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A COMPARATOR FOR THE ACCURATE MEASUREMENT OF DIFFERENTIAL BAROMETRIC PRESSURE

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A COMPARATOR FOR THE ACCURATE MEASUREMENT OF DIFFERENTIAL BAROMETRIC PRESSURE

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Summary: In attempting to improve Barometric Heighting it is necessary to determine the errors in the field instruments used. The design and manufacture of a reliable relative standard for calibration is described here. It is a mercury barometer of the Fortin Type in which, to give necessary precision, electronic contacts have been used.

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Introduction

For an investigation of methods of improving Barometric Heighting, a reliable standard is required to determine the errors in the field instruments. The normal mercurial barometer is usually supplied with a vernier graduated to one hundredth of an inch. This corresponds to a difference in elevation of some ten feet and is obviously too large for a standard instrument. The scales may be graduated finer but, since the normal method of reading involves two optical settings, another system of reading is preferred.

The use of an electronic indicating system[1] affords the necessary accuracy but necessitates several important modifications to the normal mercury barometer. In the normal Fortin barometer the mercury level is raised to a fixed index in the cistern, and the reading is made by setting a slide coincident with the top surface.

Requirements of Electronic Contacts

The use of electronic contacts for the upper level rules out the possibility of movement as the Torrecellian Vacuum must be preserved. Therefore the use of a fixed contact (or several of them) in the upper tube is imperative. The actual readings may then be made by the use of a moveable contact or micrometer on the lower level (see Figure 1).

The indicating circuits will indicate contact to at least $\pm 1 \times 10^{-5}$ inch [2] and so the selection of the lower micrometer is largely a matter of choice. In any event this micrometer will have a range of one inch or thereabouts and thus a number of fixed contacts must be placed for the upper surfact at intervals of approximately 90% of the micrometer range to allow calibration.

Construction Details

The Barometric-Comparator currently developed to calibrate Surveying Aneroids at the Department of Surveying, in the University of New South Wales, was designed to operate in the range of 550-850 mms. of mercury pressure. Thus the instrument incorporates its own pressure chamber which may be coupled to auxillary chambers containing the aneroid barometers. To facilitate the readings two servo motors have been fitted - controlled by the contact indicators - to drive the main piston and the micrometer.

During the actual construction, a number of problems were encountered which may be of interest.

1. The fixed contacts consist of platinum wires sharpened to needle points and set in the soda glass tube. Platinum wire was used as it has the same coefficient of thermal expansion as soda glass. Difficulty was experienced in obtaining a perfect seal and so the upper tube complete with contacts was cast in a solid block of Shell Epicote Resin. The glass tube has an inside diameter of half an inch to avoid meniscus problems.

2. The lower contact consists of a stainless steel shaft fixed to the micrometer spindle and machined to a fine radius point.

3. To reduce temperature effects, the measuring system was isolated from the general construction. The glass tube is held fixed about the middle of the fixed contact range and the micrometer independently attached by a mild-steel rod to the same support. The temperature of the instrument is measured by a thermometer immersed in mercury in the main cylinder. Nomograms have been prepared for temperature corrections for each fixed contact.

4. Raising the mercury to the fixed contact was achieved quickly, yet accurately, by using a large piston acting on a 26 t.p.i. thread and a much smaller concentric piston acting on a 40 t.p.i. thread. To eliminate surge or bounce, a choke was fitted in the lower end of the glass tube.

5. To reduce the number of pressure tight glands required to permit external manipulation, the pressure chamber was limited to the upper portion of the comparator as indicated schematically in Figure 2. This necessitated the use of double-acting pistons to prevent the seal being broken through the cylinder and also required special calibration techniques.

6. Since mercury reacts chemically with most metals, glass, stainless steel, platinum and a special neoprene were used throughout.

   The contact indicator circuit used is given in figure 3 and has proved satisfactory. Using a micrometer graduated to one ten thousandth of an inch the standard deviation of pressure readings including the manual setting of the mercury surface against the fixed contacts, has been found to be less than 1×10^{-4} inch.

7. Servo Motors have been fitted to reduce the labour of moving from one contact to another. These motors are controlled by the Contact Indicator Circuit (see figure 4) and hunt the selected contact and the Micrometer Reading automatically. Coarse readings may be taken whilst the motors are hunting and have been found to be accurate to

within $\pm 5 \times 10^{-4}$ inch. For fine readings, the motors are switched off and the final adjustment made manually. An automatic switching circuit has been incorporated which switches off the main cylinder motor immediately on contact between the selected fixed contact and the mercury surface at the upper level. The micrometer motor meanwhile hunts the lower level. The next contact of the micrometer spindle, after switching off the main cylinder motor, actuates the relay to switch off the micrometer motor. With the rheostats adjusted to give the lowest possible speeds, fine readings can be taken directly from the micrometer as soon as both the motors have been switched off. A series of tests were taken to determine the accuracy of reading made in this manner and the standard deviation of the readings found to be 2×10^{-4} inch. This is within the specifications of the present calibration tests and all future readings will be made in this way.

This type of barometer fitted with servo motors to operate the controls would permit the pressure to be displayed in a digital readout. Conversely a simple modification would give a control unit to maintain pressure at any selected level within very fine limits.

It should be stressed that the readings obtained from this comparator must of necessity be relative or differential readings only, although provided that a standard which is calibrated to the required accuracy could be obtained and read against the comparator the small index error could easily be determined and the readings made absolute.

The comparator was designed to determine the magnitude of a number of sources of error in the conventional surveying aneroid. These include,

1) Drift of the Index over short and long periods
2) Calibration Errors
3) Frictional Errors
4) Hysteresis
5) The effects of normal field handling on the instrument

An article in The Australian Journal of Applied Science by E.R. Harrison (2) gives an application of the use of contact indicators to measure the level of mercury surfaces. The present comparator has been independently developed and overcomes a number of weaknesses in the method proposed by Mr. Harrison in addition to applying the method to the direct measurement of atmospheric pressure.

Acknowledgements

1) Mr. T. McCartney of the Civil Engineering workshop whose advice and technical skill lead to many improvements on the original design.

2) Mr. H.W. Lewis of Pongrass Pty. Ltd. who kindly donated the necessary pressure hoses, switches and fittings.

References

1) B. Mills - A sensitive Contact Indicator, Review of Scientific Instruments 1941, 12, 105.

2) E.R. Harrison - A Mercury Surface Height Indicator, Australian Journal of Applied Science, 1960, II, 1, 198.

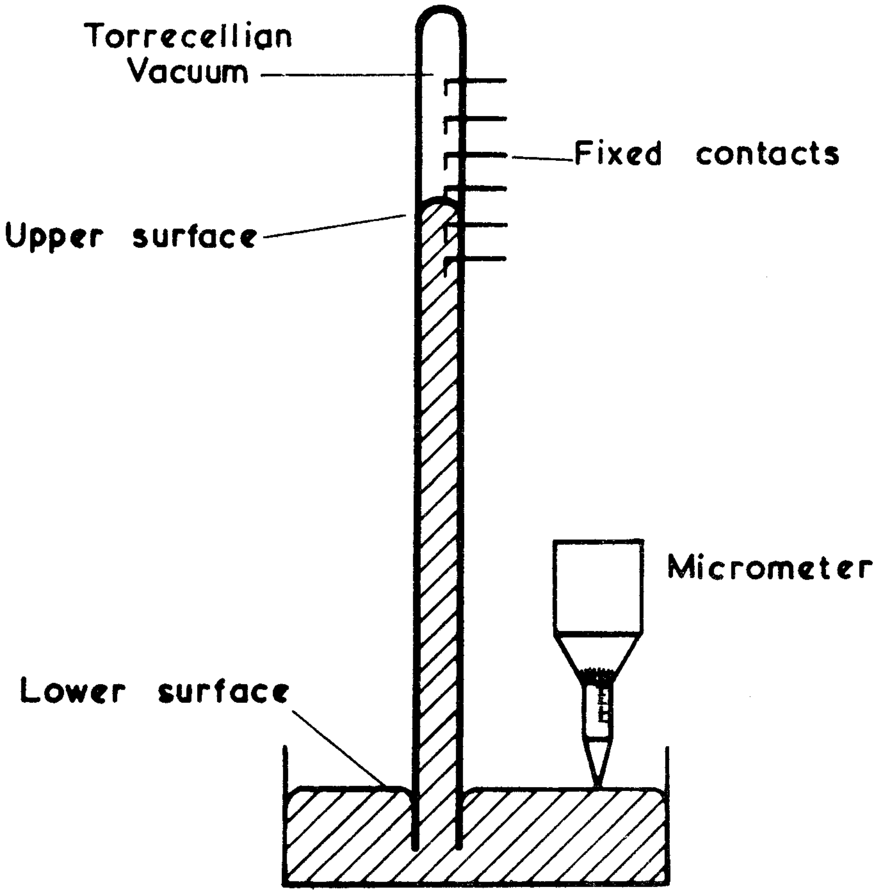
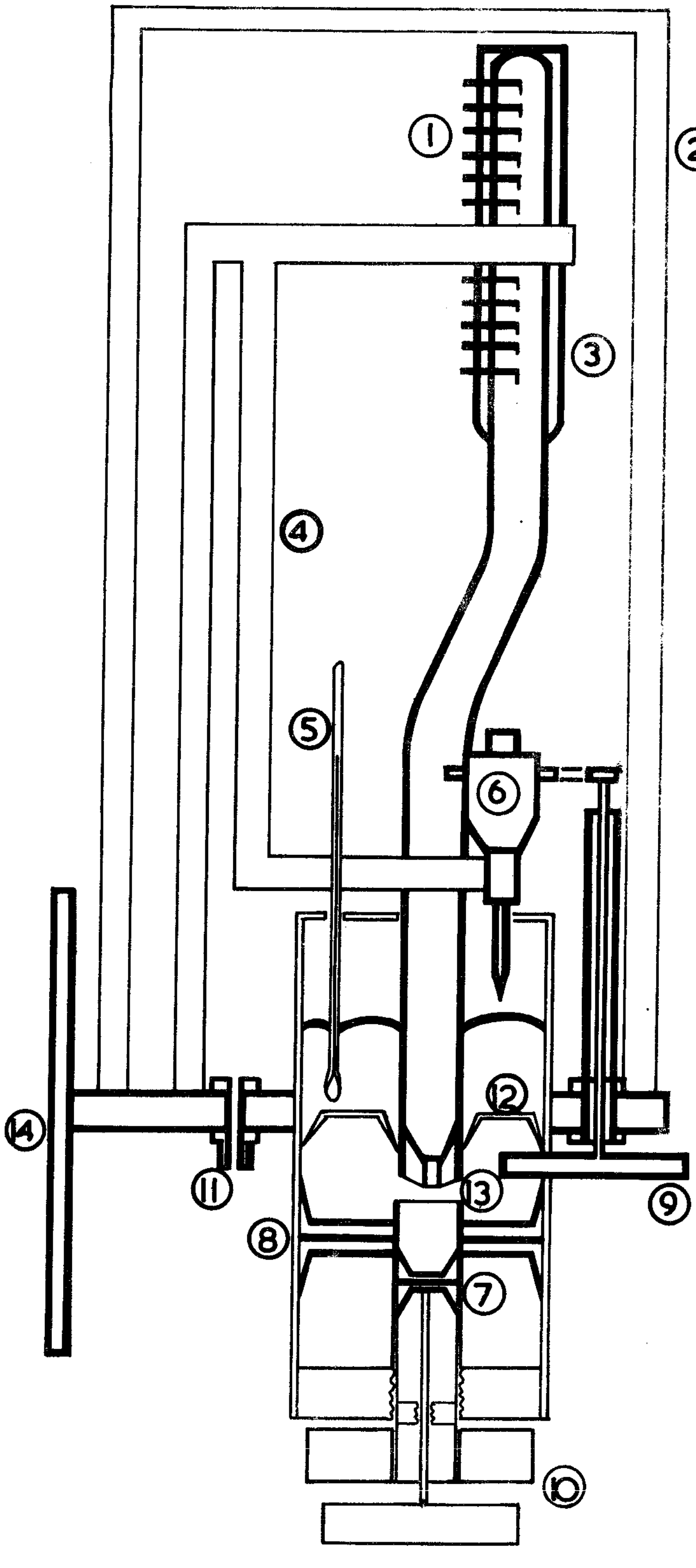


Figure 1. SCHEMATIC DIAGRAM SHOWING BASIC DESIGN.



1. Upper contacts.
2. Pressure chamber.
3. Shell Epicote Resin casting.
4. Independant micrometer mounting.
5. Thermometer.
6. Micrometer.
7. Fine adjustment piston
8. Coarse adjustment piston.
9. Micrometer control.
10. Piston control.
11. Pressure inlet.
12. Sludge trap.
13. Choke.
14. Wall mounting bracket.

Figure. 2. SCHEMATIC DESIGN OF THE BAROMETRIC COMPARATOR.

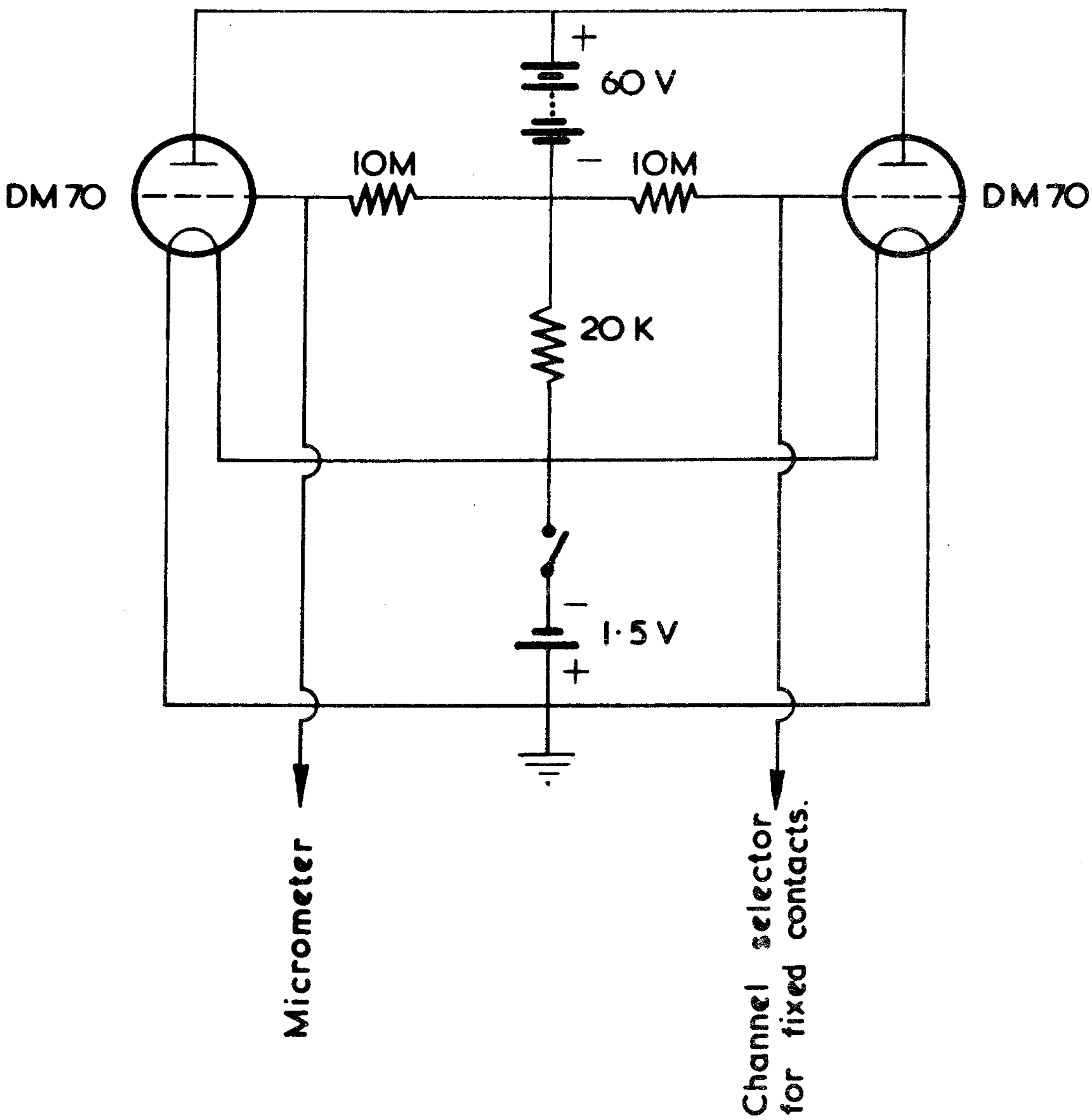


Figure 3. CONTACT INDICATOR CIRCUIT.

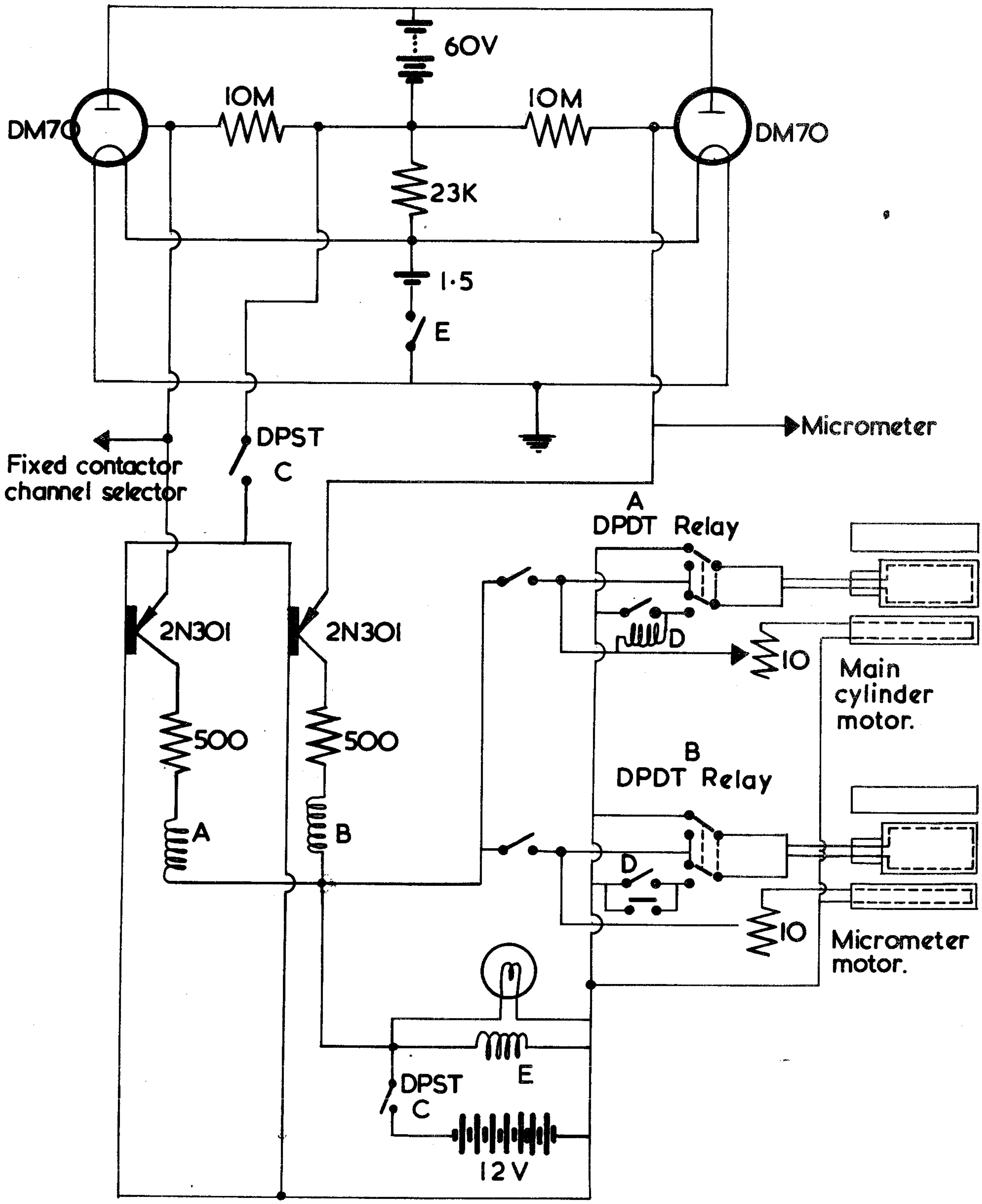


Figure 4. CIRCUIT DIAGRAM OF SERVO CONTROL.