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Drill steel investigation

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DRILL STEEL INVESTIGATION

BY

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A

THESIS

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This thesis is supplementary to the one of like title by Joseph H. Rohloff.

These theses deal with different phases of the same problem. Mr. Rohloff's thesis deals with the heat-treating of drill steels, while this paper is confined to the forging and testing of the steels.

R.J. Stroup.

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OUTLINE OF PROPOSED DRILL STEEL

INVESTIGATION.

Pufpose of Investigation

To determine the best composition of a straight carbon drill steel for drilling in granite.

Method of Investigation

1. Obtain several brands of standard grade drill steel.
   Determine analysis and transformation points of each.

2. Determine that heat treatment which gives the best drilling qualities in granite.

3. Determine the micro-structure of such steel.

4. Obtain steel of a certain specified composition considered best for the conditions and compare the results on this steel with the results pb-tained on the market products.

5. Design of heating furnace for forging steels.

It will be observed from what follows that this outline was not rigidly adhered to. It may seem that the main issues have been evaded. In fact, the work seemed to boil down to two parts, namely, (1) heat treatment, and (2) shape of bits, without particular stress being put on the carbon content of the steels used. Many of the steels run were not a straight carbon steel at all, but were alloy steels.

Five different brands of steel were used in this work.

Steel No.	Size & shape.	Brand	% carbon content.
1	1"Hollow Hexagon	Red Star	0.875
2	1" " "	F.J.A.B.(Swedish)	.89
3	1" " "	Beaver	.87
4	7/8" " "	Ludnum (Vanadium alloy)	.80
5	1" " "	Chippewa	.65

Steels numbered 1-A, 1-B etc. are Red Star brand. No. 2-A, 2-B etc.are F.J.A.B. brand and so on.

The Forging Operation.

Realizing that proper heating and forging are essentials to subsequent hardening, it was decided to build an oil-fired furnace with pyrometer control and carefully time and record each step of the heating and forging operation.

A furnace of 10 steels capacity was designed, patterned somewhat after the one used at the Copper Queen mine. The distinguishing features, as shown in the drawing on page are (1), the location of the burner at the side of the furnace, (2) the small opening through which the gases coming into contact with the steel pass, thereby heating only about 1 1/2 inches of the bit end, and (3) a water coöling jacket which was supposed to keep the heat from being conducted back into the steel, that is, it would tend to cause a sharp break between the heated and unheated portions of the steel. However, partly through mechanical difficulties, this feature was discarded and sil-o-cel brick substituted.

Considerable experimenting was necessary. The furnace was built and re-built several times before its operation was satisfactory. A Denver Fire Clay Co.'s 2 1/2" gasoline burner using fuel under 40 to 60 lb. pressure was first tried. This was only fairly satisfactory, because it took 1 1/2 hours to get the furnace up to a temperature of 1800°F. However, the control was excellent once this temperature was attained.

A high pressure burner was then installed. Kerosene, flowing into the burner by gravity, was blown into the combustion chamber by air under 90 lb. pressure. A temperature of 1800° F was attained within 15 min. after lighting the burner, and the control was fairly satisfactory.

The pyrometer outfit was kept as simple as possible. A hole was drilled through the refractories in the furnace from the back, and at the same level as the steels, through which an Alumel-Chromel thermo-couple in a quartz tube was inserted, the points extending into one of the hollow steels. This steel was left in the furnace during the entire run. Leads from the couple extended to a milli-voltmeter and the readings converted to degrees by means of a chart. While not giving extreme accuracy due to cold end correction, distance couple is extended into the hole in the steel, and other variables, it was accurate enough for this work because the object of using a pyrometer at all was not to determine the exact temperatures at which the steel was forged, but to keep the forging temperature within certain limits of about 200 Fahrenheit degrees value.

These forging temperatures were set at 1600°F for a minimum and 1800°F as a maximum. The number of trips to the sharpener was no object. As a rule from 12 to 15 heats were made in forming a new bit, and from 6 to 8 heats in resharpening. This number of heats can, of course, be done only in experimental work. But one operation, such as punching the hole, dallying, swaging, or gauging was done at a time, taking on an average of 20 to 25 seconds each and then the steel was returned to the furnace. This practically assured temperatures within the given range. As the furnace was located close to the sharpener, there was probably but little less of heat in carrying steels to and from the sharpener, but no doubt the greatest lower of temperature was caused by the hot steels coming in contact with the cold dies and dallies.

The sharpener is an Leyner-Ingersoll machine, type 5A. The bits as forged on the 1" hollow hexagonal steel were of the regular cross type having a double taper of 5° and 14° and a cutting edge of 90°. The gauge on the starters or 30" length was 1 3/4" and on the seconds or 60" length 1 5/8". From the sharpener they were allowed to cool in air before being sent to the hardening furnace.

The most serious objection to the use of the oil forge and procedure as given above appears to be in the formation of excessive amounts of scale. The flame in the furnace is highly oxidizing and forms a scale over the bit which comes off in the sharpener. The continued reheating of course multiplies the trouble. This scale prevents forming bits with clean, clear cut edges and surfaces and detracts from the appearance.

THE DRILLING TESTS.

To determine the drilling qualities of the various brands of steels that have undergone various heat treatments is the final step. Without a complete record of the performance of each steel all the labor put into forming and treating each bit would mean but little.

For this work considerable equipment was brought into use. For the most part the actual drilling was done in large blocks of red granite from Southeast Missouri. These blocks were set on concrete piers about 18" high in order to facilitate drilling. This rock proved to be very hard and well adapted for this purpose. The hardness was apparently uniform except perhaps at jointing planes. The machine, an Ingersoll-Rand #248 Leyner Drill with anvil-block chuck was mounted on an arm and column which was jacked in against a frame of heavy timbers, so the column was about 30" from the face of the rock. The holes were pointed upward at an angle of about 10° and in most cases the "second" steel broke through or nearly through the rock. The rock was bedded in concrete and was held perfectly still at all times.

Air was furnished by a Sullivan Type W B-2 straight-line compressor of about 300 cu.ft. capacity. This machine, having no regulating or unloading devices, was allowed to run continuously and the excess air blow through a "pop-off". A small receiver of some 20 or 25 cu.ft. capacity was located near the drill to equalize the pressure. A pressure gauge was also located in the air line near the drill. Upon starting a run, the air in the line is slightly above the pressure for which the "pop off" is set. Soon after opening the throttle the air pressure drops until it no longer blows through the "pop off", but the compressor is on the line and there is considerable receiver capacity so the gauge shows that the pressure does not fall much below the "pop off" point. At any rate, what variation there was in pressure is a constant in all the runs and results are comparative. The pressure used was 90 lb. per sq. inch.

It was not deemed advisable to run the bits to destruction. In most cases two to six minutes, in one minute periods, was the length of the runs. Generally, in this time the drilling speed was so reduced as to render further drilling impractical. Before starting one of the steels to be tested, a shallow hole was drilled into the face of the block with a large gauge starter. Then the steel to be run was put in the machine and the throttle opened slowly until it has drilled about 1/2 inch. This was termed "warming up", and was to prevent throwing strains on the corners of the bit from irregularities in the rock when opening the throttle suddenly. Once the bit is "warmed up", it is ready to start the run. The throttle is opened suddenly and kept open one minute, timed by a watch. The depth of the hole is measured and the gauge of the bit taken both before and after the run. Results were tabulated and correlated with the heat treatments given.

In a few cases the steel became slightly bent for no other reason than the severe pounding of the machine on it. But little difficulty was experienced in keeping the steels and holes in alignment. Lubrication was made at regular intervals.

Among the sources of error may be mentioned the following:

1. Personal equation of the operator.
2. Depth of holes.
3. Amount of water fed through machine.
4. Sticking of drill due to lost gauge.
5. Slight variations in air pressure.
6. Difference in viscosity of lubricating oil due to changes in temperature.
7. Position of machine (mounted upright on arm or slung under).
8. Variations in hardness of rock.
9. Freezing of exhaust passage.
10. Lubrication.
11. Machine getting out of alignment.
12. Bent steels.
13. Presence of joint planes in rock.

As a side issue a set of four steels F.J.A.B. brand were made up for use at the Schools Experimental Mine. The lengths were 2,4,6 and 8 ft. with gauges of 1 7/8", 1 3/4", 1 5/8" and 1 1/2" respectively. They were of the regular cross-bit type and were hardened on the electric furnace. A 16 hole round was drilled with this one set of steels and their condition at the end of the round indicated that they were probably good for another round. Owing to the limited time available for drilling and blasting this round, no record was kept except of the 4 ft. and 6 ft. lengths. The four foot length drilled 31 ft. at an average speed of 20 inches per minute. The six foot length drilled 28 feet at an average of 21 inches per minute. Air pressure varied from 70 to 80 lb. Rock was a cherty dolomite. Results are tabulated on page 29.

BREAKAGE.

Not a single piece of steel was broken in making the tests. Several bits were broken but the steel proper in every case stood up to the work. That these steels did receive a very severe hammering, one as severe as mine steels are ordinarily called on for, is shown by the number of steels which were broken in similar tests on a lot run for the Minneapolis station of the Bureau of Mines. About 50 steels were run with a breakage of about 15 %. This does not include breakage of the bits. Many of these steels were 1 1/4 inch round. The Ingersoll-Rand Leyner is a powerful machine and strikes the steel about 1600 times per minute at 80 lbs. air pressure.

Some of the following may account for the non-breakage:

1. New steel was used entirely. Probably they were not run a sufficient number of times to develop the so-called "fatigue" or "crystalline structure" if such things exist.

2. The steels were not overheated, nor were they forged at too low a temperature.

3. The bit end was annealed before hardening.

4. Only the extreme end was hardened.

5. In drilling, it was seldom necessary to "hammer" the steel to keep it free to rotate.

6. The steels were not bent by forcing in a crooked hole, nor were they strained in trying to remove when stuck.

7. No trouble was experienced at the shank end. Being

collarless and lugless, there could be no defects through forging and it was only necessary to grind the end square and harden.

8. Bits were not run to destruction.

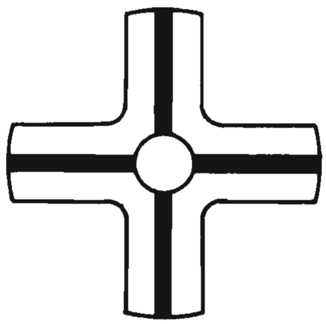
A slight chipping of the bit was not thought to be objectionable, in fact, those bits that did chip a little were the ones that drilled the best. In case one wing or even two opposite wings were broken, the drilling speed was not apparently affected but the loss in gauge was more rapid, the total distance drilled was less and it appeared as if the bit was more easily defected to one side, causing crooked holes.

SHAPE OF BITS.

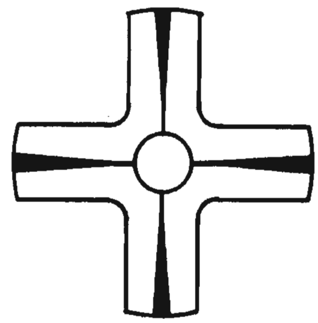
The bit selected for this work was the standard cross-bit with a double taper of 5° and 14° and a cutting edge of 90°. This is probably the most generally used as its advantages lie in its easy forging and splendid drilling properties.

Sonn, however, it was deemed advisable to experiment with other bits of slight variation in shape. Several cross-bits with single taper were run. The proved inferior to the double taper bits in speed and in total distance drilled. They lost gauge rapidly, but were capable of drilling without sticking after a greater reduction in gauge than was possible with the double taper. This is accounted for by a study of their shape. After the corners of a double taper bit became worn, the gauge was less at the cutting edge than just back of it and consequently the bit tended to stick, but with the single taper bit, there being no excess metal back of the cutting edge, the bit would continue to run with a larger reduction of gauge. But in nearly every case the double taper showed its superiority in speed, retaining gauge and total distance drilled.

In order to see if the drilling qualities of the regular cross bit could not be improved, several flat-bits were made. Regular cross-bits were taken and the cutting edge filed straight across until about 3/32 inch wide. This same idea was applied to low centered bits, but of course in this case the cutting edge tapered from about 1/8 inch at the point of the bit to knife edge toward the center as shown in the sketch.



Regular Cross-bit Flattened



Low Center Cross-bit Flattened

It was found that these bits did hold their gauge a little better, the cutting edge did not wear so rapidly, and the speed was practically the same as compared with the regular cross-bit. This might be accounted for by the following: In the hardening process, the extreme point of the bit was made the hardest and as the cutting edge wore away, a softer material was brought into use. In the regular bit the cutting edge was worn to practically the width of the edge filed on the cross-bits after three of four inches of drilling, and presented a much softer metal to the rock than the flat-bit. In any method of hardening other than the one used, this effect would probably not be so apparent.

A few regular low-centered bits having a cutting edge of 110° instead of the usual 90° were run. These bits were physically weaker than the regular type due to their design, but some excellent speeds and some good total distances were made by them. The points of the wings were liable to become broken especially in starting. This bit is probably better than the regular cross-bit, in that it is not so apt to be deflected and cause crooked holes, but because of the limited extent of the tests nothing definite could be proven along this line.

The gauge lost after the first run of about 24 inches averaged 3/64 inch. 1/8 inch change in gauge was used but this probably could have been reduced to 1/16 inch.

The next run consisted of four Hawksworth detachable bits of the cross-bit type, 1 7/8" gauge and a piece of 1 1/4" lugged steel with the end forged and machined so these bits were held in place by a dovetail. The anvil block chuck was replaced by the regular chuck, and this change probably had some effect and should be considered in comparing speeds. One of these bits drilled a little more than 5 feet at an average speed of 8 3/4 inches per minute, but the dovetail was broken as the bit was being hammered to detach same after the run. The others drilled only a short distance before breaking. These bits were made of an alloy steel but were no better so far as hardness is concerned than the straight carbon steels, and it was thought that the shape of the bit was inferior to the regular double-taper cross-bit. Therebeing apparently no way to sharpen or repair these bits, no further work was done on them.

Four McClelland bits on 1 inch hollow hexagonal steel were obtained. These bits are of the regular cross-bit type but have a hole about 7/8 inches in diameter which leaves only a ring or shell about 3/8 inch thick to do the cutting. One of the noticeable features in drilling these bits were the coarse cuttings.

See data sheets for performance of these bits on page 27.

In order to get a better comparison between the regular cross-bit and the McClelland, a regular cross-bit No.K with small hole and with a gauge the same as the McClelland was made and hardened by heating in a salt bath and quenching in water. These were run under exactly the same conditions with results as shown on page 31. It will be noted that for the first minute run, the regular bit drilled 17.25 against 14.5 inches for the McClelland, but the total distance drilled was 66.75 inches against 85.5 inches for the McClelland. However, at the end of 66.75 inches the average speed of the regular was 14 inches per minute against the 18.5 for the McClelland. After the run, the bits were tested for hardness on the Brinell machine and each showed a hardness of about 650, but two opposite wings of the regular bit were considerably softer than the others which probably accounts for this bit not drilling as far as the McClelland.

From the extent of these experiments, it is difficult to arrive at any conclusions regarding the effect of the size of hole at the bit end. Various size holes were tried from about 1/4 inch to the extreme 7/8 inch found in the McClelland bit. However, a few facts are observable:-

1. The cuttings from the large hole bits are coarser due to the breaking up of the central core rather than cutting

it up. This may mean a saving in energy.

2. It may be that a large hole bit is not deflected from a straight line as easily as a regular bit, due to the core extending back into the hole and tending to keep the bit in position.

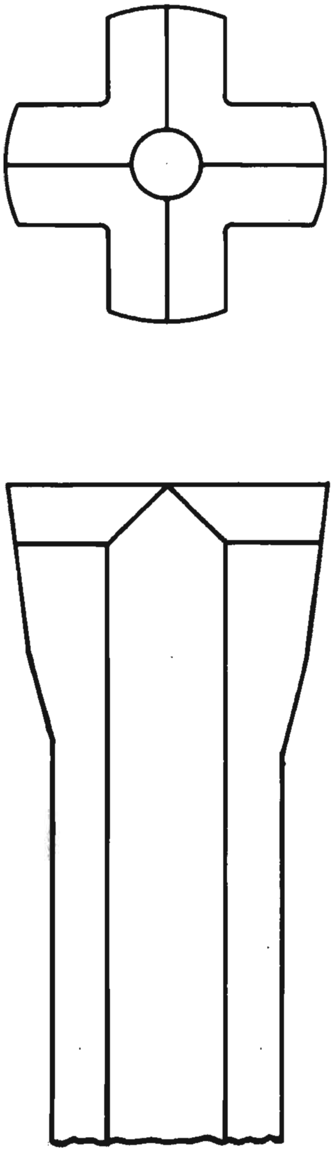
3. The extreme large hole bits look weak, and it is thought that only the very best heat treatment enables them to be used at all.

4. The large hole bits are more difficult to make. In most cases it would probably be necessary to drill out the hole.

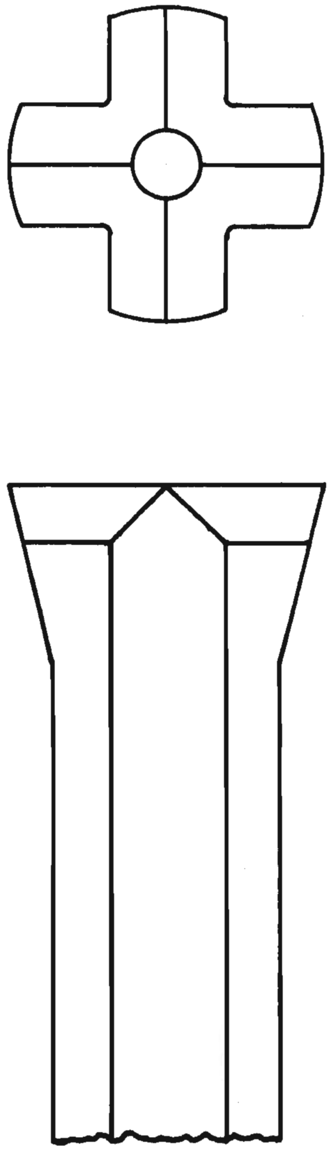
Three pieces of 1" hollow hexagonal steel were sent to a mine blacksmith in California, who is reputed to be very good at his work. Evidently he took much care in forming and hardening these steels. They had a double taper with much metal back of the cutting edge, and the wings were thick, being swaged on wide blocks and leaving only a small clearance space for cuttings. A sketch of these bits and of the regular cross-bits as made for this experimental work are on the following sheet. The results of drilling these steels are shown on page 17.

In almost every case the double taper has shown its superiority; the thick heavy wings have almost invariably drilled faster and further than the light-winged single taper bits.

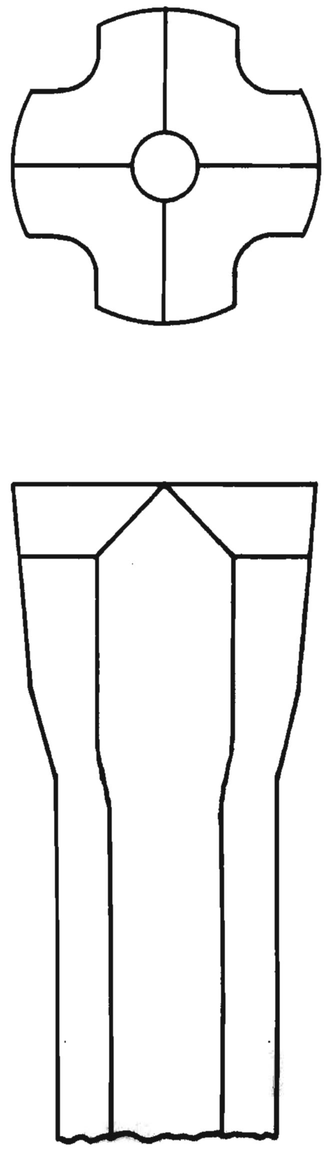
CROSS - BITS



Double Taper



Single Taper



Heavy Wing Bit Made By Mine Blacksmith in California.

1st Run #1

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Red Star Brand Steel with No. 248 Leyner. — 1" Hollow Hexagon — Rock S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Gauge Lost	Remarks
1-A	1"	10.25"	9.25"	1'	1-45/64	1-44/64	1/64	
1-A	10.25	20	9.75	1'	1-44/64	1-44/64	None	
1-A	20	26	6	40"	1-44/64	1-44/64	2/64	
Totals			25"	2' 40"			3/64	
1-B	1.5	10.5	9	1'	1-47/64	1-46/64	1/64	
1-B	9	19.5	9	1'	1-46/64	1-46/64	None	One wing chipped slightly
1-B	19.5	26.25	6.75	45"	1-46/64	1-44/64	2/64	
Totals			24.75	2' 45"			3/64	
1-D	26.25	36.25	10	1'	1-40/64	1-39/64	1/64	Bit chipped slightly
1-D	36.25	45.5	9	1'	1-39/64	1-38/64	1/64	
1-D	45.5	48.25	2.75	15"	1-38/64	1-38/64	None	
Totals			21.75	2' 15"			2/64	
1-E	23	32.5	8.5	1'	1-40/64	1-39/64	1/64	One wing chipped slightly
1-E	32.5	40.75	8.25	1'	1-39/64	1-38/64	1/64	
1-E	40.75	46.75	6	35"	1-38/64	1-38/64	None	
Totals			22.75	2' 35"			2/64	
1-F	26	36.5	10.5	1'	1-37/64	1-35/64	2/64	
1-F	36.5	43.5	7	1'	1-35/64	1-35/64	None	
1-F	43.5	39.75	6.25	40"	1-35/64	1-35/64	None	
Totals			23.75	2' 40"			2/64	

2nd Run #1

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Red Star Brand Steel with No. 248 Leyner. 1" Hollow Hexagon Rock: S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Gauge Lost	Remarks
1-B	0.25"	8.75"	8.5"	1'	1-47/64	1-46/64	1/64	
1-B	8.75	17.75	9.0	1'	1-46/64	1-45/64	1/64	Bit chipped slightly.
1-B	17.75	27.75	10.0	1'	1-45/64	1-44/64	1/64	
Totals			27.5"	3'			3/64	
1-C	0.5	9.5	9.0	1'	1-47/64	1-45/64	2/64	2 wings chipped badly.
1-C	9.5	18.25	8.75	1'	1-45/64	1-44/64	1/64	All " " "
1-C	18.75	24.75	6.0	50"	1-44/64	1-44/64	No.	
Totals			23.75	2' 50"			3/64	
1-D	27.75	39.25	11.5	1'	1-40/64	1-38/64	2/64	One wing chipped badly.
1-D	39.25	48.75	9.5	50"	1-38/64	1-37/64	1/64	
Totals			21	1' 50"			3/64	
1-E	22.5	35.0	12.5	1'	1-40/64	1-38/64	2/64	
1-E	35.0	43.0	8.0	1'	1-38/64	1-37/64	1/64	
Totals			20.5	2'			3/64	
1-F	24.75	34.75	10.0	1'	1-40/64	1-38/64	2/64	
1-F	34.75	45.00	10.25	1'	1-38/64	1-37/64	1/64	
Totals			20.25	2'			3/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Third Run Steel No. 1 — 1" Hexagon — S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
				FLATTENED CUTTING EDGE				
1-B	.5"	10.0"	9.5"	1'	1-47/64	1-47/64	None	One wing chipped slightly.
1-B	10.0	19.0	9.0	1'	1-47/64	1-46/64	1/64	
1-B	19.0	23.75	4.75	30"	1-46/64	1-46/64	None	
1-B	.75	8.75	8.0	1'	1-46/64	1-45/64	1/64	Steel bent.
1-B	8.75	16.50	7.75	1'	1-45/64	1-45/64	None	
1-B	16.5	24.5	8.0	1'	1-45/64	1-44/64	1/64	
Totals			47.00	5' 30"			3/64	
1-D	23.75	34.75	11.0	1'	1-38/64	1-37/64	1/64	One wing chipped slightly.
1-D	34.75	45.25	10.5	1'	1-37/64	1-36/64	1/64	
1-D	24.5	33.	8.5	1'	1-36/64	1-35/64	1/64	
1-D	33.0	43.25	10.25	1'	1-35/64	1-35/64	None	
Totals			40.25	4'			4/64	
			Regular Bit -	TEMPERED AFTER HARDENING				
1-A	.5	8.0	7.5	1'	1-46/64	1-45/64	1/64	One wing chipped.
1-A	8.0	13.25	5.25	1'	1-45/64	1-45/64	None	
1-A	13.25	17.00	3.75	1'	1-45/64	1-45/64	None	
1-A	17.0	19.5	2.5	1'	1-45/64	1-45/64	None	
1-E	25.75	35.75	10.	1'	1-40/64	1-39/64	1/64	One wing chipped. Others battered.
1-E	35.75	43.75	8.	1'	1-39/64	1-38/64	1/64	
Totals			18	2'			2/64	
1-F	21.5	33.25	11.75	1'	1-38/64	1-35/64	3/64	
1-F	33.25	41.0	7.75	1'	1-35/64	1-34/64	1/64	
Totals			19.50	2'			4/64	
Additional Runs on No. 1-D								
1-D	28.0	36.0	8	1'	1-35/64	1-34/64	1/64	
1-D	36.0	45.25	9.25	1'	1-34/64	1-35/64	None	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

First Run on Steel No. 2 | 1" Hexagon | S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
2-A	1.5"	9.5"	8"	1'	1-48/64	1-47/64	1/64	
2-A	9.5	19.5	10	1'	1-47/64	1-46/64	1/64	
2-A	19.5	22.75	3.25	30"	1-46/64	1-46/64	None	
	Total - - - - - - -		21.25	1' 30"			2/64	
2-B	.75	9.25	8.5	1'	1-48/64	1-47/64	1/64	
2-B	9.25	18.5	9.25	1'	1-47/64	1-46/64	1/64	
2-B	18.5	27.0	8.5	1'	1-46/64	1-45/64	1/64	
2-B	.5	8.0	7.5	1'	1-45/64	1-45/64	None	
2-B	8.0	15.5	7.5	45"	1-45/64	1-44/64	1/64	
	Total - - - - - - -		41.25	4' 45"			4/64	
2-C	.5	9.25	8.85	1'	1-47/64	1-46/64	1/64	
2-C	9.25	19.25	10.	1'	1-46/64	1-46/64	None	
2-C	19.25	27.5	7.75	1'	1-46/64	1-45/64	1/64	
2-C	1.	10.5	9.5	1'	1-45/64	1-44/64	1/64	
2-C	10.5	13.25	2.75	20"	1-44/64	1-44/64	None	
	Total - - - - - - -		38.75	4' 20"			3/64	
2-D	28.5	40.25	11.75	1'	1-38/64	1-36/64	2/64	
2-D	40.25	48.75	8.5	1'	1-36/64	1-35/64	1/64	
	Total - - - - - - -		20.25	2'			3/64	
2-E	26.5			25"	1-37/64			Battered badly.

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

First Run on Steel No. 3. 1" Hexagon S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
3-A	0	9.75"	9.75"	1'	1-47/64	1-45/64	2/64	Did not chip.
3-A	9.75	20.5	10.75	1'	1-45/64	1-44/64	1/64	
3-A	20.5	25/75	5.25	30"	1-44/64	1-44/64	None	
	Total	- - - -	25.5	2' 30"			3/64	
3-B	1.0	11.5	10.5	1'	1-46/64	1-45/64	1/64	
3-B	11.5	22.25	10.75	1'	1-45/64	1-44/64	1/64	
3-B	22.25	27.0	4.75	30"	1-44/64	1-44/64	None	
	Total	- - - -	26.0	2' 30"			2/64	
3-C	.75		.5		1-46/64			Battered badly.
3-D	26.5	37.5	11.	1'	1-38/64	1-37/64	1/64	
3-D	37.5	48.	10.5	1'	1-37/64	1-36/64	1/64	
	Total	- - - - -	21.5	2'			2/64	
3-E	27.5	36.25	8.75	1'	1-38/64	1-37/64	1/64	
3-E	36.25	46.75	10.5	1'	1-36/64	1-36/64	1/64	
	Total	- - - -	19.25	2'			2/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Vanadium Steel — 7/8" Hexagon — Rock: S-E Mo. Granite.

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Gauge Lost	Remarks
4-A	4.0"	12.5"	8.5"	1'	1-45/64	1- /64		One wing broke off at end of first minute run.
4-B	1.25	9.25	8.0	1'	1-48/64	1-46/64	2/64	2 wings chipped slightly
4-B	9.25	17.5	8.25	1'	1-46/64	1-45/64	1/64	
4-B	17.5	27.0	9.5	1'	1-45/64	1-44/64	1/64	
Totals			25.75	3'			4/64	
4-C	1.25	12.5	11.25	1'	1-47/64	1-45/64	2/64	
4-C	12.5	24.5	12	1'	1-45/64	1-44/64	1/64	Chipped slightly.
Totals			23.25	2'			3/64	
4-D	27.0	38.5	11.5	1'	1-38/64	1-36/64	2/64	
4-D	38.5	47.75	9.25	1'	1-36/64	1-35/64	1/64	
Totals			20.75	2'			3/64	
4-E	24.5	----	0	-	1-38/64	-------	----	Bit for 1-1/2" broke into small pieces.

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Second Run, Steel No. 4. 7/8" Hexagon S-E Mo. Granite

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
4-B	5.75	16.25	10.5	1'	1-47/64	1-45/64	2/64	One wing chipped slightly.
4-B	16.25	26.25	10.0	1'	1-45/64	1-44/64	1/64	
Totals			20.5"	2'			3/64	
4-C	.5	12.0	11.5	1'	1-46/64	1-45/64	1/64	
4-C	12.0	22.5	10.5	1'	1-45/64	1-44/64	1/64	Soft in center.
4-C	22.5	27.5	5.0	30"	1-44/64	1-43/64	1/64	
Totals			27.0	2' 30"			3/64	
4-D	26.25	38.25	12.0	1'	1-40/64	1-37/64	3/64	
4-D	38.25	44.00	5.75	30"	1-37/64	1-37/64	None	
Totals			17.75	1' 30"			3/64	
4-E	27.5	39.0	11.5	1'	1-37/64	1-35/64	2/64	
4-E	39.0	43.75	4.75	30"	1-35/64	1-34/64	1/64	
Totals			16.25	1' 30"			3/64	
Additional Runs on Steels Nos. 4-B and 4-D								
4-B	.75	9.75	9.0	1'	1-44/64	1-44/64	None	
4-B	9.75	17.75	8.75	1'	1-44/64	1-43/64	1/64	
4-B	17.75	26.5	8.75	1'	1-43/64	1-42/64	1/64	
4-D	27.0	34.25	7.25	1'	1-37/64	1-36/64	1/64	
4-D	34.25	43.0	8.75	1'	1-36/64	1-35/64	1/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

First Run, Steel No. 5. 1" Hexagon S-E Mo. Granite.

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
5-A	0.5"	11.0"	10.5"	1'	1-46/64	1-45/64	1/64	Bit did not chip.
5-A	11.0	22.1	11.1	1'	1-45/64	1-44/64	1/64	
5-A	22.1	27.1	5.0	30"	1-44/64	1-43/64	1/64	Shank soft.
Totals			26.6	2' 30"			3/64	
5-E	28.25	41.25	13.5	1'	1-38/64	1-37/64	1/64	1 wing chipped slightly.
5-E	41.25	49.25	8.0	35"	1-37/64	1-36/64	1/64	
5-E	27.0	38.0	11.0	1'	1-36/64	1/35/64	1/64	
5-E	38.0	42.75	4.75	30"	1-35/64	1-35/64	None	
Totals			37.25	3' 5"			3/64	
5-C	.5	----	----	5"	1-46/64	----	----	Battered badly.
5-D	27.15	28.25	1.1	30"	1-39/64			Battered badly.
5-B	5.	15.5	10.5	1'	1-47/64	1-46/64	1/64	
5-B	15.5	25.75	10.25	1'	1-46/64	1-45/64	1/64	
5-B	25.75	28.5	2.75	15"	1-45/64	1-45/64	None	
5-B	6.25	15.0	8.75		1-45/64	1-44/64	1/64	
Totals			32.25	2' 15"			3/64	

Hawksworth Bit.

1-1/4" Round Steel with Detachable Bit. No. 1.

Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time	Gauge Start	Gauge Finish	Lost	Remarks
.25"	7.25"	7"	1'	1-56/64	1-55/64	1/64	Battereed slightly on points.
7.25	14.5	7.25	45"	1-55/64	1-53/64	2/64	
.25	10	9.75	1'	1-53/64	1-53/64	None	
10.	15.5	5.5	30"	1-53/64	1-52/64	1/64	
.5	9.	8.5	1'	1-52/64	1-52/64	None	
9.	18.	9.	1'	1-52/64	1-51/64	1/64	
.75	8.75	8.	1'	1-51/64	1-50/64	1/64	
8.75	16.	7.25	1'	1-50/64	1-50/64	None	
		62.25	7' 15"			6/64	

1-1/4" Round Steel with Detachable Bit. No. 2

Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time	Gauge Start	Gauge Finish	Lost	Remarks
.5"	10.75"	10.25"	1'	1-55/64	1-52/64	3/64	
.5	7.75	7.25	45"	1-52/64	1-51/64	1/64	
1.0	9.75	8.75	1'	1-51/64	1-50/64	1/64	
9.75	15.25	5.5	45"	1-50/64	1-50/64	None	
		31.75	3' 30"			5/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

McClelland Bit. 7/8" Hole
Ingersoll No. 248 Leyner.

1" Hollow Hexagon Steel.

Length 36" and 60"
90 Lbs. Air Pressure

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Lost	Remarks
DRD-1	6.0"	19.5"	13.5"	1'	1-44/64	1-41/64	3/64	Length 36"
DRD-1	19.5	33.0	13.5	1'	1-41/64	1-40/64	1/64	
DRD-1	----	-----	----		1-40/64	1-39/64	1/64	No Measurement.
	Total		27.0	2'			5/64	
DRD-2	5.5	19.0	13.5	1'	1-44/64	1-41/64	3/64	Length 36"
DRD-2	19.0	31.5	12.5	1'	1-41/64	1-40/64	1/64	
DRD-2	5.5	17.5	12.0	1'	1-40/64	1-39/64	1/64	
	Total		38.0	3'			5/64	
DRD-3	4.0	19.5	15.5	1'	1-38/64	1-35/64	3/64	Length 60"
DRD-3	19.5	29.5	10.0	45"	1-35/64	1-34/64	1/64	
DRD-3	8.5	23.0	14.5	1'				
DRD-3	23.0	32.5	9.5	40"		1-33/64	1/64	
	Total		49.5	3' 25"			5/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

M.S.M. Mine
February 21, 1922.

Air pressure 70 - 80 Lbs.
16 Hole Round.

Rock - Cherty Dolomite.
Ingersoll-Rand Leyner Drill No. 248

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Gauge Lost	Remarks
			29.5	1.05				
			24.0	1.05				
			23.0	45"				
			23.0	40"				
			23.5	45"				
			23.5	50"				
			23.5	1' 20"				
			24.	1' 30"				
			23.	1' 20"				
			23.	1' 30"				
			23.	1' 45"				
			22.5	45"				
			21.5	50"				
			20.5	1' 25"				
			23.5	1' 35"				
			374"	18' 30"				
			18.	40"				
			19.5	45				
			20.	40				
			20.	45				
			20.	40				
			19.5	40				
			18.5	40				
			21.5	50				
			21.	1' 25"				
			19. 5	1' 20"				
			22.5	1' 20"				
			21.5	1' 35"				
			22.5	35"				
			20.	55				
			23.5	1' 15"				
			19.5	1' 35"				
			325"	15' 20"				

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

Regular Cross Bit | 1" Hollow Hexagon Steel | Length 60"

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time	Gauge Start	Gauge Finish	Gauge Lost	Remarks
K	6.5	23.75	17.25	1'	1-39/64	1-39/64	None	
K	23.75	28.5	4.75	15"	1-39/64	1-36/64	3/64	Good Condition.
K	7.	20.	13.	1'	1-36/64	1-36/64	None	
K	20.	26.75	6.75	30"	1-36/64	1-35/64	1/64	
K	6.5	19.25	12.75	1'	1-35/64	1-35/64	None	
K	19.25	26.	6.75	30"	1-35/64	1-33/64	2/64	
K	7.5	13.	5.5	30"	1-33/64	1-32/64	1/64	Stuck - gauge gone.
			66.75	4' 45"			7/64	

McClellan Bit - 7/8" Hole | 1" Hollow Hexagon Steel | Length 60"

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time	Gauge Start	Gauge Finish	Gauge Lost	Remarks
DRD-4	9.0	23.5	14.5	1'	1-38/64	1-38/64	None	
DRD-4	23.5	28.5	5.	25"	1-38/64	1-34/64	4/64	Good Condition.
DRD-4	6.5	19.5	13.	1'	1-34/64	1-34/64	None	
DRD-4	19.5	26.	6.5	30"	1-34/64	1-33/64	1/64	
DRD-4	6.75	20.	13.25	1'	1-33/64	1-33/64	None	
DRD-4	20.	27.	7.0	30"	1-33/64	1-32/64	1/64	
DRD-4	6.75	19.	12.25	1'	1-32/64	1-32/64	None	
DRD-4	19.	25.5	6.5	30"	1-32/64	1-31/64	1/64	
DRD-4	13.	20.5	7.5	40"	1-31/64	1-31/64	None	Sticking. Gauge gone.
			85.5	7' 15"			7/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION

DRILL STEEL INVESTIGATION.

Cross-bit. 1" Hollow Hexagon Steel. Red Star brand

Forged and hardenad by California Mine Blacksmith.

Steel No.	Depth of hole Start	Finish	Distance drilled	Time	Gauge Start	Finish	Lost
1-X	12.0	24.25	12.25	1'	1 46/64	1 44/64	2/64
	24.25	33.5	9.25	41"	1 44/64	1 44/64	0.
			22.5	1-41			2/64
1-Y	14.0	25.0	11.0	1'	1 44/64	1 45/64	1/64
	25.0	33.5	8.5	50"	1 45/64	1 44/64	1/64
			19.5	1'50"			2/64
1-Z	9.5	23.25	13.75	1'	1 45/64	1 43/64	2/64
	23.25	33.5	10.25	55"	1 43/64		0
			24	1'55"			2/64

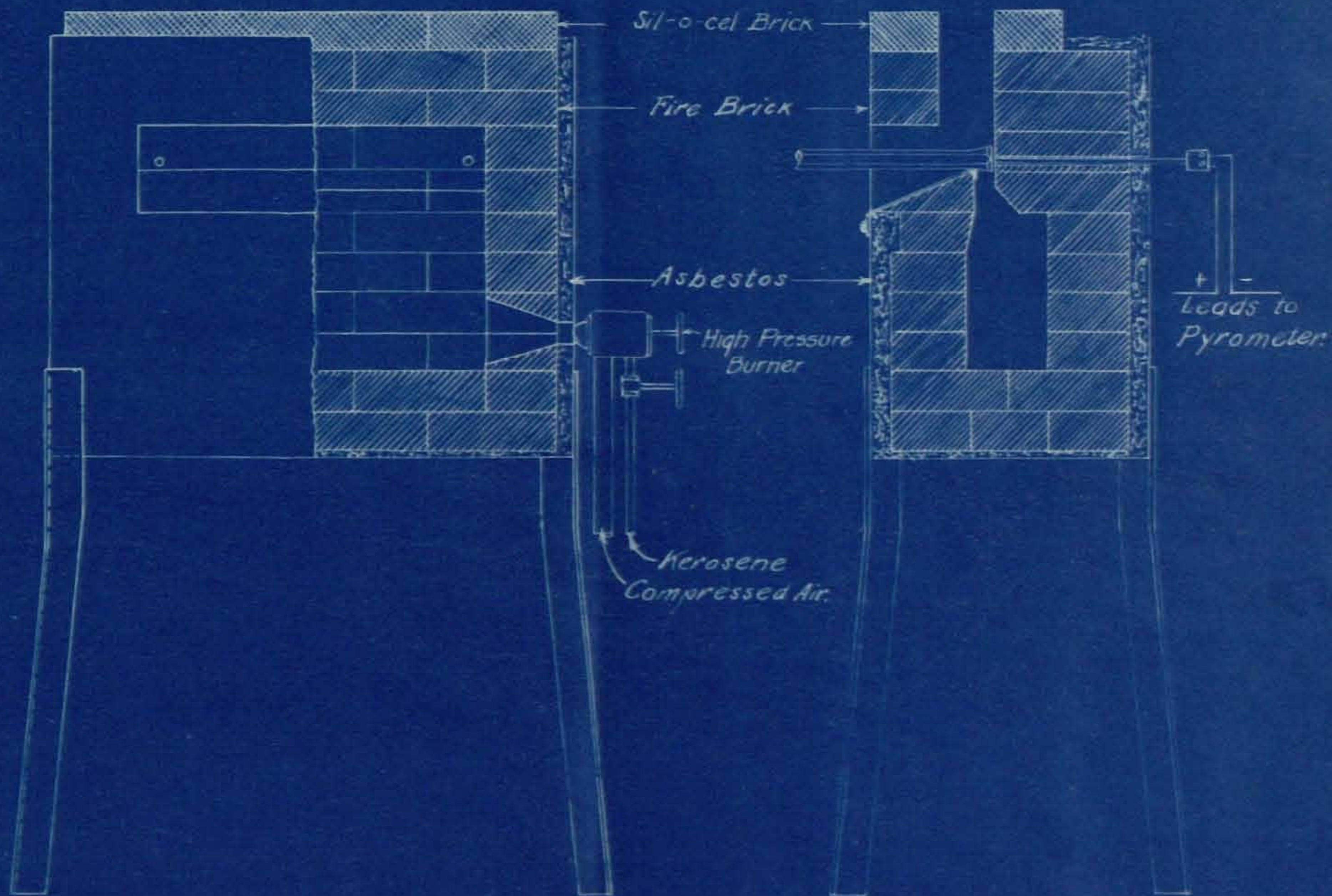
1" Hollow Hexagon Steel. Red Star

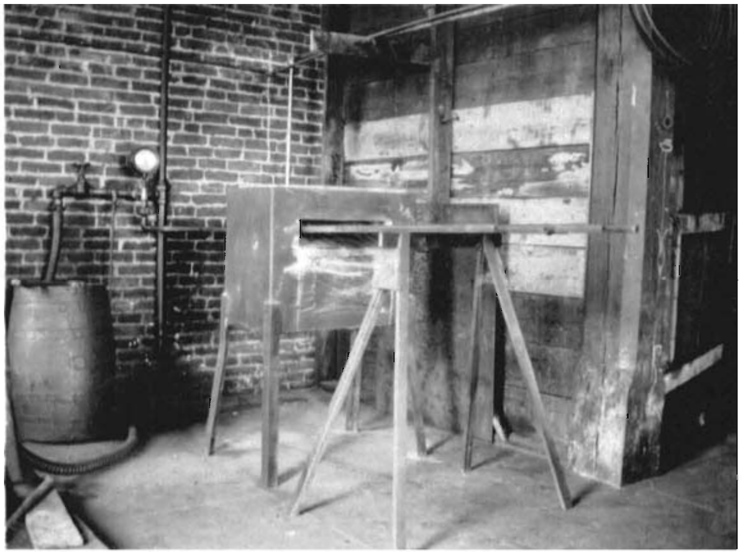
Mar.15,1922.

Resharpened and hardened in salt bath.

Steel No.	Depth of hole Start	Finish	Distance drilled.	Time	Gauge Start	Finish	Lost
1-Z	9.5	23.5	14.0	1'	1 46/64	1 45/64	1/64
	23.5	33.5	10.0	45"	1 45/64	1 45/64	No.
			24	1'45"			1/64
3-E	4.0	26.0	22.0	1'35"	1 41/64	1 38/64	3/64
1-X	9.0	26.0	17.0	1'	1 47/64	1 46/64	1/64
	26.0	33.5	7.5	30"	1 46/64	1 45/64	1/64
			24.5	1'30"			2/64

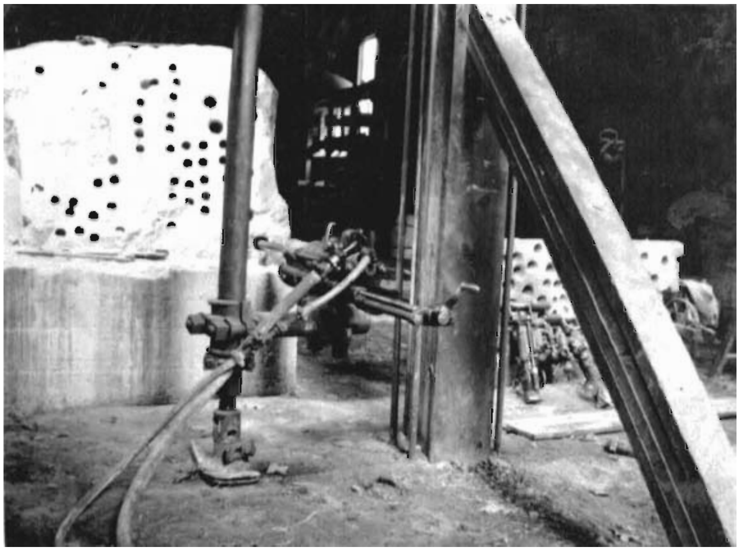
DRILL-STEEL FURNACE





Forge for drill-steels.

Sharpener



IR #248 Drill in position.

General view of sharpening shop.

SUMMARY AND CONCLUSIONS.

From the limited extent of these tests nothing definite as to which brandof steel or what carbon content is best can be determined. This is something that can be decided only after long periods of use in actual mine work. However, an examination of the drilling data shows that the steel having the lowest carbon content (.65) stood up a little better than the others, but as said above, these tests were not exhaustive enough for the results to be accepted as conclusive.

It was found that forging at the proper temperature, annealing before hardening, hardening only the extreme cutting portion of the bit and using a reasonable amount of care in drilling, practically eliminated breakage.

In regard to the shape of bit the double taper cross-bit repeatedly demonstrated its superiority over the single taper cross-bit.Those bits with a double taper, thick heavy wings with much metal back of the cutting edge and with a small clearance space for cuttings showed the best drilling speed, less loss in gauge and a greater drilling distance than the thin-winged single taper bits.

The effect of the size of hole in the bit could not be fully determined, but apparently had very little or no effect on the drilling speed. However, the large hole of the McClelland bit probably is an aid in keeping the bit in alignment and drilling straight holes.