1922

Drill steel investigation

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DRILL STEEL INVESTIGATION

By

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THESIS

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Approved by Chas. Y. Clayton,

Professor of Metallurgy and Ore Dressing.

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Several brands of standard grade drill steel were obtained; the name, chemical analysis, and transformation points were as follows:

Chemical Analysis

	Name	Size	C	S	P	Mn	Si
1.	Red Star	1" Hexagon	0.875	.027	.030	.410	.082
2.	F.J.A.B.	1" Hexagon	.89	.018	.031	.290	.056
3.	Ludlum,	1" Hexagon	.87	.035	.044	.33	.128
4.	Colonial, (Vanadium)	7/8" Hexagon	.80	.027	.010	.34	.180
5.	Beaver,	1" Hexagon	.65	.014	.014	.24	.233

Physical Analysis

	Name	Transformation Point	Brinell Number
1.	Red Star	1345° F.	286
2.	F.J.A.B.	1330° F.	286
3.	Ludlum,	1360° F.	228
4.	Colonial (Vanadium)	1355° F.	286
5.	Beaver	1350° F.	207

From the above tabulated results it is noted that steels Nos. 1, 2, and 3 are practically the same in Carbon content, namely 0.90%, and fairly uniform in the per cent of other elements. Nos. 4 is different from other steels in that it is slightly lower in Carbon content than Nos. 1, 2, and 3 and has in addition .2% Vanadium. No. 5 is a low Carbon steel having .65% Carbon. The variation in the Acl, 2 and 3 points

Plate No. I

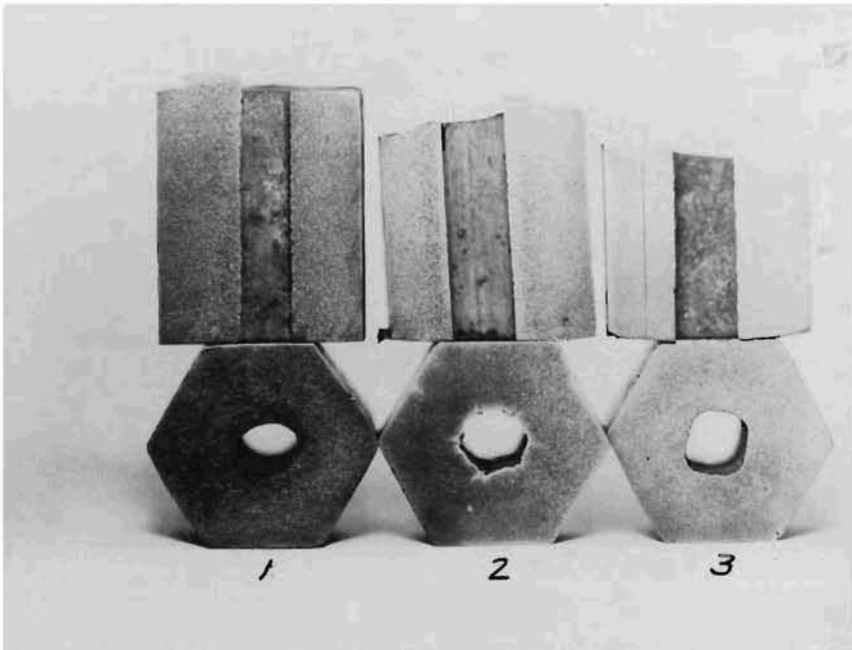

Fig. 1.

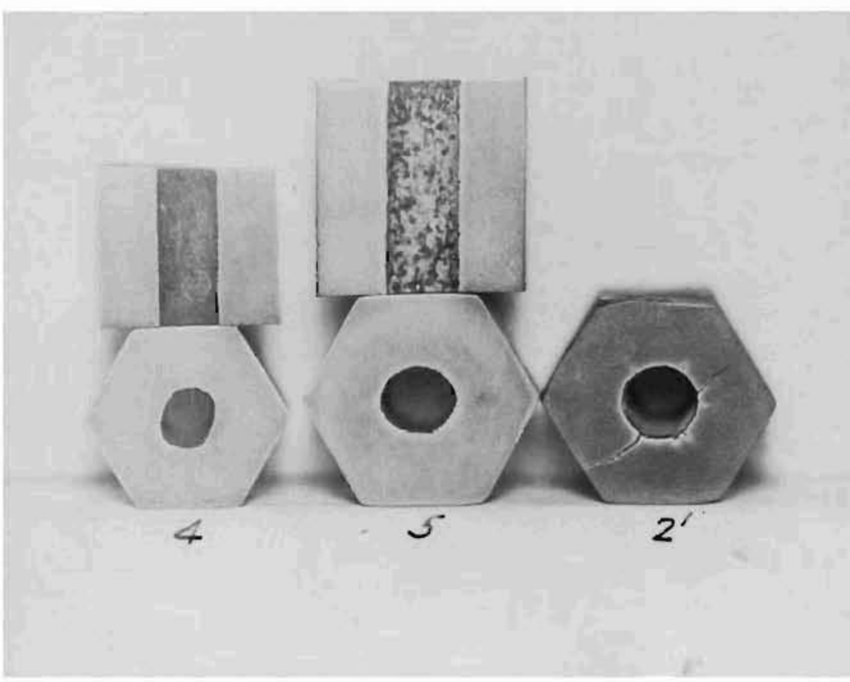

Fig. 2

PLATE II

FIG. 1

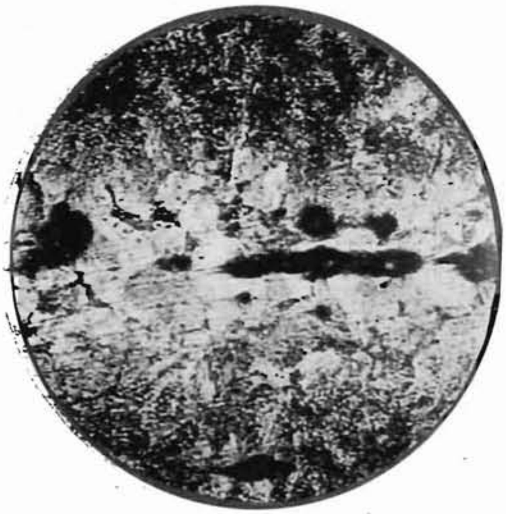

FIG. 2

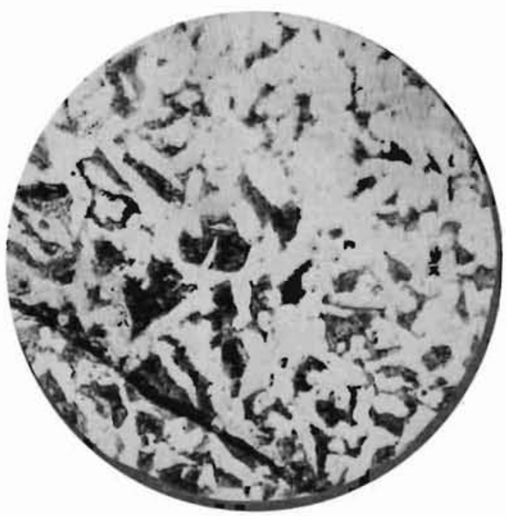

FIG. 3

MICROGRAPHS AS RECEIVED

PLATE III

FIG. 1

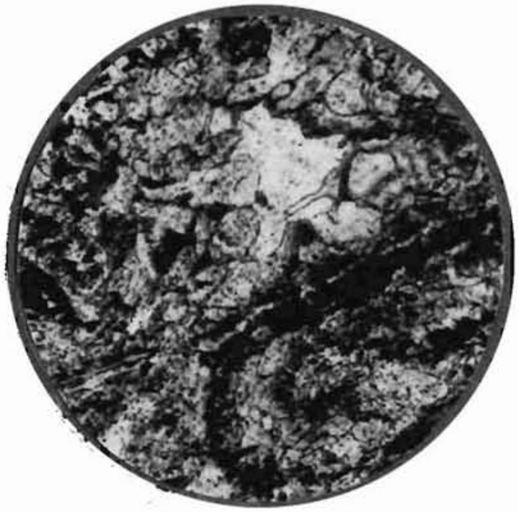

FIG. 2

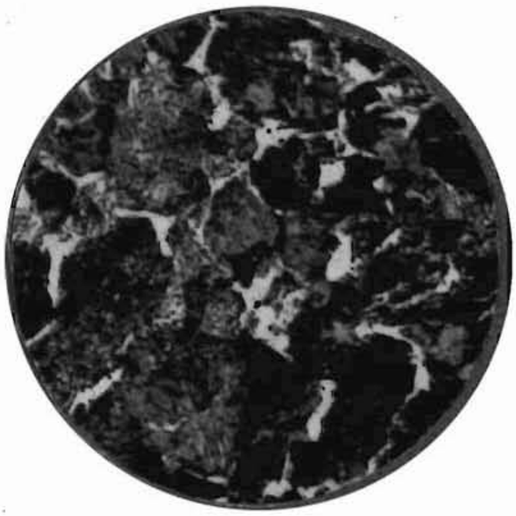

FIG. 3

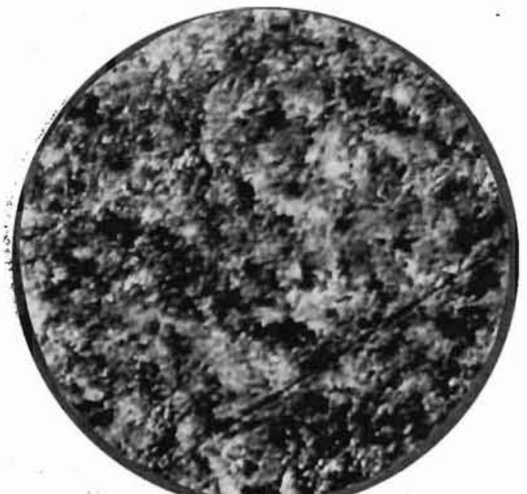

FIG 4

FIG. 5

is probably due to the slight variation in the chemical content of drill steels.

Cross sections and longitudinal sections were prepared for macrographic and micrographic study.

Plate No. 1 Fig. 1 & 2 shows macrographs of the different grades of steel. These macrographic views of the cross section and longitudinal section show a big variation in the size and shape of the water hole in the drill steels. They vary from a small elliptical eccentric hole in No. 1, a large round hole in No. 2 and No. 5, to a square hole in No. 3 and No. 4. No. 2, F.J.A.B., a Swedish mandrel rolled drill steel shows much decarburization, many incipient cracks, and inclusions around the water hole. These cracks are bound to give trouble in forging of drills or in actual drilling later on. This was proved when a shank split lengthwise in punching out water hole at forging. A cross section of this split shank is shown in Fig. 2, No. 2', Plate 1. An inclusion in this steel is shown in Fig. 1, Plate II. An inclusion streak is shown in longitudinal section of No. 3, Plate I, Fig. 1, and this is brought out very clearly by Fig. 2., Plate II. This No. 3 steel also shows decarburization on the exterior surface Fig. 3, Plate II. The photomicrographs Nos. 1, 2, 3, 4, and 5, Plate III, show the microstructure at 100 X of the drill steels as received from manufacturers. These micrographs show the usual pearlitic sorbite structure of carbon steels just after forging. Nos. 3 and 5 show a smaller Brinell number than the other steels. This is probably due to the fact that No. 3 contains more pearlite than the others and No. 5 is lower in carbon content.

Development of Suitable Furnace for Heat Treatment of Bits and Shanks.

After reading various publications on the heat treatment of bits and shanks, it appears as though nothing definite has been reached as to the proper heat treatment. It appears to be based merely on the trial and error method and guesswork on the part of the blacksmiths.

Most blacksmiths say, heat to a cherry red and quench. Cherry red may be 1450° F. or 1600° F., depending on whether the day is bright or whether the day is dark.

A large drill steel manufacturing company recommends tempering (they mean heat treating) by trial and error method, judging temperature by eye.

Breakage in drill steel as determined in 1917 by manufacturers and mines, was due to improper forging and heat treating, combined with the improper use of drills. Therefore, with the above facts in mind, it seems that the thing to do is to educate the blacksmith; develop a heat treating furnace which is fool-proof, or continue the development of the detachable bit, with which Mr. Hawkesworth has make such great progress in the last year.

PLATE IV

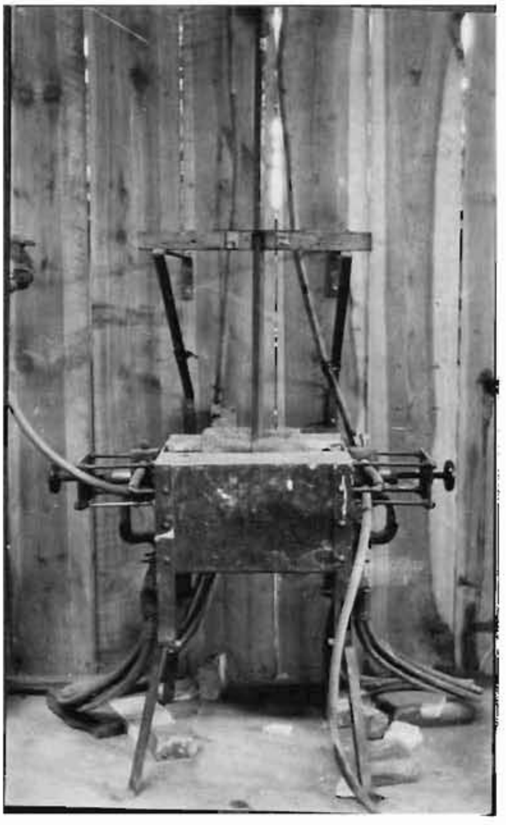

FIG. 1

FIG. 2

This same large drill manufacturing company recommends heating to 1450° F. for medium hard rock and raising 25 to 50° F. each time until the right hardness is obtained. It is reasonable to assume that the right hardness for a very hard rock is the proper hardness for a soft rock. Also if the bit of a .9 carbon drill steel has actually attained a temperature of 1450° F., which is about 90° F. above critical range, and is quenched in water, the desired hardness for any rock is obtained.

With this assumption in mind, steps were taken to develop an electric furnace which would heat the bit to the desired quenching temperature at about 3/4 inch back from the cutting edge.

D. C. Nichrome Pot Furnace.

The first attempt was a small pot furnace with a nichrome wire heating element. It was observed that the bit could be heated back to the desired distance by putting the drill in the furnace to a certain depth and insulating back of this depth. Practically, this amounted to the following: If the face of the bit is put in contact with a surface somewhat hotter than the desired temperature, the bit will heat up by conduction, provided that there is not too much radiating surface next to the bit. Insulation must be put around the bit so that the heat can only go off the heating surface through the drill by conduction. The proper temperature of the drill was obtained by inserting an Alumel Chromel couple 3/4 inch up in water hole of bit. This pot furnace was abandoned because of its delicate structure, and because it could only heat treat one drill at a time. With the idea of the heating surface being focused on the face of the vertical drill by insulating around the bit so that the bit heated up through conduction, the A. C. Carborundum Resistor Furnace was developed.

<u>A. C. Carborundum Resistor Furnace</u>

This furnace is shown in Figs. 1 and 2, Plate IV, and is constructed as follows: The resistor consisted of a 2-1/2 x 4-1/2 x 9 Carborundum brick. Three holes were drilled through the brick for three thermocouples. End plates of 1 inch cast iron were cemented to the ends of the Carborundum brick with a paste made of Carborumdum powder and water glass. This brick was set up in an insulated furnace with water cooled electrodes pressed against the ends of the brick. Three thermocouples run through the bottom of the furnace through Carbonundum brick and extend 3/4 inch above the top of the brick so that when the drill sets in an upright position on top of this brick, the thermocouple will measure the temperature 5/4 inch back of the cutting edge.

All drills tested to date were heat treated on this furnace. In our first heat treatment test a lot of trouble was experienced in getting the couples to stand up, but later this was remedied so that good results were obtained.

This Carborundum brick, when cold, takes 90 volts with about 80 amperes, but decreases very rapidly in voltage due to the decrease in resistance in Carborundum as the heat increases. The voltage rapidly decreases from 90 volts - 80 amperes, to 20 volts - 250 amperes, giving 5 K.W. This is about the right energy necessary to give the right temperature for the proper heat treatment.

Experimenting with the insulating material around the bit shows that the speed at which the bit heats up depends altogether upon the shape and depth of the insulating material into which the bit is inserted. It was found when using nonpareil brick that the best results were obtained when the hole was the shape of the bit. The depth of the hole was the thickness of the brick. The depth of this insulated pocket ~~cannot~~ must not be too shallow and must have the shape of the bit. There is a possibility of a furnace using the regular 220 - 110 D.C. or A.C. current of mine by getting Carborundum bricks that will keep the desired temperature of about 850° C. If this sort of a furnace could be developed, drill bits could be heat treated in a very fool-proof manner. The time element of the length of time a drill is left on the brick, is the only thing to consider. A drill bit heats up very nicely to the desired depth back of the cutting edge in ten minutes with the Carborundum brick at 850° C.

Brinell Hardness and Its Relation to the Hardness of Bit and Shank of Drill Steel.

Owing to the curved surface of the bit just back of the cutting edge, it was necessary to design a special holder so that the Brinell readings could be properly taken on the bit. This holder is shown on Plate ~~VIII~~ V, Fig. 1. &2 No difficulty was experienced in getting the Brinell numbers on the shanks of the drills. On the double taper bits, no difficulty was experienced on account of two parallel sides of bit.

Brinell Numbers on Bits

Owing to the fact that it was not at first considered worth while to Brinell the bits, very little data is at hand at present. However, the data at hand shows that Brinell tests for hardness of bits might be a very fertile field for future investigation.

The following table gives some idea of the Brinell hardness of bits, in relation to drilling:

PLATE V

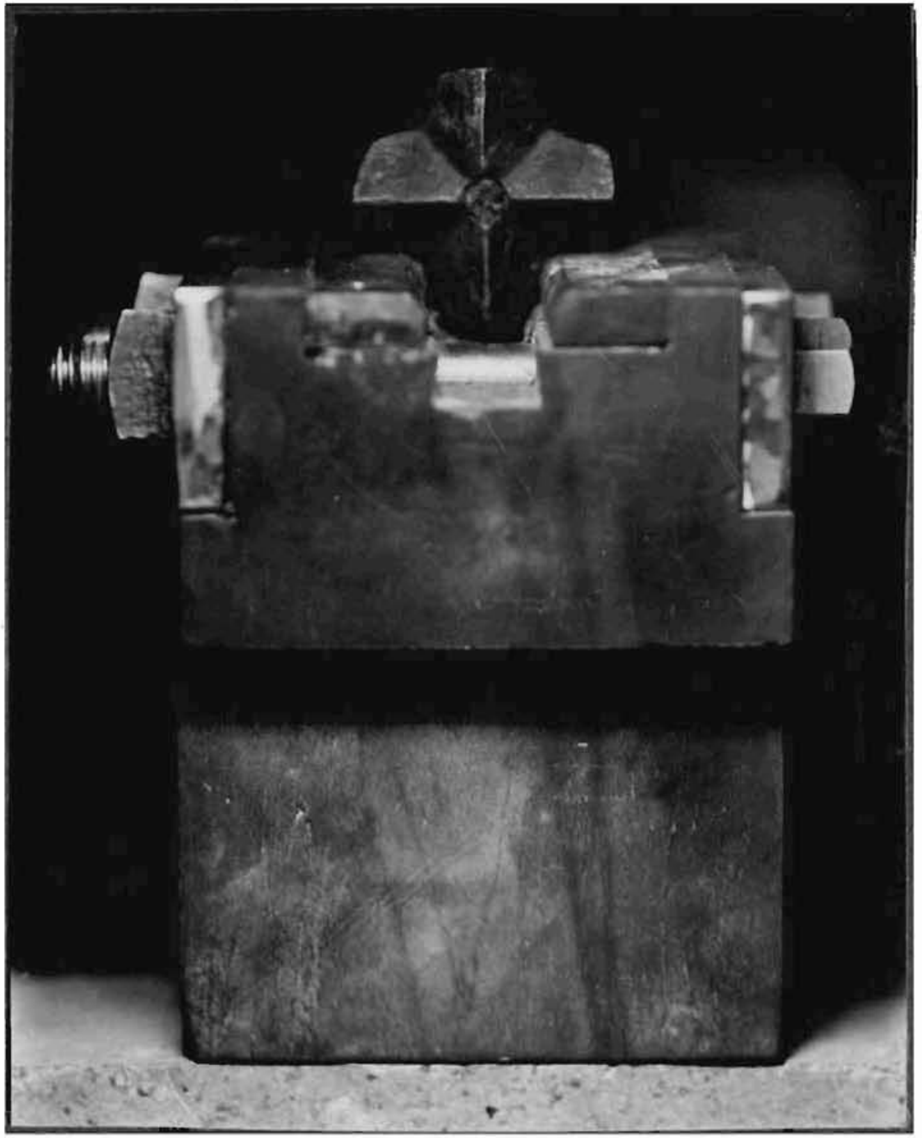

FIG. 1

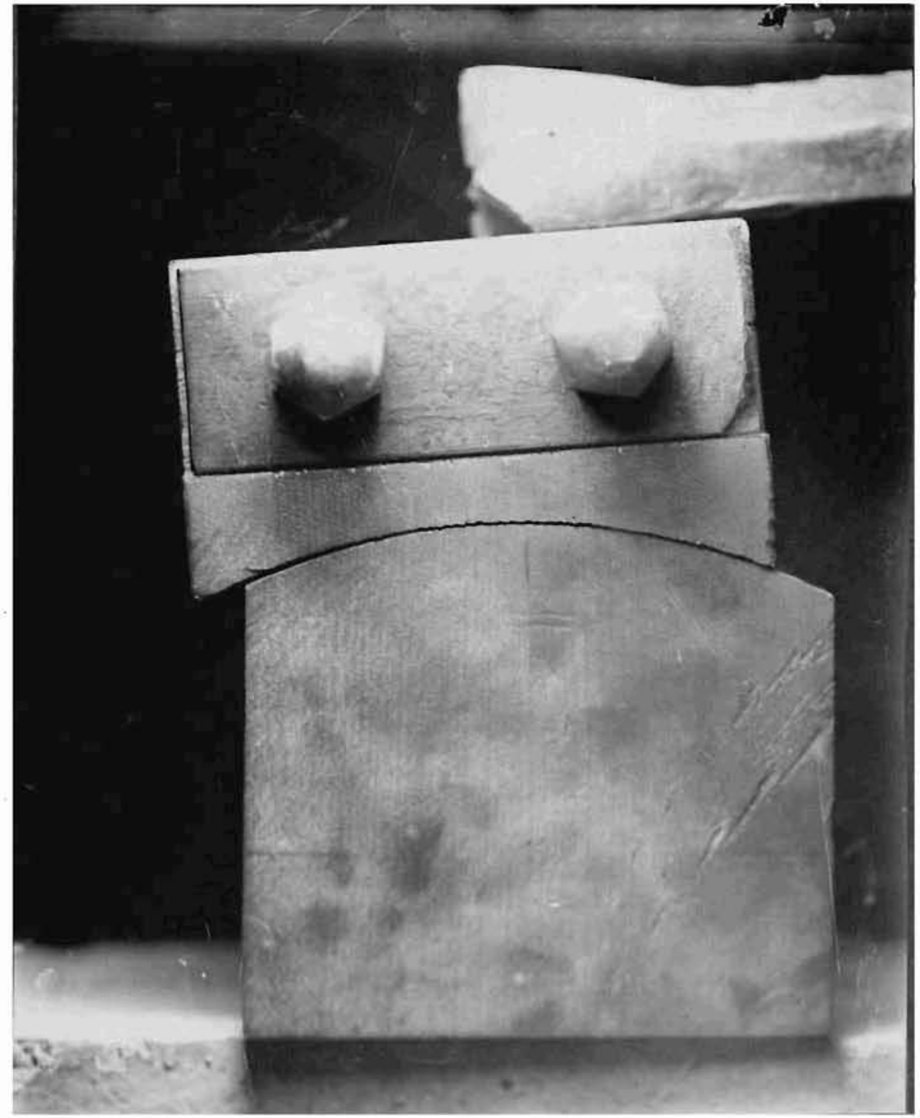

FIG. 2

No.	Kind of Steel	Gauge	Distance Drilled Per Min. 2 Min. Test	Loss in Gauge	Remarks	Brinell Number
1-A	Red Star 1" Hexagon	1-45/64	9.5"	1/64	Good Bit. Held up well.	652
1-B	" " " "	1-47/64	9	1/64	One wing chipped slightly. Held up well.	713
1-D	" " " "	1-40/64	9.5	2-/64	Wing chipped slightly. Held up well.	713.
1-E	" " " "	1-40/64	8.4	2/64	One wing chipped slightly. Held up well.	652
1-F	" " " "	1-37/64	8.8	2/64	Good bit. Held up well.	652
1-A	" " " "	1-47/64	---	2/64	Face of bit worn off.	782
1-B	" " " "	1-47/64	8.8	2/64	Good bit. Worn off.	782
1-C	" " " "	1-47/64	8.9	3/64	All wings chipped badly.	782
1-D	" " " "	1-40/64	11.4	3/64	Good condition. Good temp.	744
1-E	" " " "	1-40/64	10.2	3/64	Face of bit worn off. Hot condition when quenched.	782
1-F	" " " "	1-40/64	10.1	3/64	Good condition.	744
1-E	" " " "	1-40/64	9	2/64	One wing chipped, others battered. No good after 2nd minute.	512
1-X	" " " "	1-46/64	12.7		Good	744
1-Y	" " " "	1-46/64	10.6		Good	652
1-Z	" " " "	1-45/64	12.3		Good	744
DRD-1	1" Hexagon	1-44/64	13.5		Good	652
DRD-2	" "	1-44/64	13.0		Good	683
DRD-3	" "	1-38/64	14.6		Good	683

In drawing conclusions it seems as though a Brinell number of 600 to 744 is the desirable hardness for bits. It is seen in table that the bit of Brinell number 512 drilled well for the first two minutes test but did not hold up. It flattened out on the third minute run. It is also seen from the table that a drill with Brineil number 782 wore off badly and did not hold up. It seems that the lasting quality of a bit of 600 to 744 is very good.

The following table gives the Brinell numbers of shanks of various mining companies throughout the country and the conclusions from this data are that a Brinell number of 350 to 450 is very desirable. A Brinell number up to 555 is not too hard but to get a Brinell number above 450 shows that the steel has been heated to too high a temperature before quenching in oil. This weakens the shank, due to excessive grain growth.

HARDNESS TESTS ON THE SHANK ENDS OF DRILL STEELS

By Charles Y. Clayton and Joseph Rohloff

ANOTHER DISTRICT

Number Company	Number Drill	Name	BRINELL NUMBER Distance From 1/4"	BRINELL NUMBER Distance From 4"	Shank	End Lug
No. 7	A-1	1-1/4" Round	269	228		228
	B-1	" "	286	269		
	C-1	" "	269	255		255
	D-1	" "	286	269		269
	E-1	" "	302	286		286
	No No.X	" "	418	364		
	No No.	" "	444	418		444
	A-1	7/8" Cruciform	387	286		
	B-1	7/8" "	364	286		
	C-1	" "	512	340		
	D-1	" "	364	286		
	E-1	" "	418	269		
	WO-1	" "	444	321		
	WO-2	" "	418	286		
	A-1	7/8" Hex. Jack Hammer	418	286		
	B-1	" " " "	477	302		
	C-1	" " " "	600	302		
	D-1	" " " "	555	302		302
	No No.	" " " "	364	286		286
	No No.9	1" Hex. Carr Bit	387	302		
	A-1	" " " "	555	286		
	B-1	" " " "	302	302		
	C-1	" " " "	340	286		
	D-1	" " " "	555	286		
	E-1	" " " "	477	302		
	No No.	" " " "	477	286		
ADDITIONAL TRI-STATE DISTRICT						
No. 22	CSC-1	1-1/4" Round	418	418		418
	CSC-2	" "	460	375		460
	CSC-3	" "	402	402		402
	CSC-4	" "	387	387		375

DEPARTMENT OF METALLURGY AND ORE DRESSING
MISSOURI SCHOOL OF MINES AND METALLURGY
HARDNESS TESTS ON THE SHANK [illegible] OF DRILL [illegible]

By Charles Y. Clayton and Joseph [illegible]

Company	Number Drill	Kind	1/8"	1/4"	1/2"	1"	1-1/2"	2"	2-1/2"	3"	4"	Lug	Button
					BRINELL HARDNESS NUMBER - Distance From Shank End.								
SOUTHEAST MISSOURI DISTRICT													
No. 9	D-1	7/8" Hex. J. Hammer (Old)		782								241	
	D-2	" " " " (Old)		555				228				228	
	D-3	" " " " (Old)		600					302			302	
	D-4	" " " " (Old)		364					255				
	D-5	" " " "		255						321		387	
No. 4	1	7/8" Hex. J. Hammer		418	364	364	364						286
	2	" " " " (Old)		364	364	364	302						
	3	" " " " (Old)		364	364	302	302						269
	4	" " " "		364	364	340	302						269
No. 5	1	7/8" Hex. J. Hammer	713	444	364	286	286						364
	2	" " " " (Old)	600	444	364	302	286						364
No. 19	1	7/8" Hex. J. Hammer		430								321	
TRI-STATE DISTRICT													
No. 18	1	1-1/4" Round (Old)		387								269	
	2	" "		340								241	
	3	" " (Old)		402								255	
	4	" "		430								293	
No. 1	FD-1	1-1/4" Round		364	340	340					340	364	
	FD-2	" "		340	340	340					364	387	
	FD-3	" "		512	418	387					387	387	
	FD-4	" "		302	302	340					387	387	
No. 3	1	1-1/4" Round		196	196	196					228	286	
	2	" "		269	269	269					269	269	
No. 10	B-1	1-1/4" Round (Old)		387							387		
	B-2	" " (Old)		387							340		
No. 13	1	1-1/4" Round		402							402	402	
	2	" "		364							286	321	
No. 14	1	1-1/4" Round		444								351	
	2	" "		444								269	
	3	" "		430								375	
	4	" "		418								430	
No. 15	1	1-1/4" Round		402								351	
	2	1-1/4" Round		418								387	
No. 16	1	1-1/4" Round		387								402	
No. 17	1	1-1/4" Round		477								430	
ILLINOIS DISTRICT													
No. 12	1	7/8" Hexagonal		364							255		255
	2	" "		402							269		269
ARIZONA DISTRICT													
No. 2	Gr-1	1-1/4" Round	600	512	512	302					302		302
	Gr-2	" "	600	512	387	387					321		387
	Gr-3	" "	512	444	302	302					286		286
No. 6	1	7/8" Hex. J. Hammer (Old)		600	477	387	286				286		286
No. 8	----	1" Round		444							269		
	27	7/8" Cruciform		600							269		
	32	" "		652							321		
	28	" "		652							302		
	29	" Hexagon		555							302		
	31	" "		713							302		
No. 11	17	7/8" Round	600	477	321						340	387	
	18	" "	555	512	387						387	444	
	19	" "		387	321						286	340	
	20	" "		600	444						340	340	
	21	" "	444	444	364						340	340	
	23	" "	418	418	418						269	269	
	24	" "	652	600	512						269	255	
	25	" "		555	302						269	269	
COLORADO DISTRICT													
No. 20	DRD-1	1" Hexagon		364	332						286		
	DRD-2	" "		351	340						255		
	DRD-3	" "		340	302						228		
	DRD-4	" "		351	321						196		
CALIFORNIA DISTRICT													
No. 21	X-1	1" Hexagon		351							311		
	Y-1	" "	512								255		
	Z-1	" "		418							387		

The Possibilities of Brinell Control of Shanks and Bits.

The very short time which it would take to get a Brinell number by either the ordinary Brinell machine or by a Brinell Meter, would make this control very easy and eliminate the lugging around mines of a heavy drill which is practically worthless because of too hard or too soft a shank or ~~drill~~ bit. A Brinell machine or meter would pay for itself in a very short time by saving labor and increasing drilling speed.

Microphotographs of bit were impossible to get due to the great difficulty in polishing and mounting for photograph. The microstructure was studied by eye under ordinary microscope. All polishing had to be done by hand, which is a very tedious process.

Conclusions which were made from studying microstructure of bits, follow:

The microstructure of bits of above 700 Brinell was all martensite. From 600 to 744 the microstructure was martensite plus troostite, decreasing in troostite as the Brinell number increased. It seems that a small amount of troostite is desirable to act as a cushioning effect for the martensite. This probably bears out the fact that a bit of Brinell number 782 wears off and a bit of 512 batters. In the first case we have all martensite for cutting edge and in the second case the cutting edge was nearly all troostite.

PLATE VI

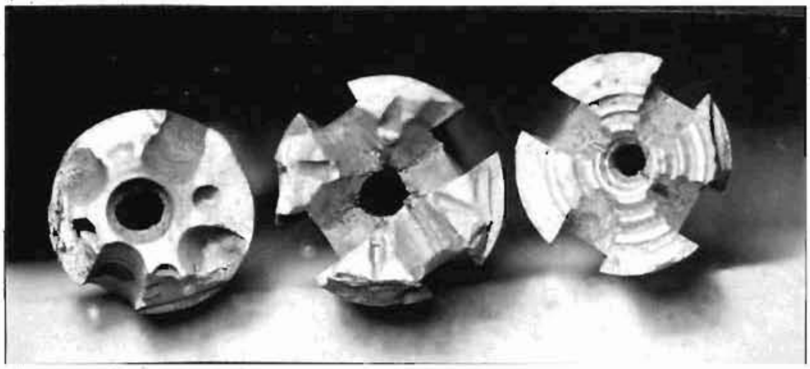

FIG. 1

FIG. 2

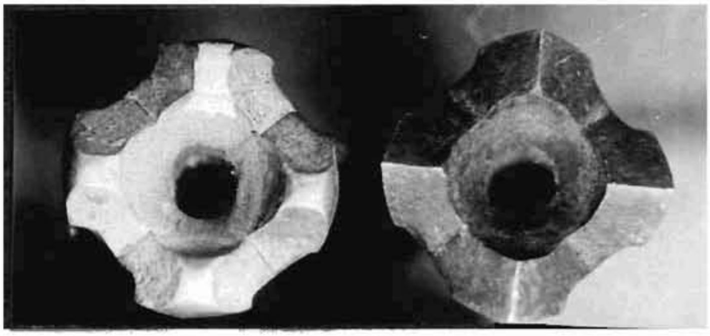

FIG. 3

PLATE VII

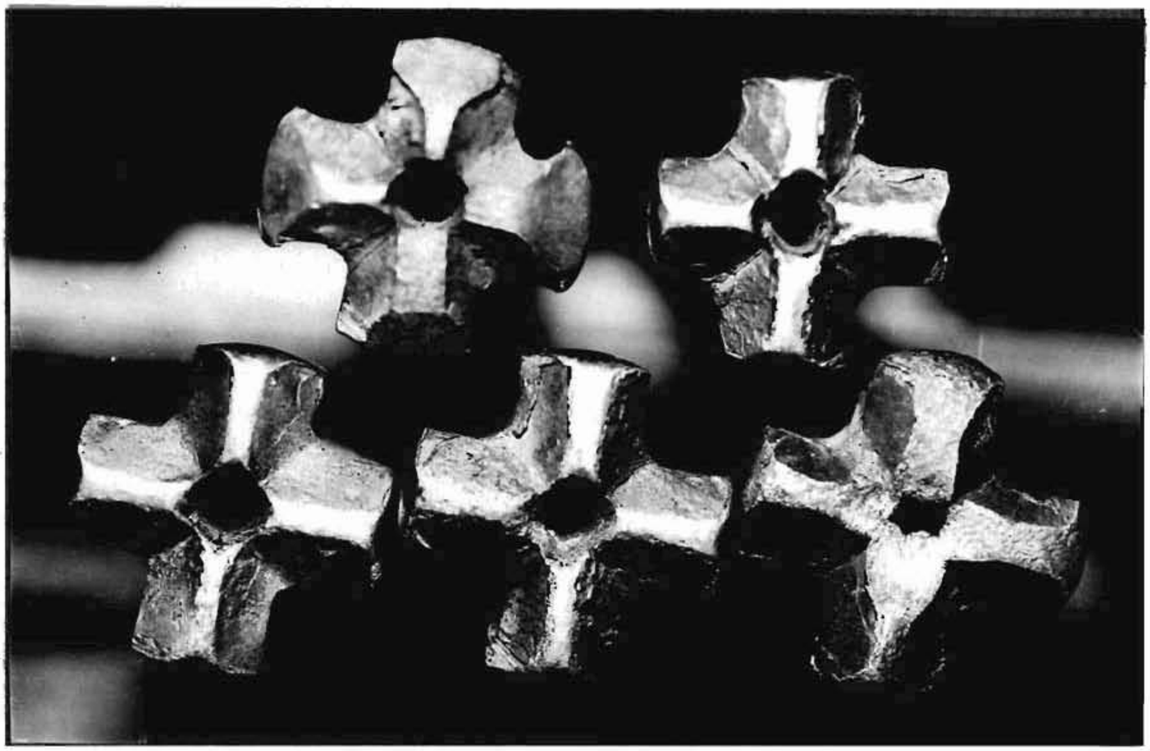

FIG. 1

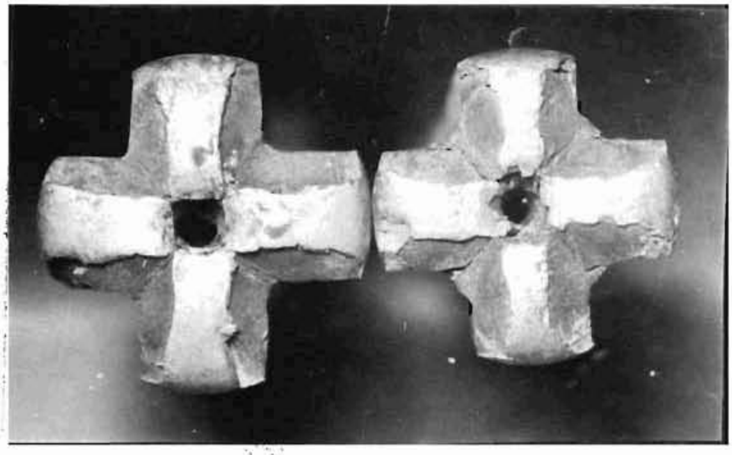

FIG. 2

PLATE VIII

Fig. 1

Shape of Bits

The cross bit was considered only in our investigation. This design of bit has proved itself to be very good and is probably not excelled.

Various ideas on shape of bits were tried out by designing and making three bits as shown in Plate VI, Figs. 1 and 2. These bits had too many thin edges which got too hard in heat treating and consequently did not hold up. Practically no distance was drilled with these bits. Their condition after drilling is shown in Plate VI, Fig. 1.

Plate VII, Fig. 1 shows drills which have been drilled. This picture shows that the region of most wear is at the outer edges of the cutting surface. Every used bit shows these corners rounded off. In the McClellan Bit in Plate VI, Fig. 3, it seems that this fact has been taken into consideration. The unnecessary part of the cutting edge has been eliminated. This makes a very large centered bit which seems to be very desirable, for the cutting speed of this bit is very good, as shown by table on page 8.

Plate VII, Fig. 2 shows results of two drills which were quenched in water for martensitic cutting edge and then annealed for 1 hour at 500° F. to obtain troostitic structure in the cutting edge. From this picture it is seen that a cutting edge which is completely troostite is undesirable because it is too soft.

A regular cross bit was made for the purpose of getting a comparison between the drilling results of a regular cross bit with a McClellan bit. These two bits of the same gauge were drilled side by side in South East Missouri granite.

The following table gives the drilling results. Platel, Fig. 1 shows the bits of these two drills after drilling.

From the table it is observed that the drill K, which had the regular cross bit, drilled faster in the first two minutes, but the McClellan bit, D.R.D-4 had much better lasting qualities. It drilled at a good rate of speed over a longer period of time than did the regular cross bit K.

It may be interesting to know that the Brinell Number of the McClellan bit was 652 while the regular cross bit varied from 683 on one wing to 744 on the other wing. This variation in Brinell Number on the regular cross bit is shown up by the photograph Fig. 1 Plate VIII. The face of the wing having Brinell Number of 744 shows less wear than the other wing. This variation of hardness between the two wings of the regular cross bit may explain the greater drilling speed of this bit in the first two minutes of drilling.

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	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

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time	Gauge Start	Gauge Finish	Lost	Remarks
DRD-4	9.0	23.5	14.5	1'	1-38/64	1-38/64	None	Good condition.
DRD-4	23.5	28.5	5.	25"	1-38/64	1-34/64	4/64	
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.	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	
			85.5	7' 15"			7/64	

Heat Treatment and Drilling Tests of the Various Brands of Drill Steels.

Heat Treatment: The bits and the shanks of the drill steels used in this investigation were heat treated on the Carborundum Resistor Furnace, developed for this work. The object was to get a good control over the temperature of the bit previous to quenching in water. This was done in the following manner: The drill was set in an upright position on the Carborundum brick which was at about 850° C. The alumel chromel thermocouple which comes up from the bottom of the furnace through the Carborundum brick, extends up in the water hole of the drill to an extent of about 3/4 inch. When the temperature at this point, 3/4 inch back from the cutting edge, reached a temperature of about 50° F. above the critical range of the steel, the bit was quenched in a barrel of water. A question might arise here as to whether the temperature in the water hole is the same as the temperature in the wings of the bit. The following experiment was carried out which proved that there is practically no difference in these temperatures. One thermocouple was placed in the water hole of the drill, 3/4 inch back from the cutting edge and two more thermocouples were placed in holes drilled down into the wings of the bit, the bottom of these drilled holes being on a level with the thermocouple in the water hole. The temperatures registered by the three couples were practically the same.

The temperature of the brick was about 140° F. greater than the temperature of bit 3/4 inch back of cutting edge. This difference of temperature is necessary so that the speed of conduction in the bit be such that the drill bit will heat up to a desired depth in a reasonable time. There is a question as to whether the cutting edge of the drill reaches the temperature of the brick. It is assumed that this does not happen, due to the great rate of conduction of heat in steel. If the cutting edge of the bit is at the same temperature as the brick, it is in this condition only to a very small depth, a depth which usually wears off in the first few seconds of drilling. The drills were set on the Carborundum brick in the same way when heating up shanks, but in a reversed position. The shanks were quenched in oil.

The first heat treatment of No. 1 and No. 4 brand, and the second heat treatment of No. 1 brand, had to be done by eye, due to the fact that great difficulty was experienced in getting the thermocouples to stand up. As a result Brand No. 1 was quenched at about the right temperature in its first heat treatment, but in the second heat treatment of No. 1 and in the first heat treatment of Brand No. 4, most of the drills were quenched at the high a temperature. This thermocouple problem was later solved by drilling holes through the Carborundum so that the couples could be run up through the brick instead of laying them flat on top of the brick as was the case at first. With this trouble remedied the rest of the drills were heat treated in a very satisfactory manner.

The following tables give the heat treatment followed by the drilling results of each brand of drill steel.

Drilling Tests:

All the drills were drilled with an Ingersoll Rand No. 248 Leyner Anvil Block Drill at 90 lbs. pressure, except the jack hammer drills which were drilled with an Ingersoll Rand No. BCR 430 Jackhammer drill with 45 lb. weight on the drill in addition to the weight of the drilling machine. The air pressure was 90 lbs.

The drill steels used with the No. 248 Leyner drilled horizontal holes in Southeast Missouri Red Granite; the cuttings were washed back by a stream of water from the water needle. The jackhammer drills drilled down holes in Southeast Missouri Granite; the cuttings were blown out by an air gun.

The following drilling data is insufficient to give any fair comparison between the different brands of drill steels, but it is seen from this data that there is practically no difference in the drilling results of one grade over another. However, it might be pointed out that brand No. 5 which is a low carbon steel of .65% is somewhat better than the .90% carbon steel. This may not be the case if extended tests were run on these various brands of drill steels. A low carbon steel requires a higher quenching temperature than an ordinary

.9% carbon steel. This fact may be a disadvantage in some mine blacksmith shops where the blacksmith is used to working with quenching temperatures of a .9% carbon. However, the use of a low carbon drill steel instead of a .9 carbon drill steel may be worthy of further investigation.

In our investigation no advantage was seen in using a higher priced Vanadium steel in place of a straight Carbon steel. The drilling results at hand show no advantage of Vanadium drill steel over straight Carbon drill steel.

Only one of the brands of steel showed defects that would discredit its use as a standard brand of drill steel. This steel is the No. 2 F.J.A.B. brand, a Swedish mandrel rolled steel. This steel is unreliable, due to the many incipient cracks around the water hole. In our tests this steel developed a split shank in punching out the water hole at forging. Outside of this split shank, the breakage proved to be negligible.

Quenching Media for Shanks.

There seems to be a great uncertainty as to the proper temperature at which a shank should be quenched and what quenching oil to use. In our investigation it was observed that a shank must be heated too high in order to get a desired hardness on the shank by quenching in heavy petroleum oil or transformer oil. Good results were obtained in the few tests that were run with fish oil as a quenching bath. Good results were obtained by heating shanks to a length of five inches to 1420° F. and quenching in fish oil. The data so far is very insufficient on the heat treatment of drill steel shanks. Realizing the great importance of this phase of drill steel investigation, preparations are being made to carry on extensive investigation on the heat treatment of drill steel shanks, using various quenching oils.

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

HEAT - TREATMENT

LOT NO. 1. Colonial Red Star. 1" Hexagon.

I. First Heat Treatment: January 12, 1932.

Heated bits of drills on Carborundum Resistance furnace. Owing to lack of temperature control, it was necessary to quench the drills by eye. Bits were quenched in water.

1-A)
1-B)
1-C) Quenched slightly above critical point. Temperature
1-D)
1-E) judged by eye.
1-F)

The shanks were also heated on same furnace. Temperature judged by eye and shanks quenched in oil.

Brinell hardness of bits and shanks 1/4" from end:

Drill	Bit	Shank
1-A	652	387
1-B	713	387
1-C	600	418
1-D	713	364
1-E	652	302
1-F	652	302

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	1-42/64	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	
			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	49.75	6.25	40"	1-35/64	1-35/64	None	
			23.75	2' 40"			2/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

b HEAT - TREATMENT

LOT NO. 1. Colonial Red Star. 1" Hexagon.

II. <u>Second Heat Treatment after Resharpening Following First Drilling Test:</u> January 30, 1922.

Again due to breaking down of thermocouples, all drills were quenched in water by eye, excepting Drill No. 1-D which was quenched just above range.

Brinell hardness of bits and shanks 1/4" from end:

Drill	Bit	Shank
1-A	782	387
1-B	782	387
1-C	782	418
1-D	744	364
1-E	782	302
1-F	744	302

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	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

HEAT - TREATMENT

LOT No. 1. Colonial Red Star. 1" Hexagon.

III. <u>Third Heat Treatment After Resharpening Following Second Drilling Test</u>. February 7, 1922.

A very good temperature control was obtained this time with Alumel-Chromel Couples. The bits were quenched when drill reached the following temperature at a point 3/4" from cutting edge:

1-A - quenched at 1418° F.	
1-B - quenched at 1418° F.	Filed down.
1-C - quenched at 1391° F.	
1-D - quenched at 1400° F.	Filed down.
1-E - quenched at 1400° F.	Through range twice.
1-F - quenched at 1400° F.	

Drills Nos. 1-A, 1-C, 1-E, and 1-F were tempered to get Troostite at 500° C., for 1 hour. Quenched in water.

These drills flattened out in drilling test.

Brinell readings were taken on Drill No. 1-E as follows:

1/8" from cutting edge - 512
3/8" from cutting edge - 512
1/2" from cutting edge - 387
5/8" from cutting edge - 302

On etching side of bit, a division line was noted at 9/16" from cutting edge showing change from Troostite to Sorbite.

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
				FLATENED 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'			[illegible]/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	1-34/64	None	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

HEAT - TREATMENT

LOT NO. 2. FJAB Steel. 1" Hexagon.

I" First Heat Treatment: February 8, 1922.

2-A)
2-B) Quenched in water at 1382°F.
2-C)

2-E) Quenching temperature unknown, due to poor thermocouple.
2-F) These two drills were previously heated and quenched at too high temperature.

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

HEAT - TREATMENT

LOT NO. 3. Beaver Brand. 1" Hexagon.

I" <u>First Heat Treatment:</u> February 2, 1922.

3-A)
3-B)
3-C) Quenched at 1436° F.
3-D)
3-E)

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

<u>First Run on Steel No. 3.</u> 1" Hexagon 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
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"			3/64	
3-C	.75		.5		1-46/64			Battered badly.
3-D	36.5	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

HEAT - TREATMENT

LOT No. 4. Colonial (Vanadium) Brand. 7/8" Hexagon.

I" <u>First Heat Treatment:</u> January 30, 1922.

4-A)
4-B)
4-C) Quenched by eye in water.
4-D)
4-E)

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

HEAT - TREATMENT

LOT No. 4 Colonial (Vanadium) Brand. 7/8" Hexagon.

II. Second Heat Treatment: February 7, 1922.

4-A quenched in water at 1409° F. 3/4" from cutting edge.
4-B quenched in water at 1432° F. 3/4" from cutting edge.
4-C quenched in water at 1409° F. 3/4" from cutting edge.
4-D quenched in water at 1432° F. 3/4" from cutting edge
4-E quenched in water at 1432° F. 3/4" from cutting edge.

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

HEAT - TREATMENT

LOT No. 5.   Ludlum Brand.

I. First Heat Treatment: February 3, 1933.

5-A)
5-B)
5-C)   Quenched at 1562° F.
5-D)
5-E)

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.

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

HEAT - TREATMENT

JACK HAMMER DRILLS.

I. First Heat Treatment: January 30, 1922.

B.F.)
V.B.) Quenched in water by eye.
V.A.)
A.F.)

Broke wing of V.B. in Brinell Machine. Showed fine grain.

Jackhammer Steels. Drill - Intersoll-Rand Jackhammer No. BCR 430.
45 lbs. weight on drill in addition to weight of machine.
Down holes in SE Mo. Red Granite. Cuttings blowed out by air gun.
Air pressure 90 lb. nearly constant.

Steel No.	Depth of Hole Start	Depth of Hole Finish	Distance Drilled	Time Min.	Gauge Start	Gauge Finish	Gauge Lost	Remarks
A-F	.25	3.5	3.25	1'	1-46/64	1-45/64	1/64	
A-F	3.5	6.5	3.	1'	1-45/64	1-44/64	1/64	
A-F	6.5	9.5	3.	1'	1-44/64	1-44/64	None	
A-F	9.5	11.5	2.	1'	1-44/64	1-43/64	1/64	
	Totals - - - - - - -		11.25	4'			3/64	
B-F	.5	3.75	3.25	1'	1-48/64	1-46/64	2/64	
B-F	3.75	6.5	2.25	1'	1-46/64	1-45/64	1/64	
B-F	6.5	8.5	2.0	1'	1-45/64	1-44/64	1/64	Tendency to Stick.
B-F	8.5	10.25	1.75	1'	1-44/64	1-43/64	1/64	" " " worse.
	Totals - - - - - - -		9.25	4'			5/64	
V-A	.5	3.75	3.25	1'	1-46/64	1-44/64	2/64	
V-A	3.75	6.25	2.5	1'	1-44/64	1-43/64	1/64	
V-A	6.25	8.75	2.5	1'	1-43/64	1-42/64	1/64	
V-A	8.75	11.25	2.5	1'	1-42/64	1-42/64	None	
V-A	11.25	13.25	2.0	1'	1-42/64	1-42/64	1/64	
V-A	13.25	15.00	1.75	1'	1-41/64	1-40/64	1/64	
	Totals - - - - - - -		14.5	6'			6/64	
V-B	.25	4.0	3.75	1'	1-46/64	1-43/64	3/64	1 wing broken in making
V-B	4.0	6.5	2.5	1'	1-43/64	1-42/64	1/64	Brinell hardness test.
V-B	6.5	9.0	2.5	1'	1-42/64	1-41/64	1/64	
V-B	9.0	11.25	2.25	1'	1-41/64	1-40/64	1/64	
V-B	11.25	13.25	2.00	1'	1-40/64	1-39/64	1/64	
V-B	13.25	14.75	1.5	55"	1-39/64	1-39.64	None	
	Totals - - - - - - -		14.5	5' 55"			7/64	

MISSOURI SCHOOL OF MINES EXPERIMENT STATION
DRILL STEEL INVESTIGATION

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

Air pressure 70 - 80 Lbs.
15 Hole Round.

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

Steel	Depth of Hole		Distance	Time	Gauge			
No.	Start	Finish	Drilled	Min.	Start	Finish	Lost	Remarks
			29.5	1.05				
			24.0	1.05				
			23.0	45"				
			23.0	40"				
			23.5	45"				
			23.5	50"				
			26.5	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"				
			[illegible]	[illegible]				