PART II

SYNOPSIS

Measurements of the rates of penetration at various throttle air pressures are presented as a function of thrust for three different rockdrills when drilling quartzites with strengths of 45 000 lb/in² and 39 000 lb/in². The rate of penetration at optimum thrust is shown to agree well with the predictions of theory and curves of air consumption as a function of throttle air pressure are presented. Man-held machines are shown to be underthrusted at throttle air pressures above 40 lb/in²g. Measurements of bit wear as a function of distance drilled are presented graphically and discussed in terms of the theory developed in Part I.

MEASUREMENTS OF PERCUSSIVE ROCKDRILL PERFORMANCE

Carefully controlled rockdrilling experiments were conducted in the footwall quartzite, with a uniaxial compressive strength of about 45 000 lb/in^2, at Robinson Deep Gold Mine and in the hangingwall quartzite, with a unixial compressive strength of about 39 000lb/in^2, at Vlakfontein Gold Mine.

In most tests the rockdrill moved along a horizontal slide, thrusted by an air cylinder and piston mounted co-axially, directly behind the machine and supplied with air from a separate pressure regulator. The rates of penetration, air consumption and other parameters were measured over a range of thrusts at different throttle air pressures. Full details of the rockdrills and drill steels used in these experiments as well of the experimental procedure are given in Appendix I.

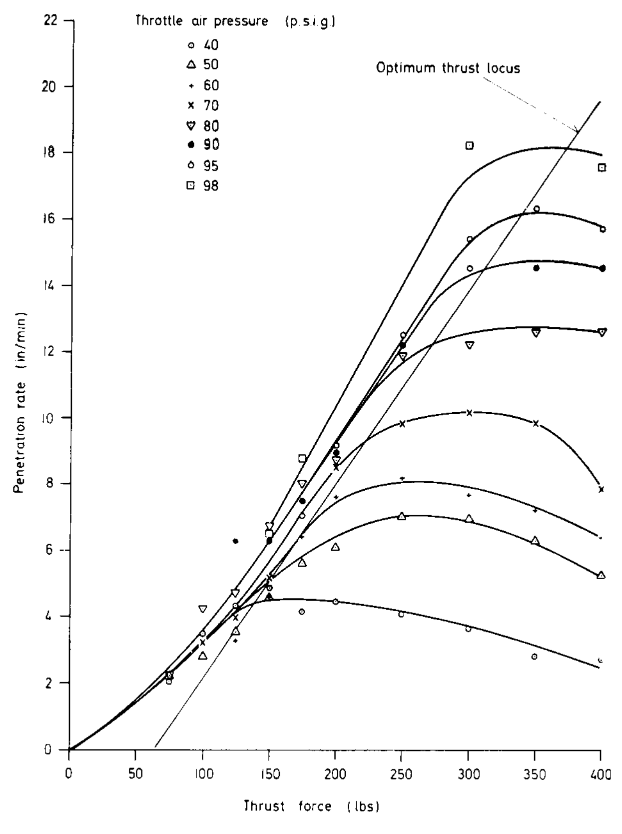

Fig 1 Penetration rate as a function of thrust for various machine throttle air pressures. Robinson Deep Mine, Rockdrill A, Rifle bar 1:55, Drill steel 1.

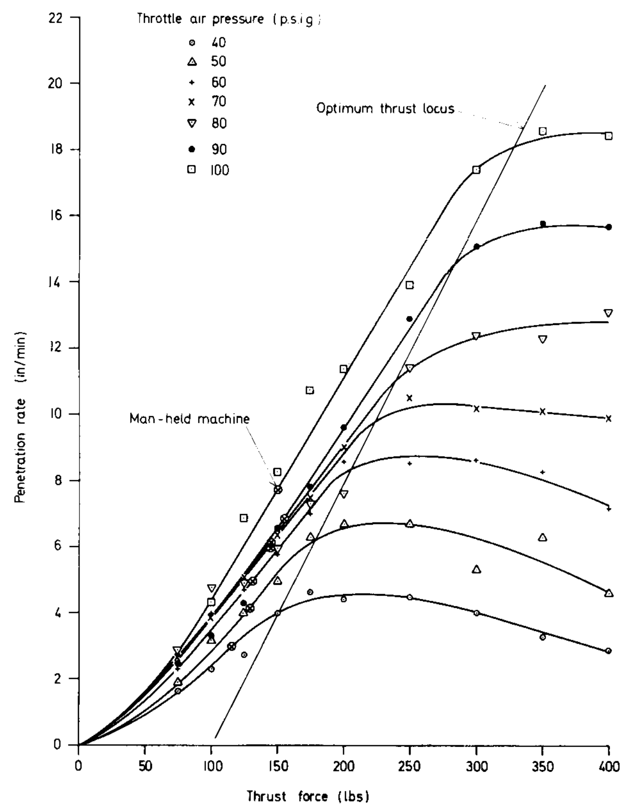

Fig 2 Penetration rate as a function of thrust for various machine throttle air pressures. Robinson Deep Mine, Rockdrill B, Rifle bar 1:38, Drill steel 1.

Thrust-penetration rate measurements

The measured values of the rate of penetration as a function of the applied thrust are shown in Figs 1 to 6 for each of the three rockdrills at both test sites. The shapes of these penetration rate-thrust curves are seen to be virtually independent of the type of rockdrill and of the value of the throttle air pressure and to be only slightly dependent upon the different types of rock at the two sites. For a given air pressure, the penetration rate increases with thrust until a maximum value is reached. As the thrust is increased further, the penetration rate decreases and the drill finally stalls. Since the curves are normally quite flat in the vicinity of the peak penetration rate, the application of a thrust lower than that at which the peak rate occurs produces only a slight reduction in the penetration rate but significantly less bit wear. Thus the *optimum thrust* can be defined as that thrust at which near-peak penetration rate is produced without excessive bit wear being caused.

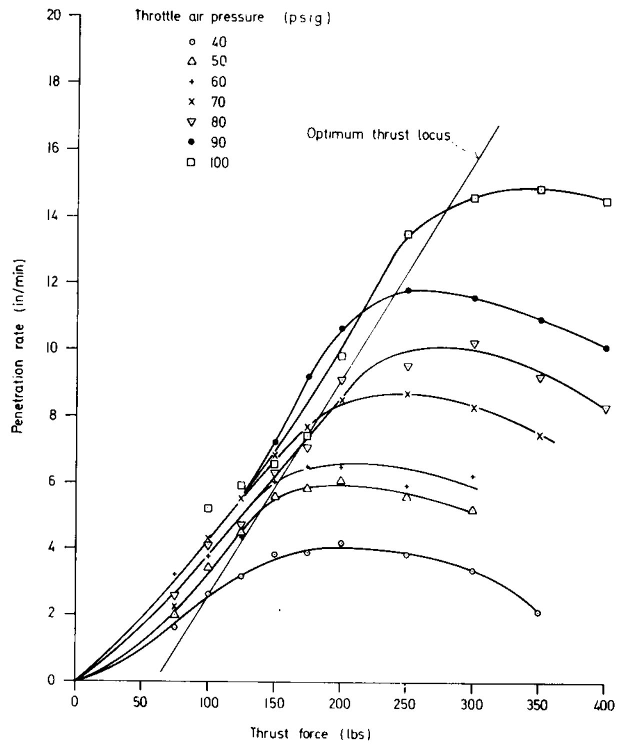

Fig 3 Penetration rate as a function of thrust for various machine throttle air pressures. Robinson Deep Mine, Rockdrill C, Rifle bar 1:30, Drill steel 1.

The loci of the knees of the curves, that is, where the curves begin to become horizontal for the different machine pressures can, as shown in Figs 1 to 6, be represented by straight lines. These loci will be assumed to coincide with the loci of optimum thrusts. The theoretical equation (14), Part I, and experimental relationships between the optimum thrust force and the machine air pressure for Figs 1 to 3 are as shown in the following table.

TABLE 1

Rockdrill	Experimental	Theoretical (Eqn. 14)
A	$F_t=3{,}5p$	$F_t=a_1\ 7{,}06p$
B	$F_t=3{,}5p$	$F_t=a_2\ 6{,}50p$
C	$F_t=2{,}75p$	$F_t=a_3\ 5{,}42$;

The values of a required for agreement between results are

$a_1=0{,}475$

$a_2=0{,}540$

$a_3=0{,}507$

There is no reason why the values of a should be different for each of these three cases and setting $a=0{,}5$ appears to be a good approximation. The optimum thrust for each machine can be predicted accurately from the expression

$$F_t=0{,}5\,Ap, \qquad (1)$$

which has been applied, also, to Figs 4 to 6.

The ratios of the optimum thrust forces for two machines operating at the same air pressure was shown earlier to be given by

$$\frac{F_{t1}}{F_{t2}}=\frac{A_1}{A_2}\,.$$

The experimental and theoretical ratios for the data obtained at Robinson Deep are compared below:

TABLE 2

Rockdrills	Thrust Ratio	
	Experimental	Theoretical
A/B	1,00	1,08
A/C	1,27	1,30
B/C	1,27	1,20

The agreement between the ratios is better than 10 percent.

Blow frequency

As shown by equation (5) Part I, the blow frequency can be expressed by

$$\bar{f}=K_o\sqrt{\frac{6pAg}{SW}}\,, \qquad (2)$$

where

$20\leqslant K_o\leqslant 30$.

The experimental values of K_o presented in Table 3 below have been obtained by substituting the appropriate machine parameters and the blow frequencies in equation (2).

TABLE 3

Machine Pressure	Values of K_o		
	Rockdrill A	Rockdrill B	Rockdrill C
40	22,9	24,2	25,3
50	22,2	23,8	23,9
60	21,6	23,0	22,7
70	21,0	22,4	22,1
80	20,4	21,9	22,4
90	20,8	21,4	22,2
100	—	21,3	22,2

These values, averaging approximately 22 for all machines, show some dependence on the machine air pressure. However, it is interesting to note that the values are closer to the lower limit of 20 rather than the upper limit of 30, assumed by Pfleider and Lacabanne[1]. When the value of $K_o=22$ is chosen, an error of less than 5 percent exists for predictions at throttle air pressures of 60 lb/in^{2}g and greater.

Piston impact velocity and blow energy

Since no strain wave data were obtained during the experiments, piston velocities and energies could not be

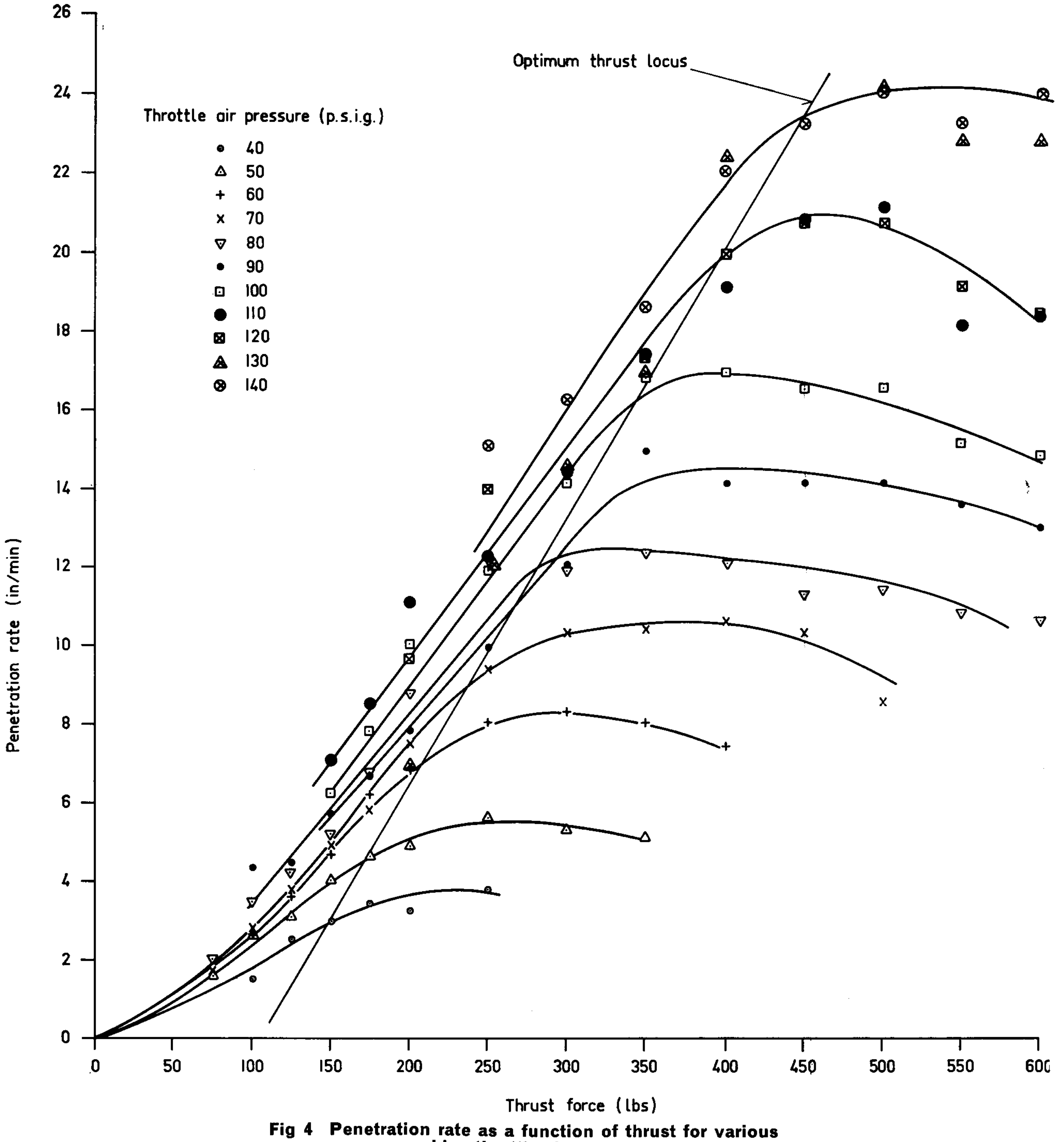

Fig 4 Penetration rate as a function of thrust for various machine throttle air pressures. Vlakfontein Mine, Rockdrill A, Rifle bar 1:55, Drill steel 1.

calculated direct. However, the piston impact velocity can be calculated from equation (6), Part I:

$$V_s=\beta_o\sqrt{\frac{SpAg}{6W}} \quad (3)$$

From equation (14a), Part I, it is known that

$$a=\frac{K_o\beta_o(1+\beta)}{30} \quad (4)$$

Using the previously determined values of a and K_o, namely,

$a=0,5$
$K_o=22$

equation (4) can be solved for β_o in terms of β.

$$\beta_o=\frac{15}{22(1+\beta)} \quad (5)$$

Since for most cases β is near zero,

$$\beta_o=0,68. \quad (6)$$

and equation (3) becomes

$$V_s=0,68\sqrt{\frac{SpAg}{6W}} \quad (7)$$

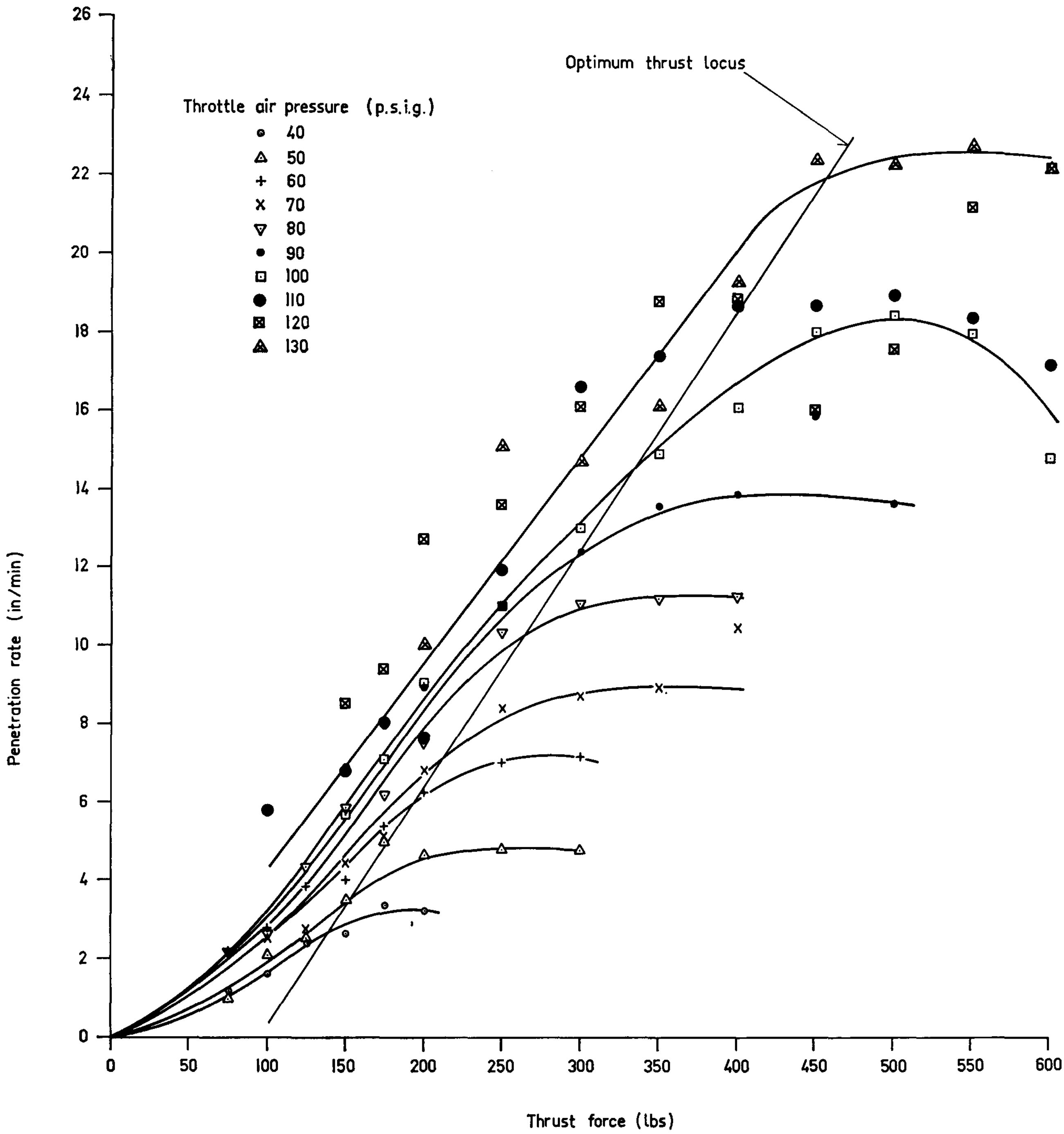

Fig 5 Penetration rate as a function of thrust for various machine throttle air pressures Vlakfontein Mine, Rockdrill B, Rifle bar 1:38, Drill steel 1.

The impact energy can then be obtained using equation (10) Part I.

Piston impact velocities and energies for the three rockdrills calculated using equations (9), Part I, and (7) are given in Appendix II, Table 1. The relationship between piston impact energy and the machine air pressure are given below.

TABLE 4

Rockdrill	Equations
A	$E_i = 0{,}816p$
B	$E_i = 0{,}688p$
C	$E_i = 0{,}496p$

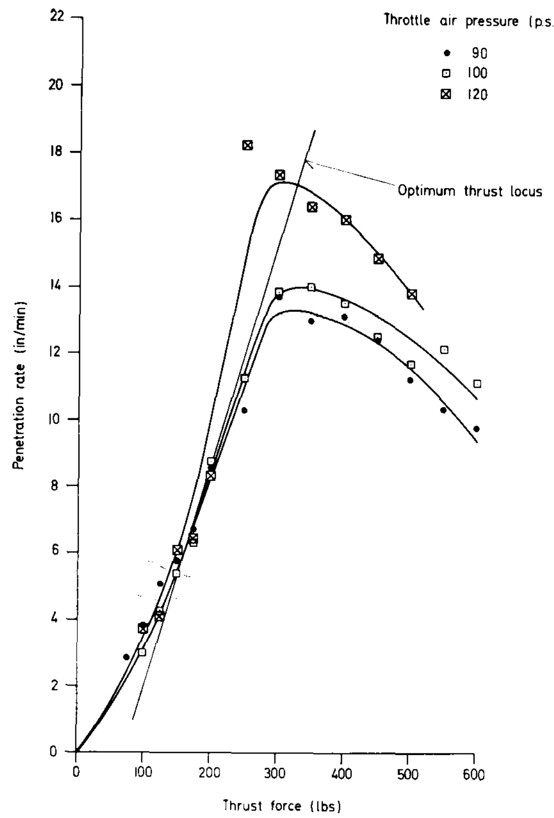

Fig 6 Penetration rate as a function of thrust for various machine throttle air pressures. Vlakfontein Mine, Rockdrill C, Rifle bar 1:30, Drill steel 1.

Prediction of penetration rates.

It is possible at this point to predict from equation (15), Part I, the penetration rate in the rock at Robinson Deep:

$$PR = 12\frac{E_i \times \bar{f} \times T_R}{A_H \times E_V} \quad \ldots\ldots\ldots\ldots \quad (8)$$

The uniaxial compressive strength (45 000 lb/in²) of the rock drilled will be used as an approximate value for E_V. The values of T_R and A_H used are:

$T_R = 0{,}8$

$T_H = 1{,}85$ in².

Actual and predicted maximum penetration rates for the three drills are given in Table 5.

In the case of the tests at Vlakfontein it is again assumed that $E_V = 39\,000$ lb/in² and that $T_R = 0{,}8$ and $A_H = 1{,}85$ in².

The penetration rate-thrust curves shown in Figs 4 and 10 for rockdrill *A* are essentially identical in spite of the fact that they were obtained using two different rifle bars.

Predicted and actual penetration rates for the rockdrills are given in Table 6:
The predicted and measured values are seen to agree reasonably well.

The agreement is very good for all three rockdrills. The actual penetration rates of rockdrills *A* and *B* are very similar while those of *C* are approximately 20 percent less.

Because the air consumptions for the three drills are different, comparisons cannot be made on the basis of penetration rates alone. The penetration rates have been plotted in Figs 8 and 9 as a function of the free air consumption. The curve

$$PR = 6{,}67 \times 10^{-4}\,(CFM)^2 \quad \ldots\ldots\ldots\ldots \quad (9)$$

describes the data for the three drills at Robinson Deep Mine very well. When a comparison is made in this manner the performance of rockdrill *B* appears to be slightly better than that of the other two drills.

The relationship between the penetration rate and the consumption of free air for the three rockdrills during drilling at Vlakfontein is shown in Fig 9. The results for all three machines can be described very well by the relationship

$$PR \simeq 6{,}25 \times 10^{-4}\,(CFM)^2. \quad \ldots\ldots\ldots\ldots \quad (10)$$

On the basis of the compressive strength ratio, a 15 percent difference would be predicted.

The relationship between the consumption of free air and the machine air pressure for the three rockdrills is given below.

TABLE 5

Machine Pressure lb/in²g	Penetration Rates (in/min)					
	ROCKDRILL A		ROCKDRILL B		ROCKDRILL C	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
40	4,6	4,6	4,6	4,8	4,0	3,5
50	7,0	6,1	6,9	6,5	6,0	4,6
60	8,1	7,9	8,7	8,3	6,6	5,8
70	10,2	9,6	10,3	10,2	8,6	7,0
80	12,7	11,4	12,8	12,2	10,0	8,7
90	14,7	13,2	15,7	14,1	11,8	10,3
95	16,2	14,4	—	—	—	—
100	—	15,6	18,5	16,6	14,8	12,0

TABLE 6

Pressure lb/in^{2}g	Penetration Rates (in/min)								
	ROCKDRILL A			ROCKDRILL B			ROCKDRILL C		
	Predicted	Measured (Fig 4)	Measured (Fig 10)	Predicted	Measured (Fig 4)	Measured (Fig 10)	Predicted	Measured (Fig 4)	Measured (Fig 10)
40	5,3	3,8	3,4	5,5	3,3		4,0	3,8	
50	7,0	5,5	4,8	7,5	4,9		5,3	6,0	
60	9,1	8,2	8,8	9,6	7,2		6,6	6,8	
70	11,1	10,6	10,7	11,8	9,0		8,1	8,5	
80	13,1	12,4	12,7	14,1	11,3		10,0	10,0	
90	15,2	14,5	—	16,3	13,9		11,9	11,6	
100	17,9	16,9	—	19,2	18,4		13,9	14,0	
110	20,8	20,9	—						
120	23,8		—						
130	26,3	24,1	—						
140	29,0		26,9						

1:30 and 1:23 rifle bars. However when the 1:64 rifle bar was used, the peak penetration rate was approximately 30 percent less than those of the other two. The optimum thrusts required in each of the three cases were identical and of the expected magnitudes. The data indicated that the 1:64 rifle bar stalls at thrusts much lower than those of the others. This is contrary to what would be expected and to the results of Cheetham and Inett[2]. It is not known why this behaviour was observed here.

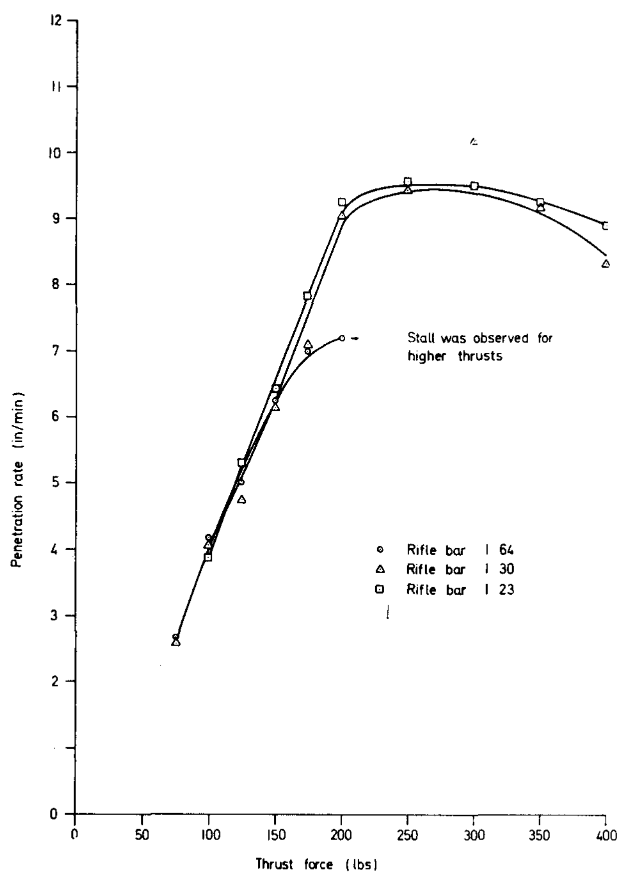

Fig 7 Penetration rate as a function of thrust for Rockdrill C, using three different rifle bars Robinson Deep Mine, Throttle air pressure 80 lb/in²g, Drill steel 1.

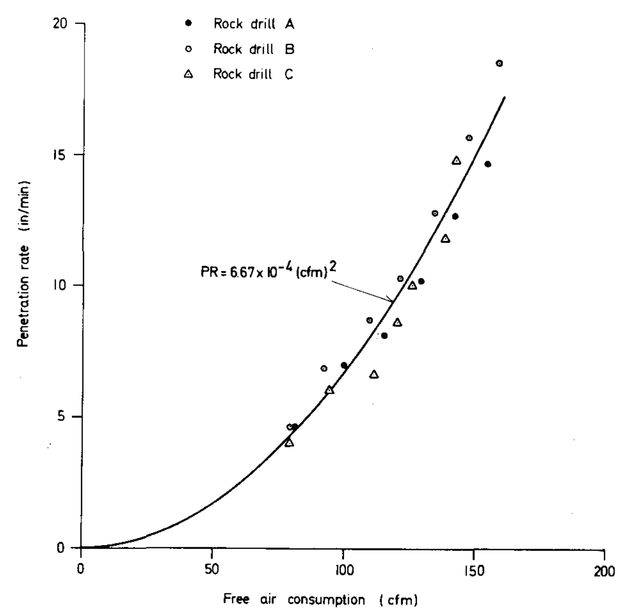

Fig 8 Penetration rate as a function of the free air consumption for three rockdrills at Robinson Deep Mine

One series of tests was run in which three rifle bars were used with rockdrill *C*. The resulting penetration rate thrust curves are plotted in Fig 7. It is observed that there is no difference between the curves for the

TABLE 7

Rockdrill	Equation
A	$CFM = 21{,}5\, p^{1/2} - 51{,}0$
B	$CFM = 22{,}6\, p^{1/2} - 67{,}8$
C	$CFM = 16{,}8\, p^{1/2} - 25{,}4$

The effects of hole diameter

Rockdrill *C* was modified for use with a 7/8″ hex drill-steel having a 30 mm chisel bit. The penetration rate-

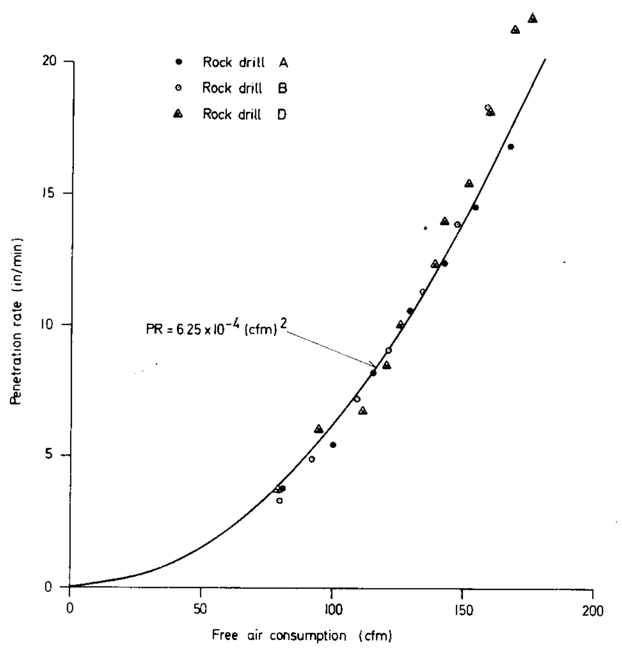

Fig 9 Penetration rate as a function of the free air consumption for three rockdrills at Vlakfontein Mine

thrust results are presented in Fig 12. A comparison of peak penetration rates taken from Figs 11 and 12 is given in Table 8.

TABLE 8

Machine Pressure	Penetration Rate (in/min)		Ratio R_1/R_2
lb/in²g	30 mm Bit (R_1)	39 mm Bit (R_2)	
40	6,7	3,8	1,78
70	12,3	8,5	1,45
90	17,2	11,6	1,48
110	22,1	15,4	1,44
140	28,0	21,8	1,28

The actual ratio assuming that the energy/volume ratio remains constant is

$$\frac{R_1}{R_2}=\frac{\frac{\pi}{4}(39)^2}{\frac{\pi}{4}(30)^2}=1{,}69\ .$$

The average error (approximately 12 percent) may be a result of poor removal of cuttings in the smaller borehole. Measured and predicted penetration rates are given in Table 9.

Agreement between predicted and measured rates is fair.

Thrusts applied by men

A series of tests was run using rockdrill *B* in which penetration rates were measured during drilling with the thrust supplied by manpower rather than by the thrust leg. The rockdrill was operated for approximately $2\frac{1}{2}$ hours per shift by a regular Bantu operator and a regular assistant. These men were given a bonus incentive depending on the number of holes drilled per shift. During drilling, both the operator and the assistant were seated on the footwall and each supported the rockdrill and forced it against the face by applying one foot to the conventional rockdrill handle. From 12 to 80 two-foot holes were drilled at each machine pressure setting. Collaring was on a vertical face, 6 to 36 inches above a horizontal footwall. Up to 22 ft of drilling was done before the bit was re-sharpened. Although the applied thrust forces were not measured, they may be deduced, from Fig 2, by the thrust intercepts corresponding to each of the measured penetration rates. The penetration rates resulting from man-held machine operation have been plotted in Fig 2, and a summary of important data is shown in Table 10.

TABLE 9

Machine Pressure lb/in²g	Penetration Rate (in/min)	
	Predicted	Measured
40	6,8	6,7
70	13,7	12,3
90	20,1	17,2
110	27,0	22,1
140	36,9	28,0

TABLE 10

Machine Air Pressure lb/in²g	Men Applied Thrust (lb)	Optimum Thrust (lb)	Men Penetration Rate (in/min)	Maximum Penetration Rate (in/min)
40	115	150	3,0	4,0
50	130	180	4,1	6,2
60	130	205	5,0	8,3
70	145	225	6,0	9,8
80	145	250	6,1	12,0
90	155	285	6,8	14,8
100	150	325	7,8	18,1

As the machine air pressure is increased the men are able to supply less and less of the thrust required for optimum operation. At 80 lb/in² for example, the applied thrust is 145 lb whereas it should be 250 lb, and the penetration rate of a man-held machine is only half that which could be obtained at optimum thrust. The drill steel life as discussed earlier would be much less than for an air-thrusted drill. This emphasizes quite dramatically the improvements that could be obtained in the drilling part of the mining operation through the use of special thrust methods.

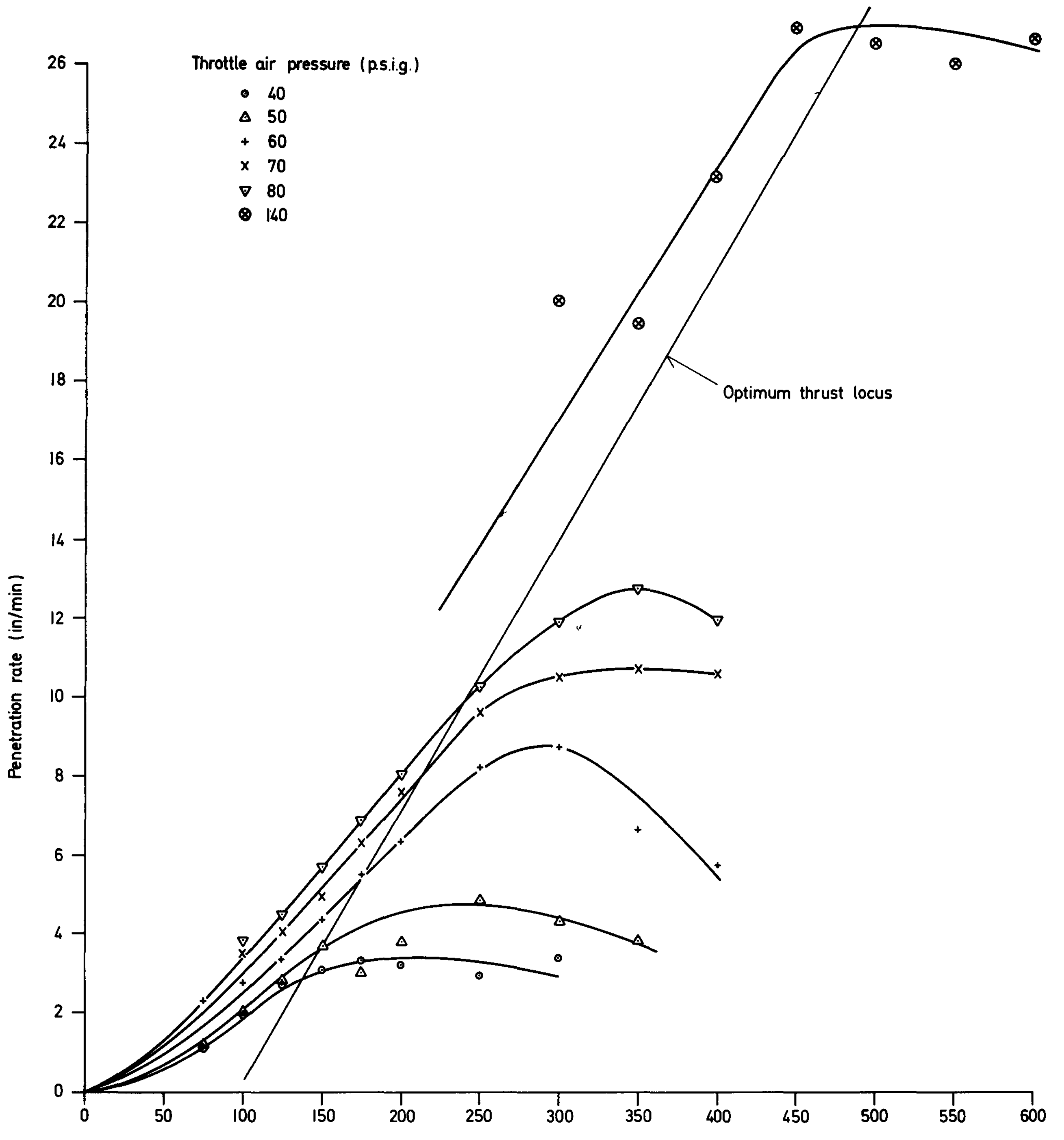

Fig 10 Penetration rate as a function of thrust for various machine throttle air pressures, Vlakfontein Mine, Rockdrill A, Rifle bar 1:30, Drill steel 2.

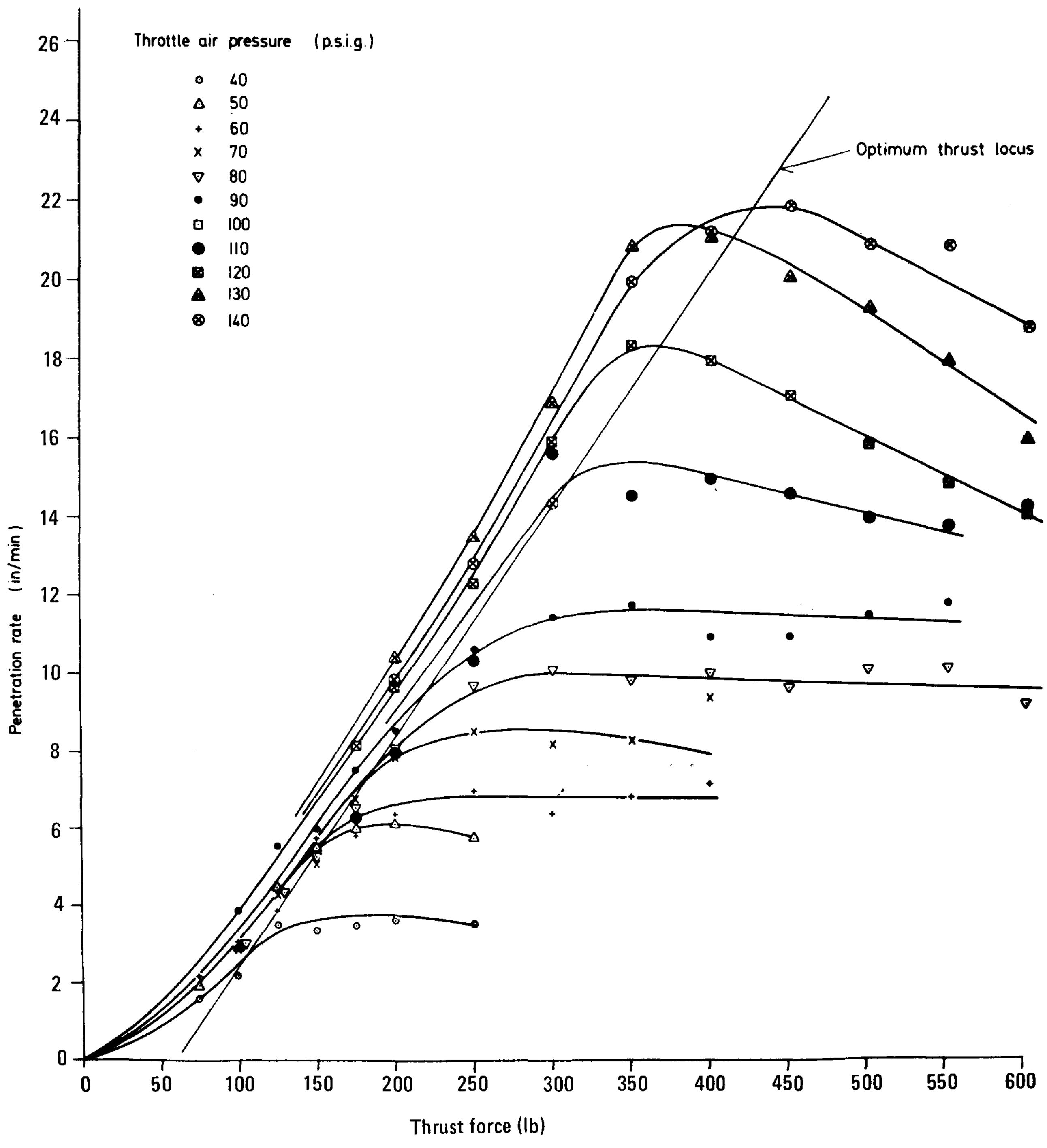

Fig 11 Penetration rate as a function of thrust for various machine throttle air pressures, Vlakfontein Mine, Rockdrill C, Rifle bar 1:30, Drill steel 4, Bit diam. 39 mm.

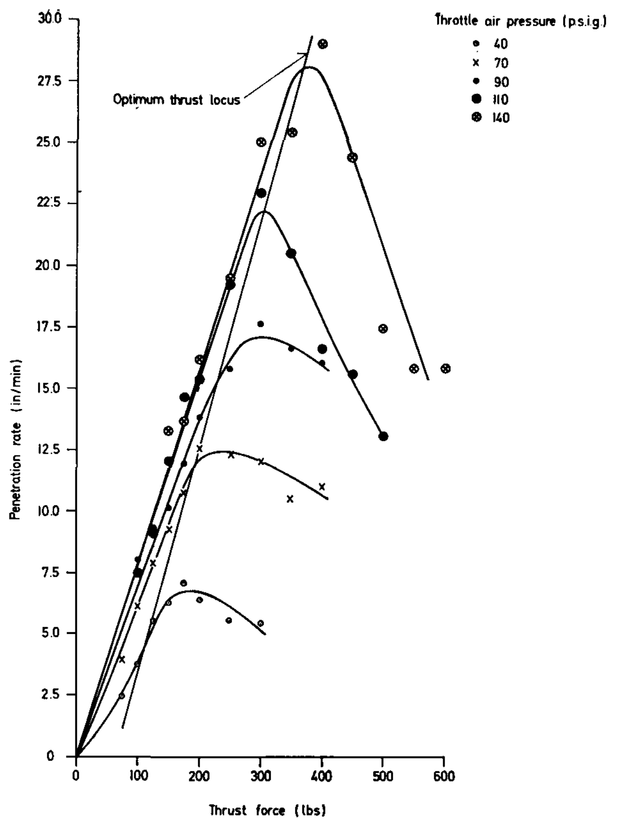

Fig 12 Penetration rate as a function of thrust for various machine throttle air pressures, Vlakfontein Mine, Rockdrill C, Rifle bar 1:30, Drill steel 3, Bit diam. 30 mm.

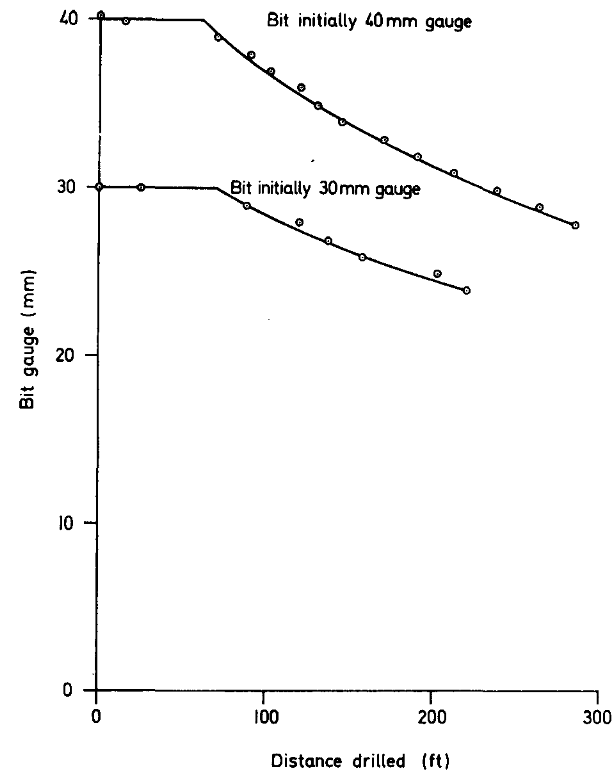

Fig 13 Bit gauge as a function of the distance drilled (Reference 3). RH67 Rockdrill, Quartzite, 7/8 in. hexagonal drill steel, 48 in. long, T.C. chisel bit.

Bit wear

It was shown above that bit gauge wear was related to the distance drilled by

$$\text{bit guage}=d_h-K'L^{\frac{1}{3}}, \quad \ldots\ldots\ldots\ldots \quad (11)$$

where

$$K'=4\left[\frac{\pi\gamma' \cos\phi \sin^2\phi\,(d_h\overline{W}-\overline{W})}{\tan\theta}\right]^{2-\frac{1}{3}}$$

Te Water and Mihulka[3] measured bit gauge wear during the drilling of blast holes in quartzite at West Rand Consolidated Mines using chisel bits having initial gauges of 40 and 30 mm (7/8″ hexagonal drill, 48 in long, RH 67 rockdrill). Their results, plotted in Fig 13, can be described very well by the following equations:

For $d=$'40' mm bit

$$\text{bit gauge}=d_h-4{,}5(L)^{\frac{1}{3}}+17{,}5,\ L>59\text{ ft} \quad . \ (12)$$

For $d=$'30' mm bit

$$\text{bit gauge}=d_h,-3{,}2(L)^{\frac{1}{3}}+13{,}5,\ L>75\text{ ft.} \quad (13)$$

Except for the constants of 17,5 and 13,5 the above equations are of the same form as equation (36), Part I. The presence of these constants means that very little gauge wear occurs (loss of bit gauge) until a certain depth is reached. This suggests that the ability of the corners of the hole to break cleanly is related to the sharpness of the bit. As the cutting edges dull, more material is left for the corners of the bit to remove.

the constants K' in equation (11) become

$K'=3{,}61$ (40 mm)

$K'=2{,}46$ (30 mm).

Assuming

$\overline{W}=0{,}2$ in

$\gamma=4\times10^{-5}$

$\phi=5°$

$\theta=45°$

The experimental and theoretical values of K' do not agree well although the equations are similar in form.

From equation (11) the ratio between the gauge losses for the two bits should be

$$R_o=\frac{(d_{h1}-\text{bit gauge})_{40}}{(d_{h2}-\text{bit gauge})_{30}}=\left(\frac{d_{h1}\overline{W}_1-\overline{W}_1{}^2}{d_{h2}\overline{W}_2-\overline{W}_2{}^2}\right)^{\frac{1}{3}}$$

Assuming that $\overline{W}=K_o d_h$, then

$R_o=1{,}21.$

From an experiment,

$R_o=1{,}41$ (slope ratio),

$R_o'=75/59=1{,}27$ (intercept ratio).

Although this agreement is not good, it is fair considering the assumptions made.

A series of tests was performed to determine the relationship between the rate of penetration and the footage drilled. An initially sharpened bit was used to drill a series of holes 2 ft in length. No re-sharpening was done during the tests and drilling was normally continued until either the drill steel or the bit failed. Results obtained using rockdrill A with a rubber collared and a staved shank drill steel each having a 39 mm chisel bit are shown in Fig 14. The penetration rates obtained

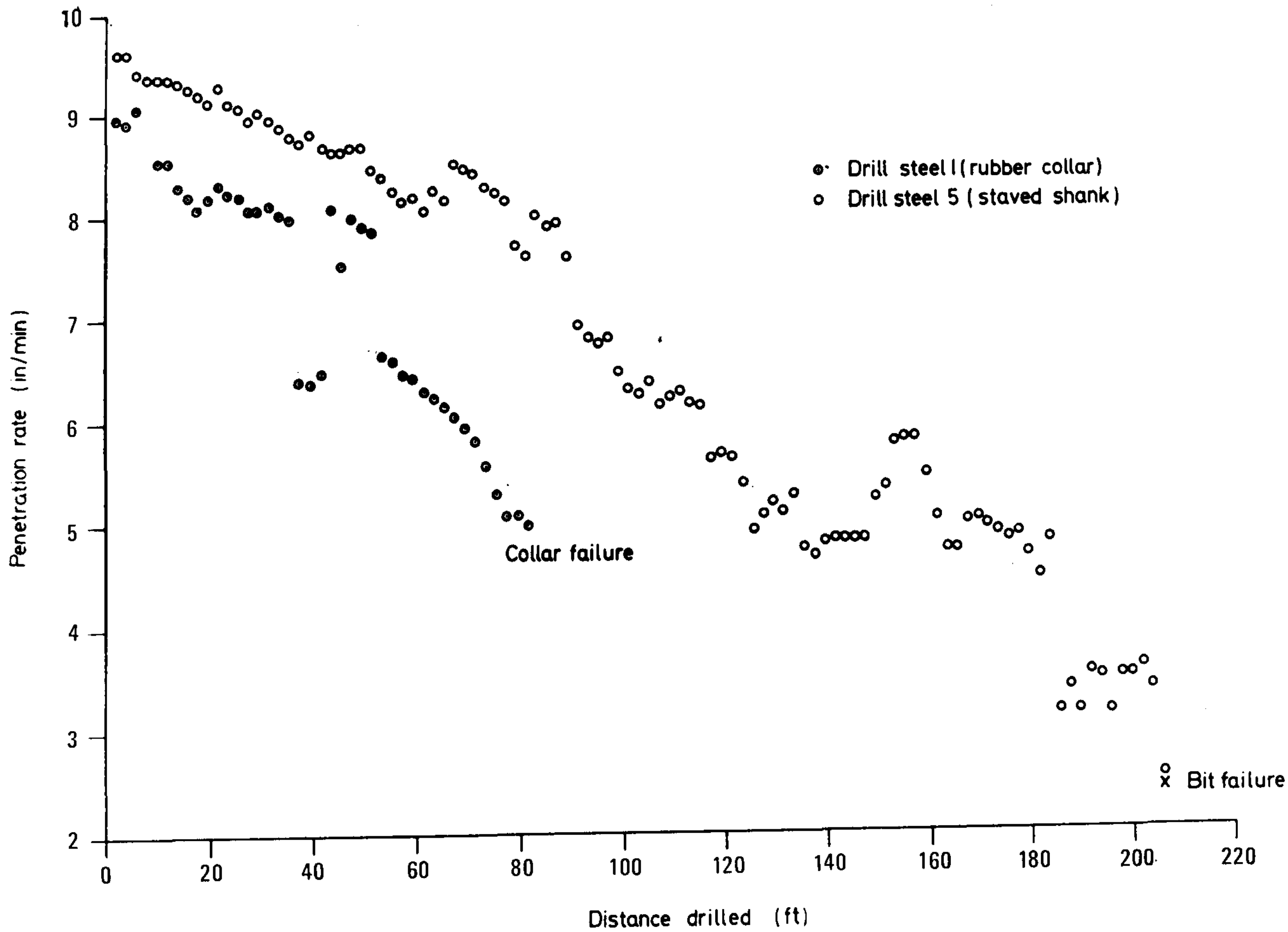

Fig 14 Penetration rate as a function of the distance drilled using an initially sharpened bit. Vlakfontein Mine, Rock-drill A, Rifle bar 1:30, Throttle air pressure 60 lb/ing ^{2}, Thrust 300 lb.

using the staved shank drill steel were somewhat higher than those obtained with the rubber-collared drill steel because of a slightly greater air consumption and blow rate during these tests. There is no other basic reason why the one should penetrate faster than the other. The initial penetration rates are similar to those in Fig 10 for the same air pressure and thrust. It is interesting to note that in this test the drill steels with the staved shank had over twice the life (measured in terms of footage drilled) of that with the rubber collar. The decrease in penetration rate with footage drilled shows the effect of bit wear on the energy transfer from the bit to the rock and on the specific energy. When the machine pressure was increased to 120 lb/in^{2}g and the applied thrust was increased to 600 lb, the staved shank drill steel drilled only 64 ft before failing, Fig 15, as compared with 206 ft for the conditions in Fig 14. This large decrease is because, firstly, the peak stresses existing at 120 lb/in^{2}g are approximately 1,4 times as large as those existing at 60 lb/in^{2}g and, secondly, because the applied thrust (600 lb) is much too high for an operating pressure of 120 lb/in^{2}g, and thus bit rotation probably occurs while bit and rock are in contact. The torsional stresses superimposed on the longitudinal stresses combine to exceed considerably the strength of the drill steel.

From the initial and final penetration rates and the distance drilled, it is found that at an air pressure of 60 lb/in^{2}g the penetration rate decreases by approximately 0,36 percent per foot drilled, while at 120 lb/in^{2}g the decrease is 0,39 percent. This would tend to substantiate the assumption that the volume of bit removed is proportional to the volume of rock drilled rather than being, for example, proportional to the rate of penetration.

Fig 16 shows the penetration rate as a function of the footage drilled for two machine pressure-thrust conditions, (Mp=130 lb/in^{2}g, *thrust*=600 lb, Mp=140 lb/in^{2}g, *thrust*=300 lb). The penetration rate-thrust curves corresponding to these sets of operating conditions are shown diagramatically in Fig 17.

The initial penetration rates are very similar in spite of very different conditions under which the results were obtained. The machine operating at 130 lb/in^{2}g was very

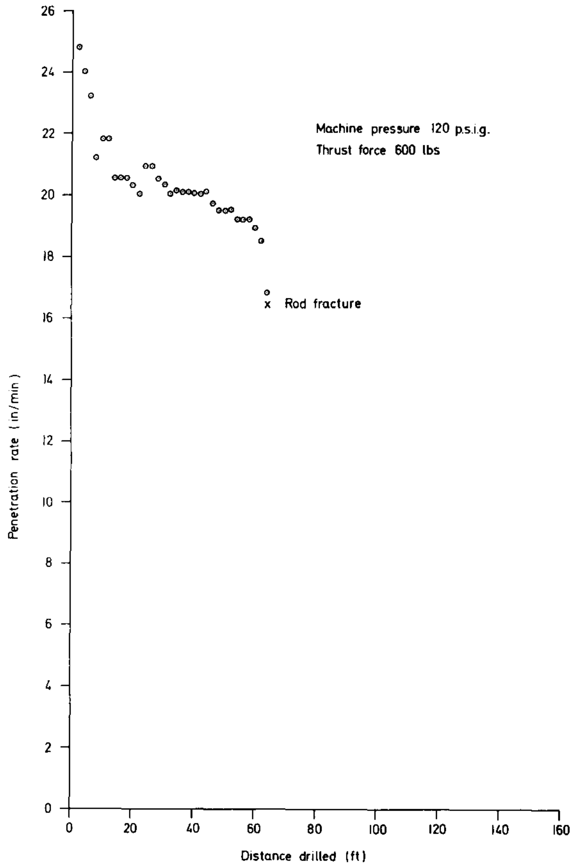

Fig 15 Penetration rate as a function of the distance drilled using an initially sharpened bit. Vlakfontein Mine, Rockdrill A, Rifle bar 1:30, Drill steel 5.

much over-thrusted and, as can be seen in Fig 16, it stalled after only 36 ft had been drilled. The penetration rate decreased much more rapidly with the footage drilled (roughly 1,2 percent per foot drilled) than with the machine operating at 140 lb/in^{2}g with 300 lb thrust (0,35 percent per foot drilled). The latter result is similar to those shown in Fig 14. Improper operating conditions have resulted in an increase by almost a factor of four in the rate at which the penetration rate decreased with distance drilled.

APPENDIX I

.Specifications of the three rockdrills used in the study are listed in Table 1.

In a typical test, measurements were made of:

(1) the throttle air pressure,

(2) the applied thrust,

(3) the time required to drill a 24 in hole after collaring,

(4) compressed air consumption,

(5) number of blows per minute, and

(6) the drill rod rotations per minute.

TABLE 1

ROCKDRILLS USED IN THE DRILLING TESTS

Author's Designation	A	B	C
	SECO S24 The Steel Eng. Co.	RH77 Delfos-Atlas Copco	HC-53 Victoria Engineering
Piston Diameter (ins)	3	2-7/8	2-5/8
Piston Weight (with rifle nut) (lb)	6,688	4,80	4,907
Rifle Bar	1:55 1:30	1:38	1:64 1:30 1:23
Nominal Piston Stroke (in)	3	2,75	2,375
Drill Steel (Integral)	1 in hex	1 in hex	1 in hex 7/8 in hex*
Chisel Bit Diam. (mm)	39	39	39 30*

*Some tests were performed with a HC-53 rockdrill which used the 7/8 inch hexagonal drill steel with a 30 mm bit.

During the tests, pressures of the compressed air supplied to the thrust cylinder and the throttle were controlled by Royles air line regulators and were measured using calibrated Bourdon tube pressure gauges.

In the measurement of penetration rate, the jackhammer was stopped after collaring, and a clear mark was made on the drill rod at a distance of 24 in from the rock face, by applying white lead paste to the drill rod. The time interval between opening of the throttle valve and arrival of the white lead mark at the rock face was measured to within one second by means of a stop-watch. Three such measurements were made and the average was taken to represent the penetration rate at each specific operating condition. Drill rods were re-sharpened after each 20 ft of hole drilled and were discarded at 1 mm gauge loss. Throughout the drilling, an abundant supply of rockdrill lubricant was provided by an air line lubricator.

Compressed air consumption was measured by means of a calibrated New Jersey 2 in Air Meter.

Hammer oscillation frequency was measured by means of a Frahm reed tachometer held against the compressed air supply hose.

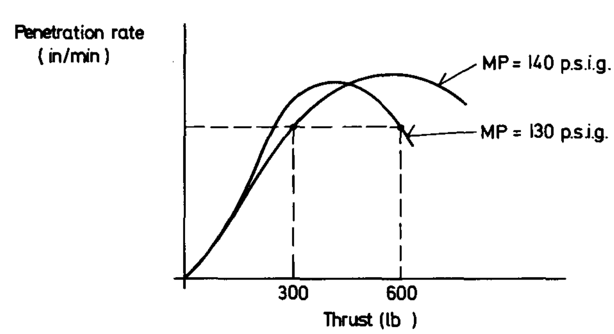

Fig 17 Diagram showing the penetration rate-thrust curves for two over-thrusted operating conditions.

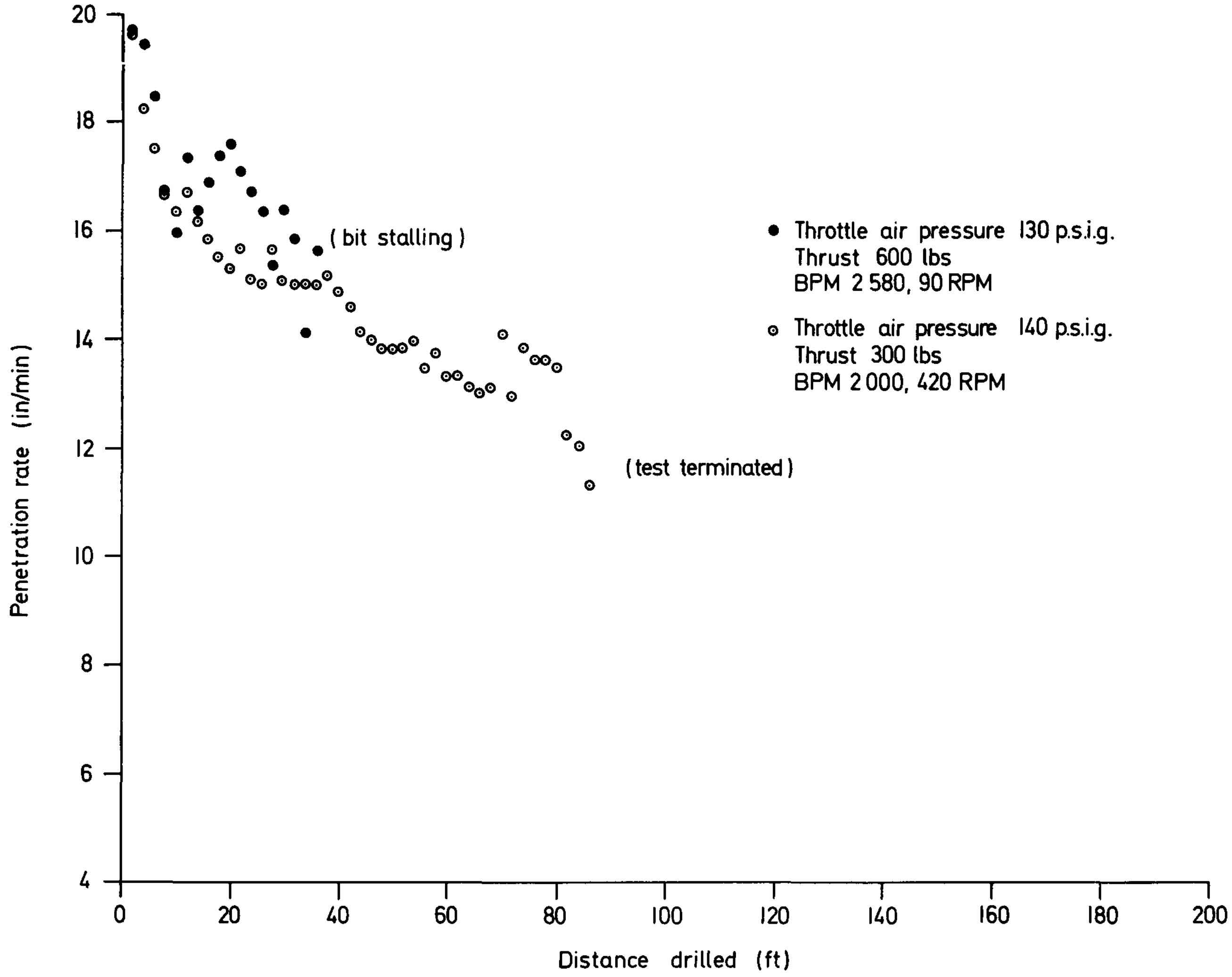

Fig 16 Penetration rate as a function of the distance drilled for two different throttle air pressure-thrust conditions. Vlakfontein Mine, Rockdrill 3, Rifle bar 1:30, Drill steel 5.

For the measurement of hammer impact rate, a vibration transducer (General Radio Co, Type 1560-P52) was held in contact with the rock face, six inches from the hole being drilled. The transducer signals were recorded on a tape recorder (Telefunken Type 300) and displayed in spectrogram form (Kay Electric Co Type 661-A) for counting of individual impacts per unit time.

Measurements of drill rod rotation speed, during actual drilling were made using a stroboscopic flashlight (General Radio Co Type 1531-A).

The several types of integral drill steels used during the testing program are described in Table 2. All drill steels had tungsten carbide chisel insert bits.

TABLE 2

DESCRIPTION OF THE DRILL STEEL USED

Author's Designation	Description
1	Staved shank, 1 in hex, 78 in long, 39 mm bit
2	Rubber collar, 1 in hex, 74 in long, 39 mm bit
3	Rubber collar, 7/8 in hex, 74 in long, 30 mm bit
4	Staved shank, 1 in hex, 74 in long, 39 mm bit
5	Staved shank (Avesta steel), 1 in hex, 72 in long, 39 mm bit.

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2. Cheetham, W. R., and Inett, E. W., "*Factors affecting the performance of percussive drills*", Trans. Instn. Min. Metall., Lond., 63, 1953-54.
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APPENDIX II

TABLE 1

PISTON IMPACT VELOCITIES AND ENERGIES AS FUNCTIONS OF MACHINE AIR PRESSURE FOR ROCKDRILLS A, B AND C

Machine Pressure lb/in²g	Blow frequency (BPM)	Piston Impact velocity (ft/sec)	Impact energy (ft-lb)
ROCKDRILL A			
40	1 200	17,8	32,8
50	1 290	19,8	40,8
60	1 380	21,8	49,3
70	1 450	23,4	57,2
80	1 500	25,1	65,5
90	1 550	26,6	73,6
95	1 600	27,4	78,0
100	1 660	28,1	81,1
110	1 720	29,4	90,5
120	1 800	30,8	98,8
130	1 850	32,0	106,6
140	1 900	33,2	114,3
ROCKDRILL B			
40	1 500	19,3	27,6
50	1 640	21,4	34,3
60	1 740	23,6	41,5
70	1 830	25,4	48,0
80	1 910	27,2	55,2
90	1 980	28,8	61,9
100	2 080	30,4	69,0
120	2 200	33,3	82,7
130	2 275	34,7	89,5
140	2 475	36,0	97,0
ROCKDRILL C			
40	1 520	16,2	19,9
50	1 600	18,0	24,8
60	1 670	19,8	29,8
70	1 750	21,3	34,7
80	1 900	22,8	39,8
90	2 000	24,2	44,6
100	2 100	25,5	49,6
110	2 180	26,8	55,0
120	2 250	28,0	59,6
130	2 300	29,1	64,6
140	2 350	30,2	69,5

PART III

SYNOPSIS

The problem of providing adequate thrust to manually operated rockdrills operating at air pressures of 70 lb/in²g to 80 lb/in²g with the aid of an air-leg is analyzed. It is shown that adequate thrust is provided by an air-leg or the stiff-leg if it is inclined at an angle to the floor of about 25°. However, this requires that the leg react against some support or protuberance, as the friction force between the leg and the floor is inadequate to contain the thrust.

Conclusions summarizing optimum thrusts, blow frequencies, penetration rates, drill steel life and bit wear are presented.

PRACTICAL IMPLICATIONS

Provision for adequate thrust

As has been pointed out previously, for the pressures at which machines are presently operating in most mines (70-80 lb/in²g) the thrusts that can be applied by a man are approximately one half of those which should be applied for optimum penetration rate and drill steel life. Because of this, it is important to consider how the required thrust might be generated. For most of the experiments discussed thus far, the thrust arrangement as shown in Fig 1 consisted of an air cylinder mounted in line with the rockdrill. This method was found to provide all the thrust required.

An alternative method of ensuring that the bit and rock were in contact when the blow arrived was by means