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TECHNICAL DIVISION

ENGINEERING RESEARCH SECTION

MONITORING THE OAK RIDGE PILE BY AIR VELOCITY MEASUREMENT

OSCAR SISMAN - Technical Division
W.H. BRAND - Instrument Department

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ORNL-357

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JUL 12 1949

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0.0 ABSTRACT

Two methods have been developed for continuously monitoring the Oak Ridge pile by air velocity measurements in order to detect slug failures through the resulting constriction in the air channel, before they plug the channel completely or discharge radioactive dust into the atmosphere.

These methods are:

1. Velocity pressure from a pitot transmitted through a strain-gage type of differential pressure gage to an electronic recorder.
2. The potential of an electrically heated thermopile in the air stream transmitted to an electronic recorder.

Either type of element can be mounted at the ends of the shield plugs in the charging face of the pile.

While the pitot-strain gage system has practically instantaneous response, the lag in the thermocouple system is only a few minutes. This is far less time than is required for the slug to rupture or to block the channel. The estimated costs of installation are respectively $100,000.00 and $50,000.00.

It is recommended that the thermocouple system be installed in the Oak Ridge pile, if a continuous monitoring system is required.

1.0 INTRODUCTION

A fuel slug will frequently swell or blister while in the pile. The reasons for this are not precisely known, but it is generally thought to be the result of either a small hole in the can or a point of poor thermal conductivity which will cause a break in the can. If this swelling is allowed to progress the slug will finally rupture. In most cases this rupture will occur before the slug has swelled enough to completely block the channel, but, at least in one instance, it is thought that rupture did not occur until after the channel was completely blocked. The consequences of a ruptured slug are that it will introduce active dust into the pile cooling air, and will eventually reduce the air flow through that channel to such an extent that other slugs in the same channel will become too hot and also rupture. Ruptured slugs are in many cases very difficult to remove from the pile.

This investigation was originally intended to find a method for detecting and locating swelling slugs at an early stage so that they could be easily discharged before further damage was done. It was thought at first that it would not matter a great deal whether the slug had ruptured or not if it was detected before it had become tightly lodged in the channel. Soon after this work was started an intensive investigation was begun to find ways to reduce air contamination by radioactive particles. It then became important that swelling slugs be detected before they ruptured so that this source of air contamination would be eliminated.

2.0 DISCUSSION

2.1 General

Slug failures in the past have been detected by monitoring the stack gas activity. When an increase is detected in the stack gas activity the pile is shut down and the channel containing the ruptured slug is located by measuring the activity of the exit air from each channel. Slug failures are never detected by this method until rupture has occurred. When the pile was new, slug failures were detected in this manner at a relatively early stage and no trouble was encountered in discharging these slugs. Accumulation of active material in the pile and in the stack, however, has raised the background to such an extent that by the time a ruptured slug is now detected by this method it has very often swelled to such an extent that it has become tightly lodged in the channel. Detection of a ruptured slug at this late stage not only means that it may require an extended shut-down period to remove it from the pile, but that a considerable amount of radioactive fission products are being discharged into the pile cooling air.

2.2 Air Velocity Monitoring

Constriction of a pile channel due to a swelling slug will cause a decrease in the air velocity in that channel, and an increase in air and slug temperature. The pressure drop remains constant since the air enters and leaves all the channels through a common plenum chamber. Laboratory tests indicated that air velocity measurements would detect

2.2 Air Velocity Monitoring (Con't.)

a constricted channel (see Figure 1) much sooner than air or slug temperature measurements, and this was further substantiated with the installation in the pile.

Several methods for measuring the air velocity were investigated, and they are outlined in a subsequent section. It was desired that a system be developed which would continuously scan the pile and indicate a constricted channel by sounding an alarm. A five channel system which would do this by comparing the air velocity in each channel to that of a reference channel was installed in the pile. It was found that the best means of doing this was to compare the flow in adjacent channels so that each was a reference for the other. A change in flow in any channel that is not accompanied by a proportional change in its partner channel will sound an alarm. This system has been operated successfully for sixty days.

In order to test the sensitivity of the air velocity monitoring device a swelling slug was simulated by pumping water into a pre-calibrated rubber jacketed slug that was placed in one channel just ahead of the monitoring element. The results are shown in Figures 1 and 2.

An investigation by S. E. Beall of this laboratory has corroborated the sensitivity of air velocity measurements reported here. In his experiments, 250° C air was passed over slugs that had small holes drilled in the can. The pressure drop across the system was held constant and

2.2 Air Velocity Monitoring (Con't.)

the air velocity was recorded as swelling progressed. Air velocity was measured with a pitot of identical construction to that shown in figure 3 and recorded on an inclined manometer. He reported a noticeable drop in air velocity when the air passage was reduced by 35%.

2.3 Other Monitoring Methods

Such methods as light reflection, sound reflection, radar, and wires strung through the channel were discarded as impractical principally because the pile channels are not very straight.

Temperature measurements, although they were never thought to be too promising, were tried. Thermocouples were placed in the air stream and on the end of a slug, and the simulated swelling slug was used to restrict the channel. Temperature changes were so small as compared with the air velocity change, and so erratic that this method was immediately discarded.

The simplest of all monitoring methods is visual scanning. The pile is shut down and the face plug removed from each loaded channel and a visual inspection made for swelling slugs. The principle objections to this method is that it is time consuming and it cannot be continuous.

Since a filter house has now been installed on the pile exit air line it is no longer essential that swelling slugs be detected at the earliest possible moment. If weekly scanning will suffice the time comsumed (a few hours) is not unreasonable. This method has been adopted

2.3 Other Monitoring Methods (Con't.)

and will probably continue to be used until such time as greater need for a continuous method is indicated.

2.4 Location of the Monitoring Elements

The choice between mounting the monitoring elements at the front or back face of the pile was not a difficult one to make. It is very difficult to get to the back face of the pile, and also difficult to hang anything on it, especially since anything that covers the channel must be mounted so that it can be removed whenever slugs are discharged. It was found to be relatively easy to mount the measuring element at the end of the front face plugs. When the plug is removed for charging or discharging slugs the element is removed with it.

3.0 METHOD

Two basic classifications may be made for the signal systems used in monitoring air flow; (1) those incorporating variation in velocity pressure, and (2) those involving temperature changes as a result of heat transfer variation.

Elements of the first class should have negligible pressure drop and should be sensitive over a wide variation in flow; such as venturi or pitot tubes. The venturi would require closure of the passage to direct all flowing fluid through its throat and would therefore present a construction problem which would be very complicated if at all possible. Pitot tubes inherently lend themselves to applications of rigid space limitations and have acceptable reproducibility characteristics. Since pitot tubes are susceptible to the

3.0 Method (Con't.)

angle of incidence of the flowing fluid the shielded type total pressure tube is a definite improvement of the impact tube. This type will provide accurate velocity pressure indication over an angle of yaw of 60°. Figure 3 shows the construction of the tube used.

In the second class is included a wide variety of units which produce a change in emf with change in temperature. These may be thermocouple or thermopile units or materials which change resistance with change in temperature. The unit used was a heated thermopile which was developed by the Hastings Instrument Company.

3.1 Pitot Method

The pitot was attached to the end of a shield plug (See figure 3) so that when placed in the pile it was located one foot inside the graphite. Static and velocity pressure tubes were brought out to the face of the pile through the shield plug. To put the signal from the pitot in a form that is easily transmitted to the control station the following methods may be used. It is essential that this equipment be small in size, easily detachable from the shield plug and readily available for checking.

1. An inclined manometer using low specific gravity fluid was used during all initial investigations. This could be extended to include pressure switching devices which successively connect pairs of pressures to a single differential pressure measuring instrument. The use of pressure selecting switches with this type of installation is not considered practical because it involves a large amount of small bore tubing and an intricate network of connections. These installations almost invariably lead to leakage errors and consequent checking and servicing time.

3.1 Pitot Method (Con't)

The adoption of a small "U" tube manometer mounted on the shield plug and fitted with a light source actuating a photoelectric or photronic tube was studied but never attempted.

2. The method used on a five channel model of the completely automatic monitoring system employed differential pressure transmitters of the strain gage type. (Stathom P5-0.2-125). These gages use small diameter constantan wire wound between the frame and armature posts in as many as twelve loops. The movement of the armature is produced by a diaphram or bellows which puts opposite legs of a bridge in tension or compression, respectively. This double resistance change, caused by changing the diameter of the wire, produces a measurable bridge unbalance which is quite linear and which has negligible hysteresis. The measuring range is 0.2 psi.

The first apparatus was designed to measure the velocity pressure of the flowing fluid and to transmit it to a control unit which indicated the pressure on a strip chart recorder. Circuits were included to adjust five such velocity readings to a common zero and to automatically switch through the five readings successively. A low reading would energize a trip circuit which switched to a reference channel which, if also low, would automatically put the control unit back in switching sequence, but if the reference channel was normal the switch sequence halted and an alarm signal showed the troublesome channel. Over-ride switches permitted checking any channel at will.

A more satisfactory system was later developed which balanced velocity pressures in adjacent channels in a single pressure transmitter (Figure 4). This had the advantage of being a null system, and also halved the number of pressure transmitters. Reduction in flow in a single channel produced an unbalance in the direction of the flow reduction. The control unit for this method included: a switching system to scan 5 pairs of channels, right and left alarm circuits which stopped switch action and held on the point producing this deflection until normal operation was resumed, and signal lights which in conjunction with the numbered switch position gave indication of the channel producting a deflection.

3. Differential pressure balanced Hydron bellows units were suggested by the Foxboro Company but never tried. Figure 5 depicts a steel microformer core held in equilibrium by the position of the bellows which is in turn acted on by two pressures. The entire unit can be gas sealed and requires only four leads. The microformer can be

3.1 Pitot Method (Con't.)

supplied with ac potential and the ac signal (either a null or compound potential) can be used as the input for a control unit. A rugged, stable system can be readily assembled. By use of an extra sensitive bellows a movement of .025 inches per inch of water is possible and the microformer can be made to be sensitive to .0001 inches of motion. Since permissible deflection may amount to .006 inches this seems entirely adequate.

3.2 Thermoelectric Method

1. Heated thermopile instruments have many advantages for scanning flow. By using small diameter wire suspended from posts of moderate mass, the wire, when heated by a superimposed ac current, runs at a temperature which is a function of air flow while the posts operate at a temperature very close to that of the flowing medium. This system produces an acceptable efm, small at high velocity gas flow and large with zero flow, which can be multiplied by adding pairs of junctions. The Hastings Instrument Company elements are mounted in 1/2 inch diameter tubes, and when connected into a regulated ac heating current system will produce a dc temperature-efm output.

   A scanning system which measures each channel separately or compares it with a similar channel must provide coincident circuits which energize proper alarm signals when the channel being scanned is over the range indicated. Figures 6 and 7 show the basic circuits of such devices with figure 6 showing the automatic system that was used for checking four channels.

   A Hastings Instrument Company test unit has been indicating wind velocity under ambient conditions exposed to the elements for more than a year and has exhibited satisfactory reproducibility during this period. These elements can be made to operate at different velocity levels by varying the spacing of the hot from the cold junction. They can be adjusted to operate at maximum sensitivity for almost any velocity.

2. Flow elements based on temperature coefficient of resistivity can be made from such materials as tungsten, platinum, nickel, hytempco and fused sintered oxides of uranium, maganese, cobalt, copper and others. If these materials are used as two legs of a bridge, and placed in regions of the same conditions and the circuit balanced, an unbalance will occur with any change in the heat transfer conditions of either leg. This unbalance, if produced by flow change, can be used to indicate the magnitude of that change.

3.2 Thermoelectric Method (Con't)

Instruments of this type, using resistance wire, were not thoroughly investigated mostly because a vendor could not be found to supply them. The Minneapolis Honeywell Company has very recently, however, developed and offered for sale an exhaust hood damper positioner which works on this principle. It is said to be extremely durable, sensitive to very small load changes, small in size, easily reproducible, and inexpensive.

The thermistor approach to this method of flow change determination was dropped when it was found that they became very radioactive when placed in the pile and thereby presented a handling and servicing problem.

3. If the temperature change in a constricted channel was large enough, the signal from a thermocouple could be used to operate the monitoring device. Thermocouples were placed in the air stream at the center of the pile and attached to the end of the first slug in the channel. The magnitude of change with increase in constriction was so small and so inconsistent that it was considered unusable. The reason the temperature change is so small is probably because of the very high thermal conductivity of the surrounding graphite.

4.0 RESULTS AND CONCLUSIONS

Installation of the filter house between the pile and the stack has, at least temporarily, reduced the necessity of a continuous monitoring system. A system of periodic visual inspection of each channel has been adopted, and the work on the air velocity monitoring system was concluded after checking the five channel installations. The switching system for continuously monitoring the entire pile automatically has not been worked out in detail, but a satisfactory system (Figures 4 and 6) was used on the five channel installations. It appears, however, that any of a number of commercial instruments could be modified to suit the large installations.

4.0 Results and Conclusions (Con't)

It is felt that a satisfactory pile monitor can be installed using the air velocity method to detect swelling slugs. Results of this investigation may be summarized as follows:

1. Constrictions in a loaded channel can be detected by air velocity measurements if the free space around the slug is reduced by 20% at any point. A constriction caused by a swelling slug can be detected at least by the time the slug has swelled to a diameter of 1.3 inches (from original diameter of 1.1 inches). In most cases the slug would not have ruptured, and if it had it would be a very small crack.

2. Two methods for indicating changes in air velocity have been operated satisfactorily for two months. Both methods were used to indicate a change in flow in one channel relative to the flow in an adjacent channel. Both methods seem to be equally good, and several other methods which were suggested but not tried will probably also work.

   Method one uses a pitot to measure the air velocity in each channel. The velocity pressure from the pitots in adjacent channels are connected to a strain gage type differential pressure gage. The signal from the gage is recorded by an electronic indicator.

   Method two uses a heated platinum-platinum rhodium thermopile as the sensitive element. The potential of the thermopile is a measure of the air velocity. Two such units in adjacent channels are connected together so that a change in flow in one with respect to the other can be detected on a recorder.

   Sensitivity of the two methods is shown in figure 2. Both are equally good as indicated by the slope of the curves. The fact that curve number 1 is lower than curve number 2 does not mean that this method is less sensitive since the magnitude of the signal can be increased by increasing the temperature of the thermopile or by increasing the number of units in the thermopile.

3. An air velocity monitoring system can be built to detect a restriction in any one channel or a group of channels but the cost of such a system will not be appreciably reduced by checking groups instead of each channel individually.

4.0 Results and Conclusions (Con't.)

4. The thermoelectric system has two principle advantages over the pitot-strain gage system.

   (a) The mechanical arrangement is simpler, and it would be easier to handle when charging or discharging slugs.

   (b) The cost of installing the thermoelectric system is estimated to be about $50,000 as compared to about $100,000 for the pitot-strain gage system.

   The principle advantage that the pitot-strain gage system has over the thermoelectric system is that the response of the former is instantaneous whereas the response from the thermoelectric system is somewhat slower.

5. The best place to mount the elements for any monitoring device of this kind is on the end of the shield plugs at the front face of the pile.

6. Air and slug temperature measurments as a means of monitoring for swelling slugs has proven unsuccessful.

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O. Sisman

W. H. Brand
W. H. Brand

OS:gd

June 17, 1949

5.0 APPENDIX

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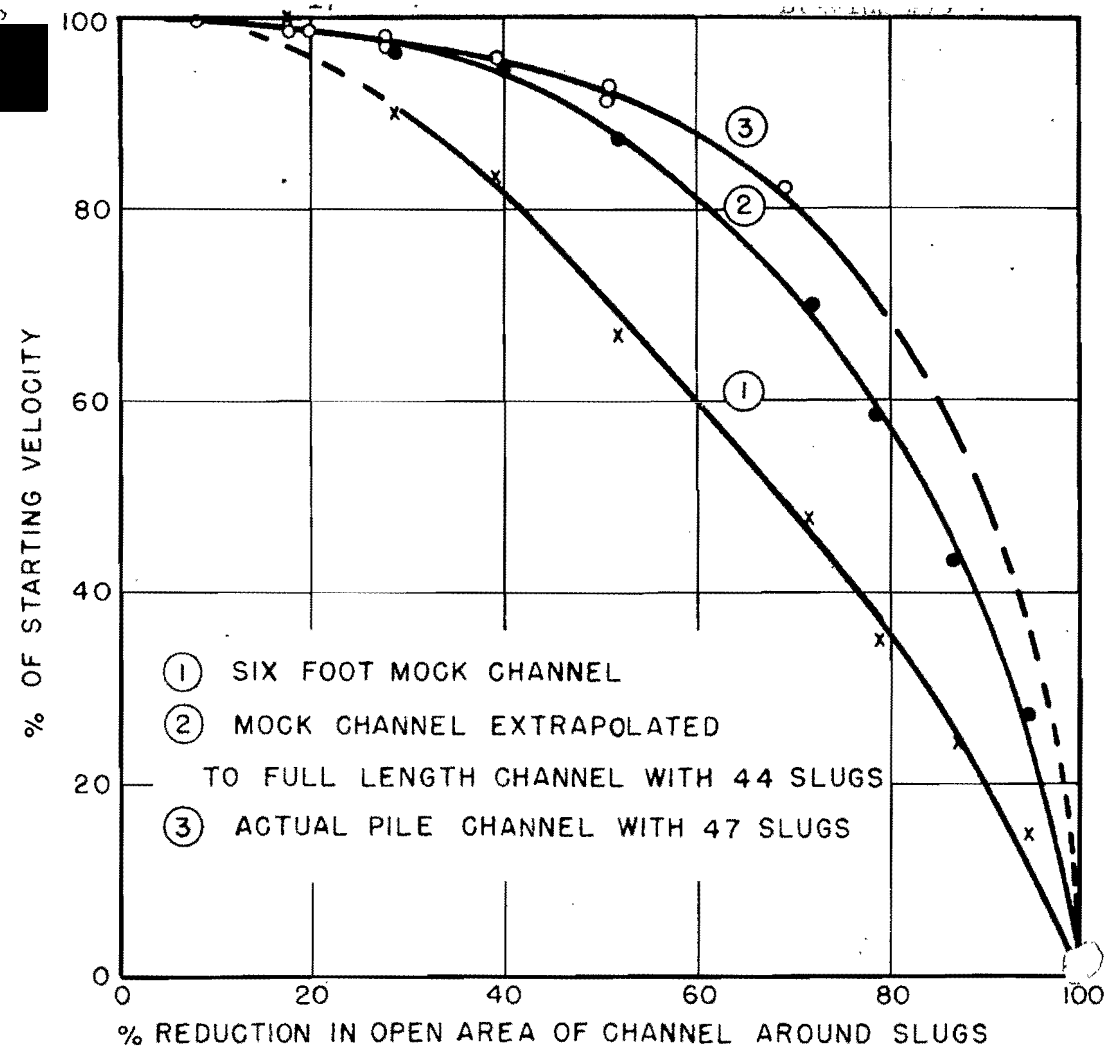
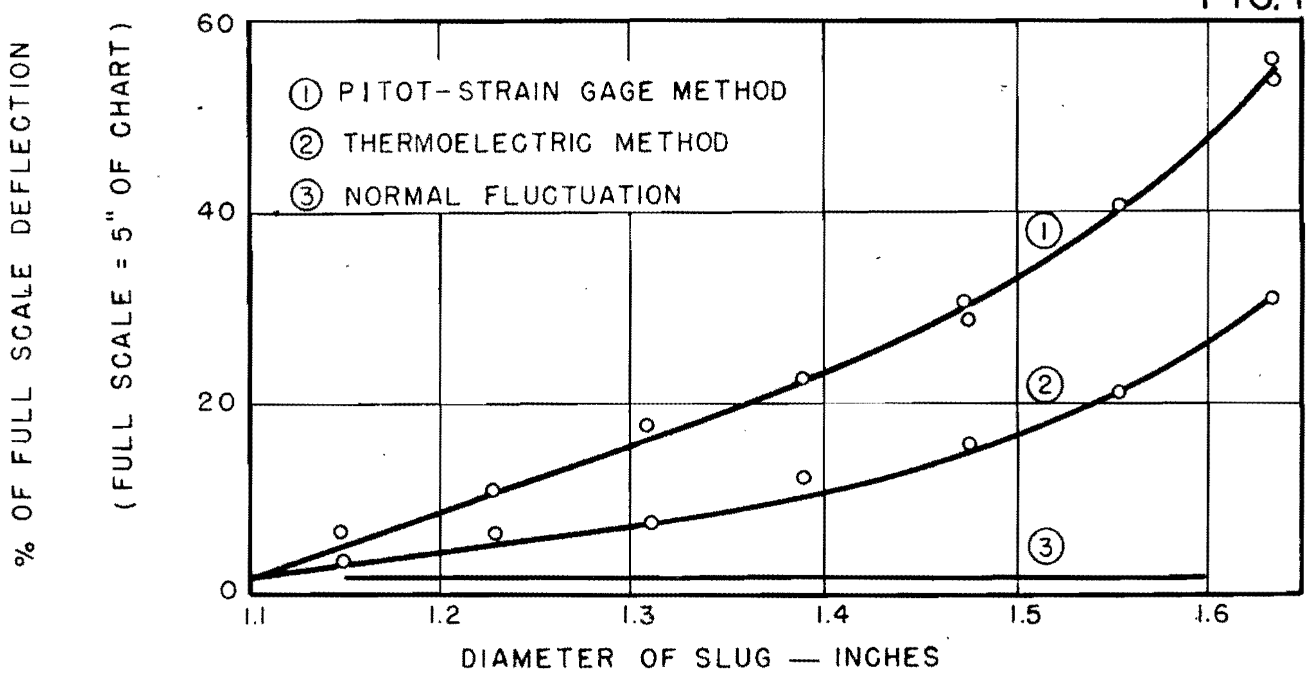


DECREASE IN VELOCITY AT CONSTANT PRESSURE DROP

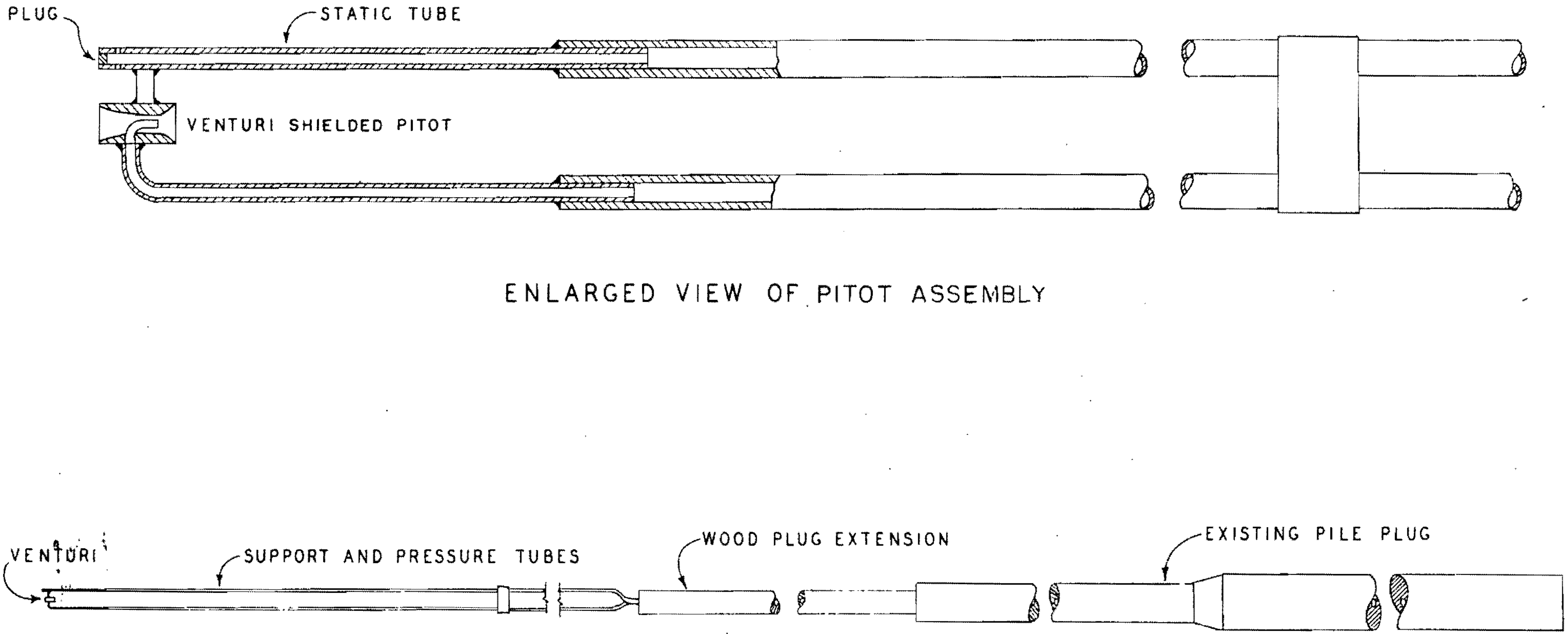
FIG. 1



SENSITIVITY OF PILE MONITOR

[redacted]

FIG. 2



COMPLETE ASSEMBLY

FIG 3

TOTAL AND STATIC PRESSURE PROBE

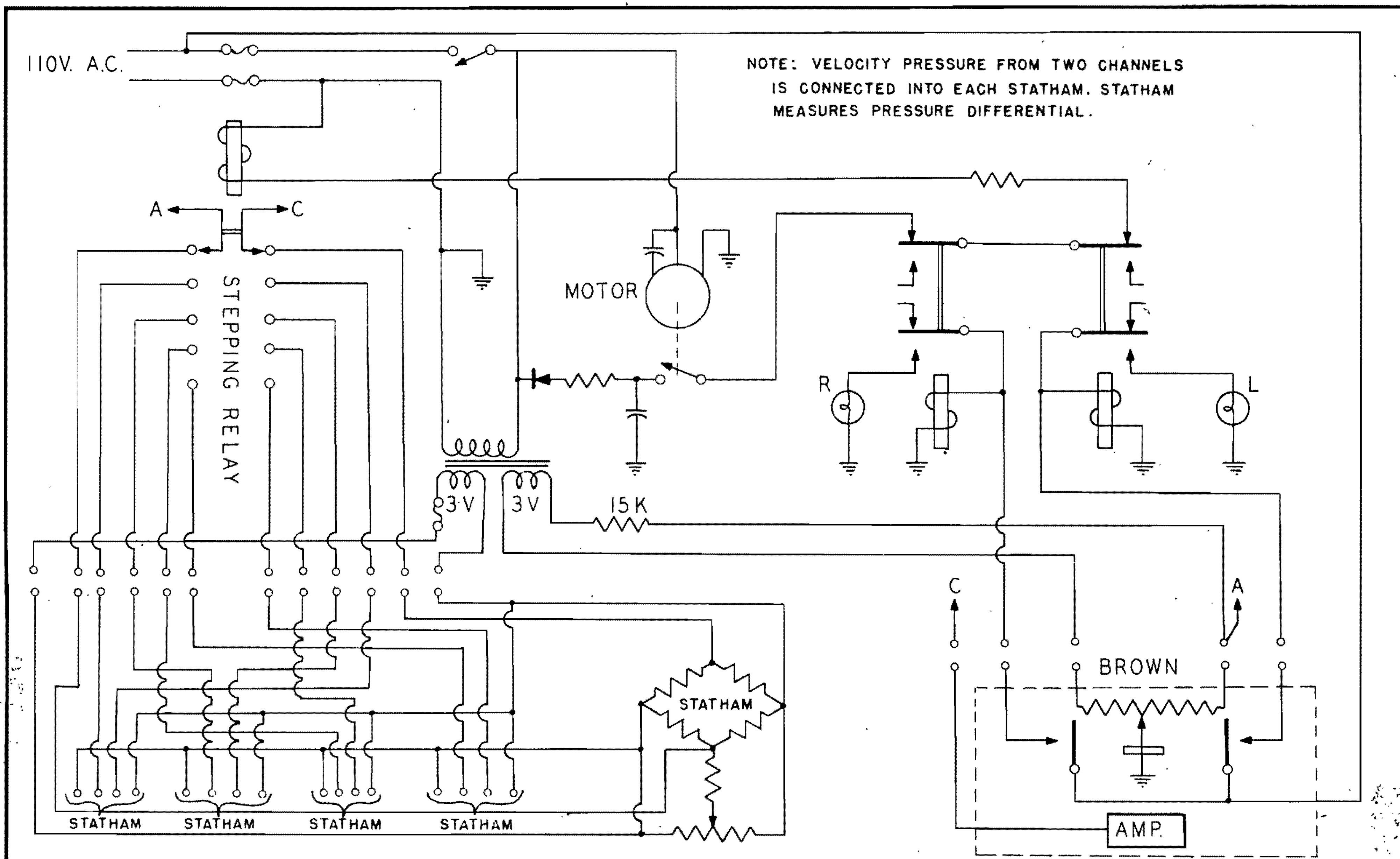
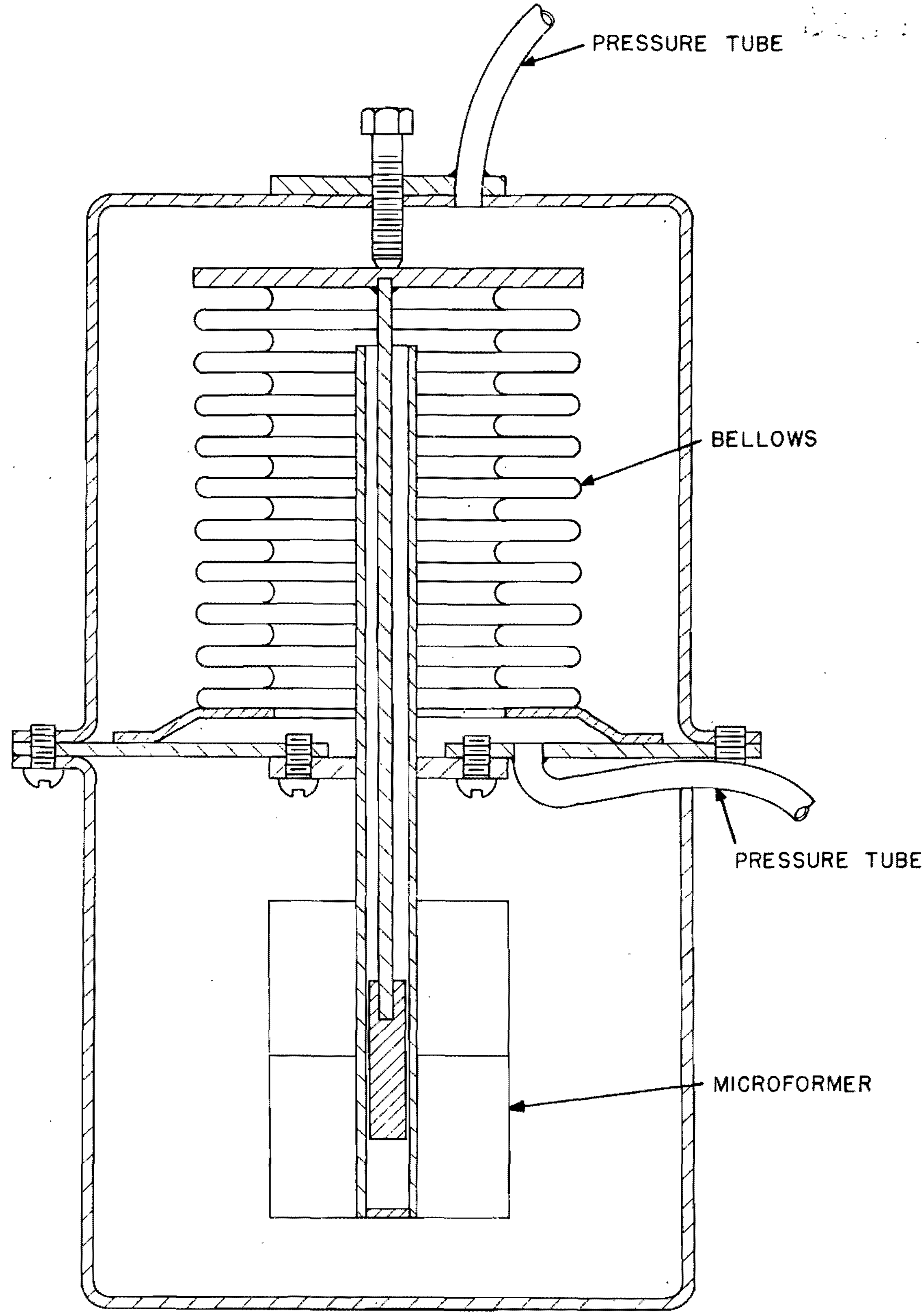
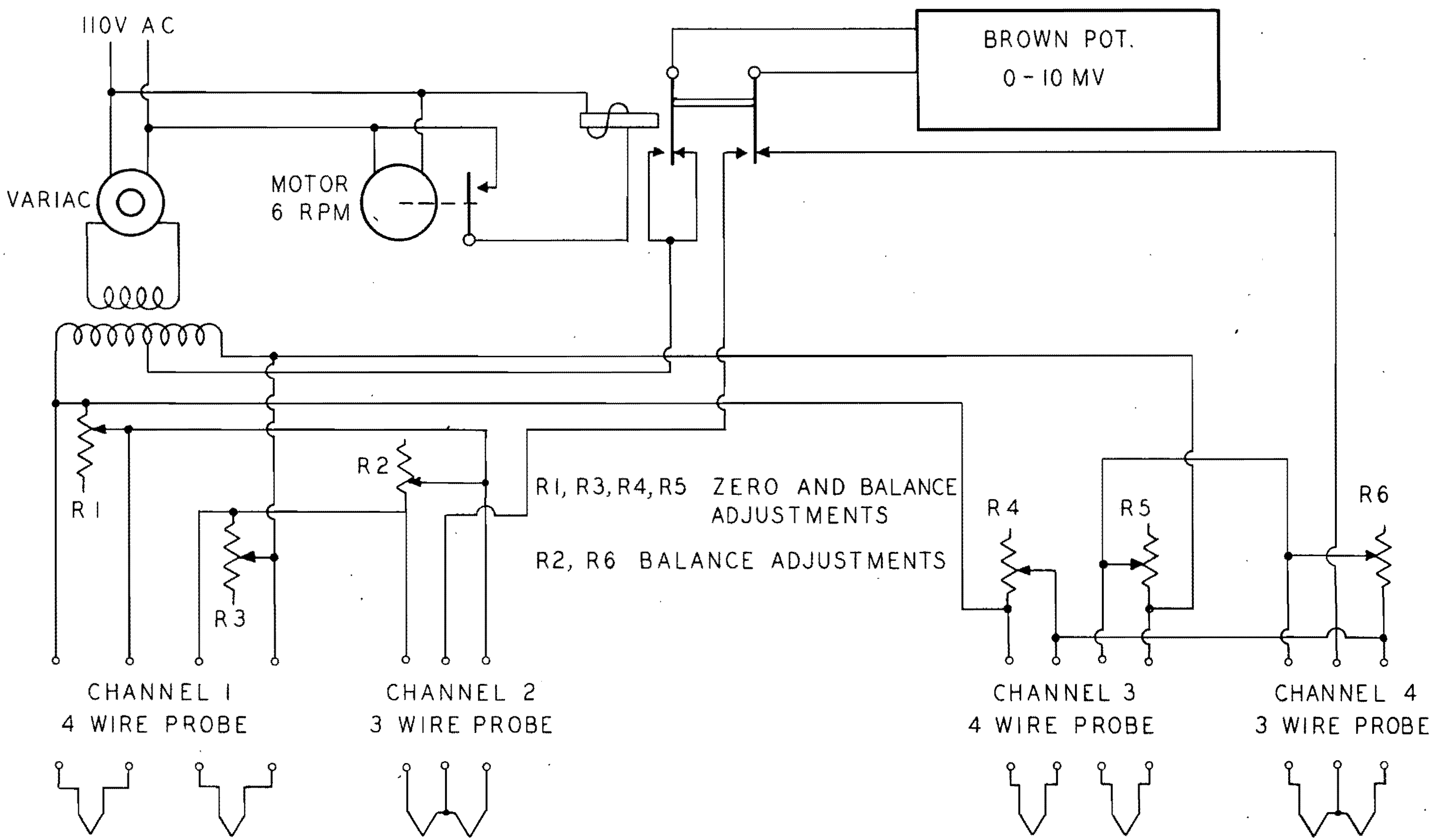


FIG 4 TEN CHANNEL SCANNING SYSTEM USING STATHAM D.P. TRANSMITTERS



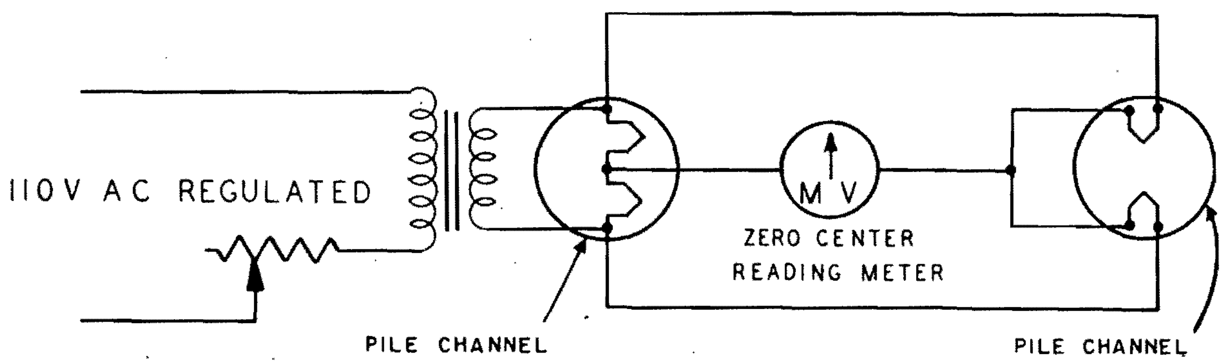
DIFFERENTIAL PRESSURE ELEMENT
WITH MICROFORMER OUTPUT

FIG 5



FOUR CHANNEL SCANNING SYSTEM
USING SERIES CONNECTED HASTINGS PROBES

FIG 6



PARALLEL CONNECTED PROBES
TO GIVE DIFFERENTIAL READING

FIG 7