Fan Efficiencies on Mines of the Union Corporation Limited

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SYNOPSIS

The duties and efficiencies of a number of main and auxiliary fans were determined by standard and thermal methods. Some observations on the effect of water and dirt accumulation on fan performance were made.

SINOPSIS

Die werkvermoë en doeltreffendheid van 'n aantal hoof en hulpwaaiers was deur middel van standaard en termiese metodes bepaal. Sekere waarnemings ten opsigte van die uitwerking van water en vullis ophoping op die werkverrigting van waaiers was ook gemaak.

1. INTRODUCTION

Before 1960, mines of the Union Corporation Group were working at moderate depths and the ventilation systems were designed to overcome the problems of dust and methane. They were not concerned to any extent with the heat problem so acute in some other Groups. Consequently no expensive refrigeration apparatus was necessary and fans were of moderate size and power. In these circumstances there was little incentive to be highly critical of the efficiency of the installations.

Since 1960, however, the trend of the mines has been to deeper workings in rock formations of higher geothermic gradients necessitating a steep rise in the size and power of ventilation units. Tests carried out on some of the new equipment indicated that efficiencies were lower than planned and consequently it was decided early this year to obtain detailed information on the operation and efficiency of as many fans as possible through special surveys and tests.

2. POWER CONSUMPTION

The relationship between total power consumed and power consumed by fans and refrigeration, by mines of the various groups, during 1969 is shown in Table I.

Translated in terms of money the table indicates an annual power bill for the industry of approximately R49 000 000, of which R9 000 000 is used for ventilation and refrigeration equipment. Union Corporation's share of the latter amount is about R900 000.

3. MAIN FANS

3.1 *Schedule of main surface fans*

A schedule of main surface upcast fans is given in Appendix 1.

Of the 46 fans presently operating, 33 are of the backward bladed centrifugal type and these fans are generally installed as twin units on the pattern shown in Fig. 1.

A number of axial flow fans which were purchased in 1950 are still operating but no new fans of this type have been installed on surface since that date.

3.2 *Measurement of fan duty and efficiency*

The recognised authority for fan testing is the British Standards Institution and their recommendation for testing fans in situ is contained in the publication BSS848/63.

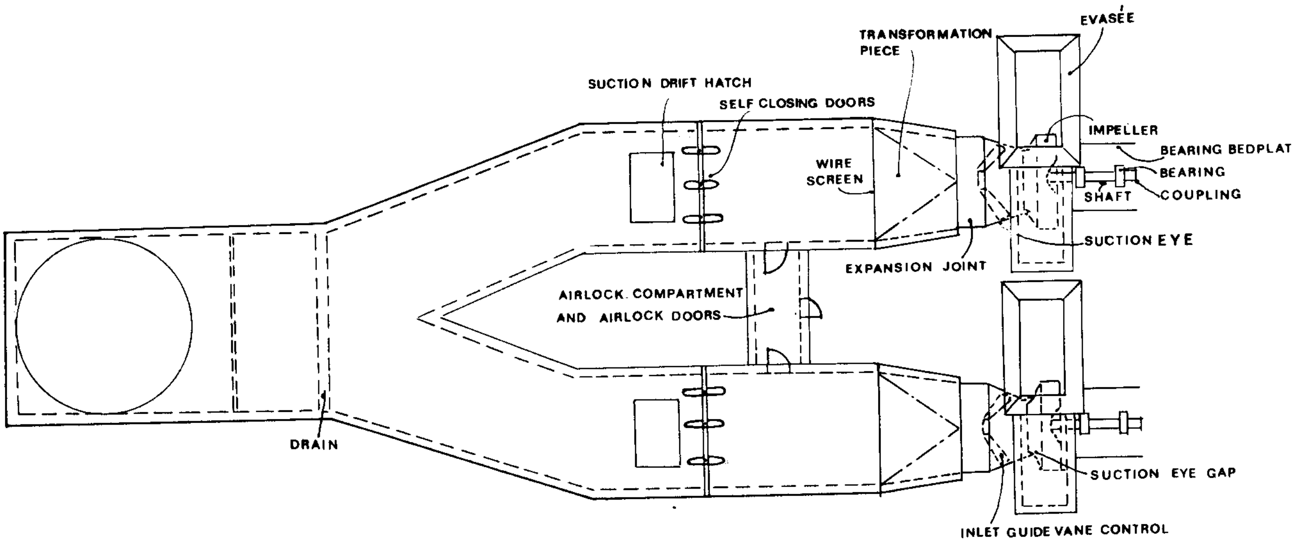
One of the requirements of this code is a test length of not less than twice the greatest dimension of the fan

TABLE I

TOTAL POWER CONSUMED AND POWER CONSUMED BY FANS AND REFRIGERATION — 1969

Group	No. of mines included	Tons broken per month (000's)	Power units consumed per month per ton broken (kWh)						
			Average	Fans		Refrigeration		Total	
				Units	% of total	Units	% of total	Units	% of Total
A/American	11	2 657	102	15	14,7	3	2,9	18	17,6
Anglo/Vaal	4	812	108	20	18,5	4	3,7	24	22,2
Rand Mines	4	937	134	22	16,4	6	4,4	28	20,9
General Mining	3	897	98	11	11,2	Nil	Nil	11	11,2
Goldfields	6	1 173	116	16	13,8	Nil	Nil	16	13,8
J.C.I.	2	310	104	8	7,7	Nil	Nil	8	7,7
Union Corporation	8	1 212	79	12	15,2	Nil	Nil	12	15,2
7 Groups	38	7 998	105	16	15,2	2	1,9	18	17,1

TWIN FAN LAYOUT



PLAN

FIG

Fig. 1—Plan of twin fan layout

TABLE II

TEST RESULTS FOR THE STANDARD METHOD

Fan installation	Volume m³/s	Static pressure mbar From Curve	Static pressure mbar Meas.	Static pressure mbar Diff. %	Efficiency % From Curve	Efficiency % Meas.	Efficiency % Diff. %
A Fan No. 1	243,6	46,4	47,0	+1,3	84,0	70,4	−13,6
Fan No. 2	278,0	38,4	44,6	+16,0	75,2	75,2	0
Both Fans	543,4	39,9	38,1	−4,5	78,5	65,3	−13,2
B Fan No. 1	152,8	25,5	17,6	−31,0	73,0	62,4	−10,6
Fan No. 2	150,3	24,4	15,8	−35,2	65,0	59,0	−6,0
Both Fans	242,6	45,0	44,1	−2,0	86,0	86,2	+0,2
C Both Fans 3 Tests	315,0	46,0	36,2	−21,3	84,8	63,9	−20,9
	325,5	44,6	36,7	−17,7	84,2	67,2	−17,0
	331,0	43,6	36,3	−16,7	83,9	67,2	−16,7
D Both Fans 3 Tests	146,0	40,2	36,3	−9,7	83,0	79,1	−3,9
	150,0	39,6	35,9	−9,3	82,8	77,0	−5,8
	157,1	38,5	36,5	−5,2	82,0	80,0	−2,0
E Both Fans 2 Tests	143,4	29,4	28,1	−4,4	84,0	82,0	−2,0
	153,2	28,6	27,8	−2,8	85,0	78,0	−7,0
F Both Fans 3 Tests	176,9	25,9	25,6	−1,2	85,0	86,0	+1,0
	180,7	25,4	23,2	−8,7	84,3	79,0	−5,3
	183,6	25,0	23,2	−7,2	84,0	80,0	−4,0

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TABLE III
COMPARISON BETWEEN STANDARD AND THERMAL METHODS

Fan	Standard Method				Thermal method		
	Volume m^3/s	Static pressure mbar	Fan shaft kW	Efficiency %	Efficiency %		
				Both Fans	No. 1 Fan	No. 2 Fan	Both Fans
A	543,4	38,1	3 169	65	—	64,5	—
D	146,0	36,2	680	78	—	75,1	—
E	146,1	26,8	495	79	79	82	81
F	168,2	24,0	528	77	83,7	84,7	84

drift which shall be straight and of uniform cross-section and free of any obstructions which modify the air flow.

Only four fan layouts on Union Corporation mines comply with this requirement and have been tested under the code. The duty and efficiency of a number of other fans have been assessed by using the Centre Spot Method.[2]

In addition a number of tests were carried out using the thermal method of testing fogged fans introduced by McPherson.[3]

Testing according to the code requires the measurement of the volume flowing, the fan pressure and a determination of the fan shaft horsepower, while for the thermal test the temperature conditions, the amount of free water in the airstream and the rise in pressure and temperature across the fan must be determined.

A summary of the test results carried out by the standard method is given in Table II and a comparison between the two methods of testing is shown in Table III.

3.3 *Discussion of results*

The majority of the fans tested were found to be operating below the duty and efficiency indicated by their performance curves, some grossly under, while others came within the tolerances allowed in the BS specification.

While there are obviously many shortcomings in fan performance, some account must also be taken of factors operating against the fan which are outside the control of the fan manufactures, such as the inaccuracies and assumptions contained in the testing procedures and the effects of fan performance of water and dirt present in the airstream.

The measurement of volume under the conditions laid down in BSS 848/63 is a laborious and time consuming process carried out in extremely unpleasant conditions which largely explains why fan testing is a rarity and not a routine procedure.

Most upcast shafts on mines of the Union Corporation are smoothlined without obstructions and of a length more than sufficient to establish classical airflow profiles and thus lend themselves admirably to the centre spot method of assessing the volume of air flowing. All the parameters necessary for calculating the flow are measured at one point and can be monitored over any length of time without exposing the observers to the unpleasant conditions in the fan drift. This simplified testing method, which probably has an average accuracy at least equal to that of the code, could, if officially approved, be written into future contracts as an acceptable means of measuring air volumes for the, in situ, testing of main fans.

The measurement of power absorbed by the fan shaft is difficult to obtain with the required degree of accuracy. Normally the input power is metered by a Watthour meter; an efficiency factor for the motor is then applied and, if belt driven, a further factor for the belts is included. In order to simplify measurement procedure in future, consideration is being given to equipping main fan motors with connections for portable high quality (sub standard) Watt meters. In addition, full efficiency curves for all fan motors would be required. Leakage between the measuring point and the fan intake may have some significance in the tests.

The thermal method of testing fogged surface upcast fans avoids most of the difficulties of the standard test. Implementation of the laboratory method for field tests, however, results in additional difficulties. For instance, exposure of the thermocouples in the evasée to sunlight resulted in the measured temperature differences being unreasonably high and the efficiencies therefore low and incorrect. When tested at night with ambient air considerably colder than the mine air induced into the evasée, efficiencies of over 100 per cent were obtained, which is absurd. Experience with this method suggests that reliable results can be achieved by carrying out the test at night with a single thermocouple circuit in which the thermocouple in the intake is fixed in one position while the other is traversed in the evasée. The highest temperature difference found would be used for calculating the efficiency.

A number of practical aspects in the use of the thermal method need to be investigated but there is no doubt that it can be a valuable tool.

Trials with the thermal method have drawn attention to the poor distribution of air in the evasée of some of the fans tested.

Improvements in this regard would not only make the thermal test easier to apply but could at the same time result in greatly improved fan performance. For example in one twin-fan unit tested the discharge area was 23,54 m^2 of which 32 per cent equal to 7,53 m^2 was

TABLE IV
EFFECT OF ACCUMULATED DUST ON FAN PERFORMANCE

Fan	Condition	Volume m^3/s	Static pressure			Static Efficiency		
			From curve mbar	Measured mbar	Diff. %	From Curve %	Measured %	Diff. %
C	Clean	332,7	43,3	38,2	−11,8	83,6	Not measured	
	+ 4 months	321,5	45,2	34,2	−24,3	84,8	63,0	−21,8
	Clean	331,8	43,5	38,8	−10,8	83,4	66,1	−17,3
	%+/−	+3,2	—	—	+13,5	—	—	+4,5
F	+ 5 months	178,6	25,3	23,0	−9,1	84,0	77,6	−6,4
	Clean	184,5	24,9	24,4	−2,0	83,5	83,7	+0,2
	%+/−	+3,3	—	—	+7,1	—	—	+6,8

downcasting ambient air, leaving a nett area of 16 m^2 to discharge a minimum of 260 m^3/s per evasée; that is the average velocity of discharge was 16,25 m/s with an outlet loss of 1,31 mbar instead of the expected 0,6 mbar. This additional loss costs approximately R1 600 per annum in power for the two fans.

3.4 *The effect of the accumulation of dust on the impellers*

Cleaning intervals vary from mine to mine. Normally when the volume and pressure drop, cleaning of the impellers and suction eye gap is carried out by either the Engineering Department or the Ventilation Department.

In order to obtain some idea of the effect that accumulated dust on the impeller has on static pressures and efficiencies cleaning was suspended on a number of fans for periods of up to 5 months. The results are shown in Table IV.

Though the indications are that frequent cleaning would keep performance and efficiency steady, many more observations are necessary to determine the optimum cleaning intervals for each type of fan.

3.5 *The effect of free water passing through the fan*

The amount of fog passing through fan installation D could be increased from approximately one gram of water per kg of air to 5 g per kg by blocking the outlet of the drain at the start of the fan drift. The effect of this increase was tested by the standard method and by the thermal method. The results are given in Table V.

On most of the fans tested the water loading was estimated to be less than 1 g/kg of air but in all instances the air was fully fogged. It still remains to be determined whether a water loading of 1 g/kg affects performance to any significant extent.

The water carried by the air in two of the shafts was analysed for acidity and solids in suspension. The results are shown in Table VI.

TABLE VI
ACIDITY AND SOLIDS IN SUSPENSION OF WATER IN MINE AIR

Mine	Analysis		Remarks
	pH	Solids in Suspension	
St. Helena	7,0	620	
Kinross	6,7	180	Blasting fumes in the circuit

The solids were mostly quartz with some organic matter.

3.6 *Main fan selection procedure*

The present procedure followed by Union Corporation when considering tenders for main fans is:

(a) The reduction of all tenders to a common basis.

(b) The assessment by the Consulting Mechanical Engineer of structural and mechanical features.

(c) The calculation of annual owning costs based on purchase price and power absorbed.

Assuming mechanical features to be equal for all tenders, the fan with the highest efficiency will in most instances also show the lowest annual owning costs and thus stand the best chance of winning the contract.

This system is unsatisfactory as it hinges on manu-

TABLE V
THE EFFECT OF WATER CONTENT OF THE AIR ON FAN PERFORMANCE

Ratio free water air	Air volume m^3/s	Static pressure mbar	Air power kW	Fan shaft power kW	Eff %	Thermal method Eff %
1g/kg	146,0	36,24	529	680	77,8	74,5
5g/kg	143,9	35,94	517	694	74,5	73,1
%+/−	−1,4	−0,8	−2,3	+2,0	−3,3	−1,4

facturers' efficiency claims and shortcomings are only found after installation. Penalty clauses have been incorporated in some contracts but at best are a poor solution to the problem. One major user of fans in this country insists on testing the full size fan at the works over the specified range of duties and the fan is not accepted if the tests do not agree with the data given in the tender. Another method advocated is to conduct tests on a scaled-down prototype when deciding on the tender.

In the above instances additional cost is involved and time for manufacture and testing must be allowed for. Advantages of the latter proposal are:

(a) Air conditions approximating those to be found in operation, i.e. air carrying water and dirt can be simulated.
(b) Adjustments to improve efficiency to meet abnormal conditions can be undertaken on the model.
(c) The unit can be tested over any desired range of duties and fan performance guaranteed over this range.

4. AUXILIARY FANS

Some 2 000 auxiliary fans ranging in size from 300 to 760 mm dia. and in power from ¼ kW to 40 kW are operating underground on mines of the Union Corporation Group as shown in Table VII.

4.1 *Efficiency tests*

Efficiency tests using the thermal method were conducted on 89 of the auxiliary fans referred to in Table VII. Results are summarised in Table VIII.

For the survey, mercury-in-glass thermometers were used for the measurement of temperatures and routine manometers for pressure. For future work, an apparatus which permits the simultaneous measurement of both the temperature and static pressure differences across the fan has been devised. The method is illustrated in Fig. 2.

Individual efficiency test results for four types of fan are shown in Figs. 3, 4, 5 and 6.

The efficiencies measured are generally lower than shown on the performance curves. Of the fans tested only 30 per cent were operating in the efficient section of their performance curves. In a number of fans investigated the low efficiency was found to be caused by blockage on the fan screens, detectable thermally, but not by means of the pressure measuring connections.

It is Group practice to fit "stone traps"[4] before and

TABLE VII

AUXILIARY FANS IN USE UNDERGROUND ON UNION CORPORATION MINES

Mine	No. of units in use						Total installed
	Auxiliary fans						
	1 to 5 kW	5 to 10 kW	11 to 15 kW	16 to 20	+ 20	Total	kW
Impala	101	12	22	11	19	165	1 836
Bracken	224	29	61	—	8	322	2 589
Grootvlei	91	52	18	—	1	162	2 296
Kinross	93	21	45	20	17	196	5 216
Leslie	163	33	24	—	11	231	2 847
Marievale	165	36	38	—	1	240	1 010
St. Helena	214	112	70	6	24	426	9 974
Winkelhaak	195	25	30	7	4	261	4 434
Totals	1 246	320	308	44	85	2 003	30 202

TABLE VIII

EFFICIENCY TESTS ON AUXILIARY FANS USING THE THERMAL METHOD

Fan diameter mm	Rated power kW	No. of fans tested	Average age Years	Average period in present position Months	Mean efficiency %
300	0,4-1,5	3	7	10	28
400	2,2-3,4	18	4	11	43
500	6,0-6,3	13	14	10	44
570	9-19	43	6	8	49
760	37	12	10	11	51
	Total/Average	89	9	8,6	46

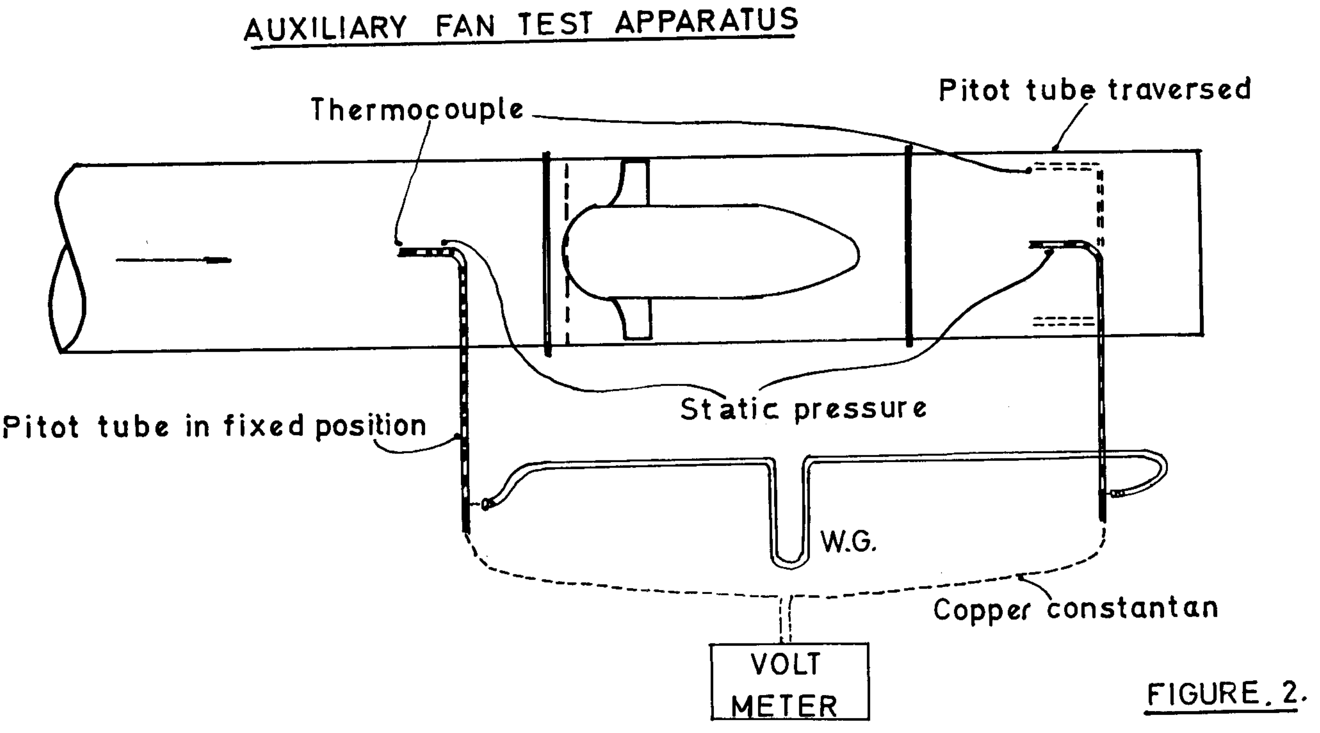

Fig. 2—Auxiliary fan test apparatus

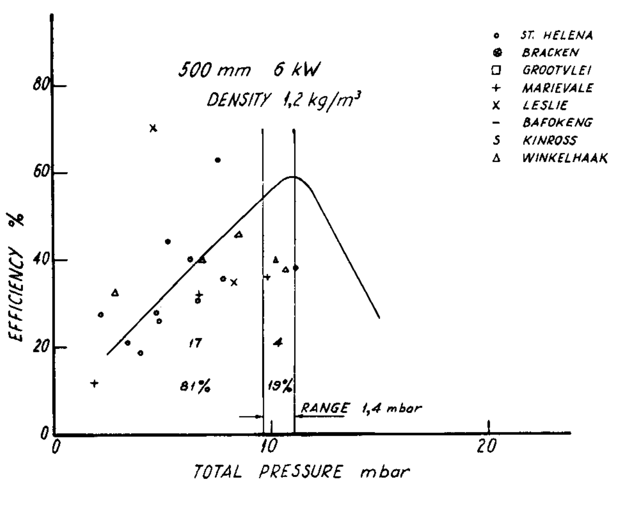

Fig. 3—Schematic diagram of 1-ton per hour pilot plant, Phosphate Development Corporation

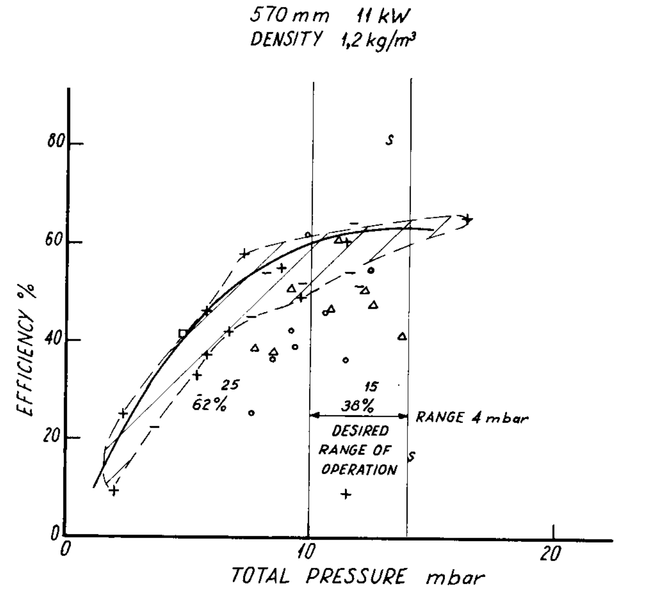

Fig. 4—Effect of residual concentration of hydrogen ion (pH) silicate and Unitol DSR on flotation of phoscorite

after any fan where the intake to the fan is hidden or where the possibility exists of rock migrating on to the impellers. The design of the "stone trap" is shown in Fig. 7.

4.2 *Effect of the accumulation of dirt*

A number of fans which had been operating continuously for one year were brought to surface and their performance tested before and after cleaning. Fig. 8 indicates the improvement in performance achieved by the cleaning for one particular type of fan. Other types showed similar degrees of improvement.

5. CONCLUSIONS

1. The performance and efficiency of main fans must be proved over a specified range before purchase, either by tests on a scaled down prototype or by factory tests at a reduced speed on the full sized fan.
2. The industry should sponsor an investigation into the testing of large fans in situ including full trials of the thermal method of testing fogged fans.

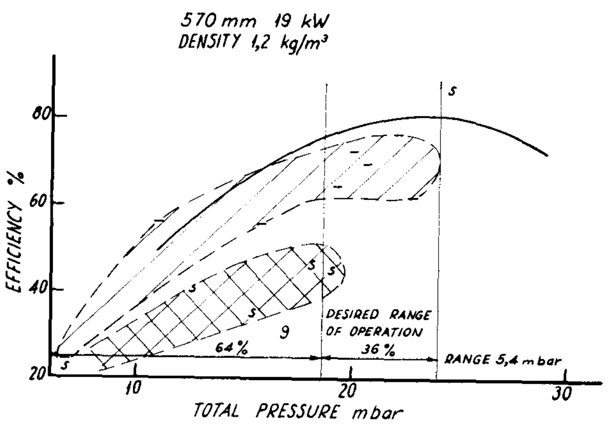

Fig. 5—Effect of residual concentrations of silicate in feed on recovery of phoscorite

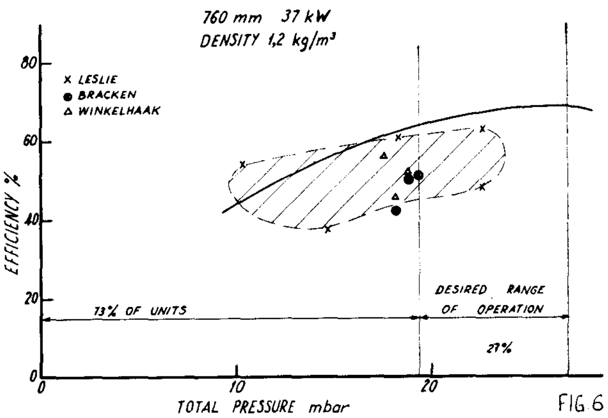

Fig. 6—Continuous flow apparatus for the study of the interaction between xanthate, galena and oxygen

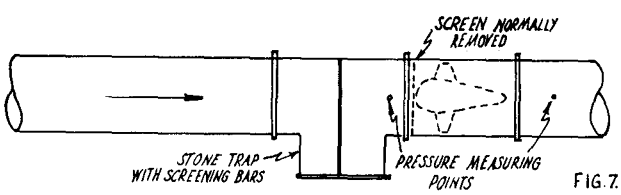

Fig. 7—Recirculating apparatus for the study of the interaction between xanthate, galena and oxygen

3. A large percentage of the auxiliary fans are being operated inefficiently.
4. The thermal method of testing auxiliary fans could with advantage be used in routine work.

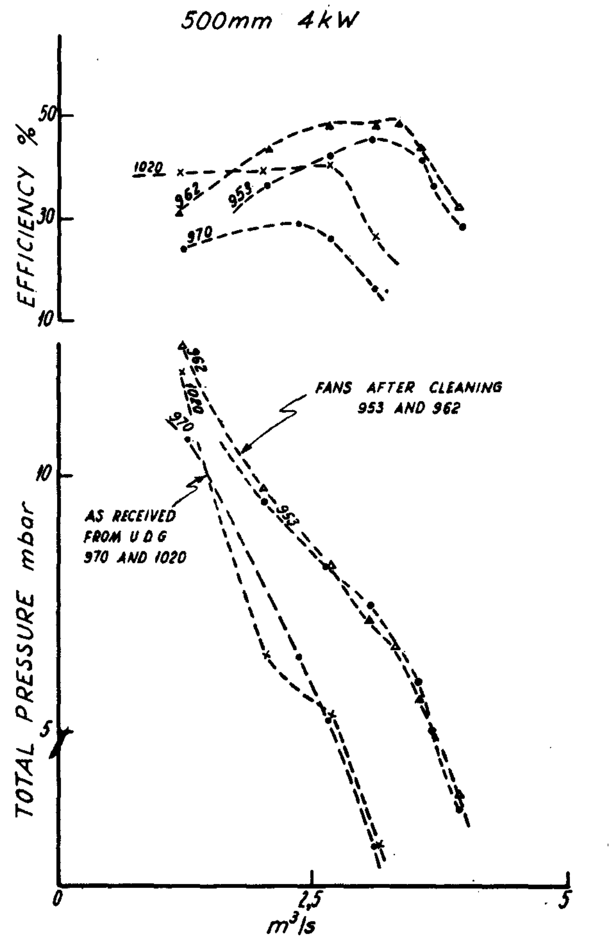

FIG.8.

6. ACKNOWLEDGEMENT

The data necessary for compiling these notes were obtained from routine records and from special tests planned and conducted by the Ventilation Departments of the various mines.

In conclusion, I would like to thank the Chief Consulting Engineer, Union Corporation Limited, for permission to publish this paper.

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*Mine Ventilation Society of South Africa.

APPENDIX 1

UNION CORPORATION GROUP OF COMPANIES SCHEDULE OF MAIN SURFACE FANS JULY 1971

Mine	Shaft	Date commis-sioned	Type of instal.	Size mm type of fan	Design duty			Present operating duty		
					Vol. m^3/s	Press. mbar	Instal. power kW	Vol. m^3/s	Press. mbar	Remarks
Impala Mines Ltd.	145 Raise	1969	Single Fan	2 500 B.B.C.	66	15	300	62	9	
	152 Raise	1970	Single	2 500 B.B.C.	71	20	410	58	23	Restricted circuit
	156 Raise	1969	Single Fan	2 500 B.B.C.	66	15	300	52	11	
Bracken Mines Ltd.	No. 1 Vert Wze	1962	Twin Fans	2 496 B.B.C.	189	22	933	110	17	Single fan
	No. 2 Vert Wze	1962	Single Fan	2 496 B.B.C.	94	22	466	119	14	
	No. 3 Vert Wze	1962	Single Fan	2 496 B.B.C.	94	22	466	105	17	
Grootvlei Prop. Mines Ltd.	No. 2 E. Geduld	1970	Multiple	$\frac{1\ 000}{2\ 000}$ Axials	85	10	150			
	5 Vert.	1950	Twin Fans	2 540 Axials	189	20	745	160,0	17	
	6 Vert.	1950	Twin Fans	2 540 Axials	189	20	745	193	21	
Kinross Mines Ltd.	No. 1A Compt	1967	Twin Fans	3 400 B.B.C.	496	45	3 284	543	38	Circuit resistance to increase

Code: B.B.C.—Backward bladed centrifugal

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UNION CORPORATION GROUP OF COMPANIES SCHEDULE OF MAIN SURFACE FANS JULY 1971

Mine	Shaft	Date commis-sioned	Type of instal.	Size mm type of fan	Design duty			Present operating duty		
					Vol. m^3/s	Press. mbar	Instal. power kW	Vol. m^3/s	Press. mbar	Remarks
Leslie Gold Mine Ltd.	No. 1 Vert Wze	1962	Twin Fans	2 496 B.B.C.	189	22	745	153	28	
	No. 1 East Vert Wze	1963	Twin Fans	2 496 B.B.C.	189	22	745	184	23	
Marievale Cons. Mines	No. 3 W1 Vert Wze	1939	Single Fan	2 500 F.B.C.	71	10	150	79	10	
	No. 2 Incline	1950	Single Fan	2 082 Axial	85	14	261	110	11	
	No. 8 Incline	1954	Single Fan	2 134 F.B.C.	57	10	186	76	9	
St. Helena Gold Mines Ltd.	No. 1 A Vert Wze	1956	Twin Fans	2 134 B.B.C.	118	24.9	410	123		
	No. 3 Incline	1959	Twin Fans	2 720 B.B.C.	236	30	970	185	32	
	No. 4 Vert Wze	1958	Twin Fans	2 057 B.B.C.	118	35	670	95	36	
	4 Upcast Comp.	1951	Single Fan	2 134 Axial	47	15	150	51	17	
	5 Vert Wze		Single Fan	2 032 Axial	59	15	225	58	14	
	9 Vert Wze	1960	Single Fan	2 032 Axial	59	15	225	80	12	
	7 Upcast Comp.	1963	Twin Fans	2 720 B.B.C.	330	45	2 165	319	35	
	8 Upcast Comp.	1967	Twin Fans	2 500 B.B.C.	165	35	820	150	35	
	2 Upcast Comp.	1957	Twin Fans	B.B.C.	47	35	300	—	—	One fan only
Winkelhaak Mines Ltd.	No. 1 A Vert Wze	1957	Twin Fans	B.B.C.	142	27	522	170	22,4	Duty to be increased
	No. 3 A Vert Wze	1957	Twin Fans	B.B.C.	142	27	522	94,4	—	
	No. 4 Vert Wze	1964	Twin Fans	2 496 B.B.C.	212	25	932	212	23,4	Single fan
	No. 5 Upcast Comp.	1968	Twin Fans	2 720 B.B.C.	236	42	1 344	165	15	Single fan