INVESTIGATION OF SOME MINE VENTILATION PROBLEMS.

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Submitted for -

The Degree of Ph.D. of Glasgow University.

August, 1940.

CONTENTS.

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INTRODUCTION.

This Thesis, which comprises investigations of some problems in practical mine ventilation, is mainly concerned with work likely to be undertaken by a ventilation engineer at a mine and is divided into sections as follows:-

1. The Measurement of Cross-sectional Areas of Underground Roadways.

The correct measurement of cross-sectional areas of underground roadways, upon the accuracy of which much of the value of the subsequent calculations of air-flow in mines depends, presents great difficulty where the cross-sections are irregular. A study was made of this problem. Some new instruments and methods of measuring irregular cross-sections were devised and are described and tested.

In particular, a method of determining areas by photography was developed and tested and, as far as the author is aware, this is the first application of photography in mines to this problem.

2. Measurement of Air Velocities by Smoke and Smell Tests.

Low air speeds are sometimes measured with the aid of smoke or smelling agents. The accuracy of such methods is often seriously questioned.
A series of tests is described comparing the results obtained by smoke and smell with those of a delicate low-reading anemometer.

3. Atkinson's Coefficient of Resistance for Underground Airways.

Very few values of Atkinson's coefficient of resistance are available for airways with modern linings such as steel arching, cambered arching, and arching with concrete or brick filling. The results of some determinations made in mines are given.

4. An Electrical Pressure Gauge.

The introduction of ventilation surveying in mines has raised the problem of devising a simple, reliable and readily portable instrument for the measurement of pressure drops in an air stream. Such pressure drops require to be measured between points within the stream and cannot be referred to a common atmosphere as with air ducts on the surface. An attempt was made to evolve a pressure gauge based on electrical principles.

5. Effect of Downstream Obstruction on Anemometer Readings.

During the measurement of air velocities in mine airways it is often impossible for the observer to stand clear of the stream. Results are given of tests made to determine how far downstream of a measuring instrument the observer would require to stand to avoid disturbing the velocity distribution at the measuring section.

6. Pressure Losses in Fan Drifts.

Results are given of tests carried out for pressure losses in badly designed fan drifts. The results show surprising losses and indicate that probably many fan drifts are consuming a disproportionate part of the ventilating power.

7. Rearrangement of the Ventilation of a Colliery.

The ventilation survey work connected with the rearrangement of the ventilation of a colliery is given. a new surface mine was proposed to meet further development and increased ventilation requirements and the question arose whether the mine should be a downcast or an upcast for lowest water-gauge with stipulated air-flow requirements.

8. The Economy of Increasing the Size of an Existing Upcast Shaft.

The question whether the expense of widening an existing upcast shaft would be justified by the saving in ventilating power is investigated. A value for the coefficient of resistance for wood-lined rectangular shafts is determined. Few values for rectangular shafts are available.

9. Air Conditions in a Deep Rand Gold Mine.

Some data relating to air conditions observed in a deep gold mine on the Rand, South Africa, are given. These data relate to dry and wet bulb temperatures, moisture content and total heat as observed on a complete air circuit of the mine.

Some notes are included relating to the incidence of pneumonia among native labour in a Rand gold mine.

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<u>The Measurement of Mine Roadway Cross-sections.</u>

Some new instruments and methods for measuring the cross-sectional areasof irregular underground roadways are described and tested.

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The Measurement of Mine Roadway Areas.

In quantity surveys of mine ventilation the cross sections of roadways require to be measured. These cross sections are often very irregular in periphery and some special methods of measuring are required in order to obtain the necessary accuracy.

The radial arm apparatus is well known and has been applied to some extent. It consists of a fixed protractor mounted on a stand, with a sliding arm pivoted at its centre. The principle of the apparatus is to measure offsets and angles from the centre of the protractor to points on the periphery of the roadway. The cross section can be plotted from the data obtained and the area determined by the use of a planimeter.

Another method used by the Bureau of Mines of U.S.A. applies the pantograph. The pantograph is mounted on the end of a tub or trolley and a section of the roadway is reproduced on paper on the spot.

Some investigations were made to find if a simpler method or if a simple, light and inexpensive instrument could be devised for the measurement of the areas of mine roadways, and the following is an account of some investigations carried out.

(1) /

(1) Fixed Protractor and Steel Tape.

The main difference between this instrument (Fig.I and the radial arm type is the replacement of the arm by a steel tape of type which remains straight when extended. The tape is 72 ins. long and is contained in a case 2 ins. diameter.

The pivot point of the tape was placed so that the centre of the protractor was at the same distance from the end of the tape as the cut-off point (where the tape enters the case) was from the diametrically opposite side of the case. Hence, when the tape was extended until the case was at the side of the roadway, the cut-off point gave a direct reading of the length of the ray.

A further modification was introduced, namely, to have the tape fixed to the protractor so that both rotated round the same central point, the reading from the protractor being obtained from a fixed pointer.

In order to test this instrument, an undistorted steel arch was selected and its area carefully measured and calculated. The results obtained were as follows:-

Calculating the area of the individual triangles obtained by joining the ends of the radial lines by straight lines, the cross section of the arch comes out as 28.3 sq.ft., the true value being 32.45 sq.ft. Thus there is an error of 4.15 sq.ft. or a percentage error of 12.75.

If, however, the radial lines are joined by a smooth curve, the area as obtained by planimeter is 32.1 sq.ft. giving a percentage error of 1.08.

Time Required:-

Measuring	.... 7 mins.	14 secs.
Plotting	........12 "	0 "
Total	........19 "	14 "

Advantages./

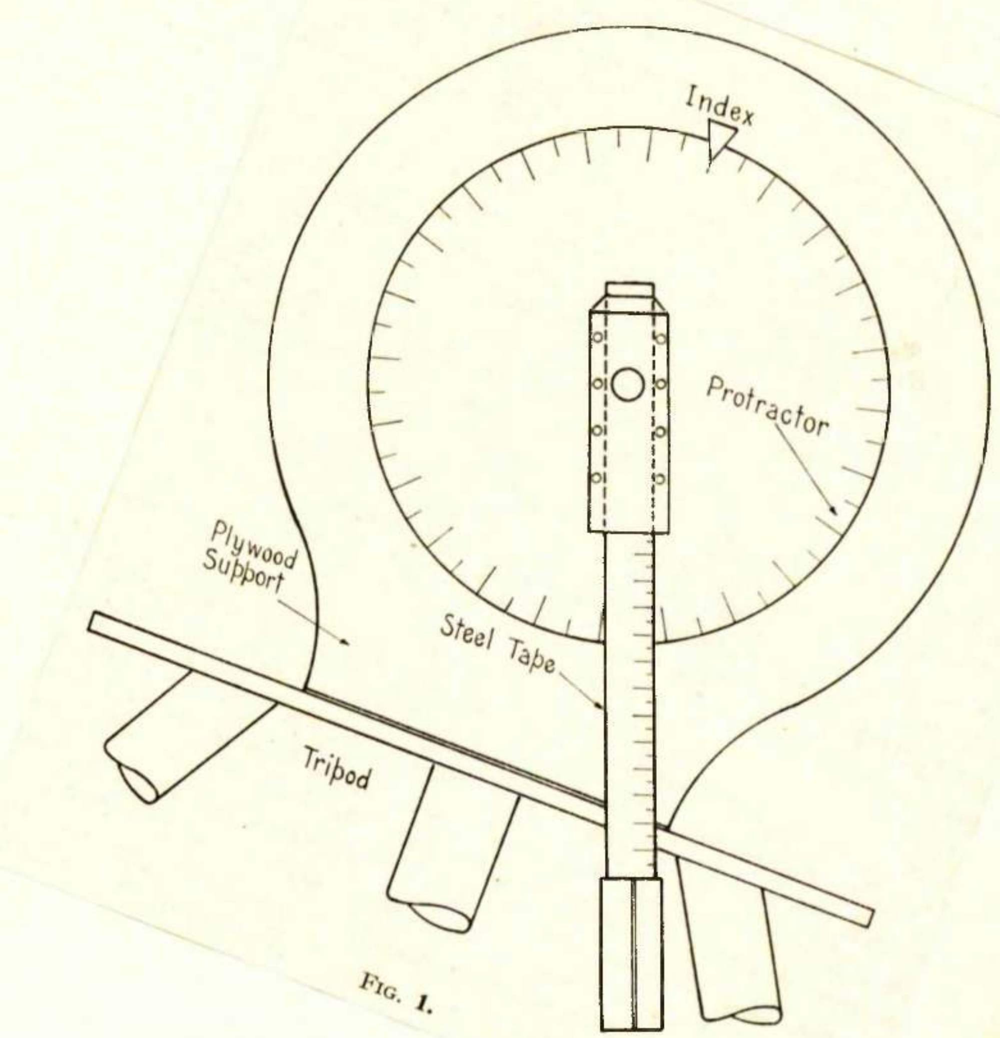

FIG. 1.

Advantages:-

(a) It is more compact, as the tape inside its case (2" dia.) occupies less space than a rigid arm.

(b) The weight of the tape is much less than the weight of a rigid arm.

(c) The instrument may be designed for sitting on the floor thus avoiding the use of a tripod.

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(2) Bowden Cable with Steel Tape.

In taking areas with the instrument described above, difficulty is experienced in reading the angles of a fairly large roadway unless an assistant is available. In order that the instrument might be used by one observer, it was redesigned to incorporate a device for marking the angles. The modified instrument is shown in Fig.2 A horizontal shaft is added, to one end of which is fixed the tape. On the other end of the shaft there is a lever system having a Bowden cable fixed at one end of the lever and a pencil at the other end.

As the shaft rotates, it carries both tape and lever system round with it. When the cable is depressed the pencil point is pushed firmly against a sheet of paper on a board so fitted to have its plane parallel with the plane of rotation of the tape. To ensure orientation of the paper for plotting purposes, pin points are fitted on the board to prick the paper.

When using the instrument, the steel tape is extended to any desired point round the roadway section; this automatically sets the pencil at the angle of the tape. The radial length is noted and at the same time the cable lever is depressed to mark the angle.

In /

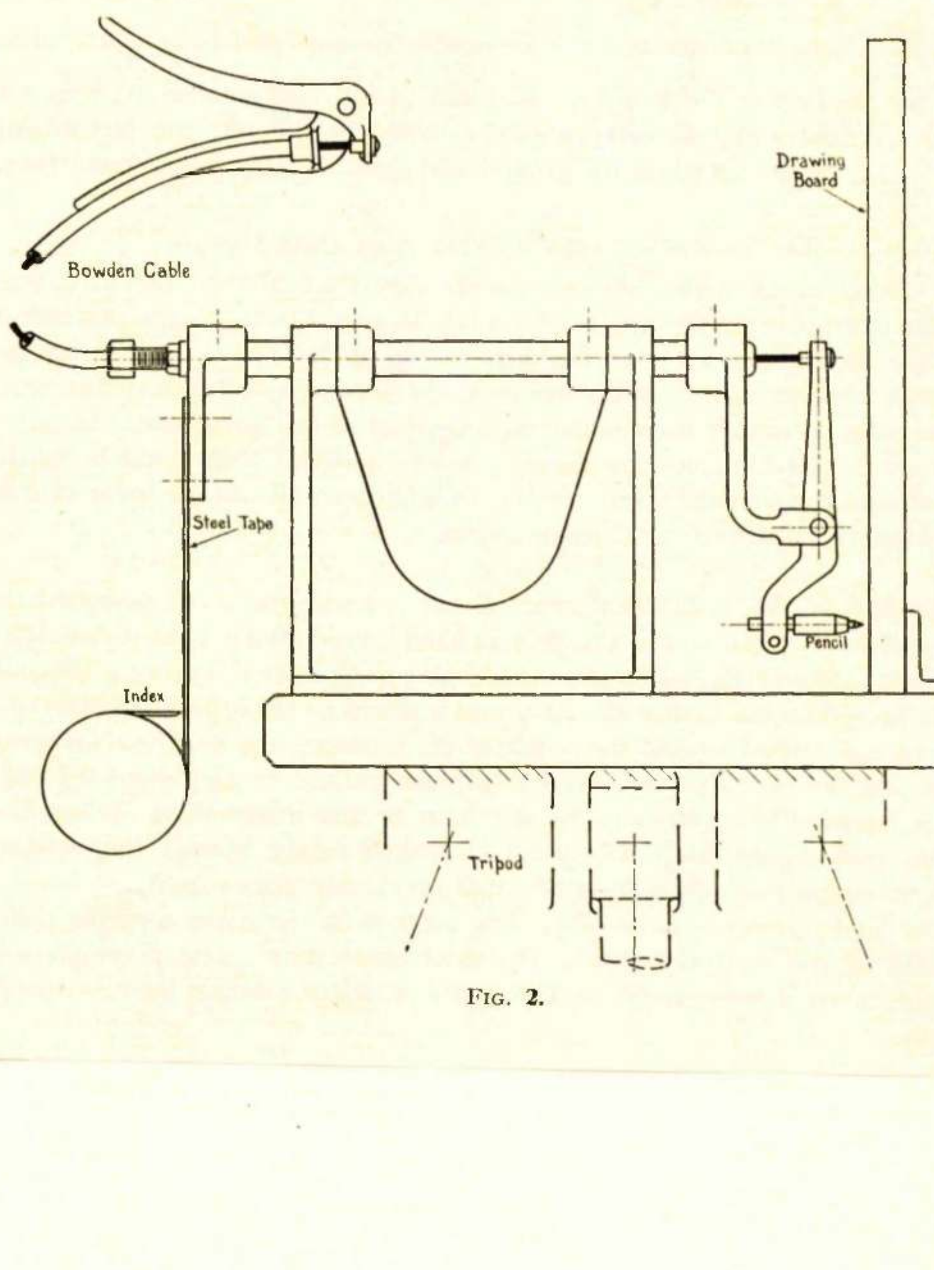

FIG. 2.

In order to speed up drawing operations, a board was constructed with a pointed spindle, 1/32" diameter, inserted at the centre of the board. A scale had a steel strip fitted to one end with a small hole bored to pass over the spindle. The paper, marked with the pencil points when taking an area, was placed on the board with the scale on top. The radial lengths can then be rapidly scaled off at the proper angles.

On test this instrument gave an area of 33 sq.ft. against a correct area of 32.45 sq.ft., the error being 1.69%.

Time Required:

Measuring	....	3	mins	44	secs.
Plotting	....	2	"	59	"
Total	....	6	"	43	"

Advantages:

(a) The time required to obtain a set of results is about one-third of that required with the previous instrument.

(b) The section of a large roadway can be easily taken by one person.

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(3) The Pantograph.

A pantograph in the form illustrated by Fig.3. was tried out. The instrument was constructed as a lattice of steel strips. A pencil point placed at the end of the first link gave a scale reduction of 5/1 in a five-link lattice, and 10/1 in a ten-link lattice.

One end of the trellis rotated round a shaft fixed on a vertical drawing board while the other end acted as the tracing point which was taken round the periphery of the roadway. The pencil point thus traced out the section to a reduced scale

On /

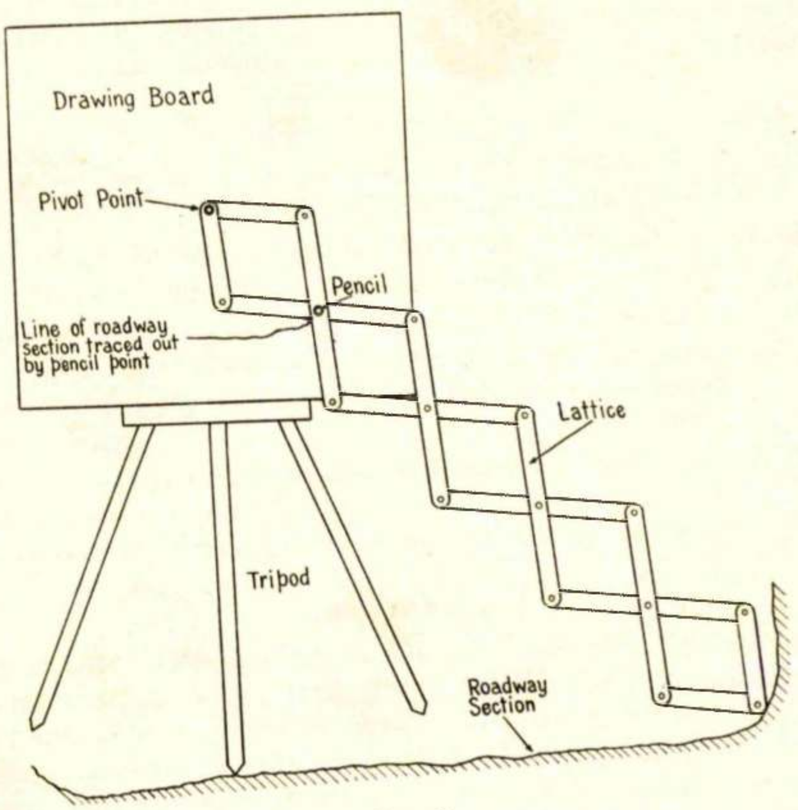
Drawing Board
Pivot Point
Pencil
Line of roadway section traced out by pencil point
Lattice
Tripod
Roadway Section

FIG. 3.

On test this instrument gave an area of 32.2 sq.ft. against the estimated correct area of 32.45 sq.ft., thus showing an error of 0.77% in area.

Time Required.

Tracing out section	....	0 mins.	54 secs.
Area by planimeter	....	1 min.	0 "
Total	....	1 "	54 "

The main advantages of the method are that the accuracy is fairly high and the time required is short. A fairly large board is required to support the paper unless a large scale reduction is adopted.

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(4) Direct Measurement by Planimeter.

An attempt was made to apply the planimeter to direct measurement of areas on the spot. A large planimeter (Fig.4.) was constructed and mounted on a vertical stand. The main difficulty encountered in the construction was to ensure that the wheel of the planimeter remained in close contact with the board. To overcome the difficulty, the small radius arm was constructed in two sections. The main section, AB, had a rigidly constructed bearing at the centre of rotation, and the extension of AB, which was the part of the arm carrying the wheel, was pivoted to AB at B, and the wheel was held against the board by a light spring.

The planimeter, of course, requires to be calibrated for zero circle and multiplying constant.

Tests with this instrument gave an average percentage error in area of 1.38%. The time to complete a determination of area was 45 secs.

The advantages of the planimeter are that the area is obtained on the spot and the time required is small. The method, however, has serious disadvantages - the size and weight are not convenient; the mechanism is delicate; and the range of the instrument is limited unless the lengths of the arms are varied.

(5) /

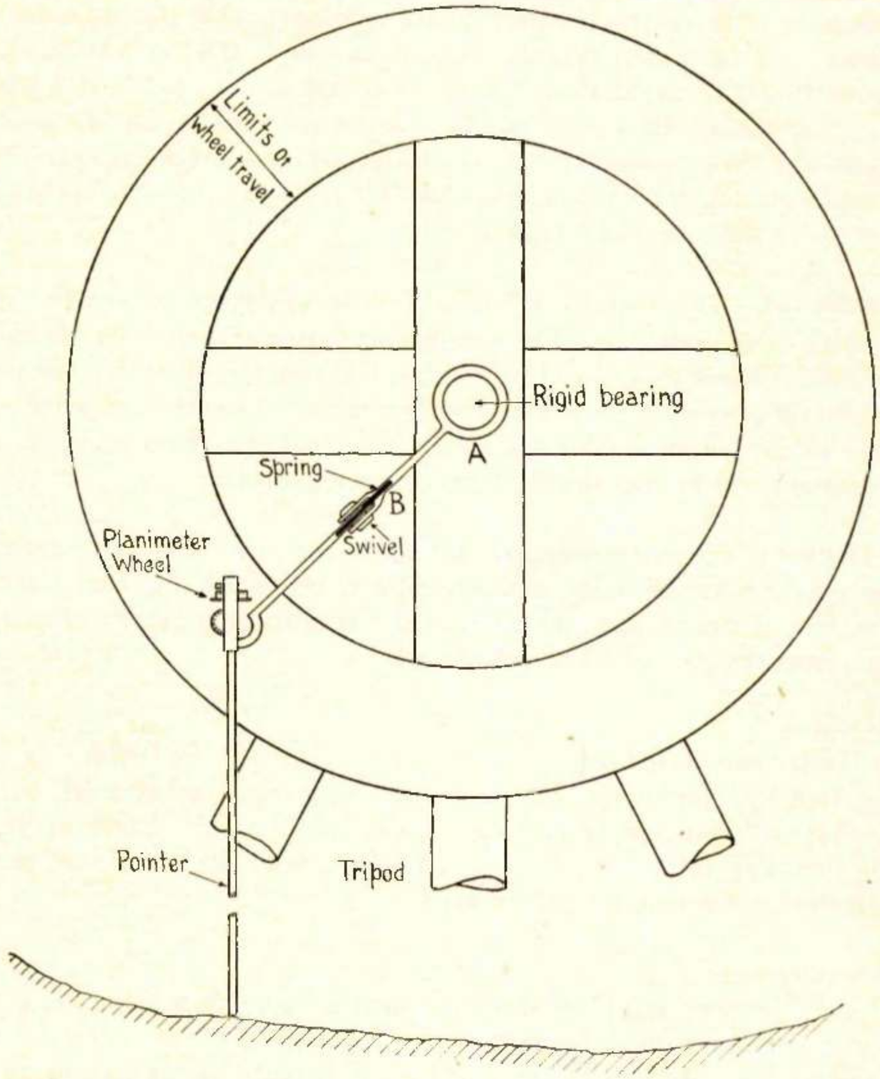

FIG. 4.

DIRECT MEASUREMENT OF AREA BY PLANIMETER.

(5) Direct Reading Instrument.

The advantages of a direct-reading instrument are apparent. As the planimeter did not hold out much promise an attempt was made to design an instrument on a different principle.

A design tried out is shown in Fig.5. The 'area recording disc' is free to revolve round its central shaft when rotated by the 'disc rotating wheel'. The disc rotating wheel was mounted on a square section shaft so that it could move easily along it when operated by the cam The disc rotating wheel is rotated by the peripheral wheel.

The cam is rotated by the 'radius length pulley' A reduction gearing was introduced between this pulley and the shaft operating the cam, but is omitted in the sketch for simplicity.

A cord, which is fixed at one end to a pivot point at the centre of the roadway, passes twice round the pulley, so that as this cord was shortene or lengthened the radius pulley rotated.

When using the instrument, the cord is pivoted near the centre of the area and the peripheral wheel is rolled round the periphery of the section. The area is obtained from the number of revolutions of the area recording disc.

The profile of the cam is designed to position the disc rotating wheel on the area recording disc so that when the area swept out by the radius from the pivot point of the cord to the peripheral wheel is two square feet, the area recording wheel makes one revolution.

The instrument as constructed in the laboratory in a makeshift manner was rather rough but nevertheless it gave satisfactory results. The average error obtained on test was 1.39% in area, and the time required for a determination wa 1 minute 4 seconds.

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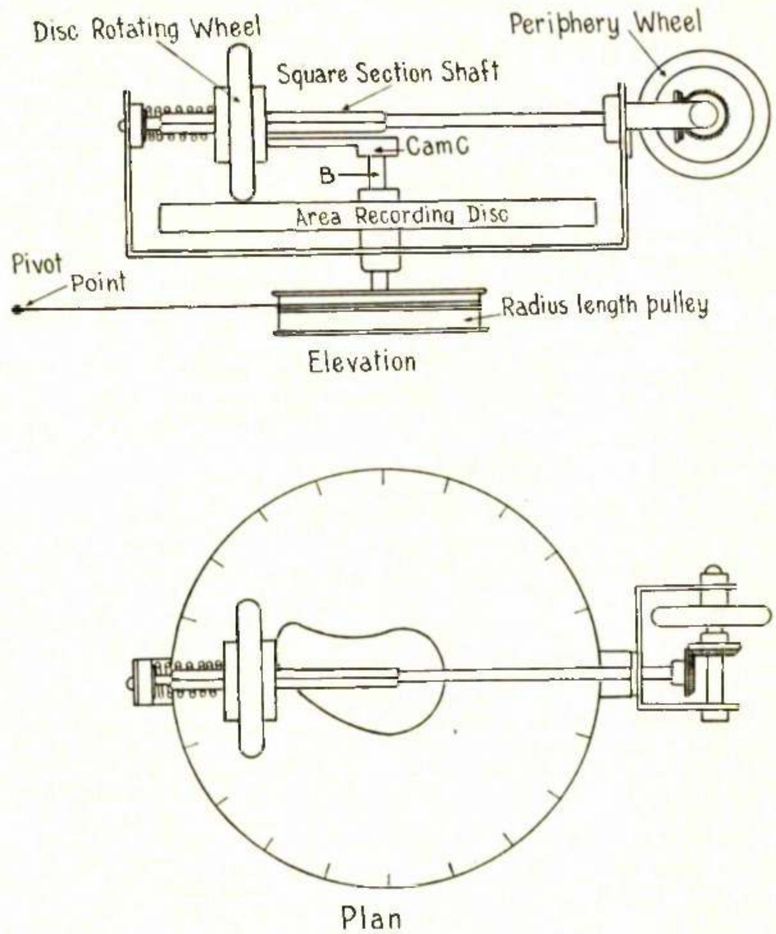

Disc Rotating Wheel
Periphery Wheel
Square Section Shaft
Cam C
B
Area Recording Disc
Pivot
Point
Radius length pulley
Elevation
Plan

FIG. 5.

The results obtained indicated that a properly constructed instrument would prove highly satisfactory and would be of convenient weight and size.

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(6) Photographic Methods.

The application of photography to the measurement of areas of mine roadways was investigated. Two methods were tried.

In the first method a white line was drawn round the periphery of the area. This line was then photographed, a scale being included. Lighting was obtained by flash powder. The area was then measured from the photograph by a planimeter.

Tests of this method gave errors of the order of 0.1%.

Figures 6, 7 and 8 show underground roadways, the areas of which were obtained by this method. The white line of Fig.8 is rather wide and gives a difference of 3.7% between the inner and outer sides. It is necessary to adopt as fine a line as possible.

The second method avoids the use of any special lighting and is suitable for safety lamp mines. The photographic plate is exposed while the lantern of a miner's electric cap lamp is moved round the boundary of the area, the light, of course, facing the camera. A trace of the boundary of the area is obtained on development of the plate.

To obtain the scale for the photograph, a board with small holes at intervals of 6 inches is used. The board is placed in the section normal to the camera and the lamp is placed behind the holes in turn, so that spots of light are recorded on the plate along with the trace of the area boundary. Figure 9 shows one result by this method.

Best /

FIG. 6.

Average Area by Planimeter = 7.2 sq.in.

Scale Ratio, 0.365 in. = 1 ft.

Area = $7.2/0.365^2$ = 54 sq.ft.

FIG. 7.

Average Area by Planimeter = 8.12 sq.in.

Scale Ratio, 0.35 in. = 1 ft.

Area = $8.12/0.35^2$ = 66.3 sq.ft.

FIG. 8.

Average Area by Planimeter -

Outer .... = 7.33 sq.in.
Inner .... = 6.88 sq.in.

Scale Ratio, 0.35 in. = 1 ft.

Area -

Outer .... = $7.33/0.35^2$ = 59.6 sq.ft.
Inner .... = $6.88/0.35^2$ = 56.2 sq.ft.

Best results are obtained when the lantern is fitted with a frosted or pearl glass so that a uniform trace is obtained on the photographic plate and so that the outer edge of this trace can be taken as the boundary of the area. In some cases the rim of the lantern may prevent the light band from reaching the boundary of the area and it is then necessary to allow for this when measuring up the area of the photograph.

The larger the photographic plate that can be used the better the result in respect to accuracy. Enlarging may prove useful but was not tried in the present case.

Fig.10 shows a result obtained in an underground roadway.

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General Conclusions.

(a) For a cheap, serviceable instrument that can be constructed in the colliery workshops, if necessary, I recommend either the Radial Arm Bowden cable instrument, or the Pantographic instrument.

(b) The Photographic method could be used to the best advantage in the following cases:-

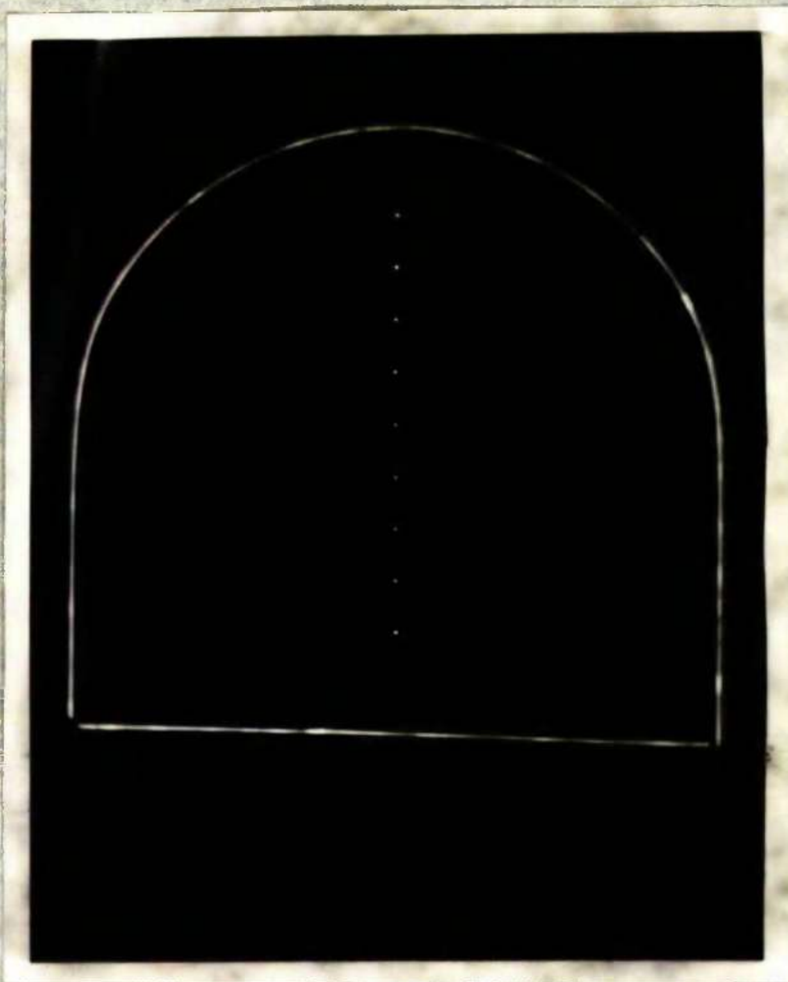
(1) When great accuracy is required.

(2) For permanent main intake and return air measurement stations.

(3) For the measurement of areas after a fire or explosion or in cases of dispute.
A disagreement about the size or shape of roadways can be settled by reproducing the full scale area on a screen.

(c) A properly constructed, direct-reading instrument would be a very useful piece of apparatus when making ventilation surveys.

FIG. 9.



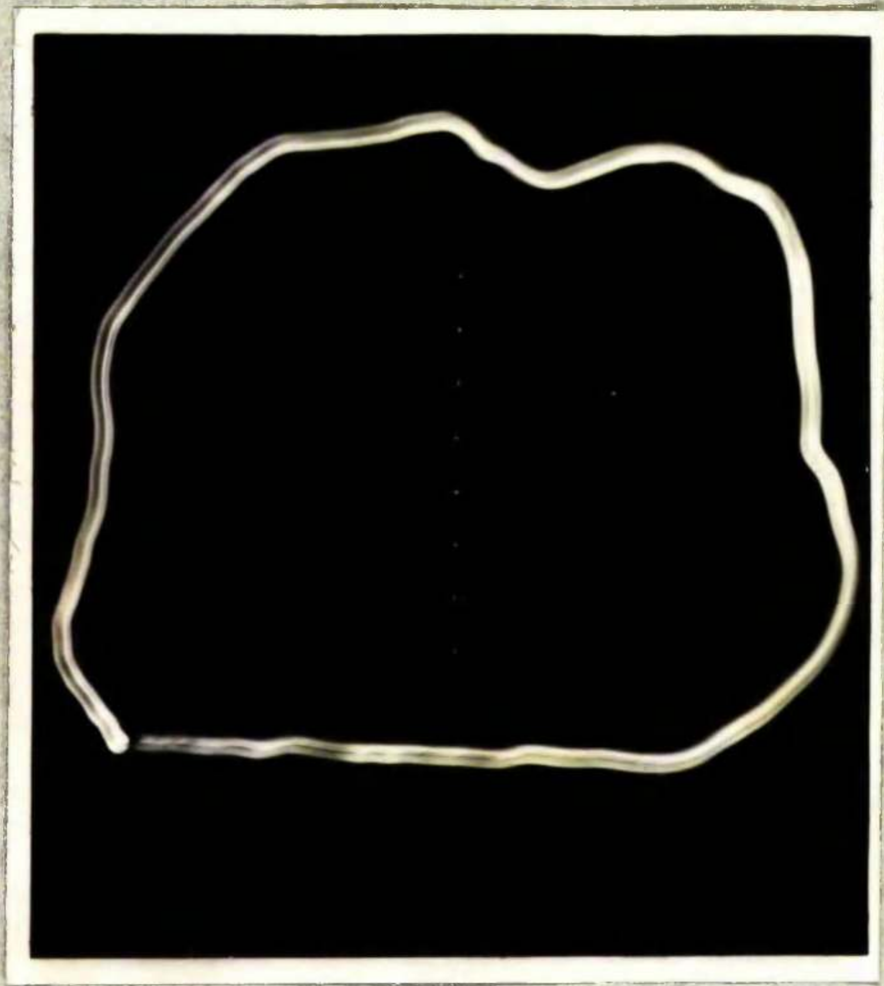
Average Area by Planimeter = 7.64 sq.in.

Scale Ratio, 0.49 in. = 1 ft.

Area = $7.64/0.49^2$ = 31.8 sq.ft.

Area by Measurement = 31.81 sq.ft.

FIG. 10.



Average Area by Planimeter = 9.44 sq.in.

Scale Ratio, 0.5 in. = 1 ft.

Area = $9.44/0.5^2$ = 37.7 sq.ft.

Peripheral Length = 11.4 in. = 11.4/0.5 = 22.8 ft.

Peripheral Correction = 22.8 x 0.277/12 = 0.528 sq.ft.

Corrected Area = 37.7 + 0.53 = 38.2.

Air Velocities by Smoke and Smell Tests.

The accuracy of smoke and smell tests in the measurement of low air velocities is investigated.

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Air Velocities by Smoke and Smell Tests.

A few tests were made to examine the accuracy of the smoke and smell tests as methods of measuring low air speeds. The equipment used in the smoke tests is illustrated by Fig.11. A small wind tunnel of cross-section 1 ft. x 1 ft.4 ins. was used. Air was exhausted through the tunnel by a fan. The smoke was liberated at A and timed over the section B to D. The air speeds as calculated from the smoke tests were compared with those obtained by an Ower Low-Speed Anemometer which was frequently calibrated during the tests.

The smoke was timed with the aid of two photronic cells, one placed inside the tunnel at B and the other at D. The cells were energised by lamps placed in the tunnel as shown in the figure. The cells were connected to suitable milliammeters. When the smoke reached the cells the readings of the milliammeters were immediately altered by the intervention of the smoke between the light source and the cells. The milliammeters were placed side by side and the time interval between the disturbances of their readings was measured by a stop watch.

The following results were obtained in one series of tests:-

Table 1.

Velocity Recorded by Anemometer.	Velocity by Timing of Smoke.
414 ft. per min.	404 ft. per min.
205 " " "	201 " " "
148 " " "	134 " " "
123 " " "	100 " " "
115 " " "	80 " " "
107 " " "	66 " " "
105 " " "	55 " " "

It will be seen that, as far as these tests go, when the velocity as recorded by the anemometer falls below 150 ft. per min. the deficiency of the smoke test becomes serious and rapidly increases with further fall in velocity.

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The photronic cell at D failed to register when the velocity was lower than 90 ft. per min., the density of the smoke cloud then being too low to interrupt the light sufficiently. Under these conditions no smoke could be observed at the window C when a miner's cap lamp was placed within the tunnel and the room was in darkness. Smoke, however, could be observed when a 60-Watt lamp was used. This indicates that the sensitivity of the photronic cells was such as to conform with the practical conditions of illumination underground.

The tests with smells were carried out with the equipment illustrated in Fig.13. The smell was released at A and the time of travel over section AB was measured. The smell was produced by liquid ammonia and perfumes, a little of the liquid being blown into the tunnel by compressed air.

The results obtained with ammonia and the perfumes were almost identical. The following is one series of results:-

Table 11.

Velocity Recorded by Anemometer.	Velocity by Timing of Smell.
149 ft. per min.	153 ft. per min.
92 " " "	98 " " "
78 " " "	72 " " "
49 " " "	51 " " "

These tests show that the smell test is more accurate than the smoke test and remains in agreement with the anemometer down to fairly low velocities.

The graph of Fig.14 compares the smoke and smell tests against the delicate low-reading anemometer.

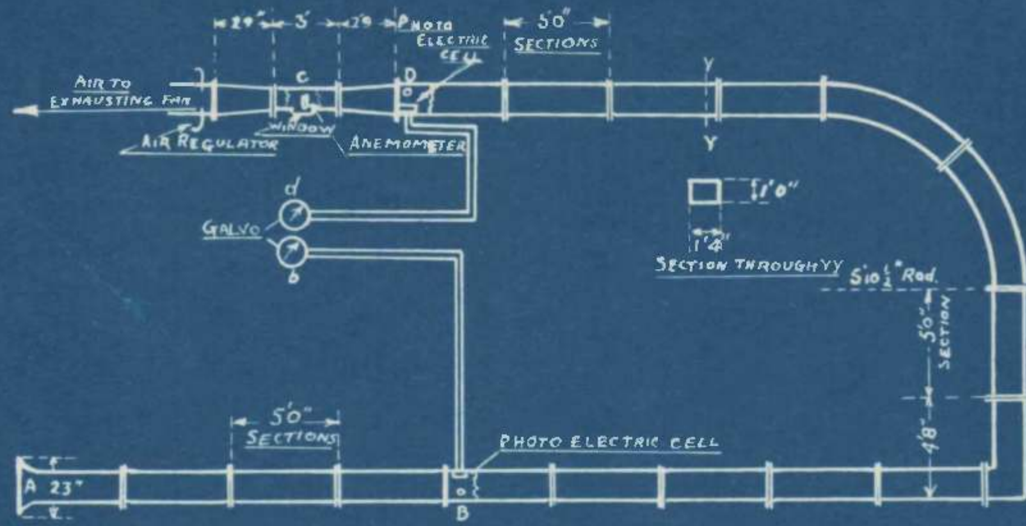


Fig. 11.

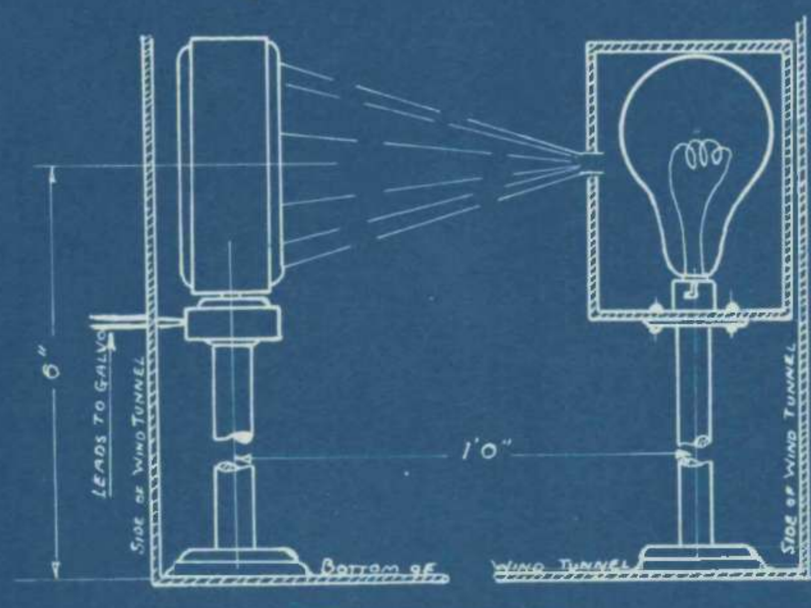


Fig. 12.

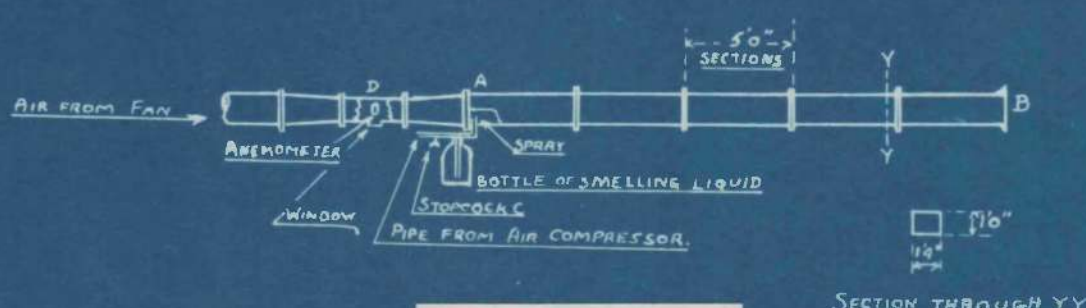
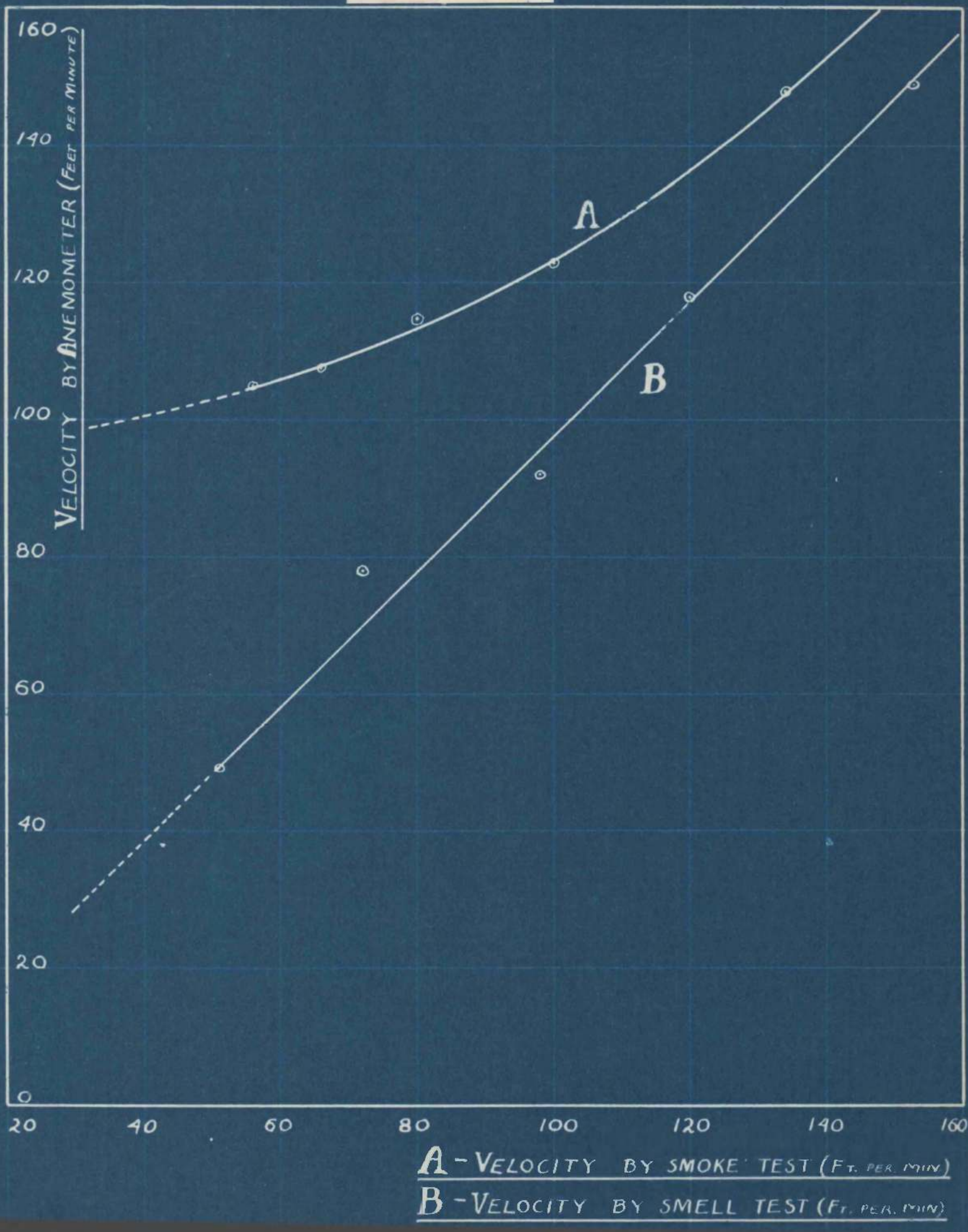


Fig. 13.

Fig. 14.



VELOCITY BY ANEMOMETER (FEET PER MINUTE)
160
140
120
100
80
60
40
20
0
A
B
20
40
60
80
100
120
140
160
A - VELOCITY BY SMOKE TEST (FT. PER. MIN)
B - VELOCITY BY SMELL TEST (FT. PER. MIN)

Values of Atkinson's Coefficient of Resistance.

Some values of Atkinson's Coefficient of Resistance are determined for modern mine roadways.

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Atkinson's Coefficient of Resistance.

Atkinson's formula for the pressure drop to provide air flow in mine airways is -

$$P = K\ S\ Q^2 / A^3$$

where P = Pressure drop in lb. per sq.ft.
K = Coefficient of resistance.
S = Rubbing surface in sq.ft.
Q = Rate of air flow in thousands of cu.ft./min
A = Cross section of roadway in sq.ft.

There are remarkably few published values of the coefficient K for the modern large roadways and modern methods of lining the roadways. While investigating some ventilation problems in mines, an opportunity was afforded to determine some values of K under modern conditions.

Pressure drops were measured with the well-known Askania Minimeter which is capable of reading to 0.02 mm of water-gauge. A standard National Physical Laboratory pitot tube was used to measure the static pressure drop. The static pressure drops were adjusted to total pressure drops by correction for the mean velocity pressures at the measuring sections.

The pressure drop over the test length was obtained with the aid of rubber tubing stretching the full length and having pitot tubes at both ends, the manometer being connected, of course, between the two pitot tubes. The method of transporting the rubber tubing is illustrated by Fig. 15.

The quantity of air flowing was obtained by an anemometer from readings in sub-sections at suitable cross sections in the test lengths.

Difficulties are usually encountered in determining values of K under practical conditions due to the difficulty of obtaining test lengths with uniform cross section and due to the variations in air flow. In the present case the cross sections were fairly uniform but, where any variation existed, average values were taken. The /

The area taken was that within the lining, and the 'rubbing surface' was assumed as the product of the perimeter within the lining and the test length. The tests were carried out on idle shifts and the rate of air flow was fairly uniform during the tests.

Tubs for normal haulage were standing in most of the test lengths, so that the values of K obtained are probably more useful for practical estimations than values obtained in clear or experimental airways.

The test results are given in Table I. The advantage of completely filling cambered arches, top and sides, as compared with side filling only, is shown. For the former, K has a value of 0.0056 compared with 0.0076 for the latter. Steel arches unfilled give much the same value as an unlined roadway.

These values are somewhat higher than a few published values for modern roadways. It seems probable that unless a roadway is completely filled between the supports, a value of 0.01 for K is still not far out under practical conditions.

FIG. 15.

Roll of Rubber Tubing and Pitot Tubes
Mounted on Bogey for Transport.

Lining	Empty tubs in Section	Full tubs in Section	Average Area Sq ft	Pressure Drop Ins. WG	Quantity ft^3/min	Atkinson's Coefficient
<u>CAMBERED ARCHES</u> concrete lined on top and sides	0	Whole Length	94	0·047	47,500	0·0050
<u>CAMBERED ARCHES</u> 5 yds Concrete lined on top and sides 194 yds concrete lined Top unlined. 70 yds concrete lined for 3 ft up sides top unlined.	Whole Length	25	97	0·292	70,000	0·00063
<u>CAMBERED ARCHES</u> 55 yds concrete lined top and sides 60 yds Concrete lined sides. Top unlined. 26 yds concrete lined 3 ft up sides. Top unlined	Whole Length	Whole Length	89	0·278	70,000	0·00076
<u>CAMBERED ARCHES</u> 335 yds Concrete lined: Top and sides. 20 yds concrete lined sides Top unlined. 25 yds not arched and unlined.	Whole Length	0	90	0·2045	49,500	0·0050
<u>STEEL ARCHED GIRDERS</u>: unlined. 90 yds Brushed to 13'×9' 170 yds unbrushed 12'×8'6"	Whole Length	0	83	0·0105	25,000	0·00070
<u>UNLINED</u>	0	0	64	0·1722	46000	0·00076

<u>ATKINSON'S COEFFICIENTS OF RESISTANCE</u>

Table 1.

Electrical Pressure Gauge.

A pressure gauge designed on the Wheatsone Bridge principle is described.

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Electrical Pressure Gauge.

An attempt was made to design an electrical pressure gauge suitable for pressure surveying in mines. It was thought that such an instrument might prove more convenient than the instruments now available for such work.

The well-known Wheatstone Bridge principle was applied as illustrated in Fig.16. Assume that the two limbs A and B of Reference No.1. are telephone transmitters. The circuit is balanced by regulating rheostat C. Suppose the limb A to be subjected to an increase in atmospheric pressure; this will compress the carbon granules in the normal way and consequently upset the balance. The balance can be restored by rheostat C. It was thought possible that the rheostat C might be calibrated to give the pressure difference on A and B.

In the tests carried out, the telephone transmitters proved to be too sensitive to shocks and were discarded in favour of small pressure boxes shown in Reference No.2. The boxes were constructed from steel and were 1¼ in. long by 1 in. diameter and were tightly packed with carbon granules. The carbon was insulated from the sides of the box by rubber ⅛ in. thick. The top was sealed over with sealing wax.

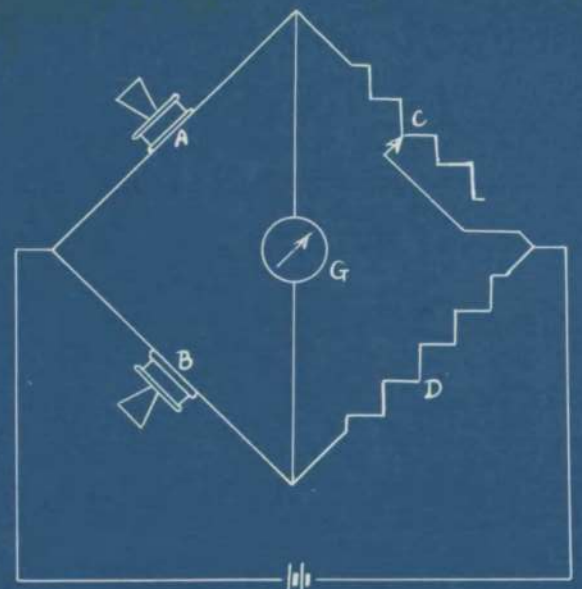
Reference No.3 shows the arrangement of the boxes for calibration. Box A was immersed in water, the level of which was varied to vary the pressure on the box. Graphs of resistances (balancing) were obtained for increasing heads and reducing heads, respectively, and are shown in Fig.17. A slight variation amounting to about 1/12 in. in W.G. is shown by the graphs.

I am convinced that, with further research into the type of pressure box and carbon granules, an instrument could be devised with an error less 1/12 in. W.G.

Reference No.4 illustrates the method of using the instrument in the mine.

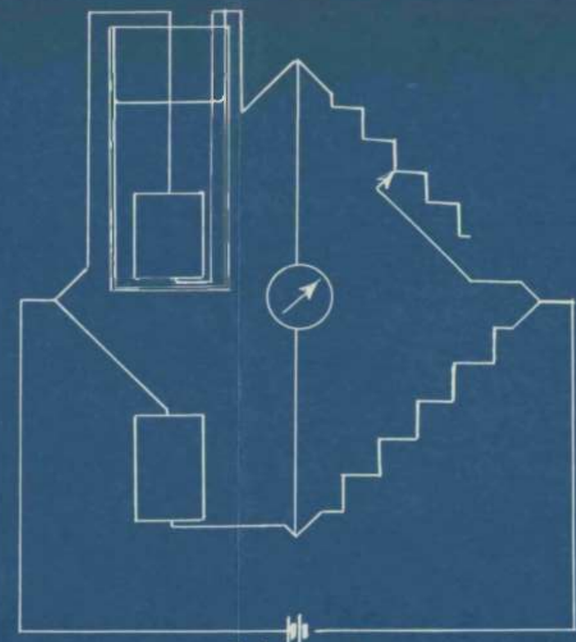
ELECTRICAL PRESSURE

DROP GAUGE

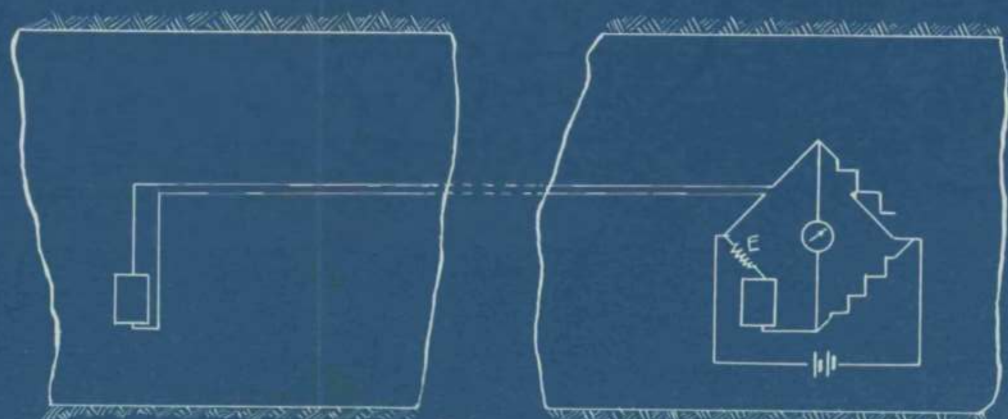


Reference 1

Reference 2



Reference 3



Reference 4

Fig. 11

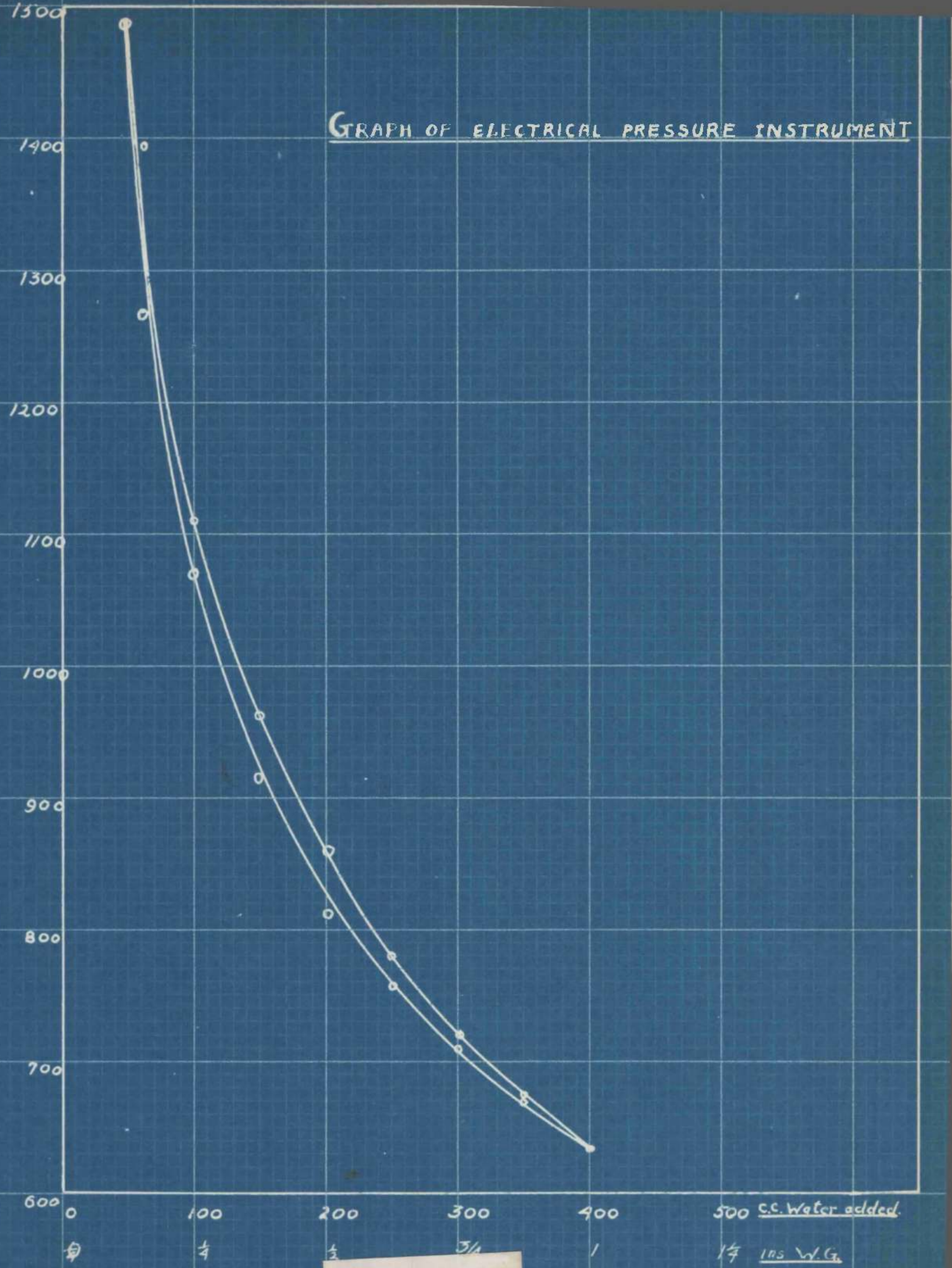

GRAPH OF ELECTRICAL PRESSURE INSTRUMENT
1500
1400
1300
1200
1100
1000
900
800
700
600
0
100
200
300
400
500 C.C. Water added.
1/4
1/2
3/4
1
1 1/4 ins W.G.

Fig. 17.

Effect of Obstruction on Anemometer Readings.

The results are given of some tests on the effect of the observer standing behind an anemometer while measuring air velocities in mine roadways.

....

The Effect of Obstruction on Air Velocity Measurements with the Anemometer.

In the measurement of air velocities in mine roadways it is very often impossible for the observer to stand clear of the current while taking measurements. Some tests were carried out to find how far downstream of the instrument the observer would require to stand to avoid disturbance of the distribution.

The tests were made in the small wind tunnel used for the smoke tests described earlier. The principle of dynamic similarity was applied and the tunnel was assumed as the model of a mine roadway on a scale of 1/6th, the velocities of the tests being six times those for the mine roadway.

The first series of tests was carried out in a smooth section 1 ft. x 1 ft. representing a roadway 6 ft. x 6 ft. A pitot tube of special design was used so that obstructions could be brought close up behind the measuring 'spot'. The 'hook' of the tube was 1½ in. long compared with the 7½ in. hook of the standard N.P.L. pattern. Compared with the standard pattern this special tube gave results a few per cent. higher, but this did not matter for the purposes of the tests.

In each test the velocities at the measuring section were measured in each of 16 sub-sections of equal area, at the centre of the section, and also centrally in front of the obstruction as illustrated by Fig. 18.

Tests. Series 1.

An obstruction representing dimensions 14½ in. broad and 6 in. deep and the full height of the roadway was placed in the centre of the roadway with the 14½ in. side normal to the air flow. Tests were made with the obstruction at different distances downstream of the tip of the pitot tube, and for each position of the obstruction the air speed was varied. The following is a record of results obtained, the figures being the sub-section velocities:-

Test /

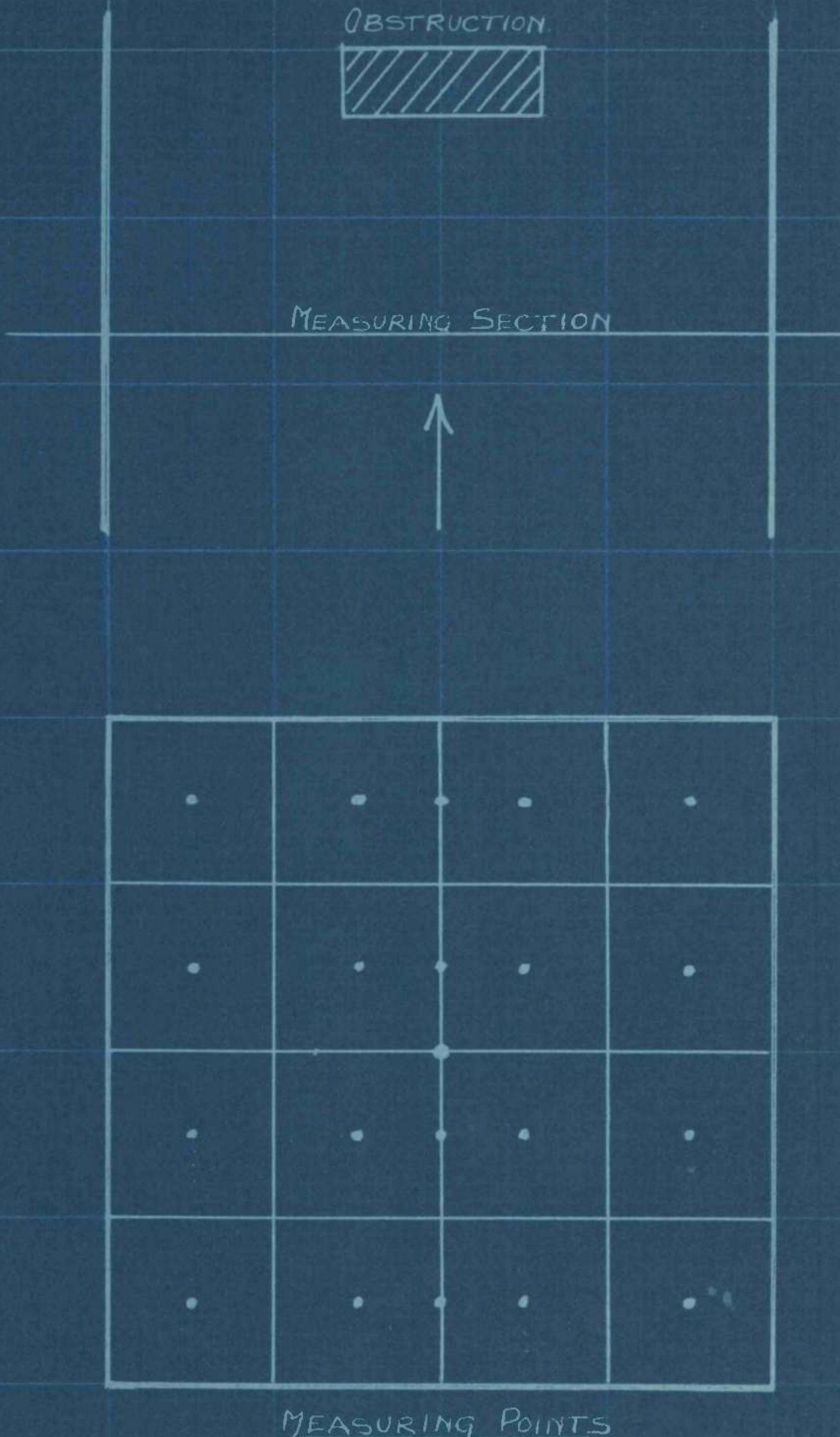


Fig. 18.

Test 1. Speed A. Duct Clear of Obstruction.

496	529	542	529	516
536	608	613	619	597
529	597	590	608	608
523	510	510	516	536

Mean velocity at section .... 553 ft. per min.
Velocity at centre of section ..... 601 " " "
Centre constant .... 0.92 " " "

The object of Test 1 was to check the centre constant for the section, i.e. the ratio of the mean velocity to the centre velocity. Many previous tests for other purposes have shown the constant to be about 0.92 as obtained in this test. The value varies but slightly for the range of velocities generally tested in this tunnel. The distribution is always a little higher at the left side of the section than the right side (looking downstream) as illustrated by figures for Test 1.

Test 2. Speed A. Obstruction 3½ ft. Downstream of Tip of Pitot Tube.

467	475	489	496	489
501	542	548	579	561
516	542	542	554	554
489	475	475	481	524

Mean velocity at section .... 515 ft. per min.
Velocity at centre of section .... 545 " " "
Centre constant .... 0.94 " " "

Test /

Test 3. Speed A. Obstruction 3 ft. Downstream of Tip of Pitot Tube.

475	496	489	501	501
501	538	562	554	548
516	533	538	538	561
489	467	460	467	523

Mean velocity .... 513 ft. per min.
Centre velocity .... 550 " " "
Centre constant 0.96

Test 4. Speed A. Obstruction 2½ ft. Downstream of Tip of Pitot Tube.

467	467	467	489	507
510	586	536	554	567
523	523	524	546	573
507	472	453	472	536

Mean velocity .... 515 ft. per min.
Centre velocity .... 530 " " "
Centre constant .... 0.97 " " "

Test 5. Speed A. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

467	445	435	472	510
516	516	516	536	567
524	510	510	542	579
501	475	435	460	554

Mean /

Mean velocity .... 511 ft. per min.
Centre velocity .... 513 " " "
Centre constant 0.99

Test 6. Speed A. Obstruction 1½ ft. Downstream of Tip of Pitot Tube.

489	445	405	478	542
546	500	475	516	585
536	489	453	507	585
523	445	397	445	554

Mean velocity .... 511 ft. per min.
Centre velocity .... 464 " " "
Centre constant 1.10

Test 7. Speed A. Obstruction 9 in. Downstream of Tip of Pitot Tube.

507	446	304	500	597
563	489	335	524	638
573	489	298	500	670
580	460	185	460	638

Mean velocity .... 539 ft. per min.
Centre velocity .... 366 " " "
Centre constant 1.47

Tests 2 - 7 show the centre constant to be increased as the obstruction is brought closer to the measuring section. At a distance of 3½ ft. the centre constant is 0.94 as against 0.92 for the clear tunnel; at 9 in. the constant is 1.47, while at 2 ft. it is practically unity. The effect of the obstruction as it comes closer /

closer to the measuring section is first to promote more uniform distribution, but when the distance becomes shorter than 2 ft. the distribution becomes more and more uneven. Figs. 19 to 24 show the distributions for these tests on a horizontal plane across the centre of section.

The introduction of the obstruction naturally reduces the flow below that of the clear duct. It should be noted that the mean velocity as obtained from the 16 sub-section values while the obstruction is in the tunnel does not vary by an amount that is of practical importance until the obstruction is less than 1½ ft. from the section.

<u>Test 8. Speed B. Obstruction 3 ft. Downstream of Tip of Pitot Tube.</u>

343	388	393	401	410
401	446	453	461	446
414	436	446	414	468
406	388	378	388	430

Mean velocity .... 414 ft. per min.
Centre velocity .... 449 " " "
Centre constant 0.92

<u>Test 9. Speed B. Obstruction 2 ft. Downstream of Tip of Pitot Tube.</u>

378	397	388	397	422
430	430	446	453	475
430	430	430	453	497
430	388	370	405	472

Mean velocity .... 430 ft. per min.
Centre velocity .... 438 " " "
Centre constant 0.99

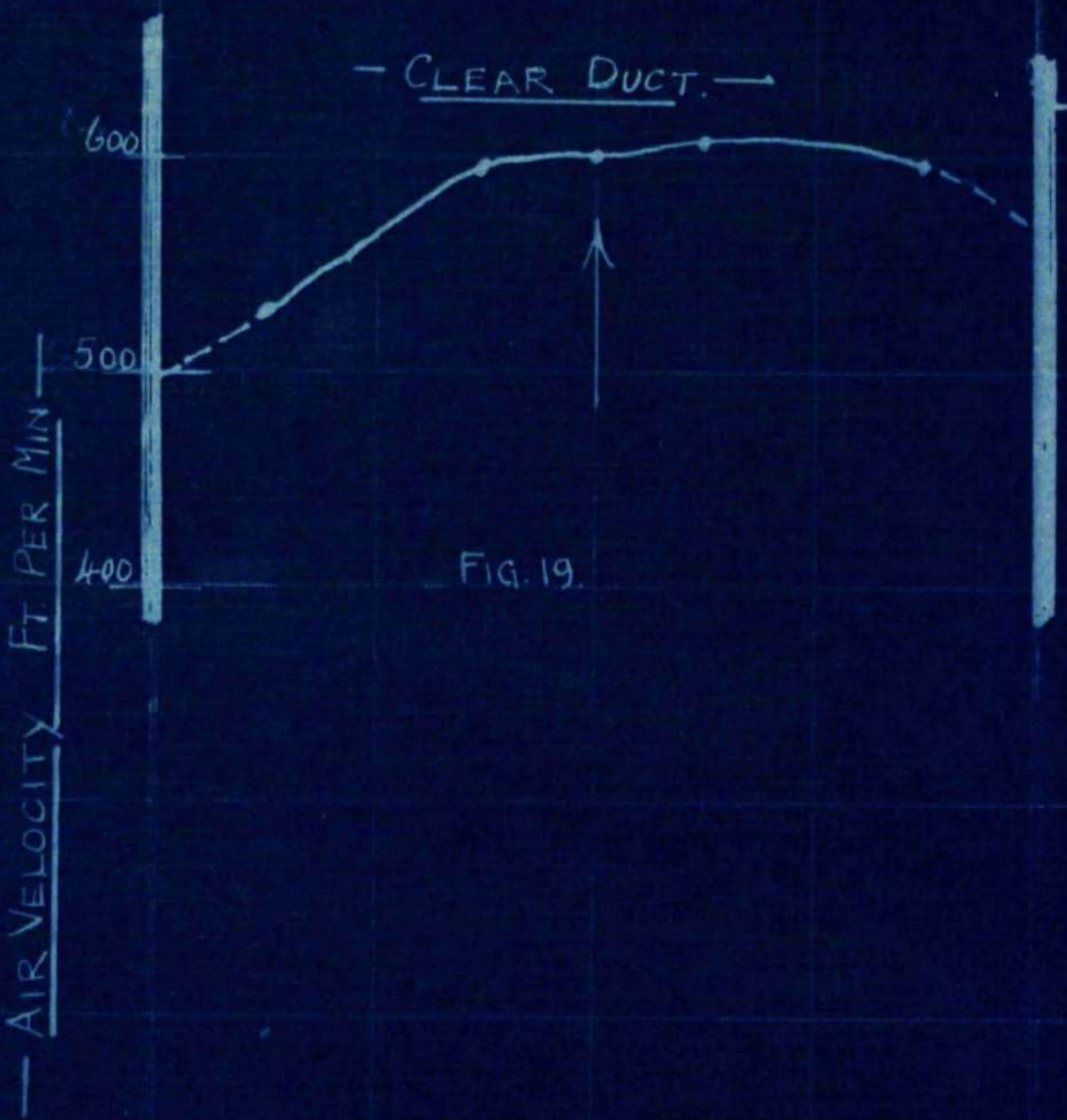

- CLEAR DUCT. -
600
500
400
- AIR VELOCITY FT. PER MIN -

FIG. 19.


- OBSTRUCTION AT 3½ FT. -
600
500
400

FIG. 20

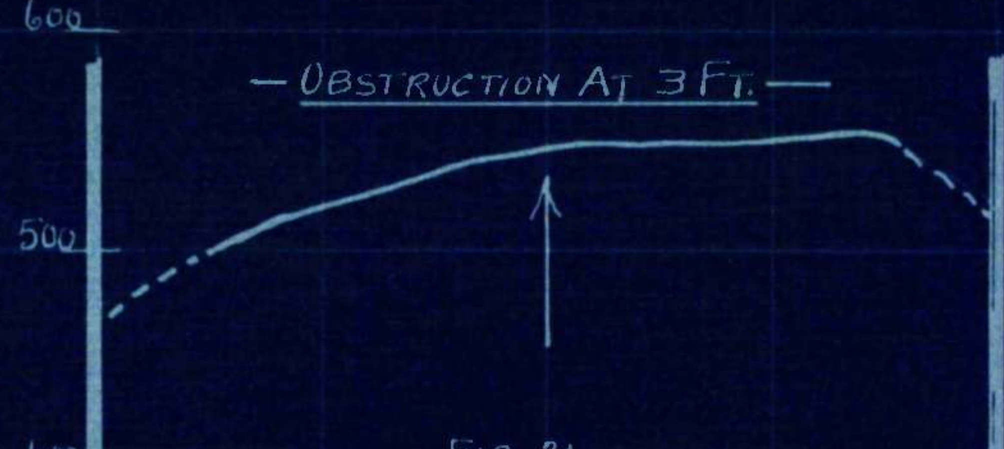


FIG 21

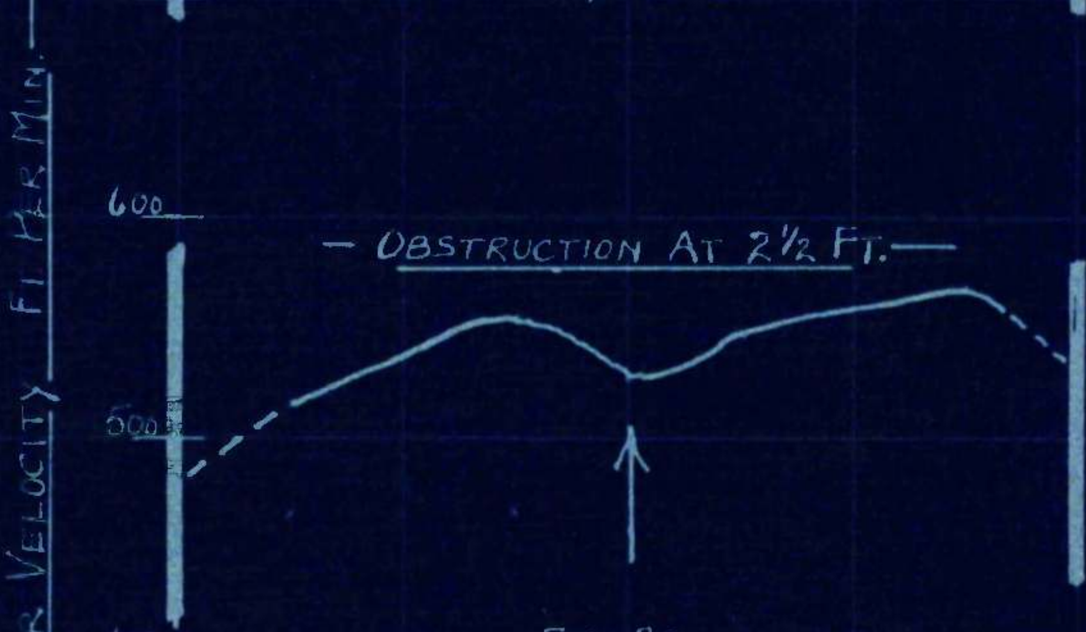


FIG. 22.

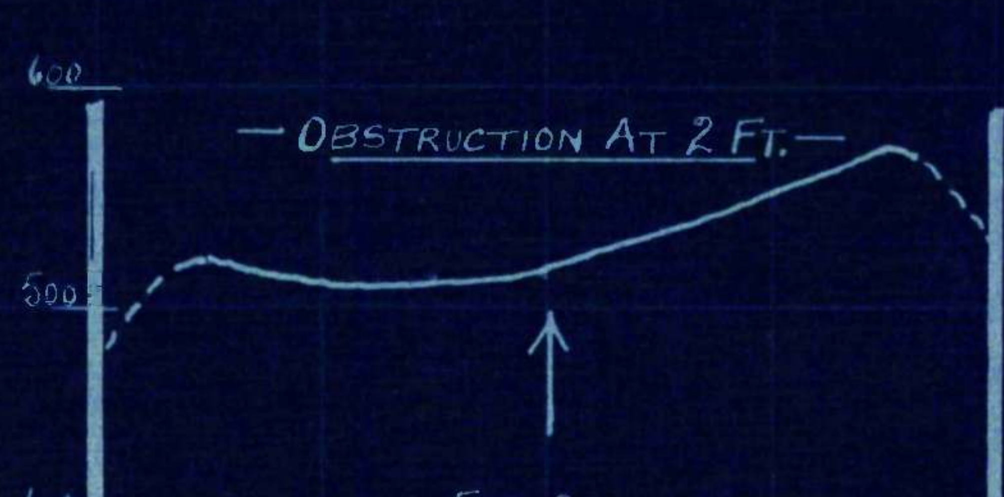


FIG. 23.

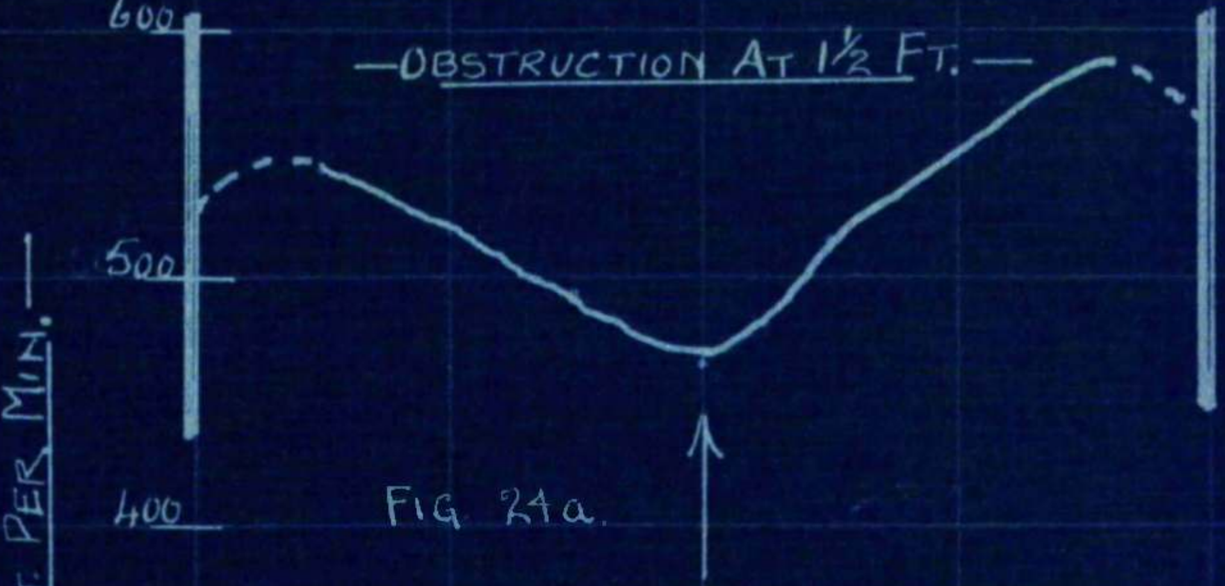


FIG. 24a.

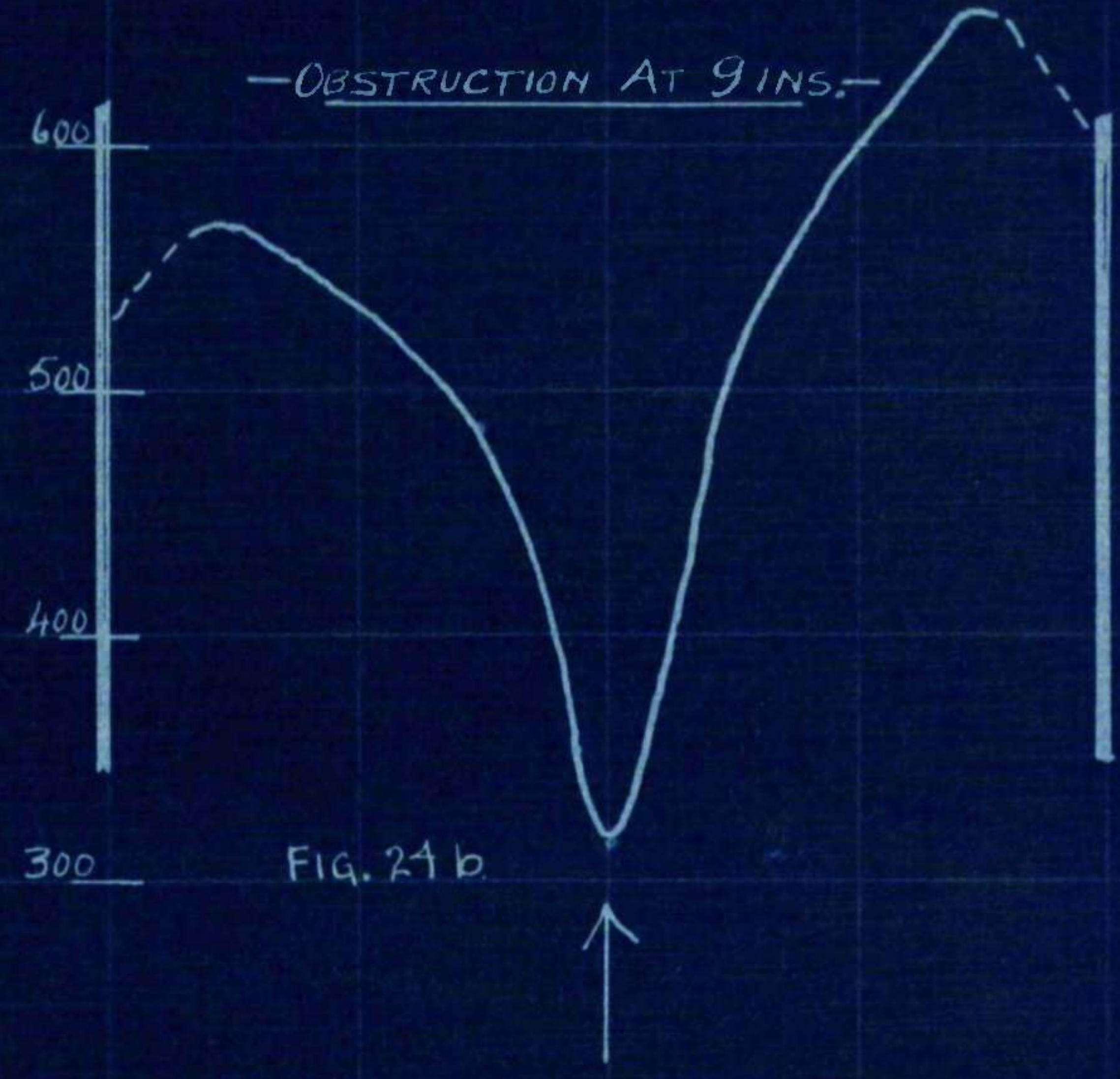


FIG. 24b.

Test 10. Speed B. Obstruction 1 ft. Downstream of Tip of Pitot Tube.

442	365	315	405	457
438	410	361	449	527
479	401	326	442	543
468	361	280	378	442

Mean velocity .... 438 ft. per min.
Centre velocity .... 343 " " "
Centre constant 1.27

Tests 8 - 10, with fan speed B lower than speed A, show the centre constant to behave as before. When the obstruction is 2 ft. downstream of the measuring section the value of the constant again is about unity, while, for a distance of 3 ft., it has the same value as for the clear duct.

Test 11. Speed C. Obstruction 3 ft. Downstream of Tip of Pitot Tube.

262	262	245	262	262
286	310	310	298	298
298	310	310	310	310
286	275	275	275	298

Mean velocity .... 287 ft. per min.
Centre velocity .... 310 " " "
Centre constant 0.92

Test 12. /

Test 12. Speed C. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

262	245	245	262	275
298	286	286	286	298
310	286	286	298	320
298	274	245	245	298

Mean velocity .... 283 ft. per min.
Centre velocity .... 286 " " "
Centre constant 0.99

Test 13. Speed C. Obstruction 1½ ft. Downstream of Tip of Pitot Tube.

275	245	234	245	286
298	298	275	286	310
310	286	262	286	341
310	274	234	245	298

Mean velocity .... 287 ft. per min.
Centre velocity .... 268 " " "
Centre constant 1.08

Test 14. Speed C. Obstruction 9 in. Downstream of Tip of Pitot Tube.

298	262	212	262	316
262	298	212	245	360
331	275	203	274	369
316	262	185	203	341

Mean velocity .... 292 ft. per min.
Centre velocity .... 207 " " "
Centre constant 1.41

Tests 11 - 14, at the low fan speed C, gave results for the centre constant almost identical with those of the previous tests.

Tests. Series 2.

This short series was carried out with the same obstruction but with a lower speed and with the centre constant of the clear tunnel altered a little by placing an obstruction some distance upstream of the measuring section.

Test 15. Speed D. Duct Clear of Obstruction.

148	148	140	165	146
153	175	183	184	173
155	183	183	177	171
157	152	147	147	157

Mean velocity .... 162 ft. per min.
Centre velocity .... 183 " " "
Centre constant 0.88

Test 16. Speed D. Obstruction 3 ft. Downstream of Tip of Pitot Tube.

142	140	130	145	137
149	171	176	185	171
160	164	168	168	180
160	142	137	142	153

Mean velocity .... 156 ft. per min.
Centre velocity .... 172 " " "
Centre constant 0.90

Test 17. /

Test 17. Speed D. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

141	137	137	145	149
157	161	157	174	180
156	160	157	166	177
149	149	149	141	160

Mean velocity .... 156 ft. per min.
Centre velocity .... 157 " " "
Centre constant 1.00

Test 18. Speed D. Obstruction 9 in. Downstream of Tip of Pitot Tube.

160	125	113	135	164
169	146	125	155	185
177	147	104	159	194
178	140	96	143	187

Mean velocity .... 160 ft. per min.
Centre velocity .... 114 " " "
Centre constant 1.40

The tests of this series again show the centre constant to be about unity when the obstruction is 2 ft. downstream of the measuring section.

Tests /

Tests. Series 3.

A third series of tests was carried out in a manner similar to those of Series 1, but with an obstruction 3 ft. wide, 6 in. deep and the full height of the tunnel. The obstruction was placed in the centre of the section of the tunnel with the 3 ft. side normal to the flow so that 50% of the area of the section was obstructed.

Test 1. Fan Speed A. Obstruction 4 ft. Downstream of Tip of Pitot Tube.

384	402	402	413	413
434	464	474	474	464
464	474	464	464	474
434	413	402	413	444

Mean velocity .... 439 ft. per min.
Centre velocity .... 469 " " "
Centre constant 0.93

Test 2. Fan Speed A. Obstruction 3 ft. Downstream of Tip of Pitot Tube.

396	384	384	396	423
444	455	455	464	474
455	444	444	459	492
434	407	390	402	455

Mean velocity .... 437 ft. per min.
Centre velocity .... 450 " " "
Centre constant 0.95

Test 3. /

Test 3. Fan Speed A. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

423	360	360	373	402
487	444	429	439	501
501	423	407	439	512
492	385	348	373	483

Mean velocity .... 440 ft. per min.
Centre velocity .... 418 " " "
Centre constant 1.06

Test 4. Fan Speed A. Obstruction 1 ft. Downstream of Tip of Pitot Tube.

573	348	241	335	581
618	348	276	321	569
618	321	259	348	612
625	307	222	276	587

Mean velocity .... 462 ft. per min.
Centre velocity .... 267 " " "
Centre constant 1.72

The foregoing tests show that, even with the large obstruction, the centre constant is practically that of the clear tunnel when the obstruction is 3 to 4 ft. downstream of the measuring section. The value of the constant when the obstruction is 2 ft. downstream of the section is practically unity as with the smaller obstruction in the first series of tests.

Two further tests at lower fan speeds were made with the same obstruction at 2 ft. downstream of the measuring section:-

Test 5. Fan Speed C. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

232	189	189	189	241
250	232	222	232	268
250	212	212	232	268
250	189	171	189	256

Mean velocity .... 230 ft. per min.
Centre velocity .... 217 " " "
Centre constant 1.05

Test 6. Fan Speed E. Obstruction 2 ft. Downstream of Tip of Pitot Tube.

94.8	67	67	94.8	106
94.8	94.8	94.8	94.8	116
116	94.8	94.8	116	116
94.8	94.8	70	94.8	116

Mean velocity .... 100 ft. per min.
Centre velocity .... 94.8 " " "
Centre constant 1.05

The centre constant thus maintains the same value - approximately unity - with the obstruction at 2 ft. for the range of speeds tested.

Tests /

Tests. Series 4.

A fourth series of tests was carried out with an obstruction blocking 75% of the cross section of the drift. This obstruction was equivalent in dimensions to 4½ ft. by ½ ft. and the full height of the section, and was placed centrally leaving 1½ ft. width of clear passage at each side.

Test 1. Fan Speed A. Obstruction 4 ft. Downstream of Pitot Tube.

212	223	219	222	226
241	260	266	275	271
263	284	266	222	254
252	230	219	238	260

Mean velocity .... 246 ft. per min.
Centre velocity .... 266 " " "
Centre constant 0.92

Test 2. Fan Speed A. Obstruction 3 ft. Downstream of Pitot Tube.

224	224	216	216	264
277	273	273	273	277
281	265	273	273	281
265	246	224	236	281

Mean velocity .... 259 ft. per min.
Centre velocity .... 266 " " "
Centre constant 0.95

Test 3. /

Test.3. Fan Speed A. Obstruction 2 ft. Downstream of Pitot Tube.

264	204	193	204	264
297	236	236	246	312
327	264	246	264	312
304	236	204	246	327

Mean velocity .... 269 ft. per min.
Centre velocity .... 241 " " "
Centre constant 1.11

Test 4. Fan Speed A. Obstruction 9 ins. Downstream of Pitot Tube.

515	151	136	151	490
545	136	136	180	496
545	151	127	151	409
520	118	127	151	520

Mean velocity .... 327 ft. per min.
Centre velocity .... 132 " " "
Centre constant 2.48

The results of this series of tests show that, even with the abnormal obstruction of 75% of the cross section, the centre constant is practically that of the clear tunnel when the obstruction is 4 ft. downstream of the measuring section. At 2 ft. the constant is not far removed from unity.

Test Series 5. /

Tests. Series 5.

The tests of this series were carried out in a model of a steel-arched roadway representing a cross section of 5½ ft. by 7 ft. approximately. The obstructions were placed centrally as before.

Test 1. Clear Tunnel.

Mean velocity	372 ft. per min.
Centre velocity	360 " " "
Centre constant	1.03

The measuring section in this case is near to a shaped entry and always gives a high centre constant.

Test 2. Obstruction 15 ins. wide placed at 4 ft. Downstream of Pitot Tube.

Mean velocity	364 ft. per min.
Centre velocity	351 " " "
Centre constant	1.03

Test 3. Obstruction 3 ft. wide placed at 4 ft. Downstream of Pitot Tube.

Mean velocity	340 ft. per min.
Centre velocity	330 " " "
Centre constant	1.03

These tests again show that, even with a different shape of cross-section and a different centre constant for the clear tunnel, the centre constant is about equal to that of the clear tunnel when the obstruction is 4 ft. or more downstream of the measuring section.

Conclusions /

Conclusions from Tests of Series 1 to 5.

A central obstruction, even up to 75% of the cross-section, and downstream of the measuring section, does not appear to affect the centre constant, at least for the test velocities 200 to 500 ft. per minute, if the obstruction is at a distance greater than about 4 ft. from the measuring section.

It would appear that if an observer holds an anemometer 4 ft. upstream of himself while standing centrally in the roadway, his body will have little effect on the distribution. The obstruction caused by his body will, of course, tend to reduce the quantity flowing, but the reduction will be slight unless the space is very confined.

In routine measurement of air speeds in mine roadways it is common to hold the instrument at the centre of the roadway. This is suspected of falsely augmenting the airflow. If the instrument is less than 2 ft. from the body, a low value is likely to be obtained. In the foregoing tests, when the instrument is about 2 ft. upstream of the obstruction, the centre velocity is about equal to the mean velocity.

Tests. Series 6. /

Tests. Series 6.

The effect of an obstruction placed at the side of the tunnel was next investigated. The procedure was as described for the tests of Series 1., the obstruction being 15 ins. wide as in that Series.

Test 1. Fan Speed A. Obstruction 4 ft. Downstream of Pitot Tube.

457	493	493	472	426
493	564	564	545	507
500	536	545	545	514
479	479	479	486	479

Mean velocity .... 500 ft. per min.
Centre velocity .... 554 " " "
Centre constant 0.92

Test 2. Fan Speed A. Obstruction 3 ft. Downstream of Pitot Tube.

486	507	507	486	414
530	570	582	567	479
527	552	555	558	493
493	493	493	500	457

Mean velocity .... 507 ft. per min.
Centre velocity .... 568 " " "
Centre constant 0.89

Test 3. Fan Speed A. Obstruction 2 ft. Downstream of Pitot Tube.

520	539	527	486	341
545	603	603	576	422
545	585	588	567	434
540	520	520	507	418

Mean velocity .... 509 ft. per min.
Centre velocity .... 595 " " "
Centre constant 0.86

Test 4. Fan Speed A. Obstruction 1 ft. Downstream of Pitot Tube.

545	576	564	520	268
588	657	652	611	331
619	636	646	614	331
591	588	588	564	309

Mean velocity .... 522 ft. per min.
Centre velocity .... 649 " " "
Centre constant 0.80

Further tests were carried out at fan speeds B and C.

Test 5. Fan Speed B. Obstruction 4 ft. Downstream of Pitot Tube.

Mean velocity .... 422 ft. per min.
Centre velocity .... 457 " " "
Centre constant 0.92

Test 6. Fan Speed B. Obstruction 3 ft. Downstream of Pitot Tube.

Mean velocity .... 424 ft. per min.
Centre velocity .... 475 " " "
Centre constant 0.89

Test 7. Fan Speed B. Obstruction 2 ft. Downstream of Pitot Tube.

Mean velocity .... 431 ft. per min.
Centre velocity .... 498 " " "
Centre constant 0.87

Test 8. Fan Speed B. Obstruction 1 ft. Downstream of Pitot Tube.

Mean velocity .... 439 ft. per min.
Centre velocity .... 539 " " "
Centre constant 0.81

Test 9. /

Test 9. Fan Speed C. Obstruction 4 ft. Downstream of Pitot Tube.

Mean velocity	267 ft. per min.
Centre velocity	292 " " "
Centre constant	0.92

Test 10. Fan Speed C. Obstruction 3 ft. Downstream of Pitot Tube.

Mean velocity	264 ft. per min.
Centre velocity	292 " " "
Centre constant	0.91

Test 11. Fan Speed C. Obstruction 2 ft. Downstream of Pitot Tube.

Mean velocity	269 ft. per min.
Centre velocity	304 " " "
Centre constant	0.88

Test 12. Fan Speed C. Obstruction 1 ft. Downstream of Pitot Tube.

Mean velocity	270 ft. per min.
Centre velocity	341 " " "
Centre constant	0.79

The 15 in. wide obstruction, when placed at the side of the tunnel, is shown by the tests of Series 6 to cause a reduction in the centre constant for all positions closer than 4 ft. to the measuring section. At 4 ft. the constant is the same as for the clear tunnel.

Tests. Series 7. /

Tests. Series 7.

A final series of tests was made with the 3 ft. wide obstruction (obstructing 50% of the section) placed at the side of the tunnel.

Test 1. Fan Speed A. Obstruction 4 ft. Downstream of Pitot Tube.

Mean velocity	423 ft. per min.
Centre velocity	466 " " "
Centre constant	0.91

Test 2. Fan Speed B. Obstruction 4 ft. Downstream of Pitot Tube.

Mean velocity	346 ft. per min.
Centre velocity	382 " " "
Centre constant	0.90

Test 3. Fan Speed C. Obstruction 4 ft. Downstream of Pitot Tube.

Mean velocity	213 ft. per min.
Centre velocity	236 " " "
Centre constant	0.90

The 3 ft. wide obstruction at the side of the tunnel section and 4 ft. downstream of the measuring section reduces the centre constant by about 0.02 which is a negligible amount in routine mine air measurements with velocities up to 500 ft. per minute.

Checks with Anemometer.

The foregoing tests, from Series 1 to Series 7, with the obstruction at 4 ft. downstream of the measuring section, were repeated with a vane type anemometer. The results obtained were in agreement with those obtained with the pitot tube.

General Conclusions./

General Conclusions.

The tests in this investigation were carried out in a straight airway with no obstructions upstream of the measuring section, and the results probably can only be applied to similar conditions. Air measurements in practice, however, are usually made in straight airways.

So far as the tests go it may be concluded that, in routine mine air measurements and with the observer filling up to 75% of the cross-section, the distribution will not be seriously affected at the measuring instrument if the instrument is 4 ft. or more upstream of the observer's body.

Quite contrary to common opinion, a central stance in the airway is better than a side stance as the distribution remains normal closer to the obstruction, especially as the obstruction becomes a large proportion of the cross-section.

Pressure Losses in Fan Drifts.

The results are given of a test for pressure loss in a fan drift.

Pressure Losses in Fan Drifts.

Mine fans are connected to the upcast shaft by tunnels or 'drifts'. These drifts include one or more bends or elbows and often they are of considerable length. The air speed in the drift is high - usually considerably over 1000 ft. per minute. The bulk of the surface leakage, which is often unnecessarily high, takes place at the air lock on the upcast shaft and therefore travels the full length of the drift. It occurred to the writer that, in the case of lengthy drifts, and particularly where there was a heavy surface leakage, the pressure and power loss in the fan drift might be seriously high. An opportunity was therefore taken to make a test on a drift.

The drift and the method of testing are illustrated by figure 25.

The Askania minimeter was used in conjunction with pitot tubes. One pitot tube was placed in the drift 13 ft. from the fan inlet. The second tube was lowered into the shaft to a position a short distance below the entrance to the drift. Both tubes were connected to the minimeter by lengths of rubber tubing.

The results obtained were:-

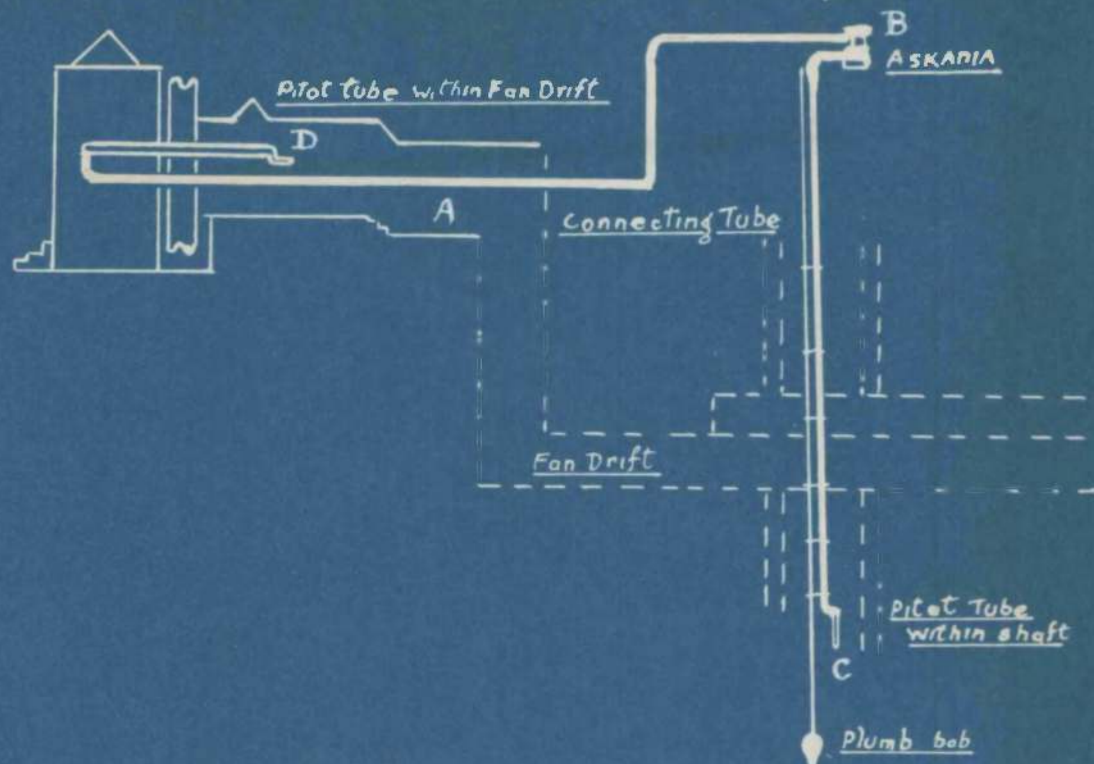
Water-gauge ventilating mine ..... 4.5 ins.
Water-gauge drop on drift .... 2.12 "

This gives:-

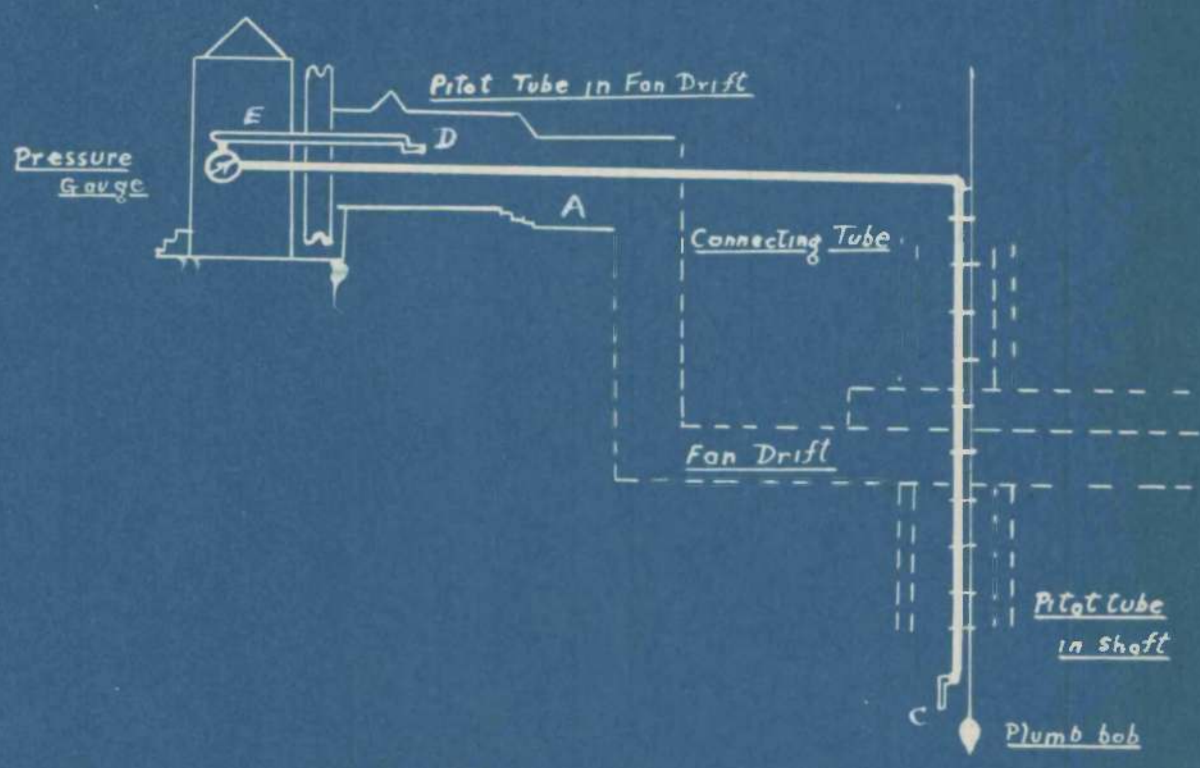
Water-gauge loss on drift = 47% of W.G. on mine.

The minimeter was replaced by the recording barograph type water-gauge commonly installed to record the mine water-gauge. The connections were as shown by figure 25. A similar result was obtained, as shown by the record in figure 26.

This /

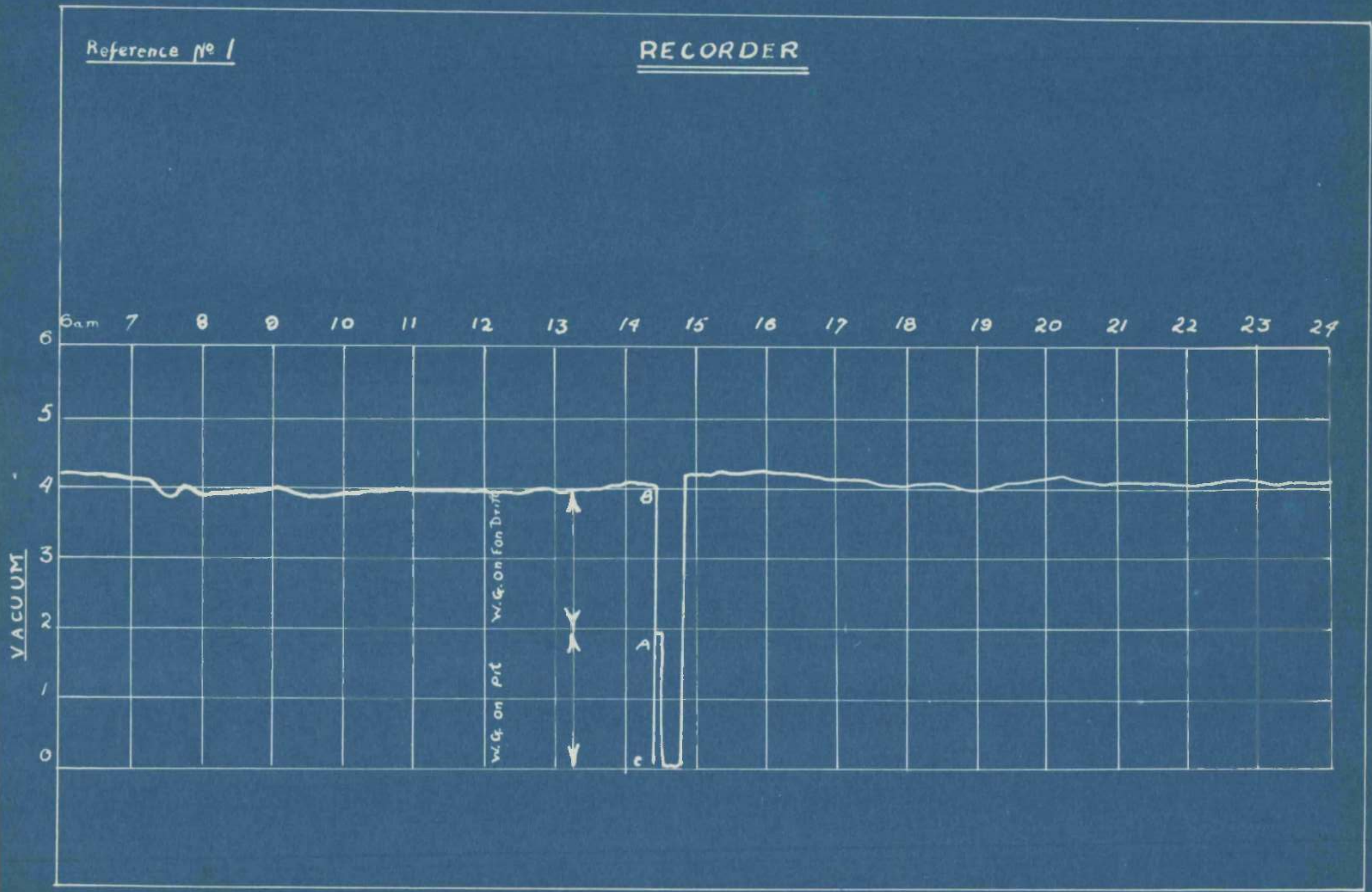


Recording Fan Drift Gauge using an Askania



Recording Fan Drift Gauge using Normal Pressure Gauge

Fig. 25.


Reference No 1
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20
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22
23
24
W.G. on Fan Drift
W.G. on Pit
A
B
C

Fig. 26.

This illustrates a wasteful source of ventilating power which the writer believes exists at many collieries. The power expended here in passing the air through the fan drift is 47% of the power developed by the fan. Another drift, in poorer condition as regards length, was tested in the same manner and showed a considerably higher proportion of the power to be expended in the drift.

It is often stated that the installation of a new fan at a mine has resulted in the circulation of the same or greater air quantity with a lower water-gauge than the replaced older fan. This is not necessarily due to any particular superiority of the new fan, but is often explained by a better fan drift.

Fan drifts should be short, as straight as possible, and of ample cross-section particularly when long. A curved entry or connection to the shaft has been suggested and might effect a considerable saving.

Leakage at the air lock is extremely wasteful, more especially if the drift is long. A leakage of 10% will increase the drift velocity by 10% and the pressure drop on the drift by 21%. A leakage of 20% will increase the pressure drop on the drift by 44%, while a leakage of 41.4% will double the fan-drift loss.

Practical Ventilation Problems.

An account is given of some practical ventilation problems undertaken by the author in the course of his investigations.

Ventilation Problems.

The following is an account of certain problems in the practical ventilation of mines undertaken by the author.

Problem 1.

Rearrangement of Ventilation of a Colliery. Referring to the sketch plan, Fig.27, there are three main ventilation districts, A, B, and C. Districts A and B have relatively low resistances and require to be regulated.

Most of future development work will be done in C and it is necessary to increase the ventilation considerably in that district. To improve the ventilation it is decided to drive a surface mine to reach the seam near the present boundary of district C. The problem is - Should the new mine be a downcast or an upcast?

It is stipulated that the new mine should pass 80,000 cu.ft. of air per minute. Ventilation districts A and B to take altogether 52,000 cu.ft. per minute. A connecting mine to be driven between B and C to take 12,000 from new surface mine if a downcast, or deliver the same quantity to the surface mine if an upcast.

As seen from Fig.27, the present arrangement has three downcast shafts, Nos.1, 3 and 4 Pits, and one upcast, No.2 Pit.

Ventilation Survey. A preliminary ventilation survey of existing conditions was made. Pressure drops were measured with the equipment already described for determinations of Atkinson's coefficient of resistance, i.e., Askania minimeter, N.P.L. pitot tubes and a length of rubber tubing to stretch the test lengths. Air velocities were measured with the aid of an anemometer, and cross sections were measured by photographic methods for the important airways, and by radial arm method for others.

The /

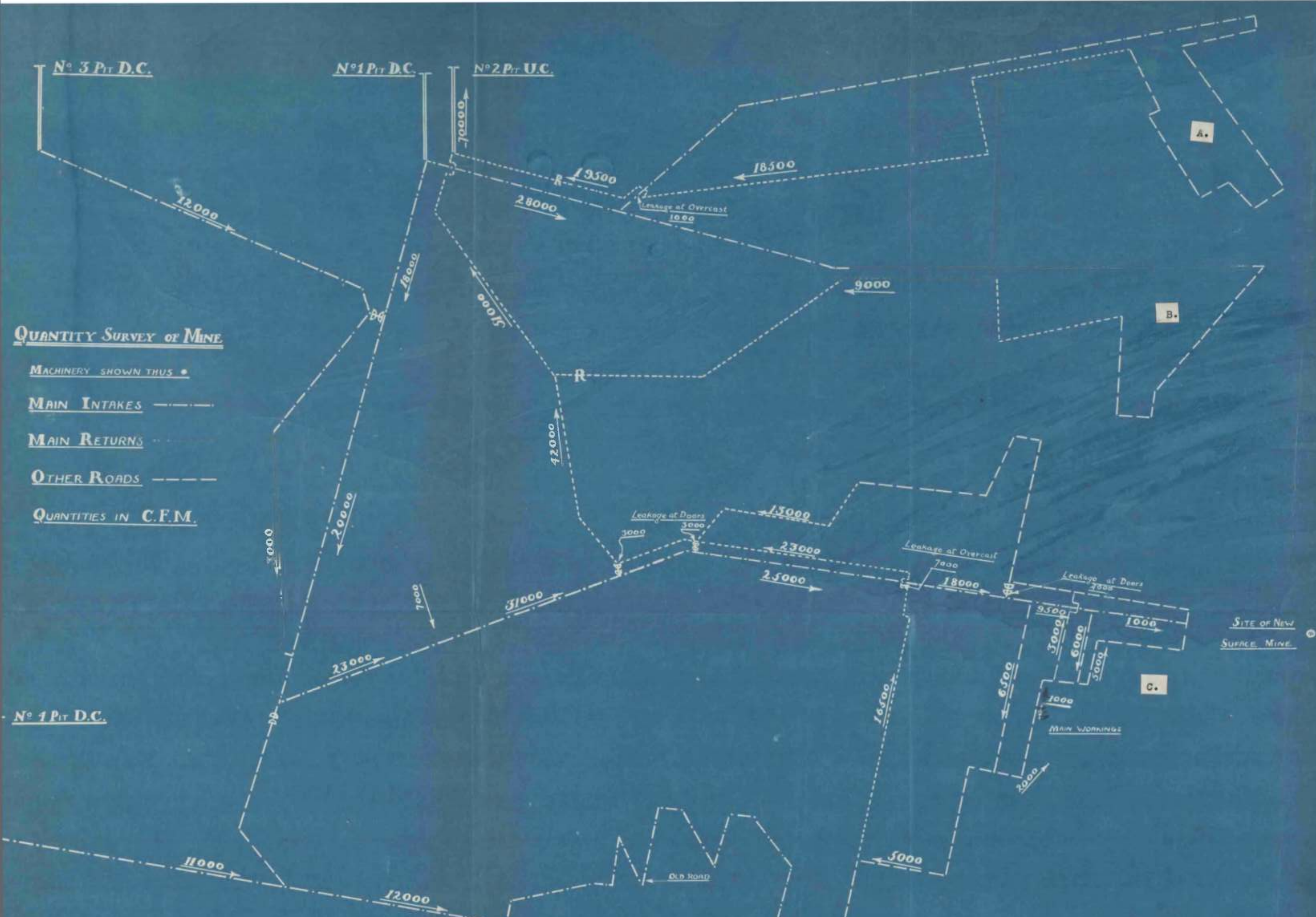

No. 3 Pit D.C.
No. 1 Pit D.C.
No. 2 Pit U.C.
Quantity Survey of Mine
Machinery shown thus •
Main Intakes
Main Returns
Other Roads
Quantities in C.F.M.
No. 1 Pit D.C.
A.
B.
C.
12000
70000
19500
18500
28000
Leakage at Overcast 1000
18000
51000
9000
R
R
42000
Leakage at Doors 3000
3000
15000
23000
Leakage at Overcast 7000
25000
18000
Leakage at Doors 2000
9500
3000
6000
1000
5000
Site of New Surface Mine
20000
3000
7000
51000
23000
16500
6500
1000
Main Workings
2000
11000
12000
Old Road
5000

Fig. 27.

Table 2 Ventilation Survey Data.

Station.	Location.	Press. Drop. Ins. W.G.	Total Press. Ins. W.G.	Average Quantity.	Resistance. Atkinsons.
1.	Pit Bottom		0.2632		
2.	No.4 M.H. South Mine	0.0207	0.2845	18,000	
3.	No. 7 M.H. South Mine	0.0456	0.3301		
4.	No. 12 M.H. South Mine	0.0659	0.3960	20,000	
5.	Intake from No. 3 Pit				
6.	End of South Mine	0.0185	0.4145	3,000	8.7
7.	Through No.2 Doors to No. 4 Pit Junction	0.1099	0.5244		
8.	60 yds. E. along split	0.0361	0.5605		
9.	Corner A.	0.1115	0.6702		
10.	60 yds. E. from A.	0.1134	0.7854		
11.	Corner B.	0.0827	0.8681		
12.	10 yds. inbye from corner C.	0.0745	0.9426		
13.	8 yds. inbye from corner D.	0.1593	1.1019		
14.	10 yds. inbye from corner E.	0.1665	1.2684		
15.	30 yds. inbye from end of No.1 Return	0.1827	1.4511	12,000	118
16.	43 M.H. on No.1 Return	0.2089	1.6599		
17.	37 M.H. on No.1 Return	0.1143	1.7742		
18.	10 yds. from overcast on No.1 Return	0.0689	1,8431	16,500	40.6
19.	25 M.H. on Main Return	0.3106	2.1537		
20.	17 M.H. on Main Return	0.2700	2.4237		
21.	N.-side of No.4 Doors.	0.0990	2.5227	23,000	24.
22.	S.-side of No. 4 Doors.	1.7596			
23.	No.-side of No.3 Doors				
24.	S.-side of No.3 Doors.	2.0528			
25.	Corner F.	0.1793	2.8703		
26.	Junction of No.2 Return	0.0952	2,9655	42,000	4.7

Table 9 - continued.

Station.	Location.	Pressure Drop.	Total Pressure.	Average Quantity.	Resistance Atkinsons.
54	East side of Regulator	1.7000	1.6403		
55	Overcast: Return side	0.0288	1.5755	19,500	90.5
56	Overcast: Intake side	0.9807	0.5948		
57	4 N.H. East Intake	0.1730	0.4218		
58	No.1 Pit Bottom	0.1578	0.2640	28,000	
59	Junction of East Return		2.9655		540.0

....

Continued -

Station.	Location.	Press. Drop ins. W.G.	Total Press. ins. W.G.	Average Quantity.	Resistance Atkinsons.
26	Junction of No.2 Return				
27	14 M.H. Main Return	0.0355	3.0010		
28	No.2 Pit Bottom	0.2376	3.2386	51,000	1.97
29 (6)	End of South Mine		0.4145		
30	5 M.H. East Haulage	0.0750	0.4905		
31	9 M.H. East Haulage	0.1102	0.6007	23,000	8.0
32 (24)	S. side No.3 Doors	0.0379	0.6386	31,000	
33 (22)	S. side No.4 Doors	0.1254	0.7640	28,000	
34	20 M.H. East Haulage	0.0435	0.8075	25,000	
35	S. side No.5 Doors	0.0845	0.8920	18,000	5.5
36	8 yds. beyond Main Return to No.3 Face	0.0215	0.9315	1,000	
37	End of Level	0.2465	1.2600		
38	N. side No.5 Doors	0.8308	2.0908	6,000	35.8
39 (35)	S. side of No.5 Doors	1.1981			
40	20 yds. from corner G	0.1090	2.1198		
41	10 yds. from corner H	0.0983	2.2981		
42	Corner I	0.1360	2.4341		
43	N. side of No.4 Doors	0.0990	2.5231	13,000	47.0
44 (37)	End of Main Haulage Level	0.2993	0.9612		150.0
45	Corner J	0.0347	0.9959	2,000	
46	End of Haulage Road to No.2 Face	0.2595	1.2554		
47	15 yds. from corner K	0.2351	1.4905	5,000	33.6
48	Junction of Main Return			6,000	26.8
49	No.3 Face Main Intake				
50	No.3 Face West Return			3,000	
51	No.2 Face Main Intake			6,500	45.6
52	No.2 Pit Bottom		3.2380		
53	No.3 M.H. Main Return of East Section	0.0663	3.3043		

The data of Table II. were obtained from the survey. The resistances between the various stations are given in Atkinsons according to the formula,

$$P = R Q^2$$

where P = pressure drop in lb. per sq.ft.
R = resistance in Atkinsons
and Q = rate of air flow in thousands of cu.ft./sec.

Leakages. Opportunities were provided for testing of leakages.

Shafts. A leakage of 9,000 cu.ft. per minute occurred between shafts Nos.1 and 2. This seems large, but perhaps is not excessive in view of a water-gauge of 4½ ins. across the shafts.

Doors. Trap doors were found to give leakages between 1,000 and 4,000 cu.ft.per minute according to the state of repair.

Leakages at doors are often not realized. The writer found photographs, as in Fig.29 and 30, very effective in illustrating the 'air-tightness' of doors as found in practice.

Air-Crossings. A 'natural' type air-crossing showed the large leakage of 9,000 cu.ft. per minute. This type of air-crossing is often recommended for its air-tightness, but very often it proves inefficient due to breaking and fissuring of the strata. Other crossings gave leakages 2,000-4,000 cu.ft. per minute.

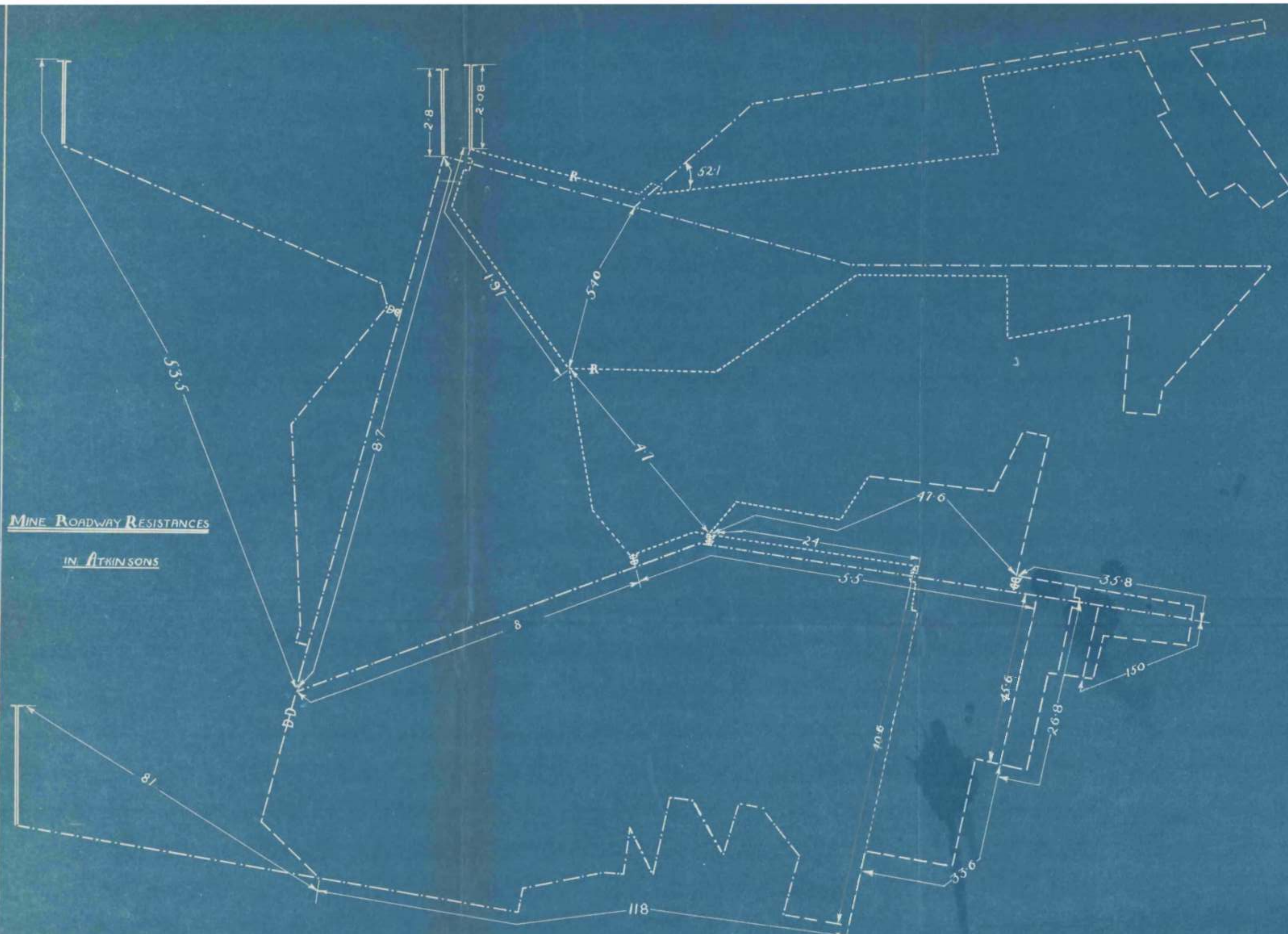
New Surface Mine as Intake. With the new mine as an intake there will be four downcasts - the mine with shafts Nos.1, 3 and 4 - and No.2 shaft as the only upcast. A new fan would be required at No.2. shaft to cope with the new quantities.

The main return airway from District C. would be as at present. Considering only the returns from the present extremity of District C, it would require 3.43 ins. of water-gauge to pass the new quantities.

New /

MINE ROADWAY RESISTANCES

IN ATKINSONS



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45	Corner J	0.0347	0.9959	2,000	
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58	No.1 Pit Bottom	0.1578	0.2640	28,000	
59	Junction of East Return		2.9655		540.0

....

New Surface Mine as a Return or Upcast. The new mine as an upcast would require a new fan (exhausting) at that mine to work in conjunction with the fan at No.2 shaft, the three downcast shaft remaining as before.

Considering the intakes from the downcasts shafts to the extremity of the present workings in District C, a water-gauge of 1.66 ins. is required for the new quantities. Hence it was decided to make the new surface mine an upcast.

Air Distribution under Proposed Scheme. The redesigned circuit for the new surface mine as an upcast is shown by Fig.28a.

The solution for the air distribution in such a network by Kirchhoff's laws becomes very involved. Kirchhoff's laws are relatively easy to apply to electric circuits since the first power of the current only is involved; for air-flow circuits the square of the current is involved and this leads to rather complex equations for simultaneous solution. The writer found that quicker solutions could be obtained by a method of trial and error assisted by graphs. For the various loops in the network graphs of pressure drop on a base of airflow were plotted from the relationship $P = R\,Q^2$. To facilitate the plotting of these graphs, values of log P against $\log(RQ^2)$ were plotted. These give straight lines so that two points were sufficient to determine the lines.

For a specified quantity in one loop of the network the pressure drop is known and, from this pressure drop, the distribution in all loops in parallel with the first loop is easily determined from the logarithmic graphs. The distribution works out as shown in Fig.28a.

Extended Workings. It is necessary to estimate the water-gauge and horse-power requirements of the new fan to be installed at the surface mine to deal with the fully-developed workings in District C. A diagram, Fig.28b, shows the possible conditions 10 years hence.

Air /

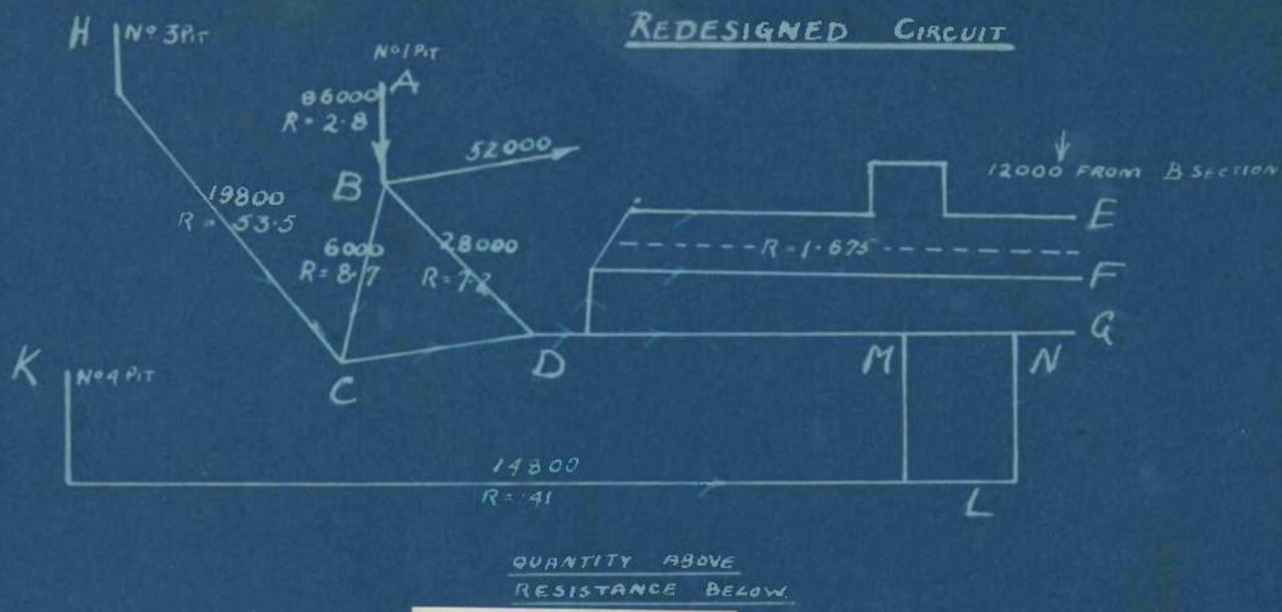


Fig. 28a.

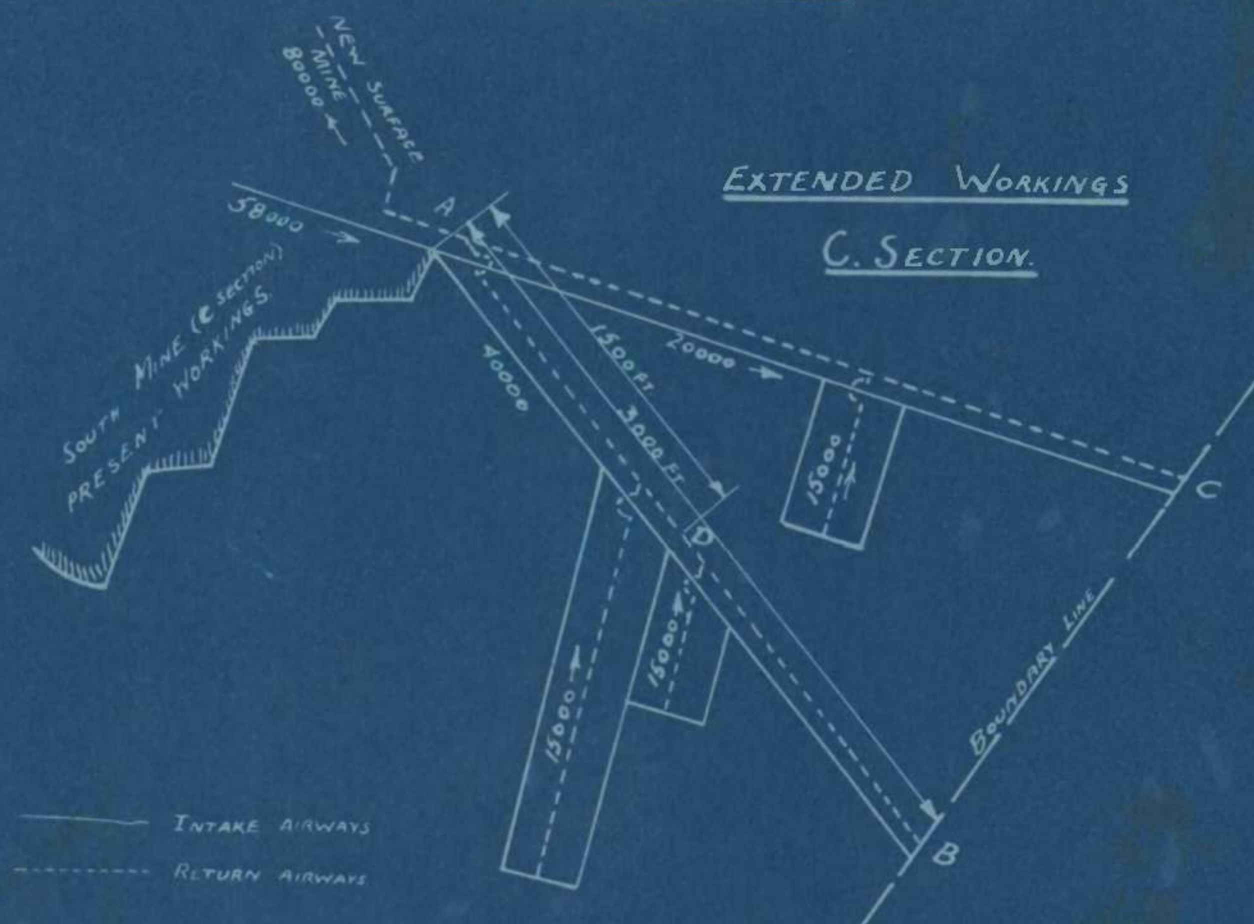


Fig. 28b.

PENETRATION OF LIGHT THROUGH SPACE AT BOTTOM OF DOOR.

If the door were airtight, the photograph would be entirely black. This photograph was taken shortly after the door was erected.

Fig.29.

PENETRATION OF LIGHT THROUGH AN OLD DOOR.

Fig.30.

Air to New Mine:-

District B	12,000 cu.ft.
No.1 Pit District	28,000 " "
No.2 Pit	6,000 " "
No.3 Pit	19,800 " "
No.4 Pit	14,800 " "
	80,000 " "

Pressure drop in New Mine. The mine to be arched 12 ft. x 10 ft. and to be 250 fathoms in length. Atkinson's coefficient of resistance is assumed to be 0.006.

$P = K\ S\ Q^2/\ A^3$

$= 0.006 \times 250 \times 6 \times 38.9 \times 80^2\ /\ 104.5^3$

$= 1.95$ lb. per sq.ft.

$= 0.376$ inches W.G.

Pressure Drop on Roadway AD:- The resistance of 780 yards of existing haulage road is 13.5 atks. Hence resistance of AD (500 yards) is 13.5 x 500/780 or 8.65 atks.

Pressure drop for 40,000 cu.ft. = 3.84 lb./sq.ft.

= 0.74" W.G.

The return will require the same water-gauge.

Roads from Main Intake and Return to Faces DE, etc.

Length of these roadways say 300 yards. Resistance is 3/5 of 8.65 or 5.19 atks.

Pressure drop for 15,000 cu.ft. = 0.062 in. W.G.

The return will require the same water-gauge.

Face:- The resistance for the face is assumed to be 30 Atkinsons which was found to be an average for faces in this district. The quantity is 7,500 cu.ft. This requires a pressure drop of 0.09 in. water-gauge.

Total /

Total Pit Water-Gauge.

The total water-gauge to be developed by the fan was found by three methods; the first purely theoretical, and the other two from practical considerations.

First Method.

Surface to present extremity of workings	1.66	ins.
Main intakes and returns	1.48	"
Sectional intakes and returns	0.12	"
Face	0.09	"
New mine	0.37	"
Fan drift (assumed)	0.10	"
Total water-gauge .	3.83	"

Second Method.

Assume that the face-road conditions remain as at present, low and restricted. The present water-gauge to pass 18,000 cu.ft. round the face area is 1 in.; the quantity is to be increased to 68,000 cu.ft. and allowing 50% leakage the actual quantity reaching the faces will be 34,000 cu.ft. The water-gauge required will be 1 in. x $(34,000/18,000)^2$ or 3.57 ins. The total water-gauge becomes:-

Surface to extremity of present workings	1.66	ins.
Face and face roads	3.57	"
Extension of main roads	0.15	"
New mine	0.37	"
Fan drift	0.10	
Total water-gauge	5.85	"

Third Method.

The distance between the foot of the main intake mine and the extremity of the present workings is approximately the same as the distance between the present extremity of the workings and the ultimate boundary. The water-gauge across the doors at the foot of this mine is 2.23 ins. From this the total water-gauge may be estimated as follows:-

Surface /

Surface to present extremity of workings	1.66 ins.
Extended workings	2.23 "
New mine	0.37 "
Fan drift	0.10 "
Total water-gauge	4.35 "

As the responsible mine management stated that the face roads would be enlarged to a reasonable size, the estimate by the second method could be disregarded. This leaves a choice of 3.83 ins. or 4.35 ins. W.G. A water-gauge of 4 ins. was actually adopted.

<u>Actual Results.</u> Since the foregoing work was done, the new surface mine has been completed and the new fan installed. The auxiliary mine from District B to District C has not been completed at the time of writing. A test of the new fan showed it to be passing 80,000 cu.ft. of air per minute with a water-gauge of $3\frac{1}{4}$ ins. The estimated value of the water-gauge for the stage of the workings at the time of the test was 3 ins. This is $\frac{1}{4}$ in. lower than the test value but the discrepancy is explained by the absence of the new auxiliary mine.

<u>Comments.</u> The foregoing problem illustrates the utility of ventilation surveying when any major rearrangement of the ventilation of a mine is contemplated. Before the above survey was made, the management of the colliery were strongly of the opinion that the new surface mine should be an intake (or downcast) for lowest resistance to distribution to meet the increased air flow.

A ventilation survey in such cases gives definite data to work upon and enables more accurate estimates to be made for future developments.

<u>Problem 2.</u> /

Problem 2.

Economy of Widening An Upcast Shaft. This problem was concerned with the economy of resinking an upcast shaft with a viewtosaving in ventilation costs. Would the saving in ventilation costs by reducing the resistance of the shaft justify the outlay in resinking?

The upcast shaft from the surface to seam C was rectangular, 13 ft. x 10 ft., with wood lining. The lower portion, from C to the bottom, was a later deepening and was circular in form, 20 ft. 2 in. in diameter, and concrete lined.

The proposal was to resink the upper portion to 20 ft. 2 in. diameter throughout, and to line with concrete.

Ventilation Survey of Shaft. It was necessary first to make a ventilation survey of the shaft in order to obtain definite data regarding its resistance. Fig.31 illustrates the method of carrying out this survey. The Askania minimeter was used in conjunction with rubber tubing and pitot tubes. The rubber tubing was fastened to the winding rope and let down to different levels in the shaft. In this way the pressure drop was obtained over different sections.

The N.P.L. pitot tube was found unsuitable due to the amount of water in the shaft. The static and total pressure holes were liable to be choked by water. Special tubes to be constructed.

The quantities of air passing in the shaft were measured in the fan drift and at the insets of B and C Sections.

The following results were obtained:-

Section	Pressure Drop.	Average Quantity
Surface to B.	2.56 lb./sq. ft.	93,600 cu.ft.
B to C	0.282 " " "	73,600 " "

Atkinson's /

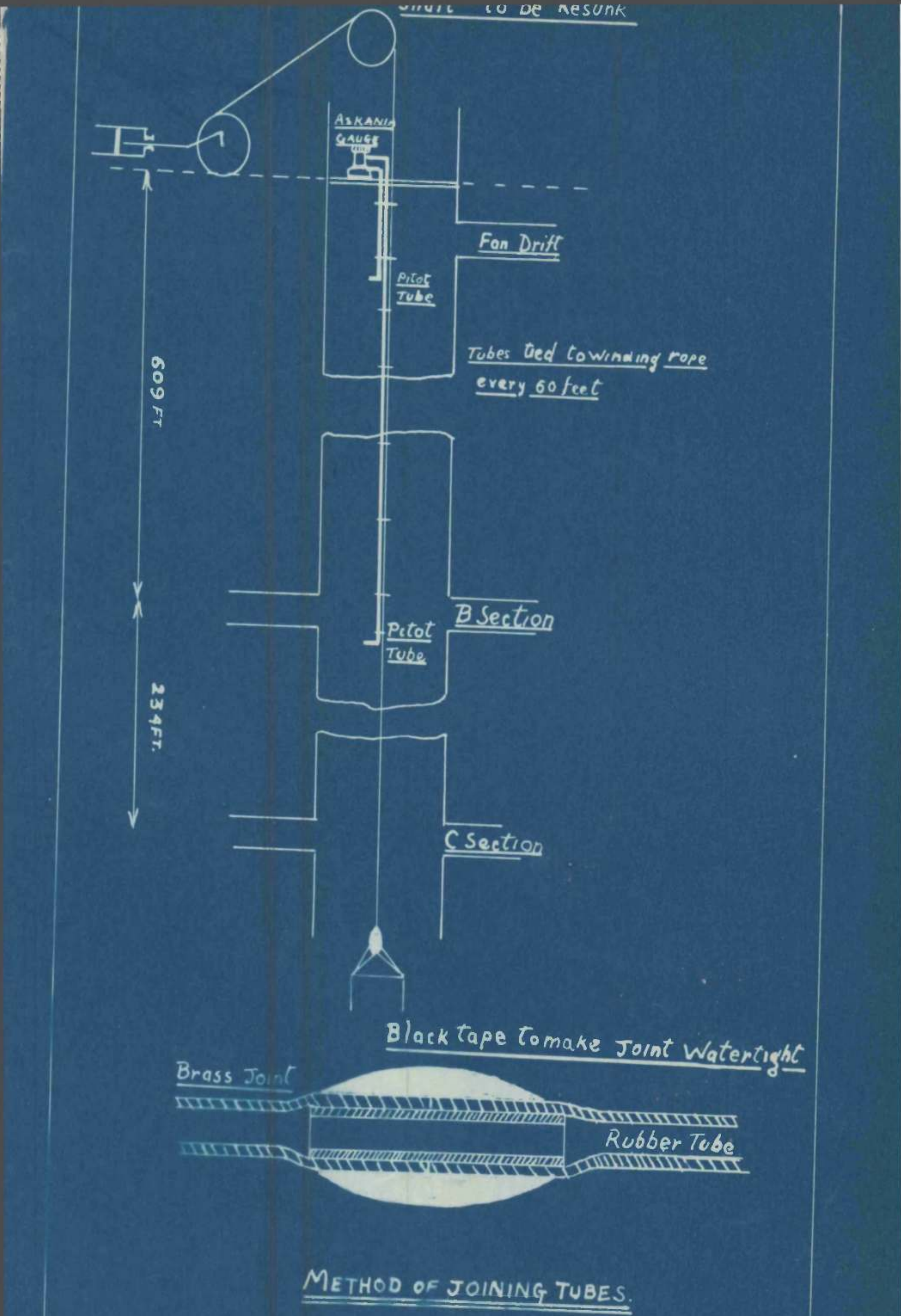

Shaft to be Resunk
ASKANIA GAUGE
Fan Drift
Pitot Tube
Tubes tied to winding rope every 60 feet
609 FT
B Section
Pitot Tube
234 FT.
C Section
Black tape to make Joint Watertight
Brass Joint
Rubber Tube
METHOD OF JOINING TUBES.

Fig. 31.

Atkinson's Coefficient of Resistance for Shaft.

The data obtained from the shaft survey gave the following values for Atkinson's coefficient of resistance.

Section.	Atkinson's Coefficient (K)
Surface to B.	0.0245
B to C	0.0210

The write is unaware of any published values of 'K' for rectangular shafts. He is of the opinion that the values obtained in this case are much higher than is commonly reckoned for such shafts. Indeed a value of 0.01 is commonly considered high for most mine airways. When one considers the obstruction by buntons in rectangular shafts, a much higher value of 'K' is to be expected than in underground roadways. The buntons are in positions to create greater turbulence It is to be suspected that in any shaft fitted with rigid conductors for the cages a fairly high value of 'K' should be adopted even if the shaft is 'smooth-lined'

Efficiency Test of Fan. As the fan in operation at the mine was to be retained, it was necessary to find the variation in its characteristics with change in equivalent orifice of the mine. An efficiency test on varied equivalent orifice was carried out on the lines of B.S. Specification relating to efficiency tests on mine fans.

Air Horse-power Costs. Section Surface to B.

With present rectangular shaft;-

Air horse-power = 2.56 x 93600/33000

= 7.25

$$\text{Kilowatt-hours per annum} = \frac{7.25 \times 746 \times 24 \times 365}{1000}$$

= 47400

Annual /

Annual power cost at ½d per kWhr. = £49.4

With a fan efficiency of 60.5% the actual cost is-

$$49.4/.605 = £81.75$$

When this section of the shaft is resunk to 20 ft. 2 ins diameter and concrete lined, the pressure drop for the same air flow, on the assumption that the coefficient of resistance is improved to 0.005, will be

$$P = K\ S\ Q^2/A^3$$

$$= 0.005 \times 36400 \times 93.6^2\ /\ 318.2^2$$

$$= 0.0495 \text{ lb. per sq.ft.}$$

The air horse-power will be 0.1405 and the annual power charge with fan efficiency of 60.5% will be £1.58.

The actual saving in power charge for ventilation by resinking the shaft over Section Surface to B would be

$$£81.75 - £1.58 = £80.17$$

Air Horse-power Costs. Section B to C.

The pressure drop of 0.282 lb. per sq.ft. for Section B to C was measured over only 130 ft. length of this section, and since the actual length was 234 ft., the actual pressure drop for the full length is -

$$0.282 \times 234/130 = 0.509 \text{ lb. per sq.ft.}$$

The annual power charge with a fan efficiency of 60.5% is £14.3.

When this section is resunk and lined with concrete, the pressure drop for the same quantity becomes 0.0124 lb. per sq.ft. The power cost per annum with fan efficiency of 60.5% would be £0.349.

The annual saving would be -

$$£14.3 - £0.349 = £13.95.$$

Total /

Total Saving by Resinking Both Sections.

The annual saving in power costs by resinking both sections and with the same air flow as at present would be -

£80.17 + £13.95 = £94.12

As future requirements of air quantities were not stipulated, it was necessary to work out the savings for a range of quantities. For this purpose Table 3 was compiled. The graph of figure 32 was constructed from this table and allows the saving to be readily obtained for any quantity of air up to the full capacity of the fan.

Suppose, for example, that 125,000 cu.ft. of air per minute are required and of this quantity B section requires 25,000 cu.ft. while the remaining 100,000 travels the full depth of the shaft from C. From the graph it is found that the saving in air horse-power costs are £18.88 for 100,000 cu.ft. traversing the section C to B, and £115.74 for 125,000 cu.ft. traversing the section from B to the surface. The total annual saving on air horse-power charges is

£115.74 + £18.88 = £134.63

Allowing for the efficiency of the fan, the total annual saving is £206.

Conclusion. For a quantity of 125,000 cu.ft. of air per minute, the annual capital and depreciation charges for sinking and fitting the shaft must not exceed £206 if the proposal is to be economic from the point of view of saving in ventilation charges. As no data were supplied regarding the estimated sinking and fitting costs, it is impossible to give a definite conclusion here.

Table 3. Saving in Ventilation Costs.

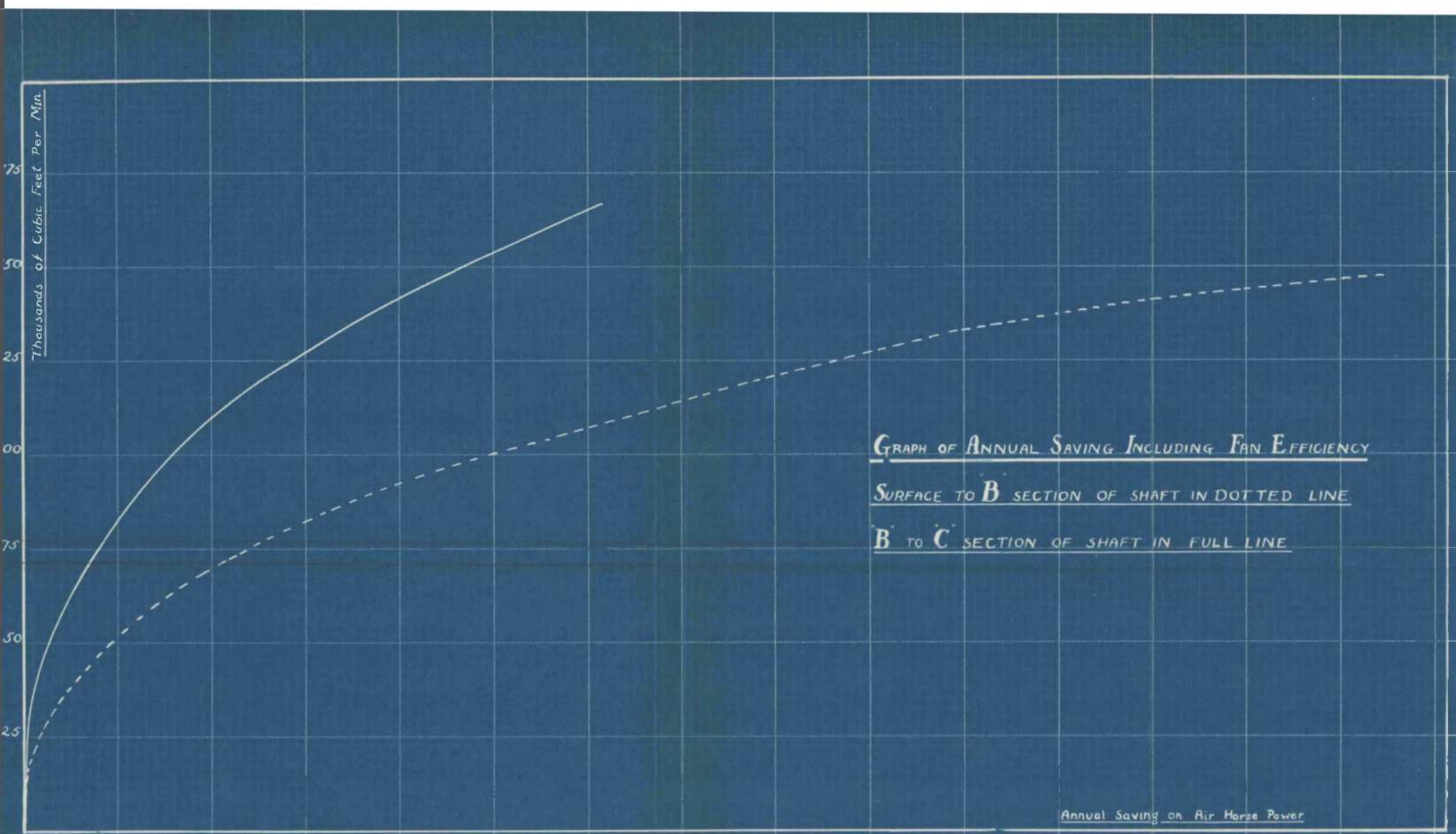
Shaft Section: Surface to B.

Quantity.	Pressure Drop. Old Lining. lb./ft^2	Pressure Drop. New Lining. lb./ft^2	Power Cost (A.H.P.) Old Lining. £	Power Cost (A.H.P.) New Lining. £	Annual Saving with New Lining. £.	Annual Saving allowing for Efficiency. £
25,000	0.183	0.0035	0.942	0.0181	0.924	3.42
50,000	0.732	0.0141	7.52	0.145	7.395	17.6
75,000	1.65	0.0315	25.5	0.487	25.012	46.3
100,000	2.93	0.0564	60.4	1.16	59.24	95.8
125,000	4.58	0.088	118	2.26	115.74	175.5
150,000	6.6	0.127	204	3.92	200.08	286

Shaft Section B to C.

25,000	0.0587	0.00143	0.302	0.0073	0.225	1.09
50,000	0.235	0.00572	2.42	0.0589	2.361	5.62
75,000	0.529	0.01285	8.16	0.198	7.962	14.75
100,000	0.94	0.229	19.35	0.472	18.888	30.5
125,000	1.47	0.0385	37.8	0.922	36.87	55.9
150,000	2.11	0.0515	65.25	1.59	63.66	90.9

P.T.O.



Thousands of Cubic Feet Per Min.
GRAPH OF ANNUAL SAVING INCLUDING FAN EFFICIENCY
SURFACE TO "B" SECTION OF SHAFT IN DOTTED LINE
"B" TO "C" SECTION OF SHAFT IN FULL LINE
Annual Saving on Air Horse Power
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
25
50
75
100
125
150
175

Fig. 32.

Air Conditions in a Deep Rand Mine.

Some data relating to air conditions in a Rand Gold Mine are given.

Air Conditions in a Deep Rand Mine.

During a summer vacation spent in a Rand Gold Mine some investigations were made of the air conditions as regards temperature, moisture content and total heat.

At a number of selected stations in the mine the wet and dry bulb temperatures and barometric pressure were noted. A whirling type hygrometer was used for temperature measurement, and an aneroid for barometric pressure. The following quantities were calculated from the observed data (Table 4.):-

1. The amount of moisture in grains per pound of air at each station.

2. The total heat picked up by the air neglecting heat due to adiabatic compression.

3. The total heat per pound of air from all sources.

4. The temperature variations due to compression and decompression.

The graphs of Fig.33 were drawn from the observed and calculated data. From these graphs the following deductions were made:-

Temperature:

Between points 1 (surface) and 2, the main influences at work are, primarily, the heating of the air by adiabatic compression as it passes down the shaft, and secondarily, cooling due to evaporation of moisture in the wet shaft. The former action being predominant causes the temperature to rise steadily as the air descends the shaft.

The marked rate of increase in temperature where adiabatic compression acts alone is seen between points 4 and 5 where the shaft is dry.

Between points 2 and 4 there is a decided increase

in /

Table 4.

Point	Type of Airway Between Points in First Column	Time A.M.	Length Feet	Depth Feet	Bar Inches Mercury	Temperatures Dry °f	Temperatures Wet °f	Temp. Diff. °f	Moisture Grs/Ft³ At 30" Bar	Moisture Corr. per Inch Bar	Inches Bar. Above or Below 30"	Total Corr.	Grains Moisture per Ft³	Air Density Lbs/Ft³	Grains Moisture per Lb.	Dew Point °f	Total B.T.U./Lb of Air	Dew Pt Corr. for Depth	B.T.U./Lb of Air Less Corr. Factor	Temp Rise Due Adiabatic Compr.	Heat Inc. Due Adiab. Compr. B.T.U./Lb	Total Heat Due Adiab. Compr. B.T.U./Lb.
1	Wet Shaft.	7-30	0	0	24.41	47.0	39.5	7.5	1.82	.03	-5.59	+.1077	1.99	.064	31.1	31.3	0	0	0	0	0	0
2	Damp ᵀ/c Fans and Hoists.	7-45	2608	2608	27.11	57.0	50.5	6.5	3.32	.026	-2.89	+.0754	3.40	.069	49.3	45.0	6.0	37.0	2.1	13.4	3.35	3.35
3	Dry Vent Raise.	8-00	3178	2760	27.55	65.0	54.5	10.5	3.42	.042	-2.45	+.1029	3.52	.069	51.0	46.7	7.0	38.1	2.5	14.2	3.20	3.55
4	Dry Shaft.	8-10	3230	2783	27.58	66.0	56.5	9.5	3.89	.038	-2.42	+.0719	3.98	.076	57.0	50.0	8.9	42	4.5	14.3	.02	3.57
5	Damp ᵀ/c.	8-25	6569	6122	30.89	83.5	66.0	17.5	4.76	.070	+.89	-.0623	4.70	.070	62.0	55.0	11.3	37.2	2.1	31.5	4.30	7.87
6	Dry Shaft.	8-40	7429	6122	30.87	79.5	67.0	12.5	5.64	.050	+.87	-.0435	5.60	.077	73.7	59.0	13.9	42.0	4.3	31.5	0	7.87
7	Damp Shaft.	10-05	8228	6613	31.39	81.0	68.5	12.5	6.00	.050	+1.39	-.0695	5.93	.078	77.0	62.0	15.5	44.0	5.3	34.0	.62	8.49
8	Damp Shaft.	10-20	8601	6854	31.64	80.0	69.0	11.0	6.32	.044	+1.64	-.0722	6.25	.078	80.1	63.0	16.1	44.5	5.9	35.3	.32	8.81
9	Wet ᵀ/c.	11-15	8911	7056	31.84	79.0	70.5	8.5	7.04	.034	+1.84	-.0620	6.98	.078	89.5	66.0	18.0	47.9	7.2	36.3	.25	9.06
10	Wet Raise.	11-00	9911	7000	31.77	80.5	74.0	6.5	8.27	.026	+1.77	-.0460	8.22	.077	105.2	71.5	22.2	54.6	10.8	36.0	-.07	8.99
11	Dry Raise.	10-40	10651	6854	31.61	86.0	78.0	8.0	9.28	.032	+1.61	-.0515	9.23	.077	120	75.0	25.2	59.0	13.4	35.3	-.17	8.82
12	Dry Raise.	9-55	11051	6800	31.30	88.0	78.0	10.0	9.01	.040	+1.30	-.0520	8.96	.076	116	74.0	24.9	58.0	13.0	35.0	-.07	8.75
13	Damp Raise.	9-30	11441	6420	31.14	88.5	78.0	10.5	8.94	.042	+1.14	-.0479	8.89	.076	117	74.0	24.9	59.0	13.7	33.1	-.47	8.28
14	Wet ᵀ/c and Damp Raise.	9-10	12006	6270	30.97	87.5	78.5	9.0	9.31	.030	+.97	-.0349	9.28	.075	122	75.5	26.5	61.0	15.0	32.3	-.20	8.08
15	Wet Stopes Raises and ᵀ/c s.	8-55	12465	6122	30.80	86.5	79.5	7.0	9.91	.028	+.80	-.0224	9.89	.073	132	77.0	27.5	63.0	16.1	31.5	-.20	7.88
16	Wet Stopes Raises and ᵀ/c s.	11-20	14965	5526	29.91	85.5	83.0	2.5	11.77	.010	-.09	+.0009	11.77	.071	101	82.0	34.5	71.1	22.6	28.5	-.75	7.13
17	Old Workings.	11-40	18665	4376	29.06	85.5	83.5	2.0	12.02	.008	-.94	+.0075	12.03	.067	169	82.5	36.5	73.4	26.9	22.5	-1.5	5.63
18		12-00	22665	2782	27.46	81.0	80.5	0.5	11.15	.002	-2.54	+.0051	11.16	.060	167	80.5	32.0	74.5	27.5	14.3	[illegible]	3.58

in temperature due to the working of electrical machinery and, to a certain extent due to the compression of the air by fans. These increases could be avoided by passing cooling air for the electrical machinery direct to the return airway, and by employing exhausting fans instead of the blowing type.

A drop in the dry bulb temperature is noted between points 5 and 10. This is due to absorption of moisture from the workings. This temperature drop increases the capacity of the air to cool by sensible heat extraction, but decreases the difference between the dry and wet bulb temperatures. The reduction in this difference lowers the rate of sweat absorption and thus lowers the cooling power.

As the air approaches the end of its journey the dry bulb drops steadily due mainly to adiabatic decompression as it rises to higher levels through caved ground. This cooling is not beneficial as the air has completed its ventilation duty.

Moisture.

Most of the moisture is picked up in the actual working places. This is unavoidable so long as wet drilling and wetting-down is required for the suppression of dust.

Beyond point 11 the moisture content drops due to the introduction of relatively dry air from another mine.

Something like 400 tons of water per day are carried out on one shaft at this mine by the air current.

Heat Increase.

Between points 2 and 4 a large amount of heat has been gained from the electrical machinery and fans.

An interesting phenomenon appears between points 4 and 5 in Graph E. Here the amount of heat per pound of /

Fig. 33.

Rand Mine Survey

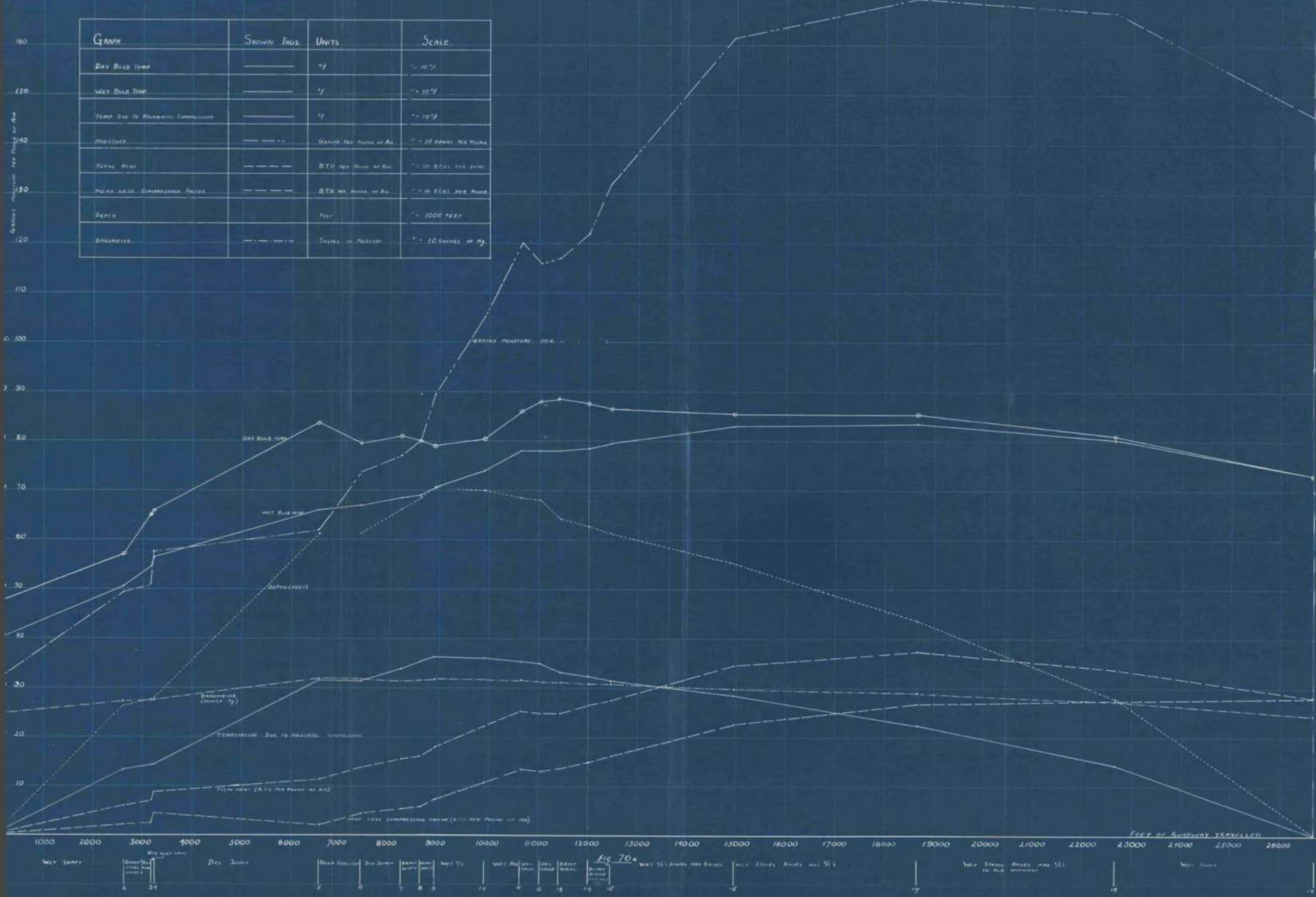


Fig 70.

of air actually diminishes. Possibly this may be accounted for by a daily change in weather conditions. The reading was taken at 11 a.m. after a night of hard frost. Thus the shaft walls had been slightly cooled during the night and were gradually absorbing heat from the downcast air when the observation was made.

The greatest rate of heat gain is in the actual working places.

Beyond point 15 the graphs all tend to be smoothed out. As already indicated the air is now in old workings.

General Deductions. The following general deductions are made from an inspection of the graphs:-

1. Adiabatic compression is one of the main sources of temperature rise. This arises from the great depths of the mine.

2. The amount of heat given out by machinery is great but could be dealt with by short circuiting the cooling air to the return.

3. A large quantity of moisture as absorbed in the stopes and development work. This is mainly due to wet drilling and wetting down which is practised in the prevention of silicosis.

4. The absorption of moisture lowers the dry-bulb temperature but decreases the differences between the dry and wet bulbs. This may have a deleterious effect on the cooling power where temperatures are high.

In order to compare the gold mine with a coal mine a temperature survey of a deep Scottish colliery was mad When the survey was made a hygrometer was not available for wet bulb readings, while steam pipes in the downcast shaft made the conditions somewhat abnormal.

The dry-bulb temperatures and depths, however, can be compared /

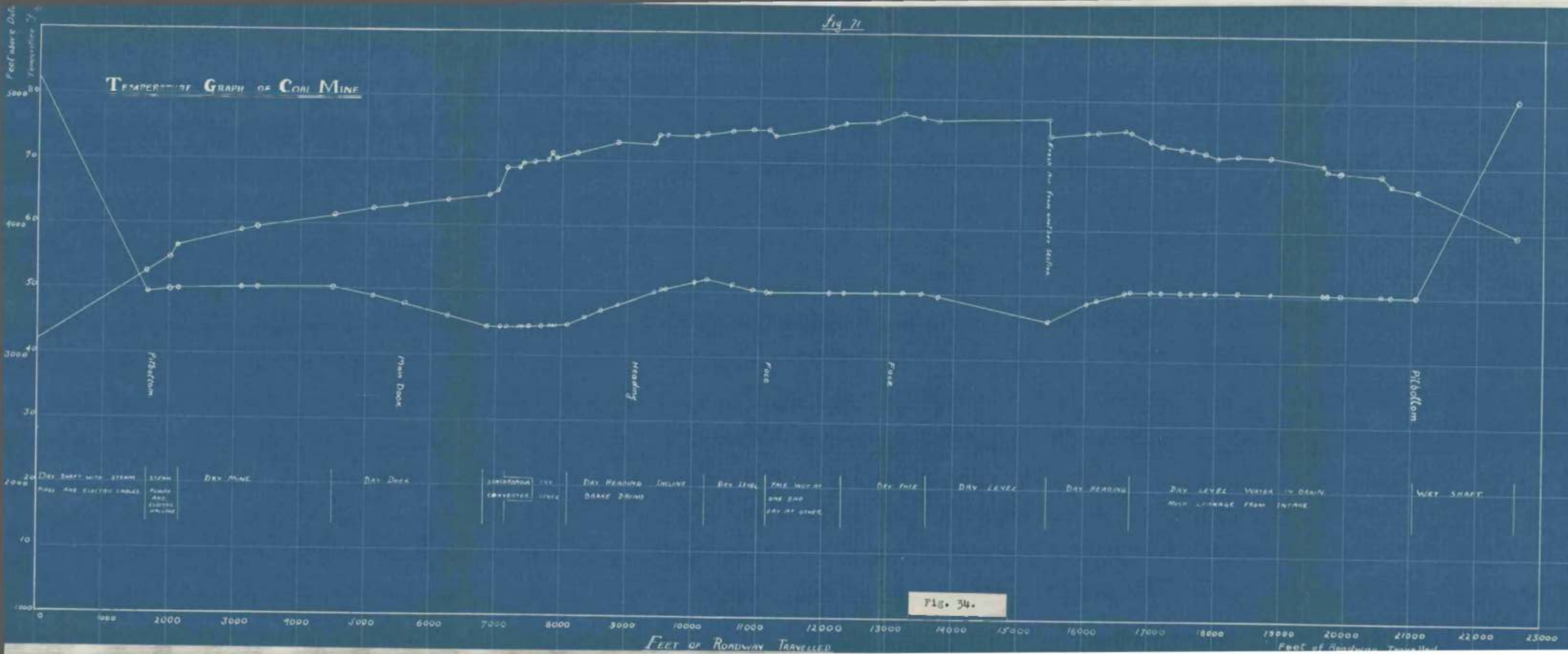
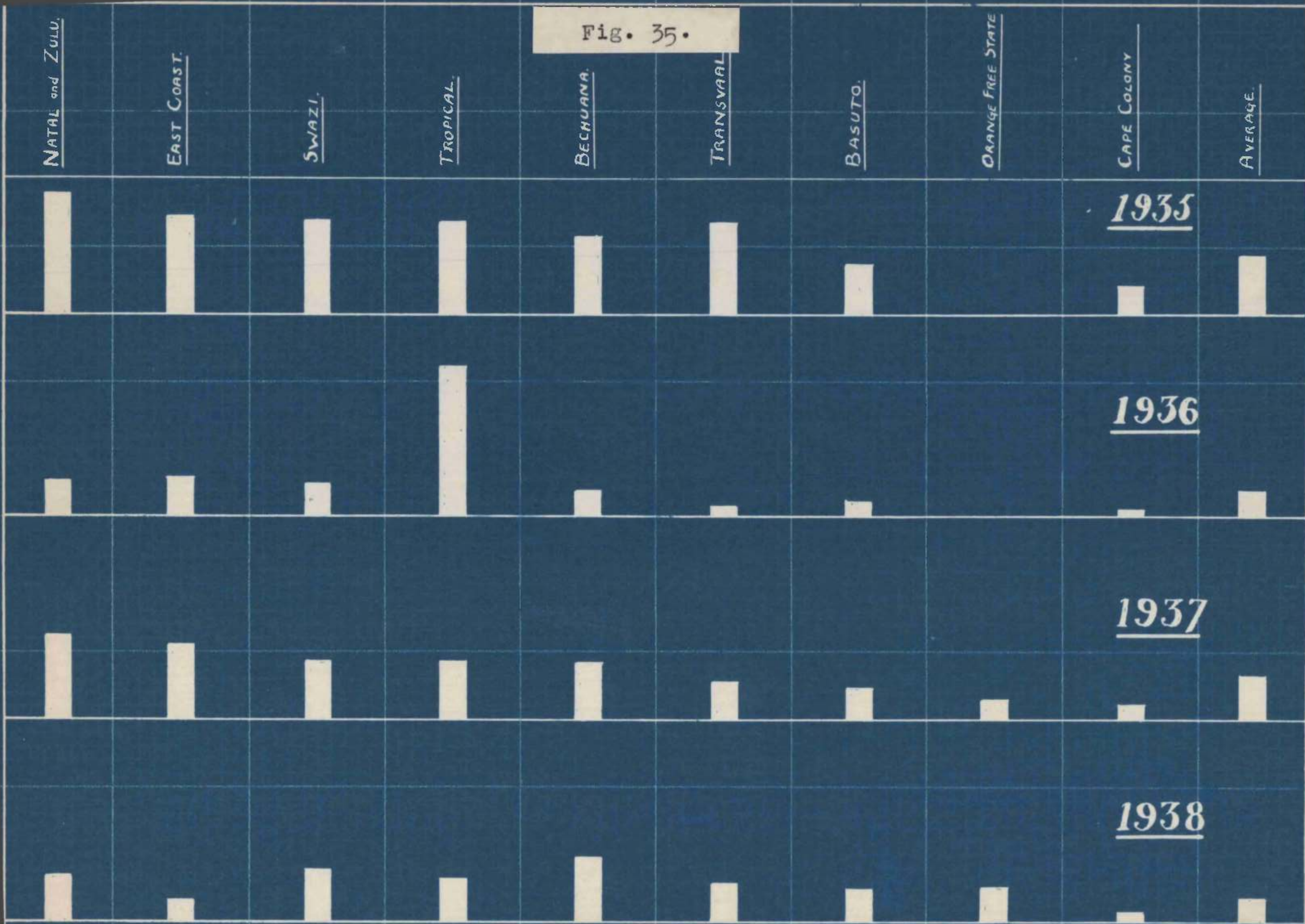


Fig 71
Temperature Graph of Coal Mine
Pitbottom
Main Door
Heading
Face
Face
Fresh Air from another Section
Pitbottom
Dry Shaft with Steam Pipes and Electric Cables
Dry Mine
Dry Door
Dry Heading Incline Brake Drums
Dry Level
Dry Face
Dry Level
Dry Heading
Dry Level Water in Drain Much Leakage from Intake
Wet Shaft
Feet of Roadway Travelled

Fig. 34.

compared. Graphs of temperature and depths for the colliery are given in Fig.34.

Fig. 35.



Tribe Distribution (Cases of Pneumonia per 1000 Natives)

Notes on the Incidence of Pneumonia among Natives in a Rand Gold Mine.

While visiting a Rand gold mine the writer collected some notes on pneumonia cases among the native miners. This illness among native labour gives some concern to the ventilation staffs of the Rand mines.

Tribe Distribution.

The following figures give the number of cases per 1000 natives of each tribe employed:-

Tribe.	Cases per 1000 Natives.			
	1935	1936	1937	1938.
Natal & Zululand	9.0	2.78	6.3	3.54
East Coast	7.36	2.99	5.5	1.71
Swazi	7.0	2.43	5.5	3.94
Tropical	6.9	11.03	4.3	3.15
Bechuanaland	5.75	1.97	4.2	4.87
Transvaal	6.83	0.73	2.8	2.90
Basuto	3.78	1.06	2.4	2.49
Orange F.S.	Nil.	Nil.	1.5	2.55
Cape Colony	2.06	0.62	1.1	0.83
Average	4.47	2.00	3.26	1.89

The diagram of figure 35 shows the distribution according to tribe more clearly. It is obvious that some tribes are more susceptible to pneumonia than others. An attempt is therefore made to recruit as much /

Notes on the Incidence of Pneumonia among Natives in a Rand Gold Mine.

much labour as possible from those tribes least prone to the illness. All natives also north of 22 degs. latitude are debarred from working in the mines.

Acclimatization.

The following figures show the susceptibility of the natives according to the period of work in the mine.

Period.	Cases per 1000 Natives. 1935.	1936.	1937.	1938.	Average.
Under 14 days	25.2	8.6	10.2	15.7	15.9
14/30 days	13.6	10.5	10.2	7.9	10.9
30/60 days	14.6	14.4	14.6	11.4	13.9
60/90 days	9.2	13.5	15.1	6.1	11.3
90/120 days	10.2	13.5	10.6	18.4	12.4
Over 120 days	21.1	39.4	39.2	40.3	35.5

To obtain a graphical picture of what happens, the total cases per 1,000 natives each month are added to the total cases up to that period, thus giving the total cases against a time period (Fig.36).

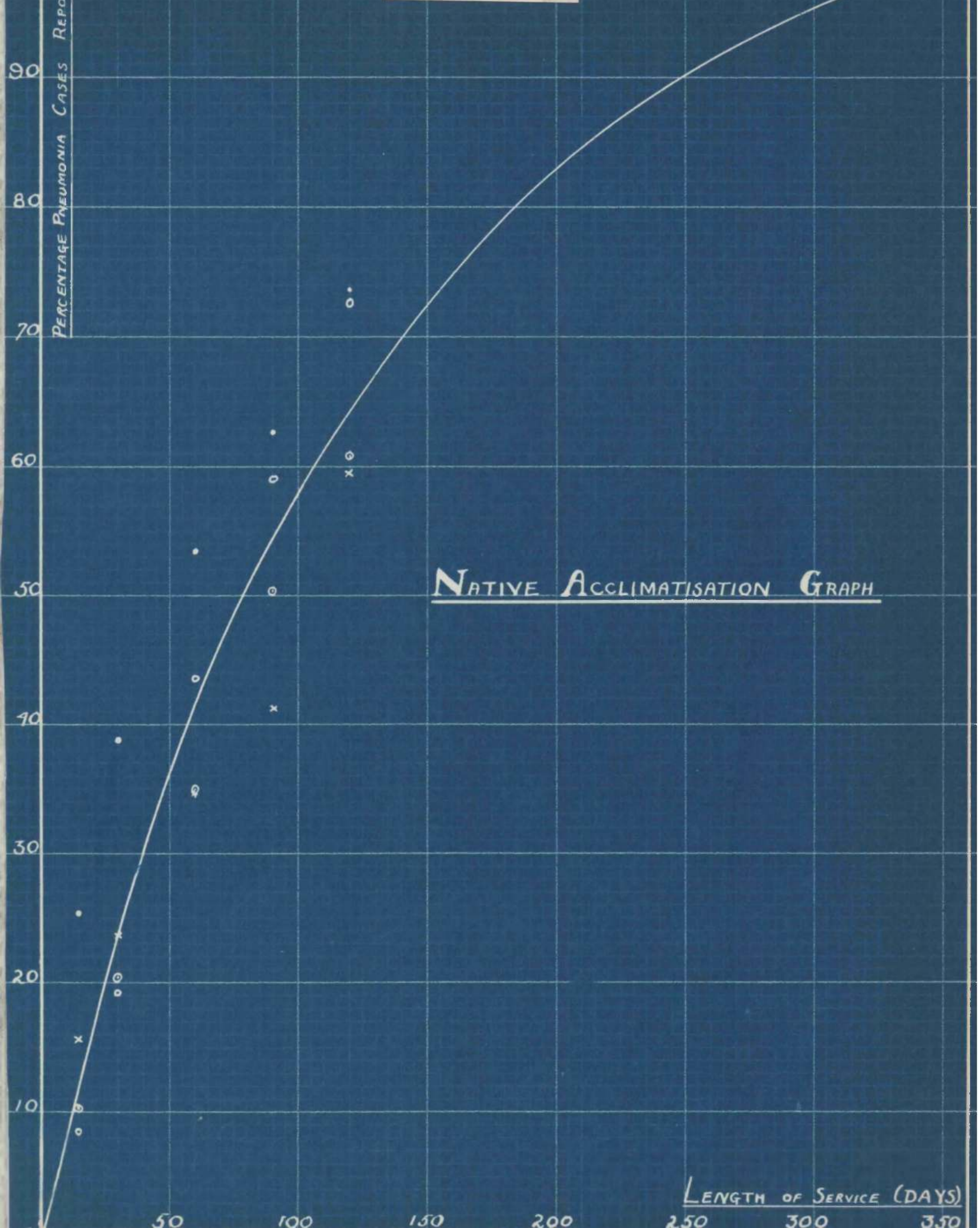
From the graph it is seen that the longer a native works in the mine the less liable he is to take pneumonia. A system has been evolved to acclimatize the natives in the upper levels with light work and fairly good temperature conditions, before employing them in the more severe work of the deeper levels.

The number of cases reported on each day of the week is interesting:-

Day.	Cases per 1000 Natives. 1935.	1936.	1937.	1938.
Monday	29.1	27.8	22.7	20.2
Tuesday	13.1	19.2	14.5	16.7
Wednesday	16.0	12.5	17.9	15.8
Thursday	15.5	15.4	14.5	13.2
Friday	14.1	12.5	12.6	20.2
Saturday	10.2	12.5	15.0	11.4
Sunday	1.9	—	2.9	2.6

The /

Fig. 36.



Percentage Pneumonia Cases Reported
Native Acclimatisation Graph
Length of Service (Days)
90
80
70
60
50
40
30
20
10
50
100
150
200
250
300
350

The graph of 'total cases' up to any day (Fig.37) is plotted against the time interval from the beginning of the week. A straight line graph might be expected, but instead, a curve is obtained showing that the rate of incidence is very high at the beginning of the week, and tapers off towards the end of the week. The explanation of this is that on Sundays the natives invariably hold a war dance and drink a great deal of Kaffir beer, with the resultant effect that they have a low vitality at the beginning of the week, but gradually recover as the week progresses.

It is not considered desirable to stop these war dances meantime as difficulty is often experienced in recruiting labour if the native recreation is interfered with.

Temperature.

It was formerly thought that pneumonia was contracted mainly by natives who were employed in hot workings with low air velocities, and were chilled by coming out into the colder airways. Old army tunics were distributed to keep them warm at the end of the shift, but the experiment had disappointing results, as there was no appreciable reduction in reported cases.

Another experiment tried was to inoculate against pneumonia. This also failed, as in one year, out of 148 cases reported, 67 had been inoculated and 81 had not. Seven cases of those inoculated died, while there were only 6 deaths among those not inoculated.

A further point under consideration is the lack of sunshine while underground. The natives on the nightshift during the winter months are much less liable to contract the malady than the dayshift. This is thought to be due to the former getting more sunshine, and experiments are being tried with artificial sunlight in the bath houses.

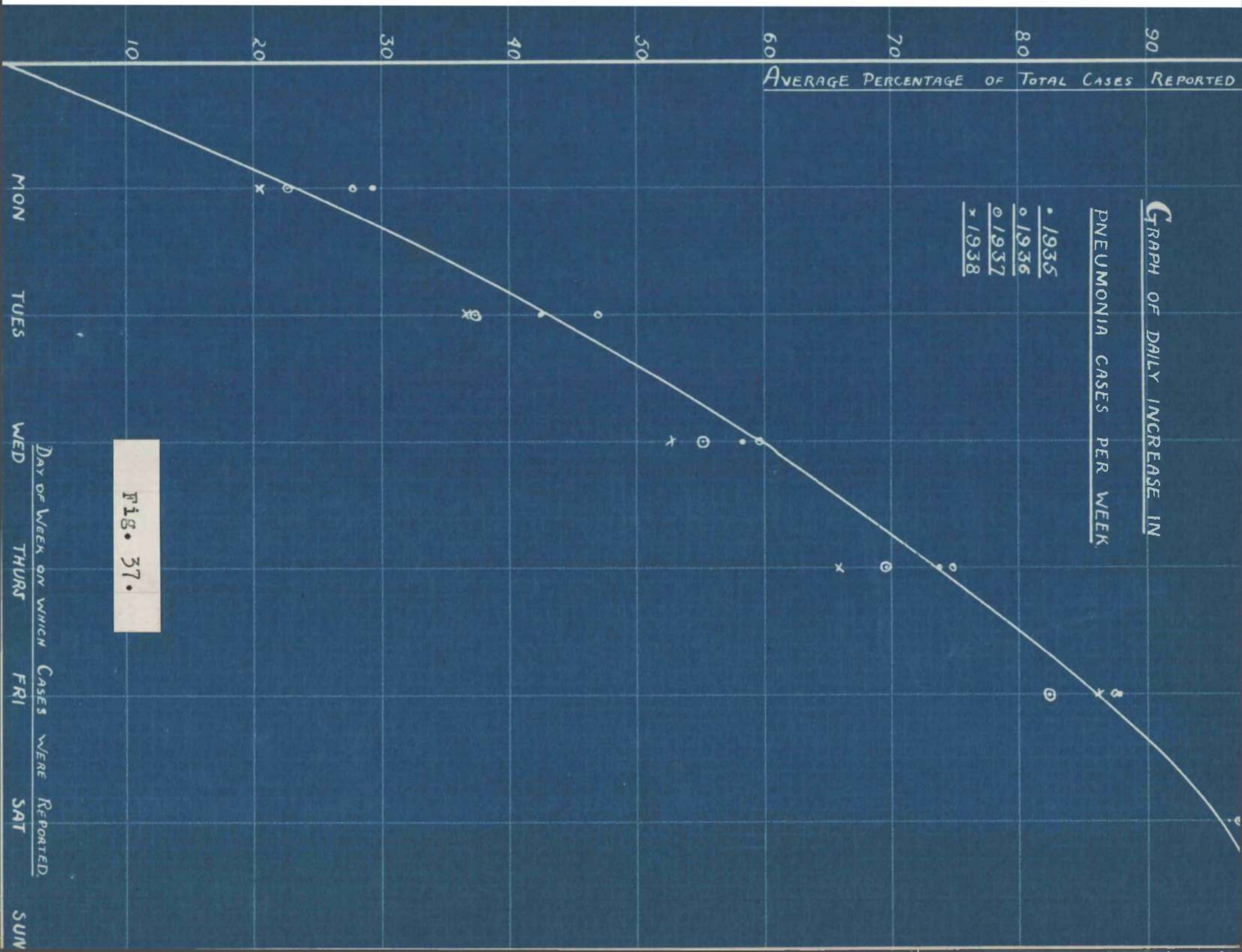

GRAPH OF DAILY INCREASE IN
PNEUMONIA CASES PER WEEK
• 1935
∘ 1936
⊙ 1937
× 1938
AVERAGE PERCENTAGE OF TOTAL CASES REPORTED
10
20
30
40
50
60
70
80
90
MON
TUES
WED
THURS
FRI
SAT
SUN
DAY OF WEEK ON WHICH CASES WERE REPORTED.

Fig. 37.

General Summary of Conclusions.

General Summary of Conclusions.

1. While a simple, cheap, light, handy and reasonably accurate instrument can be constructed for the measurement of irregular cross-sections of mine roadways either by offsetting or by giving direct results, the author considers that photographic methods are more accurate and are more convenient and speedy during field work underground.

2. The smoke test is shown to be unreliable for the measurement of low air velocities. The inaccuracy increases rapidly as the air velocity becomes lower, reasonably accurate results being obtained only down to about 200 ft. per minute.

   The smell test gives better results and agrees closely with the low-reading anemometer down to speeds as low as 50 ft. per minute.

3. Normal traffic obstructions in mine roadways appreciably raises Atkinson's coefficient of resistance which, as determined by the author underground, for some modern linings of roadways shows values that are somewhat higher than generally accepted values. These values would appear to be applicable only to roadways clear of tubs, which is not the normal condition of a mine roadway.

   It would seem that, with traffic obstruction even in large modern roadway having comparatively smooth and regular lining, the value of Atkinson's 'K' taken at 0.01 is by no means too conservative.

4. Tests tend to show that, for mine ventilation surveying, a convenient and entirely new type of pressure gauge based on the Wheatstone Bridge principle and employing the varied resistance of carbon granules by compression, is possible, and that further research is justified to afford definite conclusions on the reliability of the principle.

5. /

5. In the measurement of air velocities in mine airways, the centre constant is not seriously affected with the observer standing centrally in th airway at distances greater than about 4 feet downstream of the measuring section. This holds for obstruction up to about 75% of the cross-section of the airway.

Contrary to general opinion a central stance is better than a stance at the side of the airway as the distribution remains normal up to shorter distances from the central obstruction.

6. The pressure and power loss in long fan drifts with bends may be much higher than is generally considered. Air velocities in fan drifts are high and if the drift is long and contains some bends or elbows, a considerable water-gauge may be absorbed.

The losses are greatly augmented if there is a serious leakage at the air-locks.

7. A ventilation survey prior to any major rearrangeme of a ventilation system is strongly recommended. The most economical distribution can be worked out and the requirements of any new plant can be closely estimated.

8. The resistance to airflow in wood lined rectangular shafts is very high. A value of 0.02 was found for Atkinson's coefficient of resistance in one cas

9. A survey of air conditions in a deep gold mine showed adiabatic compression due to depth, electrical machinery underground, and underground fans to be the important factors in raising the air temperature. Heat from electrical machinery underground is generally considered to have negligible effect in raising the atmospheric temperature, but in the case examined it is an important factor. Underground fans of the forcing type add much heat to the air.

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Acknowledgements.

I wish to thank Professor Bryan and the Staff of the Mining Department of the Royal Technical College for the very valuable assistance they have rendered me. Their criticisms have always been constructive and helpful.

I am also indebted to the following Firms who have given me facilities to study the practical application of Mine Ventilation:-

The Wemyss Coal Company Limited, Fife.

Wm. Baird & Company, Limited, Dumbartonshire.

Crown Mines, Limited, Johannesburg.

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