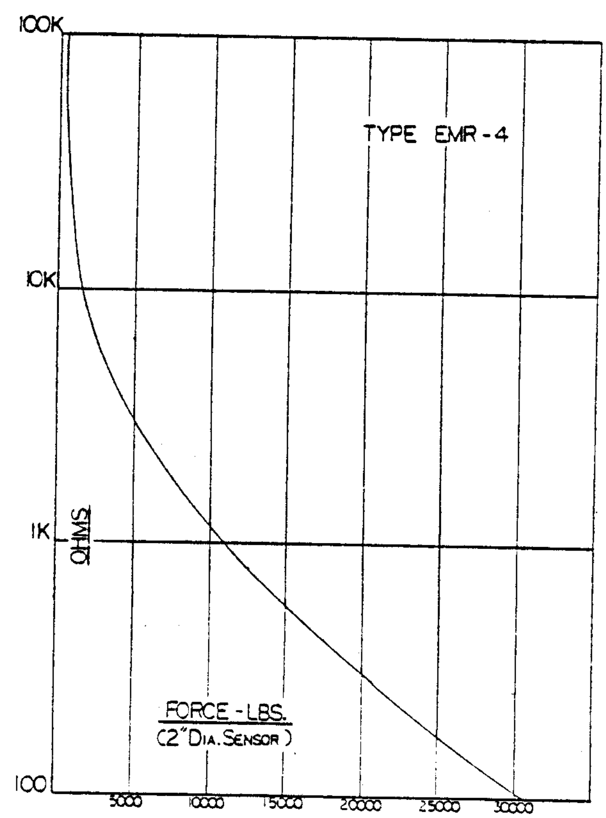
Bulletin
EM45
3/82

FORCE — PRESSURE SENSING PRODUCTS





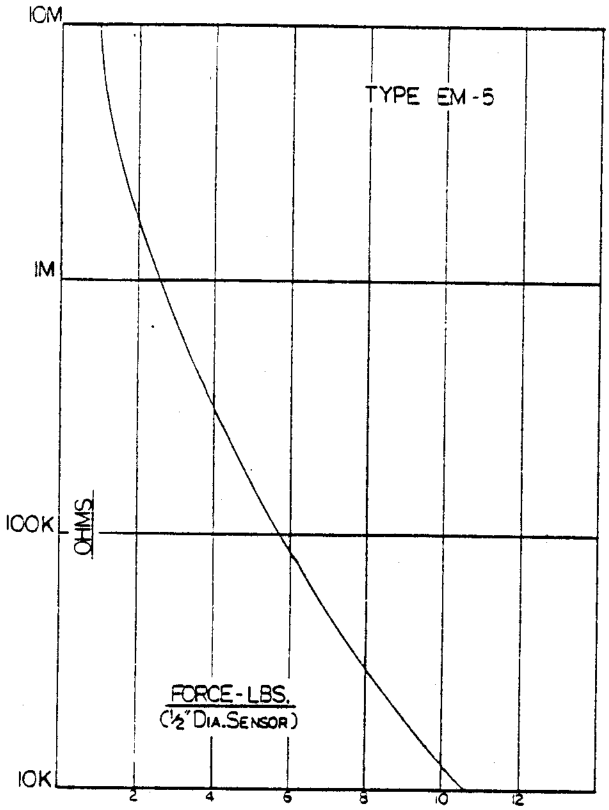


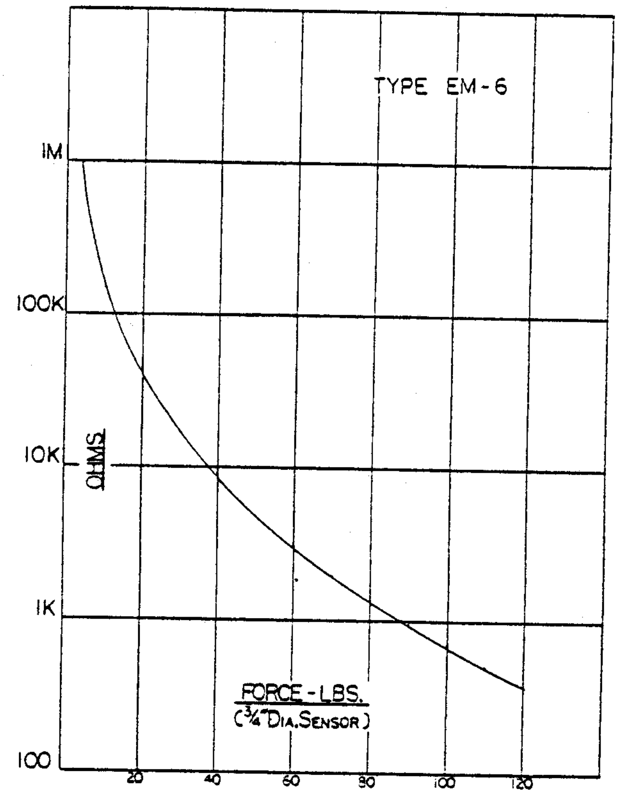


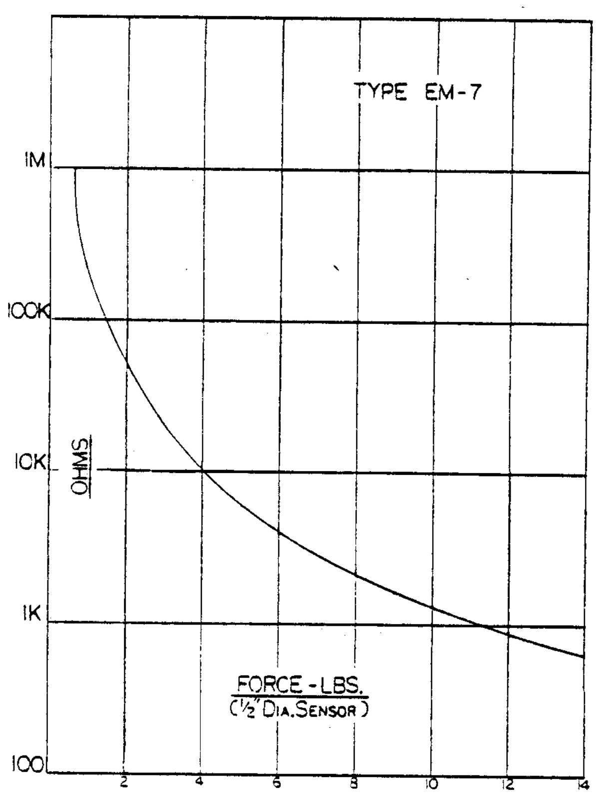
These are graphical representations of typical resistance curves obtained with Microducer Force or Pressure Sensitive Materials. Resistance curves may be raised or lowered depending upon material thickness and/or contact surface area.

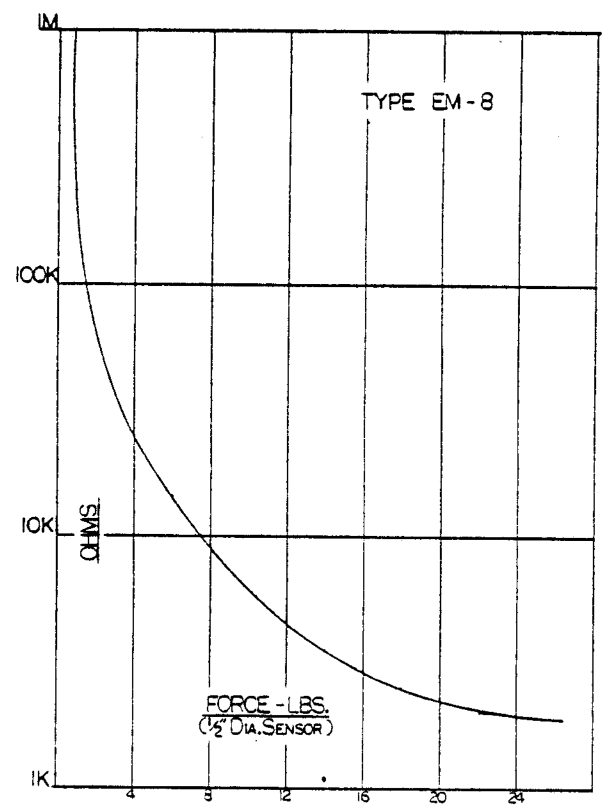
ELAB

FORCE — PRESSURE
SENSING PRODUCTS









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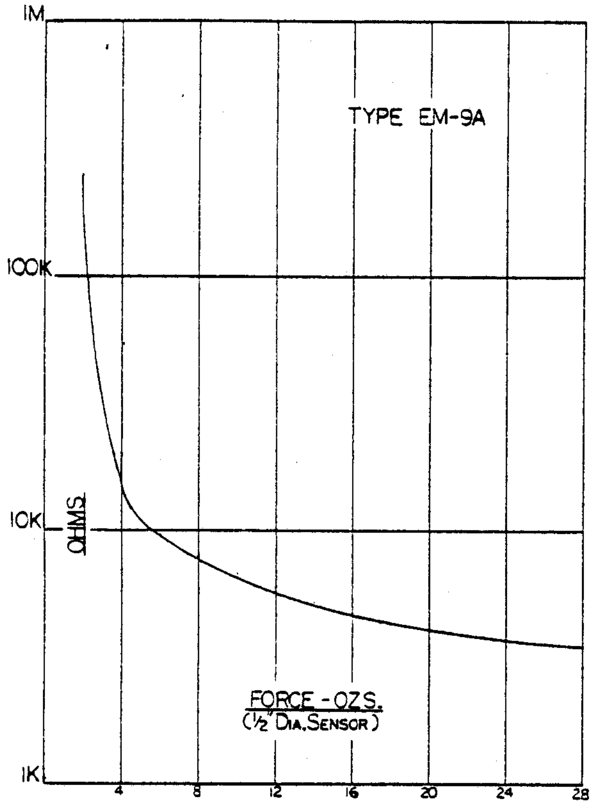
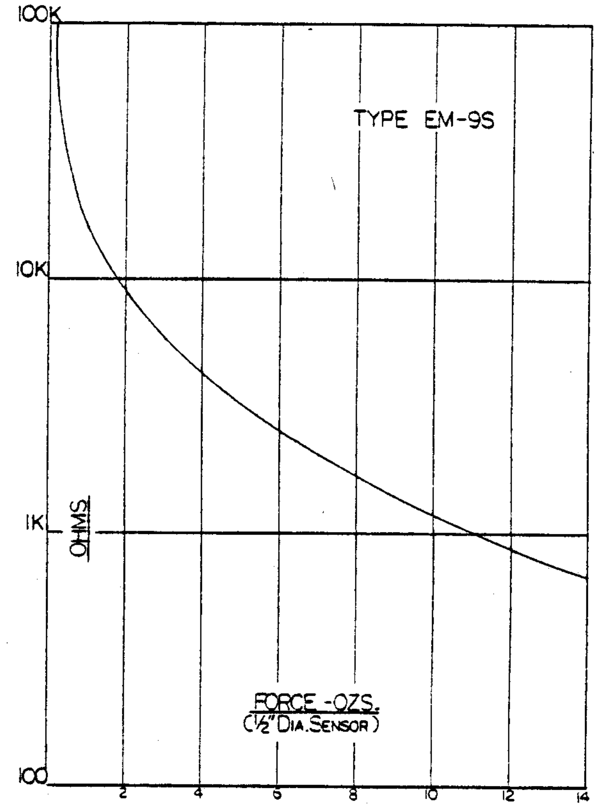
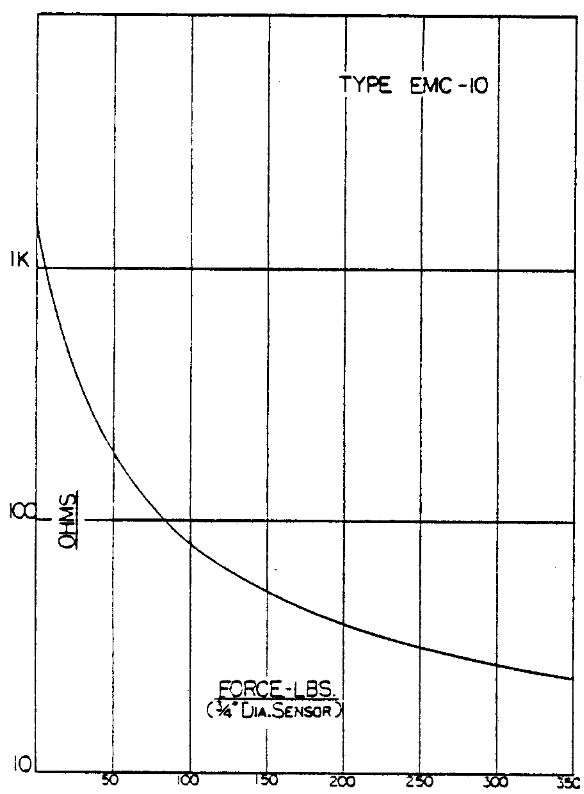
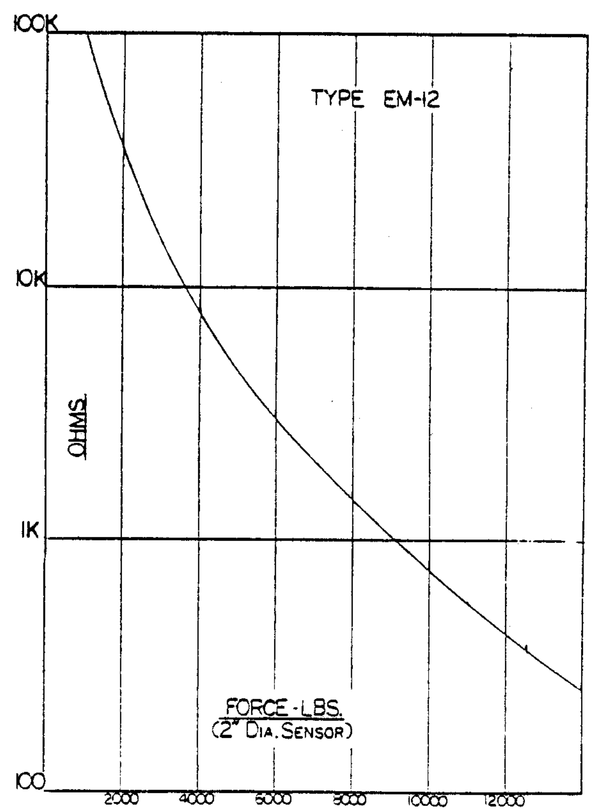
ELAB FORCE — PRESSURE SENSING PRODUCTS









These are graphical representations of typical resistance curves obtained with Microducer Force or Pressure Sensitive Materials. Resistance curves may be raised or lowered depending upon material thickness and/or contact surface area.

INSTRUCTIONS FOR USE OF MICRO-DUCER PRESSURE SENSITIVE PAINT

1. SURFACES

Paint must be applied to a CLEAN conducting surface. It will adhere to most metallic surfaces such as brass, stainless steel, aluminum, aluminum foil, coated Mylar, printed circuit boards, etc. A non-conductive surface can be converted to a conductive surface by applying Electronic Grade Silver Preparation No. 4929, made by Dupont Electro-Chemical Dept. Wilmington, Delaware. For flexible surfaces, such as when making pressure sensitive fibre-glass cloth or ribbon, use No. 7941 Silver preparation or Gold paste No. 8294 also made by Dupont.

2. HARDWARE DESIGN

The simple basic construction of the cell — two electrical contact surfaces with the sensitive material between them — gives almost unlimited flexibility for hardware design. The basic fundamentals for hardware design are: (1) an electrical connection for each contact, (2) contacts must be insulated from each other, (3) a means of mounting the sensor in order to adopt it to the use intended of it.

A method of sealing the sensor from moisture and contaminants is essential. The sealant selected must not contaminate the paint. Dow Corning Silastic 732 RTV adhesive/sealant, or equivalent is recommended.

A method of applying a pre-load is usually necessary. It can be incorporated as part of the hardware or by the method of application.

Figures I & II below illustrate the basic elements of design discussed above. Fig. I shows two washers, one with paint applied, held together with a Nylon machine screw through the center hole. Sealant has been applied to the area where the edge of the paint is exposed on the outside and between the Nylon machine screw and the washer hole. The pre-load can be adjusted by tightening or loosening the machine screw nut. The mounting base (separate) supports the bottom contact and permits compression of the paint when force is applied to the head of the machine screw. Fig. II in principle is similar to Fig. I. This design incorporates a metal machine screw for mounting and pre-load. It is insulated from the contacts by Nylon shoulder washers. In this case the mounting is accomplished by the machine screw being put thru a hole in the mounting base. This hole is large enough to permit the machine screw to move when force is applied to the head of the machine screw. The pre-load adjusting nut, in this case, completes the mounting. This design also permits use of standard connecting lugs for the electric connections.

In either case, two contact washers can be mounted on a screw, then sealant can be applied to the outside, and the sensor unit can be removed from the screw after sealant has set. The sealant will hold the two washers together as an independent unit. The exposed center hole can be sealed, thus provided a totally sealed independent washer sensor.

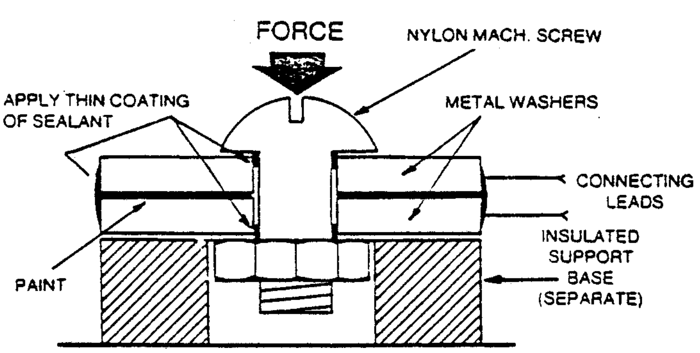


Fig. I

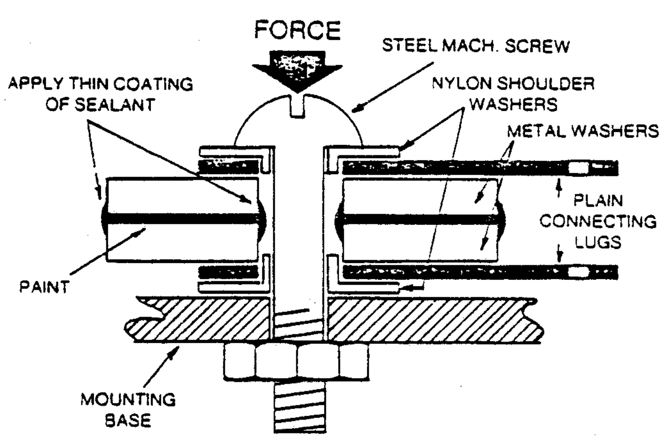


Fig. II

ELAB MICRODUCERS
3178 Pullman Street
Costa Mesa, CA 92626
Phone (714) 754-7841

Bulletin EM-50

Figures III & IV illustrate pressure type units. In Fig. III, sealant has been applied to an aunular space between the top and bottom contacts. The unit in effect becomes a sealed bellows and will react if put in a pressure environment. If the two contacts are held together with some force when the sealant is applied and allowed to cure, some pre-load effect will occur. Fig. IV shows a method of making a pressure sensor that can be screwed into a pressure chamber. The nut provides for pre-load adjustment. If a spring and washer are mounted between the nuts and the bottom contact, the sensor would react to vacuum.

IMPORTANT — Hardware design should provide for FLAT AND PARALLEL contact surfaces. Force application must be PERPENDICULAR to these surfaces for maximum repeatability and accuracy.

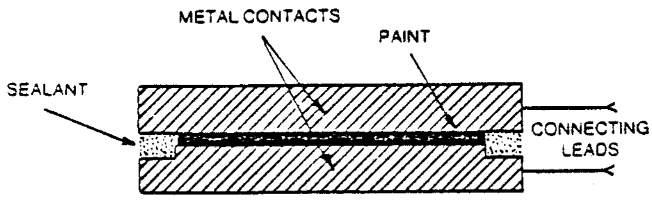


Fig. III

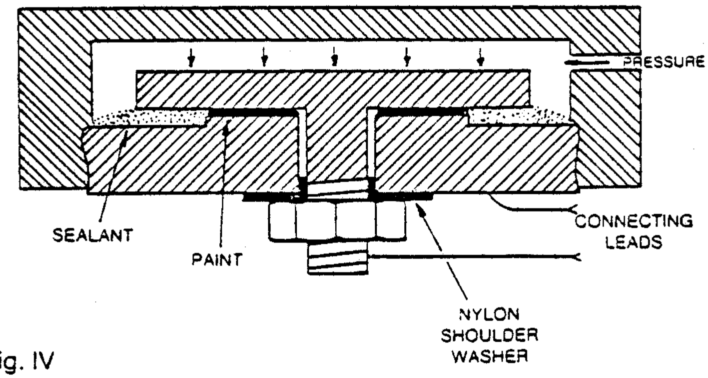


Fig. IV

3. APPLICATION

a. Stir paint THOROUGHLY with stirring rod provided. When thoroughly stirred, paint should drip off stirring rod in a uniform manner.

b. The stirring rod can normally be used as an applicator. Following is the recommended procedure:

1. Continue stirring with rod.
2. Allow excess paint to drip off of rod.
3. After a few seconds, dripping will slow down to the point that there is time between drops to transfer a drop from the rod to the surface to be painted.
4. Touch the paint drop to the cleaned contact surface and the paint surface tension will cause the drop to transfer from the rod to the contact surface. The drop will spread and can be extended by continued contact of the stirring rod. Repeat this procedure until area is covered. Normally a drop will cover a ½" diameter surface. The surface tension of the paint will permit it to spread to the edge of the surface to be painted.

Care should be used to prevent any contamination to either the paint, stirring rod, or the painted surfaces. With a little practice, it is easy to apply the paint in a uniform manner.

Control of paint thickness will require some trial and error. The thinner the application, the higher the sensitivity and the lower the resistance. Normally, paint thicknesses are in the 0.012" to 0.016" range. Paint thickness can be as thin as .002" for the very low force material to in excess of .050" in the very high force material.

Wattage limits of a sensor will depend on the paint area and thickness as well as the thickness and area of the contacts.

c. Do not let the bottle containing the paint to remain open to atmosphere any longer than necessary. Replace the cap and screw on tightly. If evaporation causes paint to thicken, a few drops of MICRO-DUCER THINNER (EM-472) added to the paint will bring it back to its original consistency.

CAUTION: MICRO-DUCER paints are flammable until dry. Avoid skin contact and keep fumes away from eyes.

4. **DRYING**

The paint must be thoroughly dry before any hardware assembly. Generally 24 hours in a dust free, low humidity environment is sufficient. Acceleration of the drying can be accomplished with a hot plate or drying oven set at approximately 200°F. If hot plate or oven is used, allow paint to dry for approximately 5 minutes before use of the hot plate or oven.

5. **ASSEMBLY**

Assembly is made after the paint is completely dry. Sealing should occur as soon as possible to prevent contaminations. Use Dow Corning Silastic 732 RTV adhesive/sealant or equivalent.

6. **EXCERCISING**

Prior to calibrating (or use) it is recommended that the sensor be exercised by applying 50 to 100 cycles from no-load to 50% over design load. The deflection of the sensor will generally be less than 0.001" from no-load to full-load.

7. **PRE-LOAD**

For most applications, pre-loading is desireable. Pre-loading can be accomplished by hardware design or by use of an external force (STATIC LOAD). The amount of pre-load will depend on the intended application of the sensing unit. Increasing the pre-load, reduces the sensitivity of the sensor, however, it improves its linearity and repeatability. Pre-loading can also assist in matching sensors.

8. **CALIBRATION**

Use a regulated power supply. Usually 1/2-2 volts and approximately 50-100 ma is used. Higher voltages increase sensitivity — Sensor output can be measured with ohmmeter, ammeter, scope, bridge circuit, or recorder. Force application should be perpendicular to sensor contact surfaces.

9. **TEMPERATURE**

Paint will operate effectively at 0° to 150°F. If the application requires a wide temperature variance, a temperature compensating bridge circuit can be incorporated. See fig. 1.

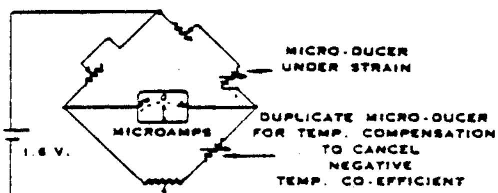


FIG. 1

Maximum recommended temperature for paint is 250°F. If higher temperatures are required, inquire about ELAB MICRO-DUCER POWDER.

10. **REPEATABILITY**

Sensor output will follow its design force vs. resistance curve. Sensors made with the same material will follow the same curve. Variations can occur due to thickness of paint applied.

11. **SENSOR SIZE**

Sensor size depends on the size of force to be recorded. The amount of force that can be applied to the paint is a function of the type of paint used and its thickness. As a rule of thumb, it is recommended that a 3000 lbs./sq. in. be the maximum used. On larger sensors (over 2" dia.) forces as high as 10,000 lbs./sq. in. can be accommodated. If forces in excess of 30,000 lbs. are involved, multiple sensors placed between steel plates can be used.

12. **RELIABILITY**

As far as is known, there is no limit to the life of paint once it has been installed in a sensor and sealed to protect it from contamination and moisture. Millions of operating cycles have had no depreciating effect.

USING THE ELAB MICRODUCER AS A "CONTACTLESS" SWITCH

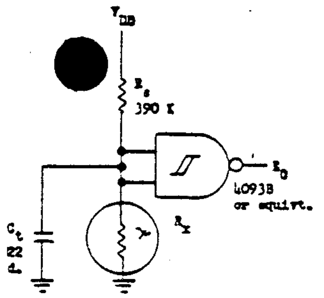


Figure 1
Normally open switch.

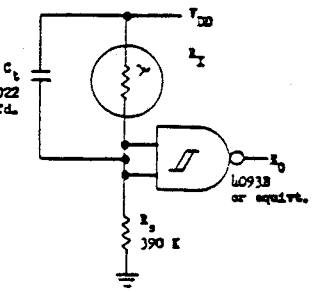


Figure 2
Normally closed switch.

The two circuits above demonstrate the application of the ELAB microducer in a pure switching mode.

While a NAND Schmitt trigger is shown and is the heart of both circuits, an AND Schmitt trigger may be used.

The circuits take advantage of the low current requirements of the CMOS logic family, however with suitable adjustment to the values of C_t and R_s, TTL will provide identical functions.

The major advantage gained by these circuits is a switch which has no arcing contacts, which is very sensitive, and will provide extremely long life.

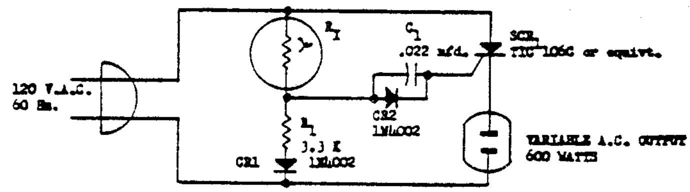
Applications would include

- : Limit switches
- : Pushbutton switches
- : Keyboard entry switches
- : Explosion proof applications.
- : Reliable automation control functions.

An interesting variation of the above circuits is to raise the value of C_t several magnitudes which then provides a delaying action; thus the circuit of figure 1 will delay turning off after pressure has been released. The circuit of figure 2 will delay before returning to it's normally on condition.

These circuits serve as one of many logic interface possibilities. The ELAB microducer [is com]patible with all logic families.

MOTOR SPEED / LAMP DIMMER CONTROL



The above circuit show an application of the ELAB microducer in high current A.C. control circuits.

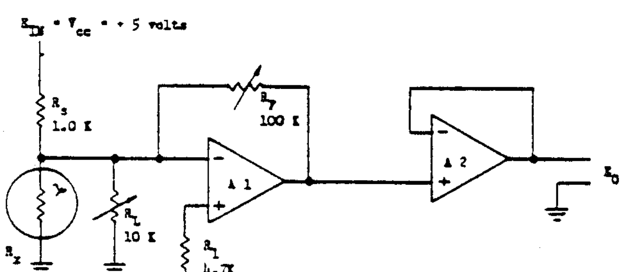
While this circuit is strictly "bare-bones" in nature, it is quite useful in areas of industrial controls. It further serves to demonstrate the high voltage characteristics and capabilities of the ELAB microducer.

As an example of practical application, the above circuit can be constructed into a "footpedal" type assembly, thus providing a foot controlled motor speed device.

The circuit is primarily a half-wave phase control which may be used with most small appliances up to 600 watts capacity. No over-current protection or R.F.I. filtering is shown for clarity.

Many high power control circuits may be realized employing the ELAB microducer. A good SCR and Triac applications manual can provide much design information. In most applications, the ELAB microducer is generally substituted for one resistive element within the circuit.

TYPICAL ANALOG INTERFACE CIRCUIT



In the above circuit, the transducer acts as the lower half of a voltage divider which include R_s and R_L

The combination of R_F and (R_x ‖ R_L) set the D.C. gain of operational amplifier A1.

R_L and R_F are made variable in order to adjust the required output voltage over some desired force range. Many combinations of these adjustments are possible for practically any output voltage.

Op amp A2 is used here as a voltage follower and provide a high degree of output buffering.

If a suitable adjustment combination has been reached, it is suggested that the value of R_1 be changed to a value equal to the parallel combination of R_s · R_x · R_L — R_F

$$\text{thus: } R_1 = \frac{1}{\frac{1}{R_s} + \frac{1}{R_x} + \frac{1}{R_L} + \frac{1}{R_F}}$$

This circuit is provided here to serve as a "starting-point" experiment in order to demonstrate the versatility of the ELAB microducer

BASIC INTERFACE CIRCUITRY

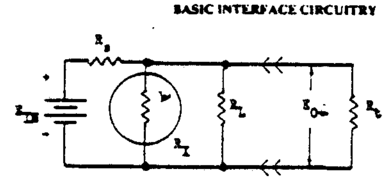


Fig. 1

$$E_{O-} = E_{IN}\left[1 - \frac{\frac{1}{R_L} + \frac{1}{R_t} + \frac{1}{R_X}}{\frac{1}{R_s} + \frac{1}{R_L} + \frac{1}{R_t} + \frac{1}{R_X}}\right]$$

(see fig. 1)

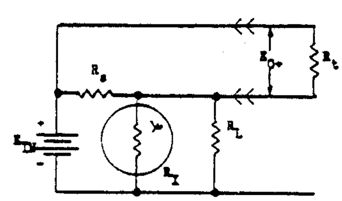


Fig. 2

$$E_{O+} = E_{IN}\,\frac{\frac{1}{R_X} + \frac{1}{R_t}}{\frac{1}{R_s} + \frac{1}{R_L} + \frac{1}{R_t} + \frac{1}{R_X}}$$

(see fig. 2)

where:
- E_{IN} = Excitation voltage
- E_{O+} = Output voltage (non-inverting with force)
- E_{O-} = Output voltage (inverting with force)
- R_s = Series resistance
- R_L = Effective load resistance. (see note)
- R_t = Total shunt resistance of interface.
- R_X = Transducer resistance

NOTES:
1) These equations do not include the ΔE/ΔR characteristics, but are accurate for most all applications.
2) R_L electrically is the same basic function as mechanical static loads.

APPENDIX B

Validyne Engineering Report

VALIDYNE
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Telephone (213) 886-8488 Telex 65-1303

April 11, 1983

Professor C. W. Caldwell
Department of Electrical Engineering
UNIVERSITY OF ARKANSAS
Fayetteville, Arkansas 72701

Dear Professor Caldwell:

In attempting to test the pressure sensitive plates you sent us, we found their impedance to be extremely unstable. As pressure was applied with either AC or DC excitation, the units would change between high and low impedance in an unpredictable manner.

We were unable to use the plates to measure pressure (force) and have returned the equipment to you.

Sincerely,

Gerald A. Merritt
Director of Engineering

GAM:ljd