and its use; to that data Mr. Bilton had added the results of more than a year's continuous research work.

Mr. H. J. I. BILTON read his paper, illustrating it by lantern slides of his diagrams appearing in the present issue, together with others recording the results obtained by other investigators. Actual examples of apparatus were also on view.

The President said that the hour was late, therefore there could be no present discussion on either the preceding or present paper. He was struck with the immense amount of careful, painstaking labour which Mr. Bilton had put into his work. Remembering that each station dot on the numerous diagrams represented an experiment and a reduction, they could recognise how fully the author's leisure must have been occupied. He moved a hearty vote of thanks to Mr. Bilton for his paper and demonstration.

The vote was carried by acclamation.

Mr. H. J. I. BILTON, in responding said it gave him much pleasure to investigate these matters. He was never so happy as when so employed.

At 10.35 p.m. the meeting terminated.

PAPERS.

A SIMPLE, SENSITIVE, TWO-LIQUID DIFFERENTIAL GAUGE FOR MEASURING SMALL PRESSURES.

By Jas. Alex. Smith

(President).

INTRODUCTION: In the progress of engineering the differentiation of small component pressures, or velocities, has become of marked importance, especially as a means of analysing fluid flow, not only in the laboratory, but in general practice also.

The quantities usually dealt with are small, yet the methods of isolating them are effectively simple and reliable; the limit lies not in the difficulty of isolation, but is imposed by the imperfections of the gauge.

There are many types of gauge; few applicable to the end in view; it must be remembered that not only small, differing pressures, but small differences in considerable pressures are in question. The most successful types are designed on the differential principle; that to be described is of that type, and may prove of some interest to those requiring to solve problems relating to small static or velocity heads.

DEFINITIONS: By differential is meant, not the direct comparison of the indications of one liquid under differing conditions, i.e., two columns of the same liquid under differing pressures, but de-
terminations attained by the use of two distinct fluids in the same
gauge.

By *sensitive* is meant definite response to pressures, of
the order of the one-twenty-thousandth of one pound (0.0005 lb.)
per square inch, and the less positive detection of smaller quan-
tities.

By *small* pressures are meant those pressures usually ex-
pressed in terms of "inches of water," and varying from zero
to 1½ to 3 inches on that scale, or similar values existing between
differing pressures of considerable magnitude.

**GAUGES GENERALLY:** Briefly, gauges usually either magnify
mechanically the effect of a pressure acting through a small
space, or they optically magnify the equivalent of a barometric
column variation.

The writer is unaware of any instrument of the first kind
of sufficient delicacy and simplicity to serve in the present con-
nection. Very easily continuously moving meters there are
which build up inconsiderable effects into observable totals, but
their use is strictly limited; they require flows of relatively large
section, they do not compare differing flows positively. In com-
mon with other mechanical gauges, whilst capable of excellent
work in certain fields, they are intermediaries between the test
to be made and a standard of known accuracy; they are not
standards *per se*. The corrections at low velocities may be a
large proportion of the qualities to be measured, and the con-
stancy of frictional resistance and adjustment must necessarily be
open to doubt.

Instruments of the barometric type are truly 'self-standards';
with them some of the most refined investigations in the science
of engineering have been accomplished. But, with a single fluid,
the readings are frequently too minute to be discerned except by
the cathetometer, microscope, and other laboratory refinements.

A barometric gauge, a fluid about one twentieth the specific
gravity of water, free from fluid friction and viscosity,
would be the ideal. No such fluid exists; but the low density
characteristic can be approximated to any desired degree by
selecting two fluids, immiscible, and slightly differing in specific
gravity, and so employing them that the unbalanced difference,
not the total of their weights, is the operative factor. In regard
to fluid friction and viscosity: these act, not to vitiate ultimate
accuracy, but to defer the time of attainment of that accuracy.

**THE INSTRUMENT** is of the two-fluid type, and consists of few
and simple parts—an inverted glass syphon, a cistern at-
tached to each limb, each with a pressure connection, a pair of
indices and a simple pendant supporting board.

**The Syphon** should not, for manipulative reasons, much
exceed ¼, or be less than ½ inch bore. If smaller, motion is
sluggish and the fluid column is apt to break. If larger, and
if the liquids are nearly equal in S.G., the junction of the common
surface is liable to become non-symmetrical in form and indeter-
Differential Gauge for Small Pressures.

Differential Gauge for Small Pressures.

Minute in position. The length may be about thirty times the
range for a similar pressure on the water gauge. If short tubes
are used for small pressures, the rapidity of attaining equilibrium
is accentuated. With tubes 12 inches long and \( \frac{1}{4} \) inch bore
inertia effects are scarcely perceptible, and readings can be taken
immediately. When the tubes are about 4 feet by \( \frac{3}{4} \) inch bore,
possibly a minute must be allowed for the surface to reach its
true position.

Two-Fluid Differential Gauge.

Scale—\( \frac{1}{2} \) full size.
Magnification—10" = \( \frac{3}{4} \) " water.

C, C—Cisterns: area = 25 square centimetres each.
P, P—Pressure connections: (plus pressure on right).
V, V—Valves: (oil in right-hand limb).
S—Syphon.
I, I—Indices.
Short syphons are best made of stout barometer tube bent in the blow pipe flame, the cut ends also being surface fused by the same means. The bend should be well annealed. If these precautions are neglected there is liability to spontaneous fracture at a subsequent, and perhaps distant, date.

For long gauges two parallel tubes joined at the bottom by a thick-walled rubber tube may be used. The bore throughout—in glass and rubber—is best if uniform. The attachment to the cisterns is by rubber tube sleeves, or stuffing boxes, according to pressure; valves at these points render the gauges portable.

_Cisterns:_ The arbitrary ratio of 100 to 1 as compared with tube area has been found the most generally suitable. Calibration is facilitated if the area is a non-fractional multiple of the square inch or of the centimetre. The depth may be about 2 in.

_Fluids:_ After considering many, kerosene and spirits of wine tinged with an aniline colour (any 'spirit' dye soluble in spirits, insoluble in oil, will answer) have been selected. They are sensibly immiscible, mobile, do not freeze at temperatures far below 0 degrees F., and are universally obtainable. The S.G. of the kerosene is about 0.820 to 0.830; that of the spirits may be made to approximate as closely to those figures as desired by the addition of water.* It is advisable that the diluted spirits should be heavier than the oil. If the S.G. difference is less than one-twentieth, sensitiveness will continue to increase, but difficulties will also be increased unduly. If methylated spirit is used it should be free from petrohs soluble in kerosene. If there be doubt the two liquids may be kept in the same bottle in order that complete solution shall ensue before use. The liquids can be drawn off by pipettes when required.

If vapour tension is a consideration connection of the sources affected should be confined, if possible, to the oil cistern only, and the spirit or water surface may be sealed by a thick layer of oil.

_Indices and Scales:_ Thin metal spring sleeves, sliding on the tubes, widely split and with a projecting point to mark the levels, answer well. They are adjusted to the initial and final reading, and the separation read by detached scales graduated in inches, centimetres, pounds per square inch, inches of water, or the velocities commensurate with the velocity head of any particular fluid, in order that the readings may be direct.

_Pressure Connections_ may be direct if gases are in question. If liquids are being dealt with, the intermediary medium must be a gas. It is frequently possible, either in the case of constrained or free flow of liquids, to arrange that the liquid entering an intermediate vessel shall expel a portion of the air thence to the gauge, thus communicating the pressure. There must, of course, be no interference with the true pressure by rise

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* The use of water instead of diluted spirit limits the magnification to about 6. When that degree of magnification suffices, and there is no question of freezing, the use of coloured water is advised.
of level in these vessels. Care must be observed, when differences of large pressures are being determined, to admit the pressures simultaneously to the two cisterns.

Adjustments: Pour the spirit into one cistern until both limbs of the syphon are nearly full. Pour kerosene into the other cistern, and continue adding spirits and oil alternately until there is not less than ½ inch of liquid in the cisterns, and the common surface is in a convenient position. Adjust the index to that position—which is zero—and the instrument is ready for use.

Principle of Action: Image columns of spirits and oil of equal sections supported at the opposite extremities of a balance. They will equilibrate when the heights are inversely proportional to the S.Gs. That is the condition of the apparatus when adjusted. If a weight be added to one of the columns—say, to the heavier spirit column—equilibrium will be disturbed; it may be restored by a displacement to a position of lesser availability (i.e., by horizontal spread at cistern surface level) of a portion of the oil displaced by transfer of an equal volume of spirits to the oil side of the balance. That is what occurs when the external pressure ceases to be equal upon the fluid of both cisterns.

It will be noted that a lighter volume is displaced by a heavier volume, therefore the displacement is measured by the whole exchange volume, but the weight change is measured by the difference only of the weights of the displacing and displaced volumes.

By constricting the intermediary channel the whole volume passing is displayed or the motion can be magnified* within certain limits. That is the function of the tubes and cisterns.

Calibration: The instrument was designed to permit facile calibration rigidly accurate in principle.

It is immaterial whether the equilibrium be disturbed by an imponderable force, a solid piston or a liquid weight. If, therefore, to one of the cisterns there be added a height of the liquid in use in that particular cistern, equal to a definite height of water, then the motion of the common surface of the fluids, due to that addition, is the magnified gauge scale reading of that equivalent added height. The fact that the cisterns are even inches, or centimetres, in area, permits the added height to be readily determined by adding a known volume of liquid from a graduate or pipette.

Obviously the S.G. of at least one of the fluids used must be known. If water is used the S.G. is known to be unity. If water is not used, the S.Gs. may be determined by hydrometer, or simply in the syphon itself, thus:—About half fill both limbs of the syphon with coloured water. Pour kerosene upon one

* The maximum magnification when the cistern area is indefinitely great in relation to the tube area may be expressed, thus:—

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magnification = \frac{(S.G. \ of \ Spirits)}{(S.G. \ of \ Spirits) - (S.G. \ of \ Kerosene)}.
\]
surface of the water until that limb is almost full. Measure the respective heights of the columns of water and of oil above the level of the common surface. Call the water height \( r \), then the kerosene height expressed as a decimal of the water height is the oil S.G.

**APPLICATIONS:** The determination of the small static pressures found in air and gas ducts, in chimneys and flues, in ventilation, and in meteorological work, is obvious. The pressure, or pressure difference of liquids can be equally approached in the manner already indicated.

Perhaps the gauge finds its most special use when employed in the measurement of those differences of pressure which indicate flow either in closed ducts or open channels. The local differences which exist in every flow can be measured either in cross or longitudinal section, and the lines of equi-pressure or equi-velocity can be plotted. The losses, for instance, due to friction in a few feet of length can be clearly picked out, and the degree to which the flow conforms to undisturbed stream line flow, or deviates from it can be clearly shown. Low velocity air flows can be determined, probably, more accurately thus than by any means other than actual measurement of cubic volume.

The means of differentiation is extremely simple—the insertion of two tubes, which may be as small as desired, into the flow. One tube is exposed to the multidirectional tendency of the flow, but is shielded from the unidirectional component due to the lines of flow. The second tube is placed with its axis coincident with the stream direction, and its aperture facing the current. The first tube transmits static, the second static plus velocity pressure. The gauge receives both impulsions, balances the static pressures against each other, and records the differences, i.e., the pressure equivalent of the flow.

The differentiation is wonderfully delicate, for example.—It is easy to read a gauge to one-fourtieth of an inch; the gauge magnifies, say, twenty times; therefore, the reading represents a water head of one-eight-hundredth of one inch; this in turn corresponds to the pressure on its base of a column of air only about one inch high. These heights connote velocities of about two feet per second for air, and about an inch per second for water. These minute quantities are not mere abstractions; they require to be measured, and are measurable in practice.

Connected through tubes as minute as possible to closed receivers as large as possible, the instrument constitutes an extremely delicate differential gas thermometer. It eliminates the difficulty of the non-existence of a single fluid of sufficiently low specific gravity to permit open scale readings of the pressure of a vertical column, the only barometric method not open to question. By the use of the differential gauge a scale on which 1 degree F. equals 15 inches, or more, is attainable.

Many other uses will doubtless present themselves to those
interested in the subject, and to whom the ordinary water gauge fails to offer a means adequate to their requirements.

The Author illustrated the paper by actual instruments; one with a 12 inch, one with a 4 feet, and one with a 6 inch syphon. The latter instrument was designed to give continuous records by photography, the non-actinically coloured spirit intercepting the light in its course to a band of sensitive paper wound around a clock-driven drum enclosed in a dark chamber.

The methods of determining specific gravities and calibrating the instrument were demonstrated.

The use of the apparatus was shown in various ways. Amongst other methods a glass tube 18 inches long, open at both ends, was inverted over an open but unlit gas burner, then connected to the gauges. The ascensional pressure of the cold gas in the tube depressed the gauge about \( \frac{1}{8} \) of one inch.

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PITOT TUBES, AND THEIR USE IN MEASURING THE VELOCITIES OF WATER, GAS AND AIR.

By H. J. I. Bilton.

(Member of the Council).

Although the use of the Pitot tube is not unknown in Victoria, it has come to play such an important part in modern hydraulics, that it is advisable to preface this paper with a description of its history and purpose, after first giving a list of the abbreviations and terms used.

NOMENCLATURE.

A = Sectional area of pipe in square feet.
B.W.I. = Black wrought iron (commercial pipe).
C = Coefficient.
C.F.M. = Cub. feet per minute.
Comptd. V = Velocity as computed by a formula applicable to the nature of the pipe.
D = Diameter of pipe in feet.
d = Diameter of pipe in inches.
Dgm. = Diagram.
e or effec. = effective.
eq. or equiv. = equivalent.
g = acceleration due to gravity = 32.2 ft. per sec.
G.W.I. = Galvanised wrought iron (commercial pipe).
H = Head of water in feet (used in a general sense).
Hn. = Loss of head at entry.
\( \text{H}_{100} \) = Loss of head per 100 ft. length.
Hv. = Velocity head.
Hvc. = Head giving the water its velocity at centre of pipe.
Hf. = Friction head.
ht. = Total head of water in inches.
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