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A comparative study of some rock drill bits

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A COMPARATIVE STUDY OF

SOME ROCK DRILL BITS

BY

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A

THESIS

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Approved by ______________________
Assistant Professor of Mining Engineering

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INTRODUCTION

The detachable single-use rock-drill bit has attracted considerable attention in the mining industry of the United States during the past few years. While this type of bit has been used for some time in other countries, it has been only recently that these bits have been manufactured in the United States.

It was decided to test this type of bit and make a comparative study of a single-use bit and a widely used detachable rock-drill bit.

It should be remembered that this comparison is made from the standpoint of the drill bits alone, and that the life of the bits were considered at an end when dullness or failure of the bit occurred. Consequently, the advantage gained by resharpening the four-point drill bit is disregarded as are several advantages of the single-use drill bit.

The experiments performed were of two types; the first, a determination of the efficiency, wear and life of the drill bits; the second, a study of the initial dulling of the drill bits. Profiles of the bits were made during all of the experiments so that a satisfactory study of the wear was afforded.

REVIEW OF LITERATURE

T. M. Waterland and G. E. apRoberts have found that the distance a bit can drill efficiently is controlled by two factors.[1] These are:

(1) Waterland, T. M. and apRoberts, G. E., Some New Ideas in Rock Drill Bit Design, Transactions, C.I.M.M., Volume XLIX, pp. 123-129, 1946.

(1) The area of the reaming face exposed to rubbing action against the side of the hole.

(2) The strength of the corners, or the ability of the bit to resist having the reaming angle reversed.

This is in accordance with the results found by Eaton who stated that "within reasonable limits the depth to which a hole can be drilled is dependent primarily upon the loss in gauge or diameter of the bit".[2]

(2) Eaton, Lucien, Refinements in Design of Rock-Drill Bits, Mining Technology, Volume 3, No. 5, T.P. 1095, September 1939.

Eaton also found that the principal advantage to be derived from reducing gauge loss is the increase in drilling speed, that drilling speed varies inversely as the square of the Diameter of the hole or inversely as the volume of rock removed, and that drilling speed is dependent also on the shape of the bit.

The shape of the drill bit for maximum efficiency must be such that the energy developed will produce maximum penetration in the rock. Every drill bit has four important functions to perform and the character of the material to be drilled will determine which of the four functions is the most important. These functions are as follows:(3)

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(3) Birckhead, L. B., Recent Developments in the Drilling of Large Blast Holes, Pit & Quarry, Volume 38, No. 11, pp. 76-77, May 1946.

(a) Penetration

(b) Reaming

(c) Crushing

(d) Mixing

Certain features of design of drill bits must be given careful considerations, both in the original bit and in the resharpening of the bit. These features are:(4)

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(4) Ibid. pp. 76-77

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1. Angle of clearance
2. Angle of penetration
3. Wearing surface
4. Reaming edge
5. Area of crushing face
6. Area of water course
7. Contour of penetrating edge
8. Cross-section of bit

Speaking on the same subject Mosier states:(5)

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(5) Mosier, McHenry, Progress Report on Investigation of Detachable Rock Drill Bits. U. S. Bureau of Mines Information Circular No. 6877, February 1936.

> "Many Things enter into the design of a bit. The first consideration is the general type, as, for example, chisel bit, cross bit, or rose bit. Then follows such details as clearance tapers, whether single or double, and the degree of each; the angle between faces, which may be acute or obtuse or 90 degrees. The dimensions of the wings including their height and width; the amount of reaming effect from the edges of the wings; and the position of the hole through the bit which may have a center or side outlet."

While this paper discusses the costs from a standpoint of the bit alone the tangible factors that affect the total cost per foot drilled are:(6)

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(6) Ibid.

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1. Cost of transportation of drill steel and bits from sharpening shop to working face and return.

2. Shop operating expense for reconditioning drill steel and bits.

3. Rate of penetration or cutting speed.

4. Number of feet drilled per bit dulled.

5. Feet drilled per machine shift.

6. Loss of drill steel from all causes.

7. Drill machine repairs.

8. Hazards in transportation and use of drill steel and bits.

9. Capital expense.

At the present the mining industry is watching the drilling outcome critically. Rock drills and detachable steel bits are still responsible for the major part of the ore and rock that is being broken. The recent rapid advance to favor of the single-use, or throwaway, type of bit suggests that the multiple-use detachable bit is decreasing in demand.(7)

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(7) Hubbell, A. H., Mining Industry Watches Drilling Outcome, Engineering and Mining Journal, volume 150, No. 2, pp. 96-105, February 1949.

Competition appears to be keenest between the single-use bit and the carbide bit, which are respectively the cheapest and the most expensive.

Hubbel[8] states that, "an Idaho company has drawn

(8) Hubbell, A. H., Mining Industry Watches Drilling Outcome, Engineering and Mining Journal, Volume 150, No. 2, pp. 96-105, February 1949.

interesting conclusions from a limited use of tungsten-carbide bits and a throwaway type of steel bit. With the throwaway bit, the bit cost per foot of hole is a third to a quarter of that obtained with the carbide bit, but detachability remains a problem. Once that is solved, they believe the single-pass bit will be the answer to the question of reducing drilling costs."

Single-use steel bits present some interesting developments. Rip Bits, Ltd., British owners of the Padley and Morgan bit, claim sales in 1947 of 60,000,000 bits in South Africa and Canada, where they license manufacture. Other manufacturers of a single-use bit are Hayes Steel Products, Ltd., Western Rock Bit Manufacturing Co., Thompson Products Ltd., Throwaway Bit Corporation, and the Joy Manufacturing Company.

APPARATUS AND MATERIALS

The tests described in this paper were performed at the Experimental Mine of the School of Mines and Metallurgy of the University of Missouri which is about 1½ miles southwest of Rolla, Missouri.

Tests were made in two types of rock, the first a dolomitic limestone known as the Jefferson City Dolomite. This rock is composed of dolomite and chert, the chert adding an abrasive quality to the rock. This rock has the following composition:(9)

Dolomite	92 per cent
Chert	8 per cent

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(9) Terrasson, Paul Louis P., A Comparative Study of Some Rock Drill Bits, Thesis, Missouri School of Mines and Metallurgy, Rolla, Missouri, May 1948.

The second type of rock used in testing the drill bits was a pink granite. This granite was quarried in the form of blocks in southeast Missouri and brought to the experimental mine. Mr. E. McCracken of the Missouri Geological Survey found that the granite has the following composition:

Feldspar	75 per cent
Quartz	20 per cent
Mica	5 per cent

Terrasson found that toughness of the limestone was 2 2/3 cm. and that the toughness of the granite was 8 cm. This indicates that the granite is much tougher than the limestone. These tests were made using the method given in the 1939 book of A. S. T. M. Standards (10) which lists

(10) A. S. T. M. Standards Book 1939, Part II, Non-metallic Materials, p. 383, 1939.

the following definition of toughness:

> "Toughness as applied to rock, is the resistance offered to fracture under impact, expressed as the final height of blow required of a standard hammer to cause fracture of a cylindrical test specimen of given dimensions, (cylinder 25 mm. in diameter, 25mm. in height)."

A Cleveland HC10-1R Drifter was used in all of the drilling tests in limestone. The bore of the cylinder of this machine is 2 5/8 inches. This machine was mounted on a crossbar with a pneumatic column and has a 44 inch pneumatic feed-arm controlled by a lever on the body of the machine.

A Cleveland H-10 Sinker, hand held, was used in all of the drilling tests in granite. This 45 lb. machine has a ~~bore~~ cylinder bore of 2 5/8 inches.

Standard drill steel sections two feet in length were used with the sinker. The standard drill steel sections used with the drifter were the two, four and six foot lengths.

An Ingersoll-Rand diesel driven two-stage compressor, with a capacity of 215 cubic feet per minute, supplied the air for the drilling machines.

The air pressure at the machine was measured by an air gauge inserted in the line between the line oiler and the air inlet to the machine. The average drilling pressure in granite was 100 lbs. per square inch and the average drilling pressure in limestone was 90 lbs. per square inch. The range of pressure during the tests was from 80 to 100 psi. in the tests in limestone and 95 to 105 psi. in the tests in granite.

Wet drilling was used in all of the tests. The water for the machines was kept under a constant pressure of 50 psi. by compressed air that entered the top of a water tank through a valve that automatically maintained this pressure. The water was supplied from a pump in the mine and was pumped into the tank by a small air-driven pump.

The types of bits tested in this project were the Ingersoll-Rand 1½ inch center-hole plain four-point drill bits shown on page 12, and the Joy 1½ inch center-hole Thro-Way drill bits shown on page 14.

This bit is of massive design and has a cutting angle ranging from 85 to 95 degrees and a reaming angle of about 5 degrees. Clearance for the cuttings is provided by grooves between the wings of the bit. The bit is connected to the drill steel by Buttress threads on the inside of the socket of the bit. The flat end of the drill steel rests on the end of the socket of the bit so that little stress is placed on the threads. The Ingersoll-Rand bits were used with 1 inch hexagonal Ingersoll-Rand drill steel which is fitted with an external thread designated as type 1.


Wing
Thickness
Reaming Angle
Taper Angle

A Rockwell Hardness Tester was used to test the hardness of the bits. The average hardness of the cutting edges was 61.5 Rockwell scale C and the average hardness of the skirt was 73 Rockwell scale B. The skirt is not heat treated as are the cutting edges so that the skirt is softer and has the toughness necessary for the connecting threads to hold the bit securely on the drill steel. This testing procedure is fully described in Appendix A.

The Joy Thro-Way drill bits were used with Joy AR 1 inch hexagonal drill steel. This steel is fitted with an internal Whitworth thread in a collar at the end of the steel that has an outside diameter of 1.4 inches.

The Thro-Way bit is of lighter design than the Ingersoll-Rand bit and has a cutting angle ranging from 85 to 95 degrees and a reaming angle of about 5 degrees. Clearance for the cuttings is provided by grooves between the wings. The depth of these grooves is less than that of the Ingersoll-Rand bits so that the flow of cuttings from the hole was not steady at all times.

The bit is connected to the drill steel by Whitworth threads on the neck of the bit. The body of the bit rests on the entire shoulder of the drill steel so that during power transmission the stress on the threads is small.

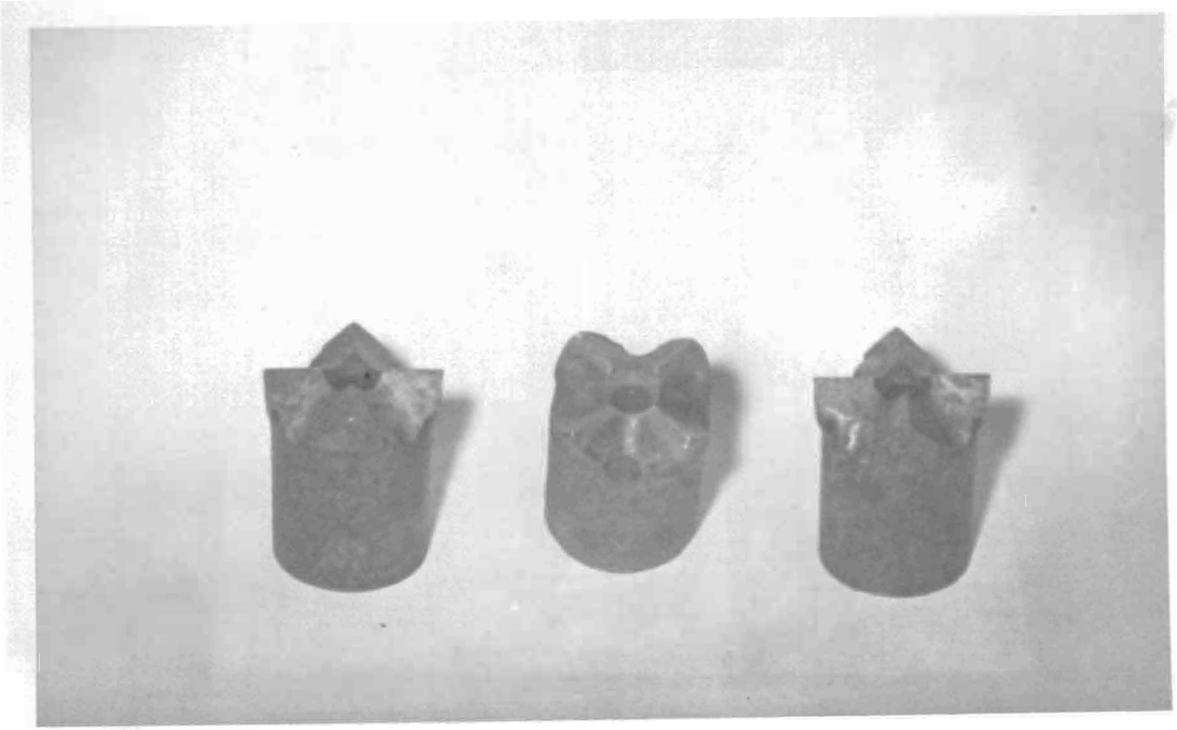


Figure 2. Ingersoll-Rand Four-Point Drill Bits

A Rockwell Hardness Tester was used to measure the hardness of these bits and the averages are as follows:

Cutting edge	64 Rockwell	scale C
Skirt	43 Rockwell	scale B

See Appendix A for the complete data and the testing procedure.

A profile-tracer was used to afford a study of the wear of the bit. This apparatus was developed by Bloemsma.(11)

(11) Bloemsma, J. H., Ramsay, R. and Deane, O., Some Experiments with Tungsten Carbide Tipped Drill Steels, Journal of Chemical, Metallurgical and Mining Society of South Africa, pp. 243-283, January, 1947.

The apparatus consists of a steel base and a clamp, perpendicular to the base in which the drill bit is securely held. The image of the profile of the bit is recorded on a sheet of paper on the base of the apparatus by a profile-tracer which is a steel prism with a sharp pointed pin in it so that as the profile-tracer is moved around the profile of the bit a succession of pin pricks in the paper projects the image of the bit on the paper. The pin pricks are made by pushing down on the pin, the pin springs back into the body of the steel prism when the pressure on the pin is released.

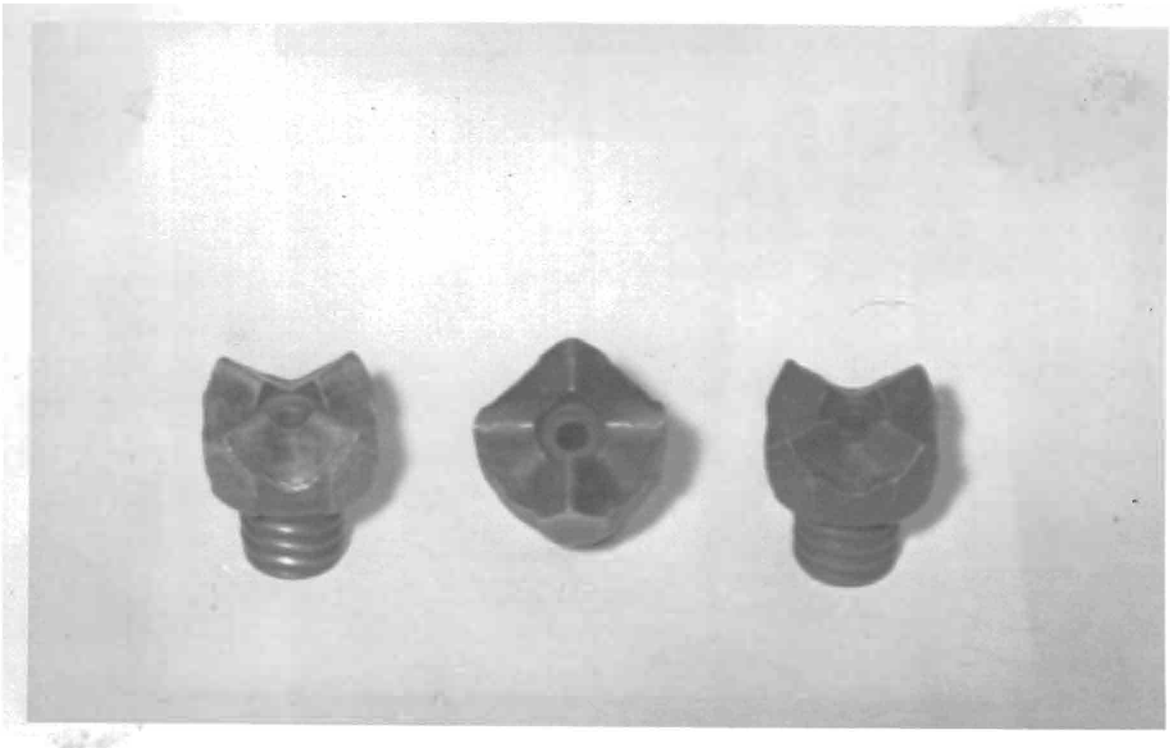


Figure 3. Joy Thro-Way Drill Bits

It was necessary to make successive profiles of the bits by placing the bit in the clamp at the identical position used for the first profile of the bit. This was accomplished by marking points on the sides of opposite wings and lining up these points at the same height with the profile-tracer each time a profile of the bit was taken.

METHOD OF INVESTIGATION AND DATA RECORDING

The following data was recorded as accurately as possible in making this study of rock drill bits.

(A) The distance of travel or penetration of the bit.

(B) The original gauge and the losses of gauge of the bit.

(C) The drilling speed or penetration per unit of time of the bit.

(D) Profiles of the bit.

The following conditions were observed during the tests at all times.

(1) The same drifter was used in all of the tests in limestone and the same sinker was used in all of the tests in granite.

(2) The water pressure was constant.

(3) The air pressure was kept constant between definite limits.

(4) All holes were collared with separate bits.

(5) Wet drilling was used in all of the tests.

(6) The machine was run at full throttle in all of the drilling tests.

A. The Penetration of the Bit

The footage of the bit was measured on the feed-arm of the drifter when testing in limestone. All holes were collared with a separate bit. After a hole was collared, the test bit was screwed on the drill steel and run into the hole, then a mark was placed on the feed-arm at the point where the arm projected from the body of the machine.

At the end of the run, the distance between the original mark and the point of the projection of the feed-arm from the body of the machine was measured and recorded.

The above procedure could not be carried out in the tests in granite since a sinker was used in these tests. The method used in the tests in granite was to use a steel tape to measure the depth of the holes.

B. The Gauge of the Bit

A micrometer was used to measure the gauge of the drill bits. Measurements were taken of the original gauge, the gauge after every drilling test and the final gauge of the drill bit when possible to do so.

Measurements were taken between the diameters of opposite wings of the drill bit in all of the experiments. These measurements were usually the same but when one of the measurements differed, then the largest one was recorded. The few differences that were noted were never more than 0.002 inches.

C. The Drilling Speed of the Bit

The drilling speed was measured in feet per minute for the tests in limestone and in inches per minute for the tests in granite. Drilling tests were made in the initial, final and intermediate stages of the life of the bits.

All drilling tests were run for 60 seconds when possible. When it wasn't possible to run a drilling test for 60 seconds then the length of the drill steel was run out as far as possible and the drilling speed computed on the basis of 60 seconds time.

The average drilling speeds were computed by a graphical method from the data obtained for each test. This method consisted of plotting a line determined by finding equal areas above and below the graphical representation of the drilling speed.

When using the drifter in the tests in limestone, considerable effort was made to keep the bit rotating at a desirable rate of speed at all times by careful control of the advance of the feed-arm.

The pressure exerted on the sinker used in the tests in granite was dependent directly on the operator. Considerable effort was expended in these tests to obtain a desirable and uniform rate of advance of the bit.

D. Profiles of the Bit

Profiles of the bits were made before the start of each test. Profiles were taken after each drilling speed test during the life of the bit and usually a profile was taken to show the wear of the bits at the end of their life. A few of the bits tested sheared off and lodged in the hole during the tests, so for this reason the final profiles and gauge measurements are not recorded for all of the bits.

EXPERIMENTS ON THE PERFORMANCE OF THE DRILL BITS

The object of this series of experiments was to find the efficiency, wear and life of the drill bits. Tests were run in limestone and in granite.

In this series of tests three bits were used for each type of test and a composite average of these drill bits was used in the comparison of the performances of the two types of bits. The profiles of the wear of the bits may be seen in figures 7 and 11.

Experiment No. 1

This experiment consisted of finding the efficiency, wear and life of the 1½ inch Ingersoll-Rand center-hole four-point drill bit and of the 1½ inch Joy center-hole Thro-Way drill bit in dolomitic limestone.

The drilling was done in the side of a drift in the mine with a Cleveland HC10-1R drifter. The water pressure was 50 psi. and the air pressure averaged 90 psi.

The following data were recorded:

1½ inch Ingersoll-Rand four-point bit

Bit No. 1

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.513	0.000
5.75	1.95	1.490	0.023
24.70	1.30	1.484	0.029
68.97	1.65	1.473	0.040
92.45-bit sheared in hole			

Bit No. 2

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.510	0.000
5.25	1.65	1.502	0.008
10.75	1.72	1.492	0.018
28.15	1.30	1.491	0.019
66.75	1.05	1.479	0.031
97.49	1.61	1.465	0.045
113.55-bit sheared in hole			

Bit No. 3

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.510	0.000
5.60	1.80	1.498	0.012
11.05	2.03	1.491	0.019
29.60	1.77	1.483	0.027
70.27-bit sheared in hole			

1½ inch Joy Thro-Way bit

Bit No. 4

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.507	0.000
4.08	2.13	1.504	0.003
17.68	1.80	1.490	0.017
40.18	2.25	1.471	0.036
86.92	2.04	1.467	0.040
112.75	---	1.463	0.043

1½ inch Joy Thro-Way bit (continued)

Bit No. 5

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.507	0.000
2.80	2.08	1.505	0.002
18.50	1.95	1.499	0.008
45.32	2.20	1.488	0.019
81.39	2.25	1.480	0.027
118.19	1.62	1.468	0.039

Bit No. 6

Advance feet	Speed ft./min.	Gauge in.	Gauge Loss in.
0.00	---	1.504	0.000
2.95	1.70	1.503	0.001
19.52	1.65	1.498	0.006
44.57	2.19	1.493	0.011
94.91	1.93	1.480	0.024
142.58	1.17	1.459	0.045

Comparison of the Performance of the Drill Bits

The following average drilling speeds were found using figures 4 and 5.

Type of Bit	Speed(ft./min.)
1½ inch Ingersoll-Rand	1.53
1½ inch Joy Thro-Way	1.98

These figures show that the Joy Thro-Way bit has an average drilling speed 29 per cent greater than that of the Ingersoll-Rand four-point bit in dolomitic limestone.

The following average gauge losses were computed from the recorded data and from figure 6.

Type of Bit	Gauge Loss(in./ft.)
1½ inch Ingersoll-Rand	.000435
1½ inch Joy Thro-Way	.000345

These figures prove that the Joy Thro-Way bit has an average gauge loss 20.7 per cent less than that of the Ingersoll-Rand four-point bit in dolomitic limestone.

The following averages for the life of the bits were computed from the recorded data:

Type of Bit	Penetration(ft.)
1½ inch Ingersoll-Rand	92.10
1½ inch Joy Thro-Way	124.50

These figures prove that the 1½ inch Joy Thro-Way bit has a life 35 per cent greater than that of the same size Ingersoll-Rand four-point drill bit in dolomitic limestone.

The cost of the bits when purchased in small quantities are as follows:(12)

Type of Bit	Cost
1½ inch Ingersoll-Rand	$0.45
1½ inch Joy Thro-Way	0.22

---

(12) Personal communications from the manufacturers.

Using the above costs in computing the cost of the bits per foot of hole drilled yielded the following averages:

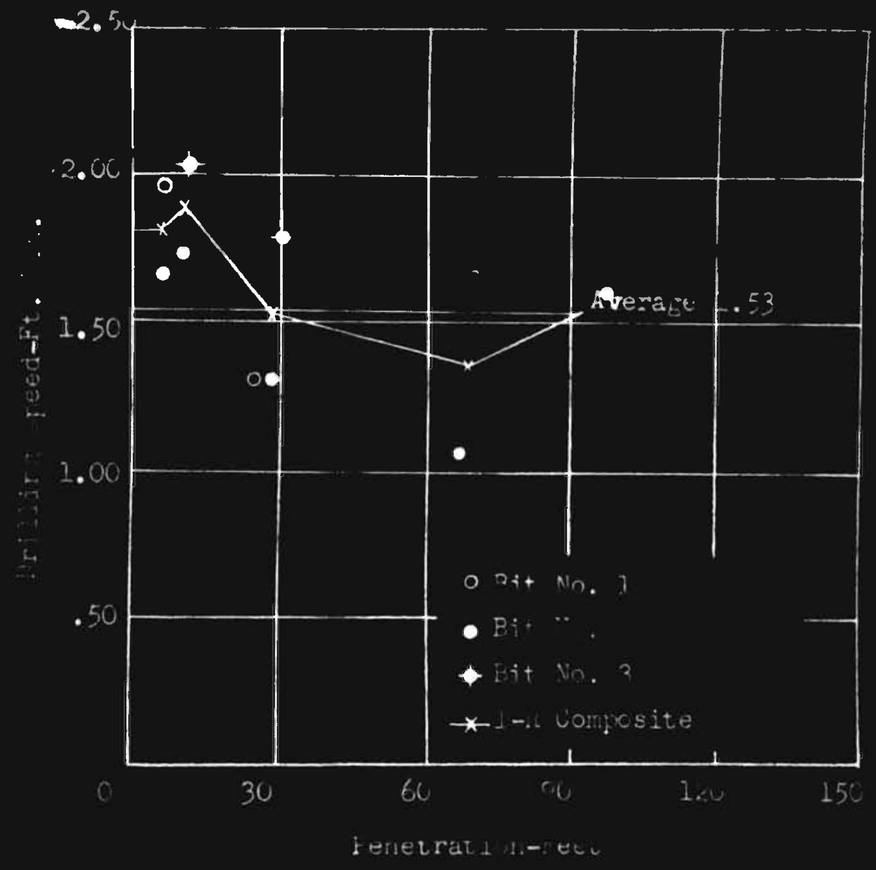
Type of Bit	Cost($/ft.)
1½ inch Ingersoll-Rand	.00489
1½ inch Joy Thro-Way	.00177

The figures on page 23 show that it costs 63.8 per cent less to use the $1\frac{1}{2}$ inch Joy Thro-Way bit than to use the $1\frac{1}{2}$ inch Ingersoll-Rand drill bit in dolomitic limestone.

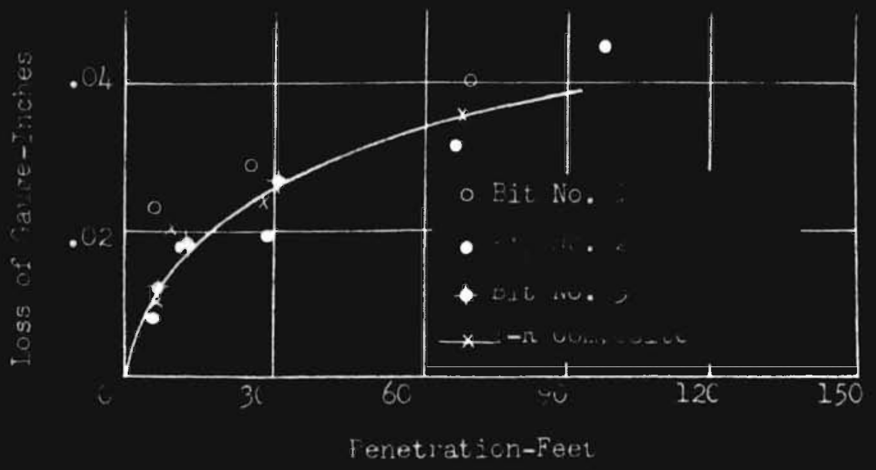
The flow of cuttings from the hole is steadier when using the Ingersoll-Rand bit than when using the Thro-Way bit. Several times when using the Thro-Way bit, the flow of cuttings from the hole was in spurts. A more adequate clearance for cuttings is needed on the Thro-Way bit.

Generally, it was easier and quicker to remove the Ingersoll-Rand bit from the steel than it was to remove the Thro-Way bit from the steel. In removing the Thro-Way bit from the steel, care had to be taken to prevent chipping the wings of the bit. The greater hardness of the Thro-Way bit makes this bit easier to chip than the softer Ingersoll-Rand bit.

The machine used for this experiment was not ideally suited for the use of Ingersoll-Rand bits. Previous papers, in which other machines were used with the Ingersoll-Rand bit, list the life of the bit to be considerably greater. The life of all of the Ingersoll-Rand bits used in Experiment No. 1 was terminated by the bit shearing in the hole.

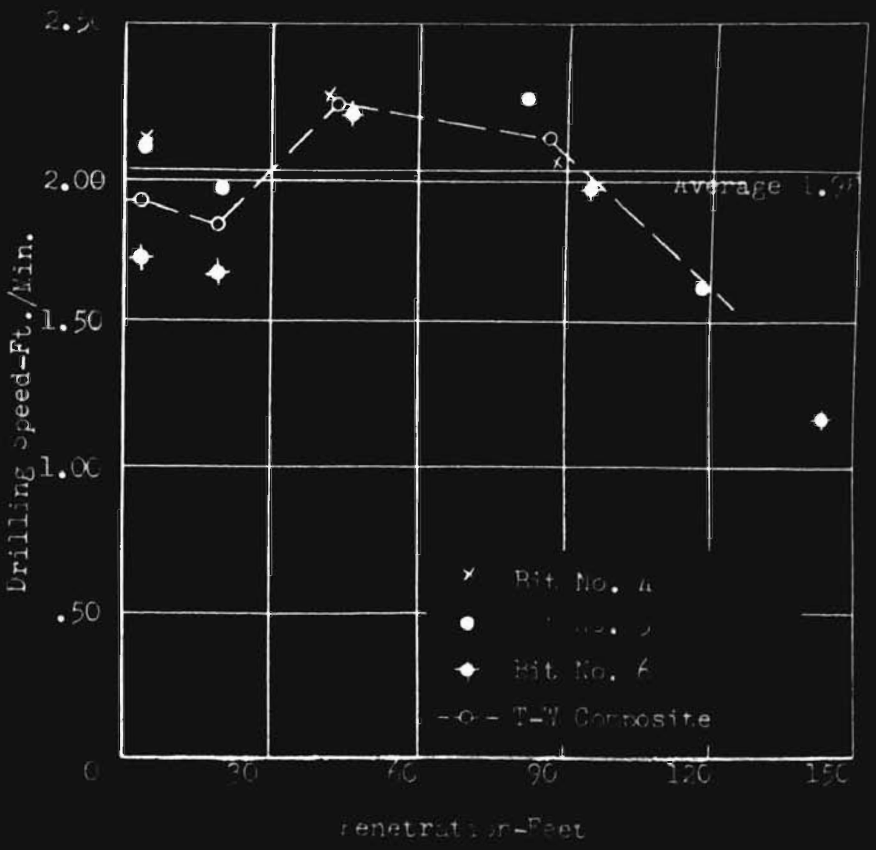


Graph A: Drilling Speed

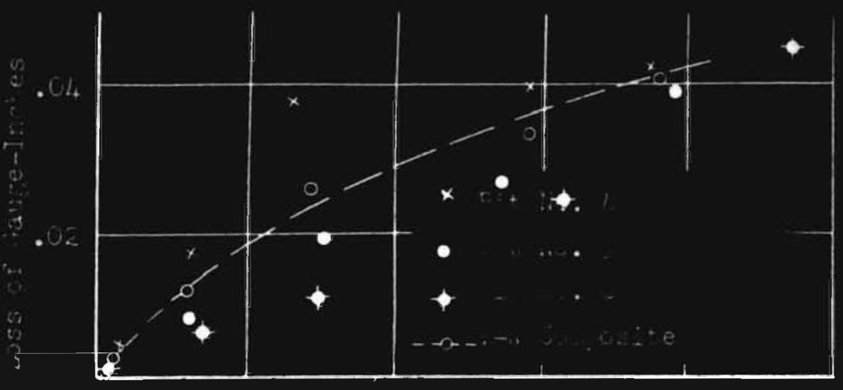


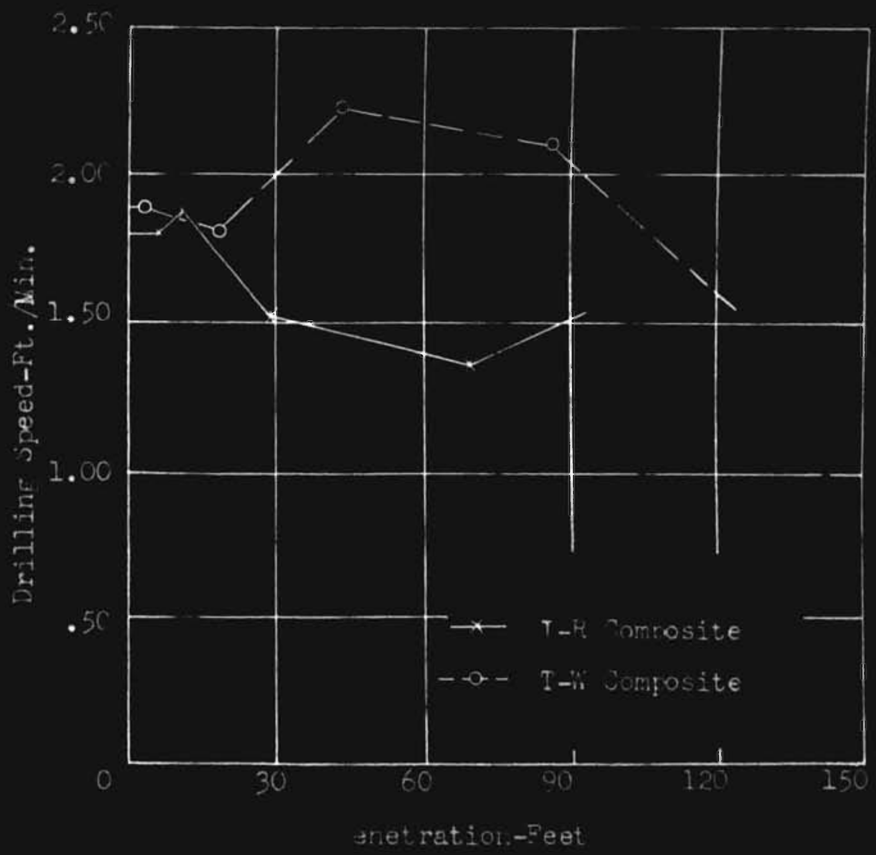
Graph B: Gauge Loss

Figure 4. Experiment No. 1

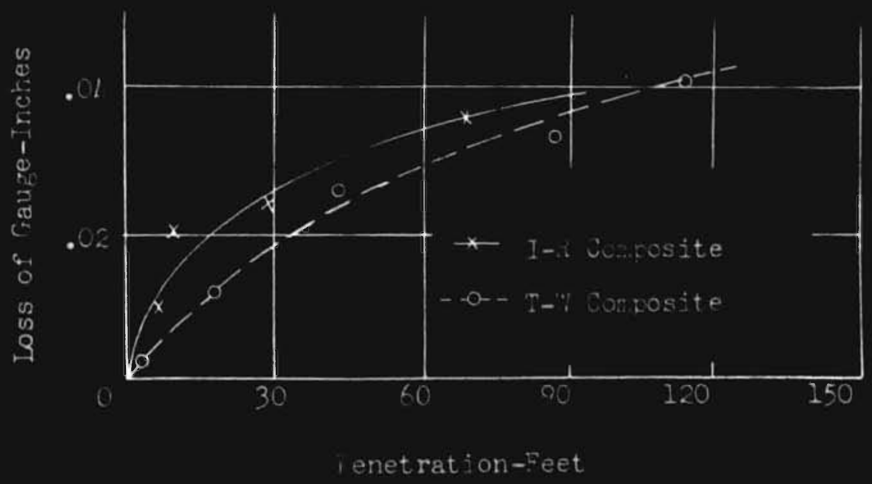


Graph C: Drilling Speed



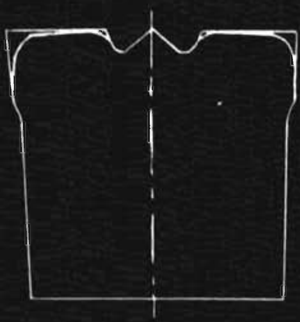


Graph E: Drilling Speed



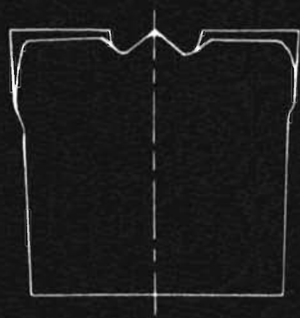
Graph F: Gauge Loss

Figure 6. Experiment No. 1



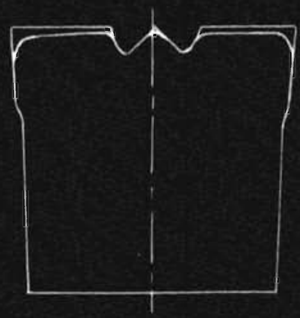
Bit No. 1

Profile Taken At:
0.00 Feet
68.97 Feet



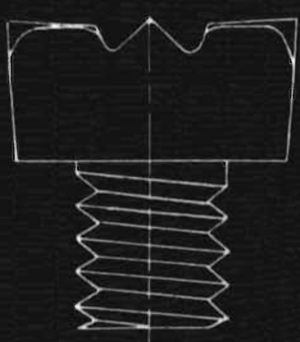
Bit No. 2

Profile Taken At:
0.00 Feet
97.49 Feet



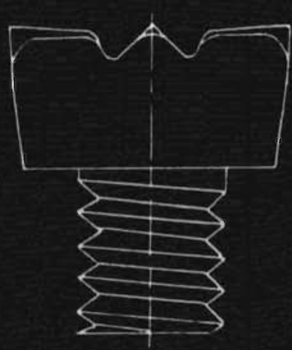
Bit No. 3

Profile Taken At:
0.00 Feet
29.60 Feet



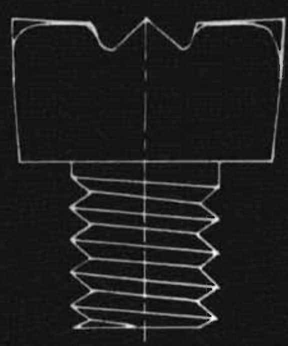
Bit No. 4

Profile Taken At:
0.00 Feet
11[illegible] Feet



Bit No. 5

Profile Taken At:
0.00 Feet
118.19 Feet



Bit No. 6

Profile Taken At:
0.00 Feet
142.58 Feet

Experiment No. 2

This experiment consisted of finding the efficiency, wear and life of the 1½ inch Ingersoll-Rand four-point drill bit and of the 1½ inch Joy Thro-Way bit in pink granite.

The drilling was done in granite blocks near the mine entrance using a Cleveland H-10 sinker. The water pressure was 50 psi and the air pressure averaged 100 psi.

The following data were recorded:

1½ inch Ingersoll-Rand four-point bit

Bit No. 7

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.513	0.000
4.00	4.00	1.485	0.028
19.50	3.00	1.458	0.055
35.75	2.00	1.423	0.090
38.62	1.62	1.415	0.098

Bit No. 8

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.516	0.000
3.75	3.75	1.484	0.032
19.88	2.62	1.454	0.062
30.88	2.62	1.440	0.076
42.62	2.62	1.421	0.095
48.12	2.50	1.409	0.107

Bit No. 9

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.511	0.000
9.00	3.50	1.469	0.042
25.38	3.38	1.450	0.061
32.50	2.50	1.444	0.067

$1\frac{1}{2}$ inch Joy Thro-Way bit

Bit No. 10

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.507	0.000
4.25	4.25	1.497	0.010
12.50	3.50	1.482	0.025
21.75	2.75	1.466	0.041
36.75	3.00	1.441	0.066

Bit No. 11

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.506	0.000
11.00	4.62	1.485	0.021
18.00	2.50	1.470	0.036
34.00	3.00	1.442	0.064

Bit No. 12

Advance in.	Speed in./min.	Gauge in.	Gauge Loss in.
0.00	---	1.513	0.000
3.62	3.62	1.493	0.020
18.00	2.75	----	----

bit sheared in hole

Comparison of the Performance of the Drill Bits

The following average drilling speeds were found using figures 8 and 9.

Type of Bit	Speed(in./min.)
$1\frac{1}{2}$ inch Ingersoll-Rand	3.1
$1\frac{1}{2}$ inch Joy Thro-Way	3.5

These figures show that the Joy Thro-Way bit has an average drilling speed 11.3 per cent greater than that of the Ingersoll-Rand four-point bit in pink granite.

The following average gauge losses were computed from the recorded data and from figure 10.

Type of Bit	Gauge Loss(in./in.)
1½ inch Ingersoll-Rand	.00246
1½ inch Joy Thro-Way	.00182

These figures show that the Joy Thro-Way bit has an average gauge loss 26 per cent less than that of the Ingersoll-Rand four-point bit in pink granite.

The following averages for the life of the bits were computed from the recorded data.

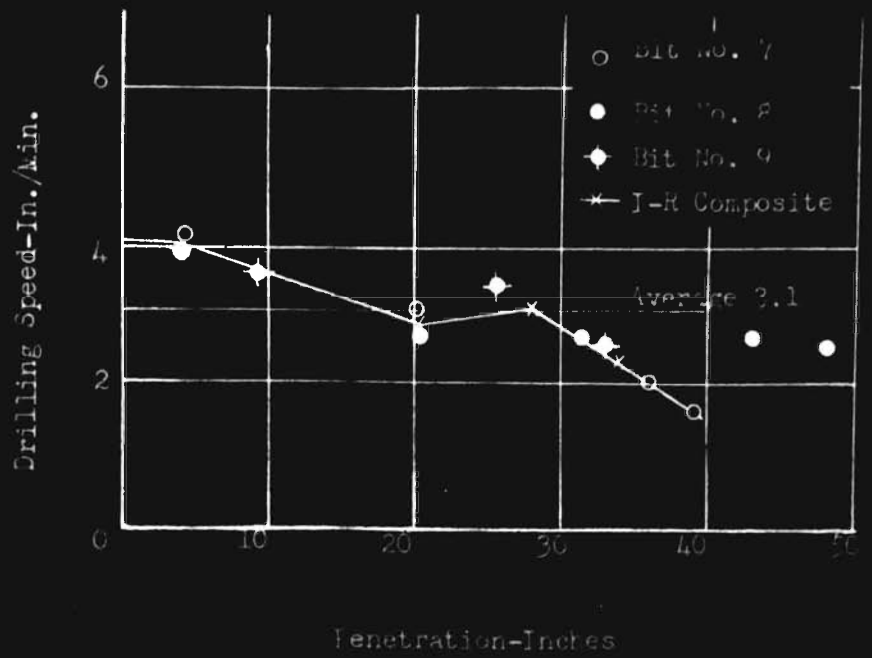
Type of Bit	Penetration(in.)
1½ inch Ingersoll-Rand	39.75
1½ inch Joy Thro-Way	29.60

These figures show that the 1½ inch Ingersoll-Rand bit has a life 34.5 per cent greater than that of the Joy Thro-Way bit in pink granite.

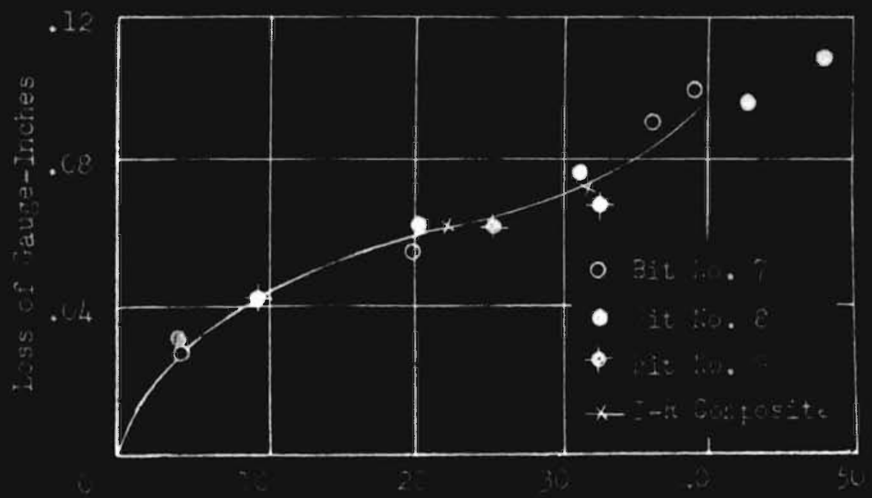
Using the costs cited on a previous page, the costs of the bits per inch of hole drilled yielded the following averages:

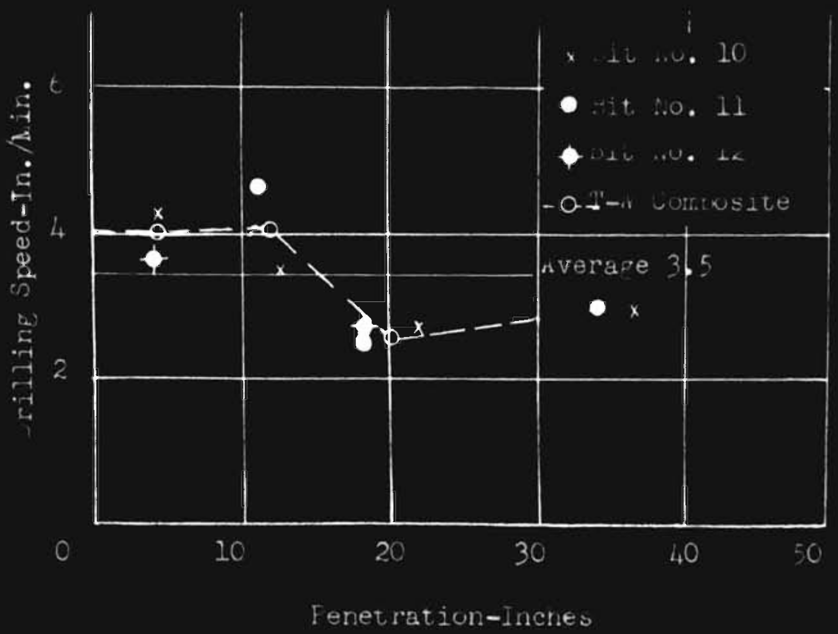
Type of Bit	Cost($/in.)
1½ inch Ingersoll-Rand	0.0113
1½ inch Joy Thro-Way	0.0075

The above figures show that the 1½ inch Joy Thro-Way bit costs 33.7 per cent less to use than the Ingersoll-Rand bit in pink granite.

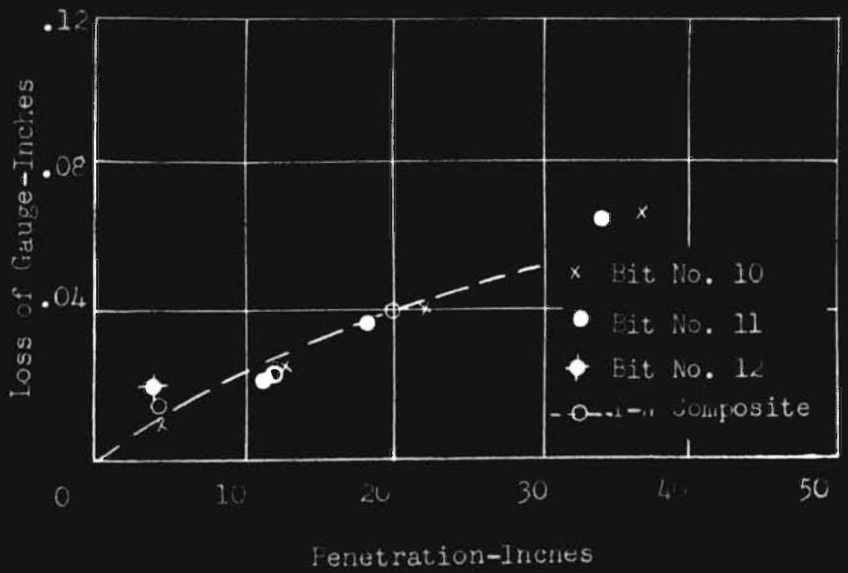


Graph A: Drilling Speed



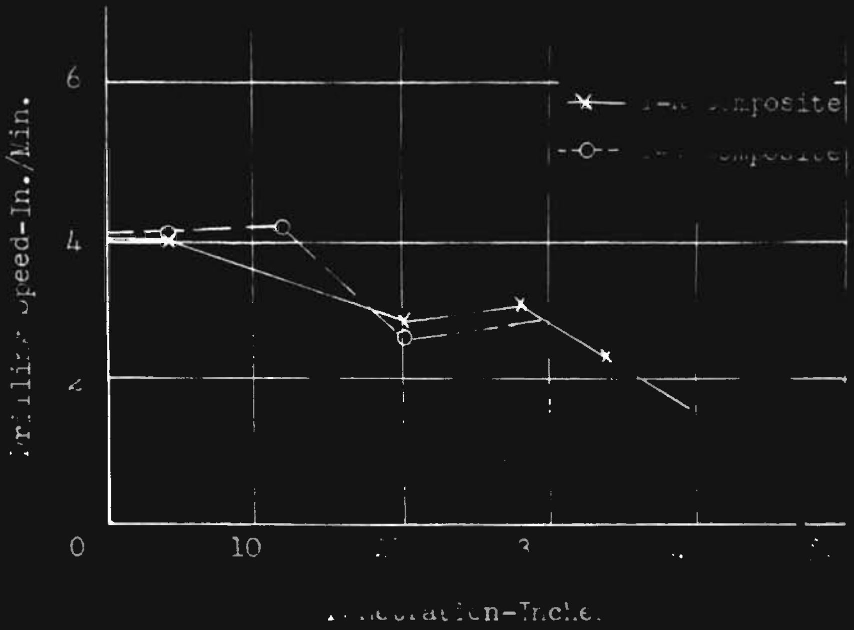


Graph C: Drilling Speed

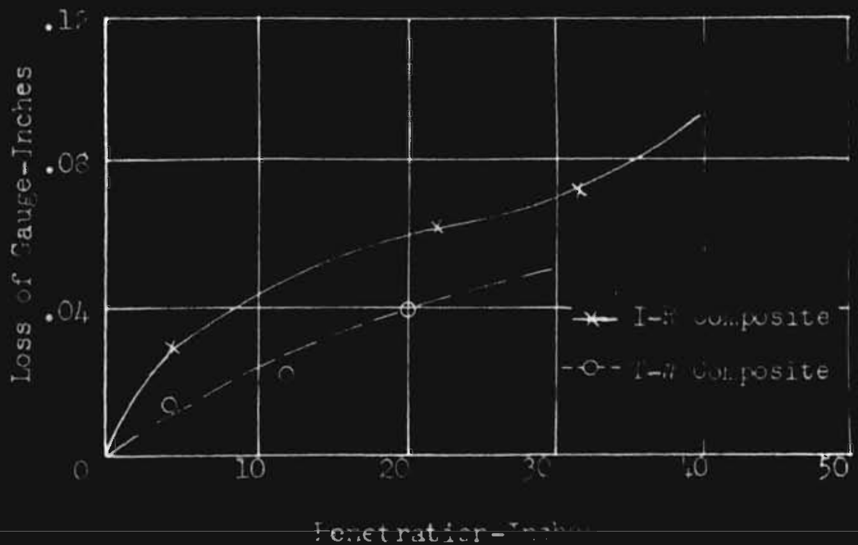


Graph D: Gauge Loss

Figure 9. Experiment No. 2

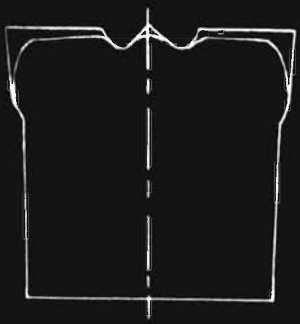


Graph E: Drilling Speed



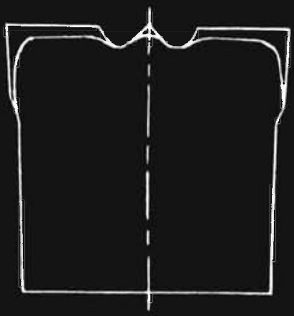
Graph F: Gauge Loss

Figure 10. Experiment No. 2



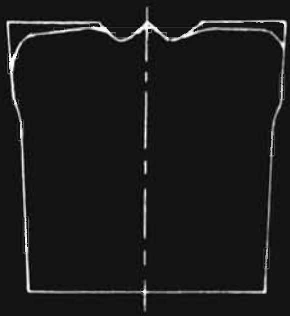
Bit No. 7

Profile Taken At:
0.00 Inches
38.62 Inches



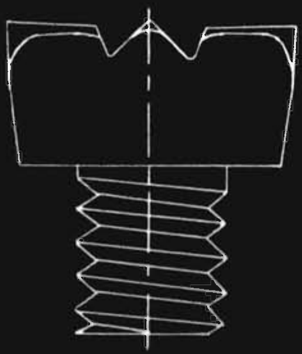
Bit No. 8

Profile Taken At:
0.00 Inches
48.12 Inches



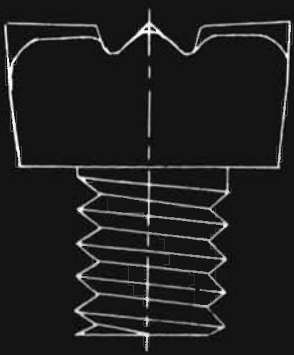
Bit No. 9

Profile Taken At:
0.00 Inches
32.50 Inches



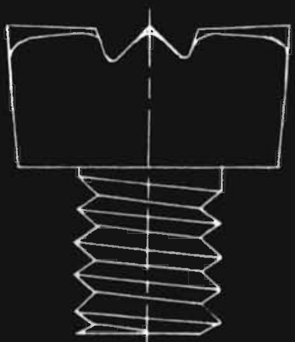
Bit No. 10

Profile Taken At:
0.00 Inches
36.75 Inches



Bit No. 11

Profile Taken At:
0.00 Inches
34.00 Inches



Bit No. 12

Profile Taken At:
0.00 Inches
3.62 Inches

Figure 11. Experiment No. 2

Greater care had to be used in drilling with the Thro-Way bit than with the Ingersoll-Rand bit. As the difference between the diameter of the upset end of the Joy drill steel (1.4 inches) and the Thro-Way bit (1.5 inches) became smaller, there was a tendency for the bit to bind and shear off in the hole.

EXPERIMENTS ON THE INITIAL DULLING OF THE DRILL BITS

The object of this series of experiments was to study the dulling rate of the bits during the initial minutes of drilling and to find when the greatest loss of gauge occurred.

Profiles of the wear of the corners of the bits may be seen in figures 13 and 15.

Experiment No. 3

The object of this experiment was to find when the greatest loss of gauge occurred and to study the initial loss of gauge in limestone.

The drilling was done in a side of a drift in the mine using a Cleveland HC10-1R drifter. The water pressure was 50 psi and the air pressure averaged 90 psi.

A record was made of the penetration time rather than of the penetration or distance drilled.

The following data were recorded:

1½ inch Ingersoll-Rand four-point bit

Bit No. 13

Advance sec.	Gauge in.	Gauge Loss in.	Total Gauge Loss in.
0	1.5205	0.0000	0.0000
5	1.5118	0.0087	0.0087
10	1.5108	0.0010	0.0097
20	1.5092	0.0016	0.0113
40	1.5080	0.0012	0.0125
60	1.5068	0.0012	0.0137
120	1.5060	0.0008	0.0145

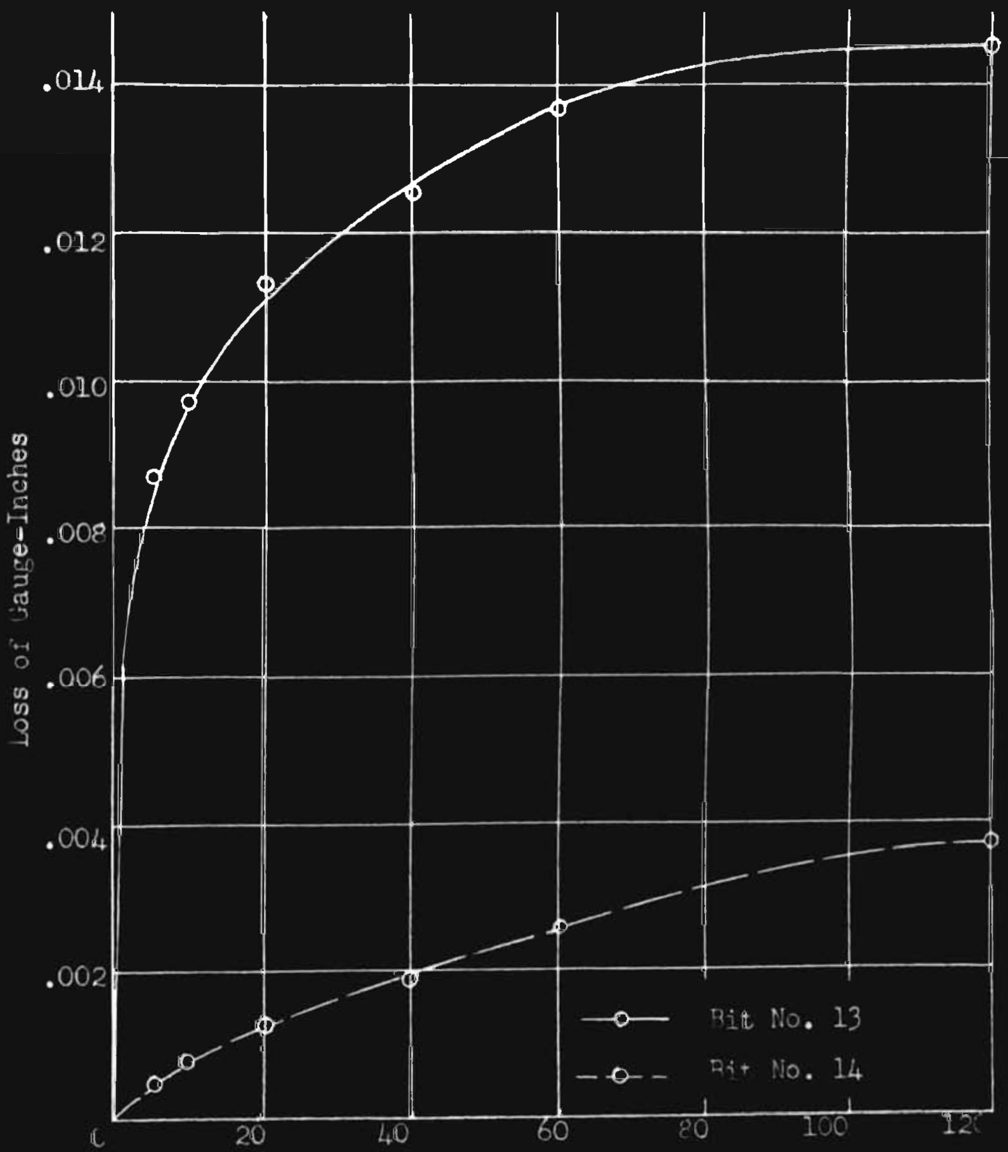
1½ inch Joy Thro-Way bit

Bit No. 14

0	1.5085	0.0000	0.0000
5	1.5080	0.0005	0.0005
10	1.5078	0.0003	0.0008
20	1.5075	0.0004	0.0012
40	1.5068	0.0007	0.0019
60	1.5058	0.0007	0.0026
120	1.5048	0.0011	0.0037

Comparison of the Performance of the Drill Bits

The recorded data amd figures 12 and 13 show that the greatest gauge loss of both the Ingersoll-Rand and the Thro-Way bit occurs in the first five seconds of drilling and that the gauge loss is much less in the Thro-Way bit than in the Ingersoll-Rand bit. Figure 13 shows that the Thro-Way bit has a much stronger wing corner than the Inger-soll Rand bit, a desirable feature in a rock drill bit.



Penetration Time-Seconds

Graph A: Rate of Dulling

Figure 12. Experiment No. 3

Profile 0 Sec. | Profile 5 Sec. | Profile 10 Sec. | Profile 20 Sec.

Profile 40 Sec. | Profile 60 Sec. | Profile 120 Sec.

Bit No. 13-Profile of Corner

Profile 0 Sec. | Profile 5 Sec. | Profile 10 Sec. | Profile 20 Sec.

Profile 40 Sec. | Profile 60 Sec. | Profile 120 Sec.

Bit No. 14.-Profile of Corner

Figure 13. Experiment No. 3

Experiment No. 4

The object of this experiment was to find where the greatest loss of gauge occurred and to study the initial drilling rate of the drill bits in pink granite.

This test was run in a granite block using a Cleveland H-10 sinker. The water pressure was 50 psi. and the air pressure averaged 100 psi.

The procedure of recording penetration time as was followed in Experiment No. 3 was used in this experiment.

The recorded data is shown below.

1½ inch Ingersoll-Rand four-point bit

Bit No. 15

Advance sec.	Gauge in.	Gauge Loss in.	Total Gauge Loss in.
0	1.5080	0.0000	0.0000
5	1.4900	0.0180	0.0180
10	1.4870	0.0030	0.0310
20	1.4820	0.0050	0.0260
40	1.4760	0.0060	0.0320
60	1.4730	0.0030	0.0350
120	1.4635	0.0095	0.0445

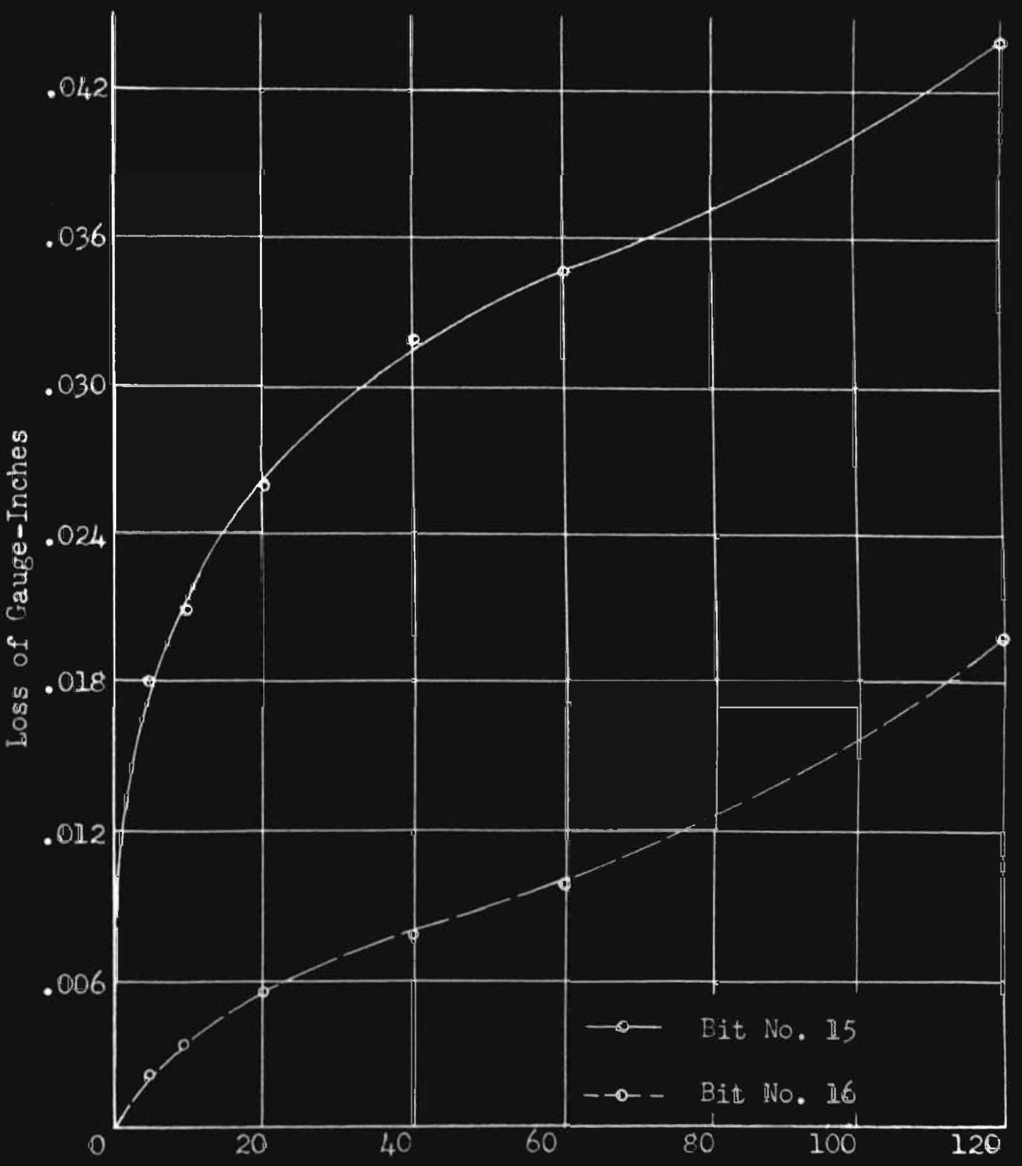
1½ inch Joy Thro-Way bit

Bit No. 16

0	1.5060	0.0000	0.0000
5	1.5038	0.0022	0.0022
10	1.5025	0.0013	0.0035
20	1.5005	0.0020	0.0055
40	1.4980	0.0025	0.0080
60	1.4960	0.0020	0.0100
120	1.4860	0.0100	0.0200

Comparison of the Performance of the Drill Bits

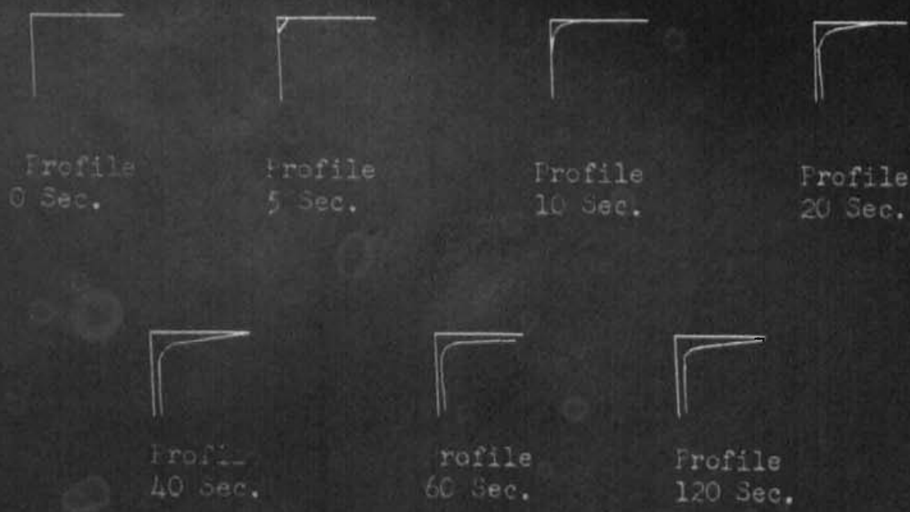
The same results were found in this experiment in granite as in the similar experiment in limestone. The recorded data and figures 14 and 15 show that the greatest loss of gauge of both drill bits occurred in the first five seconds of drilling. Figure 14 shows that the gauge loss of the Thro-Way bit was less in granite than was the gauge loss of the Ingersoll-Rand drill bit.



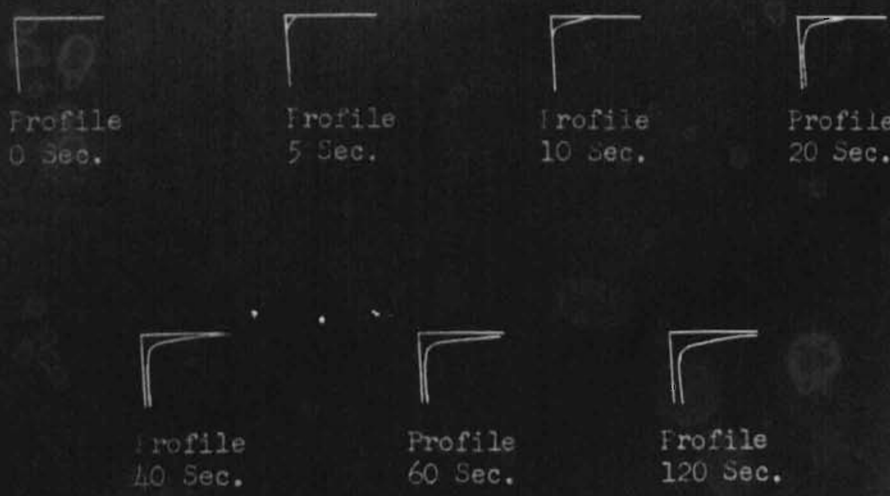
Penetration Time-Seconds

Graph A: Rate of Dulling

Figure 14. Experiment No. 4



Bit No. 15-Profile of Corner



Bit No. 16-Profile of Corner

Figure 15.-Experiment No. 4

CONCLUSIONS

The following conclusions are based on the limited tests made by the author. The results are necessarily dependent on the ability of the operator to maintain a desirable and uniform rate of drilling speed throughout the tests.

1. The drilling speed of the Joy Thro-Way bit is greater than the drilling speed of the Ingersoll-Rand plain four-point bit. The drilling speed was 29 per cent greater in dolomitic limestone and 11.3 per cent greater in pink granite.

2. The Joy Thro-Way bit has a longer life than has the Ingersoll-Rand plain four-point bit in dolomitic limestone but in pink granite the Ingersoll-Rand plain four-point bit has a longer life than the Joy Thro-Way bit, however, the cost per unit distance drilled is less when using the Thro-Way bit in both types of rock. The life of both types of bits could have been extended by resharpening.

3. The use of a profile-tracer gives a more adequate study of the wear of a bit than when using the loss of gauge as the only criterion of wear.

4. The loss of gauge of the Joy Thro-Way bit is less than that of the Ingersoll-Rand bit. This is true because the hardness of the cutting edges of the Thro-Way bit is greater than the hardness of the cutting edges of the Ingersoll-Rand bit.

5. The greatest loss of gauge in both the Ingersoll-Rand bit and the Thro-Way bit occurs in the first five seconds of drilling.

SUMMARY

Two types of experiments were performed in this comparative study of the Ingersoll-Rand plain four-point bit and the Joy Thro-Way bit.

The first type of experiment consisted of finding the efficiency, wear and life of the drill bits. The second type of experiment consisted of a study of the initial dulling rate of the drill bits. All of the factors except the type of drill bit used were kept constant in the experiments.

In the first type of experiment in limestone the Thro-Way bit was found to have a greater drilling speed, a smaller gauge loss and a greater life than the Ingersoll-Rand bit.

In the first type of experiment in granite, the Thro-Way bit was found to have a greater drilling speed and a smaller gauge loss than the Ingersoll-Rand bit. The Ingersoll-Rand bit had a longer life in granite, however, the cost per unit distance of the Thro-Way bit was less than that of the Ingersoll-Rand bit.

The second type of experiment showed that the Thro-Way bit had a smaller gauge loss than the Ingersoll-Rand bit, both in limestone and in the pink granite.

The greatest loss of gauge in both types of drill bits tested occurred in the first five seconds of drilling. This was found to be true in both the limestone and in the pink granite.

APPENDIX A

Hardness of the Drill Bits

A Rockwell Hardness Tester was used to determine the hardness of the drill bits used in these experiments.

The drill bits, selected at random from among those used in the experiment, were measured on scale B and on scale C.

The wings or cutting edges of the bits were ground until a flat was obtained and measured on scale C which utilizes a sphero-conical diamond as the penetrator with a load consisting of a 150 kilegram weight. The skirts of the bits were measured on scale B, which utilizes a one-sixteenth inch steel ball with a load consisting of a 100 kilogram weight.

The tests showed the following results:

1½ inch Ingersoll-Rand four-point bits

Wings of bit-Rockwell hardness scale C

1	2	3	4
62.0	62.5	59.0	61.0
64.0	63.0	62.0	61.5
64.0	58.0	62.5	61.5

Average hardness of the wings- 61.5 scale C

1½ inch Ingersoll-Rand four-point bits

Skirts of bits-Rockwell hardness scale B

1	2	3	4
64.0	69.0	59.0	57.5
91.0	85.5	93.0	81.0
63.0	75.0	77.5	62.0

Average hardness of the skirt-73 scale B

1½ inch Joy Thro-Way bits

Wings of bit-Rockwell hardness scale C

1	2	3	4
63.0	63.0	64.0	64.0
63.5	64.0	66.0	64.0
63.5	65.0	65.0	64.5

Average hardness of the wings-64 scale C

Skirts of bits-Rockwell hardness scale B

1	2	3	4
57.0	51.0	41.0	20.0
58.0	54.0	44.0	11.5
54.5	54.0	51.5	24.5

Average hardness of the skirt-43 scale B

BIBLIOGRAPHY

A. S. T. M. Standards Book 1939, Part II Non-metallic Materials, P. 383, 1939.

Birckhead, L. B., Recent Developments in the Drilling of Large Blast Holes, Pit & Quarry, Volume 38, No. 11, pp. 76-77, May, 1946.

Bloemsma, J. H., Ramsay, R. and Deane, O., Some Experiments with Tungsten Carbide Tipped Drill Steels, Journal of Chemical, Metallurgical and Mining Society of South Africa, pp. 243-283, January, 1947.

Eaton, Lucien, Refinements in Design of Rock-Drill Bits, Mining Technology, Volume 3, No. 5, T. P. 1095, September, 1939.

Hubbell, A. H., Mining Industry Watches Drilling Outcome, Engineering and Mining Journal, volume 150, No. 2, pp.96-105, February 1949.

Mosier, McHenry, Progress Report on Investigation of Detachable Rock Drill Bits, U. S. Bureau of Mines Information Circular No. 6877, February, 1936.

Noren, C. H., The Influence of Cartridge Diameter on the Effectiveness of Dynamite, Thesis, Missouri School of Mines and Metallurgy, Rolla, Missouri, January 1948.

Terrasson, Paul Louis P., A Comparative Study of Some Rock Drill Bits, Thesis, Missouri School of Mines and Metallurgy, Rolla, Missouri, May, 1948.

Waterland, T. M. and apRoberts, G. E., Some New Ideas in Rock Drill Bit Design, Transactions, C. I. M. M., Volume XLIX, pp. 123-129, 1946.

VITA

Charles Roger Knopp was born in Hannibal, Missouri on November 18, 1926.

He was educated in the Hannibal public schools, and after graduation from Hannibal High School in December 1943 entered Culver-Stockton College, Canton, Missouri to study pre-engineering. He interrupted this course of study to enlist in the U. S. Navy in October 1944, and following his discharge from this service in April 1946, attended the summer session at Culver-Stockton.

He transferred to the School of Mines and Metallurgy of the University of Missouri, Rolla, Missouri in September 1946 and received a degree in Mining Engineering in January 1949, after which he entered a program of graduate study at this school.