A Study of the Development of Rock Drill Bits with Special Reference to the Calumet and Hecla Copper Company Bits

By Param Jit Singh
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Param Jit Singh

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Approved:

Clifton W. Livingston
C. W. Livingston
Picture of a Monument built to the Miners of Copper Country, Michigan, showing a drill machine on the boat
Acknowledgments

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The author is also thankful to Mr. Ernie Orchard, foreman of the steel and bit shops of the above company, without whose cooperation the study of old bits and the tracing of their history would have been very difficult.

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Conclusion

The problems presented by the native copper found in the lodes are peculiar to the copper country of Calumet, Michigan. The main trouble in drilling was the choking of the front water hole by a spike of copper.

It was found that conventional bits on regular drill steel, giving maximum clearance for escape of drill cuttings, and having a side hole, gave best results.

Early tests conducted by the Calumet and Hecla Consolidated Copper Company, showed a slightly greater speed of drilling by detachable bits over that of the conventional bits. A greater footage of drilling was obtained per detachable bit dulled as compared to conventional bit. One difficulty, however, with the use of detachables, was in the extraction of drill steel from the holes, which difficulty was never encountered with conventional steel. The tendency of the copper cuttings to fill the space back of the bit, thus causing it to stick, was believed to be responsible for this difficulty in extracting the steel from the hole.

In later tests a new design was developed giving greater clearance at the back of the bit and thus reducing the clogging tendency.

For some time Timken detachable bits were used in the Calumet and Hecla mines and in 1946, the new Liddicoat detachable "one-pass" bit with driving fit on steel was developed. This bit has three planes
of rock cutting, with a semi-circular central hole, to
give an eccentricity to the hole and avoid its being
choked by a spike of massive copper.

The following data, obtained after exhaustive
tests run by the company, justify the adoption of this
bit in preference to the Timken detachable bit, which
had formerly been used there.

<table>
<thead>
<tr>
<th></th>
<th>Standard Timken Bit</th>
<th>Liddicoat Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches drilled per bit use:</td>
<td>77.8</td>
<td>230.0</td>
</tr>
<tr>
<td>Overall ratio of footage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>drilled (for C &amp; H Mines)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per bit use:</td>
<td>1</td>
<td>2.5 to 3</td>
</tr>
</tbody>
</table>
| Cost in cents per bit includ-
| ing depreciation on plant and | 10.0               | 12.2          |
| all other items (cents)    |                     |               |
| Number of regrinds:        | 5                   | -             |
| Speed of drilling (inches/min.): | 10.43              | 11.81         |

The Liddicoat bit being one-use bit, does not
have to be reconditioned, a fact conducive to saving in
the capital otherwise required for heat treating and
sharpening plant.

Four out of the eight of the company's mines
have been switched over to the use of Liddicoat bit,
while the remaining four are consuming the Timken bits
in the company's stock.
Introduction

Too much emphasis cannot be laid on the importance of selecting the proper type of drill bits and drill steel, to suit the conditions of the ground and type of drill machines available.

If the bits of right temper, shape, and sharpness are always available, the drilling operations will proceed efficiently, whereas any delay in supply of bits, or failure of any bit when put to service, might mean lowering the efficiency of the whole mine.

This paper does not claim to deal with all the aspects of the past investigations and subsequent developments of all types of drill bits of this country. It is primarily an effort at studying the general background of the drill bit problems with special reference to the bit types, experimented with or developed by the engineers and operators of the copper country in Calumet, Michigan.

The Calumet and Hecla Consolidated Copper Company has a sizeable collection of old and recent drill bits that have, at one time or other, either been used in actual underground mining or merely been experimented with, some of them dating as far back as 1895.

It has been attempted to draw a more or less continuous picture of the evolution of the recent type of bits, particularly the copper-country "Liddicoat" bit, explaining the various features of designs of different types, in their development in sequence of time.
It has been necessary to supplement whatever information was available, with theoretical discussion of the fundamentals of bit design.

The scanty past and recent records of the Calumet & Hecla Consolidated Copper Company have been added to, by information obtained from other sources. The steel shop practices of many other companies have also been briefly discussed.

A brief description of each of the outstanding bit types, old and recent, has also been included.

The author paid a visit to Calumet, to take photographs of the old drill bits from the collection of the above company and to study their recent bit shop practices.
CHAPTER I

BIT DESIGN

From the practical point of view, a drill bit may be defined as an appliance for converting the pressure power of the drill machine into the cutting power acting on the rock. The efficiency of the whole drilling system, therefore, depends upon the proper shape, sharpness, and strength of the drill bit.

In the earlier designs of the bits, before 1910 or so, major consideration was given to the improvement of the staying quality of the bit rather than of the cutting quality, mainly because of the labor required for hand sharpening and also because of the cumbersome process of changing steel.

With the improved drill chucks, steel changing became easy, and compact, small, mechanical sharpeners brought laying of more and more stress on the better designs incorporating accurate gage and proper shape of the bit, factors which are conducive to better cutting qualities. This investigation into the problem of better designs of drill bits was further helped by the installation, in a great many cases, of the underground sharpeners with oil or coke-fired furnaces.

Below are briefly discussed, the main requisites of a drill bit for the average conditions obtained in a drilling operation.
The factors which determine the qualities of a bit to be used for any specific job are the force and frequency of the blow transmitted from the drill to the bit; the speed and strength of rotation applied on the steel; the physical characteristics of the rock—namely its cohesion, abrasion, and hardness; and finally the method employed for the ejection of the rock cuttings.

General Features

1. Angle of Cutting Edge.—Depending on the hardness of the rock, the angle of the sides of the cutting edge should be so designed as to give the maximum of chipping or cutting action when it falls on the rock. If the angle is much smaller than required, a wedging action rather than fracturing or chipping of the rock results and if, on the other hand, it be much flatter than required, the crushing or pulverizing action is more predominant. It has been demonstrated that comparatively sharper or smaller angles work better in softer rocks. Smaller angles have the advantage of speed but lack in the strength of the cutting edge and also have the disadvantage of penetration beyond the zone of fracture; thus the mudding power of the bit is reduced.

In a hard and brittle ground, the rock particles of which can be readily shattered or disintegrated, it is very advantageous to use a single bit with a blunt angle at the cutting edge, because it possesses a greater crushing than wedging power, which is more desirable in brittle ground. This crushing action, if advantageously utilized, results in
a faster rate of penetration.

It is natural to imagine that a sharp angle of the bit would mean a faster rate of cutting, but in a hard rock, just the reverse is true. In Figure 1 below, is explained the reason for this.

![Diagram](image)

Let BB' be the bottom of the hole and let there be two cases (a) and (b), having the same kind of obstacle O and having two bits with a flat and a sharp angle of cutting edge respectively. If a condition of the rotation of the bit in the hole be imagined, it would appear as if the edge of the bit were drawn along the plane BB'. In case (a), the bit would be able to pass over the obstruction much more easily than the acute-angle bit in case (b), where the bit either has to break the obstacle by its force of impact to continue in its process of turning, or has to slow down or stop from turning. Most often the latter would occur, and, since the machine is delivering continuous blows on the bit, the relative depth of the bit with obstacle (or the height of obstacle above bit edge) would go on increasing during the period, hence the turning of the bit is obstructed. Ultimately the height of the obstacle might become so great as to completely eliminate any possibility of the turning of the bit, a condition amounting to very slow drilling speed and a great damage to the machine and
A value of 90 degrees seems to be suitable for the average drilling conditions obtained in rocks of slightly varying hardness.

2. Wing Thickness and Clearance. - The cuttings of the rock made by the edge of the bit, are got rid of during the process of drilling by being pushed toward the back of the bit through clearance between the wings. The sharp rebound of the drill steel when striking the rock face, together with the positive recovery of the machine, do the job of pulling the cuttings out. The wings have to be so designed that they have the minimum thickness possible to give them enough strength against breaking. On the other hand, if the wings are too thick and the cuttings do not have enough clearance to be ejected, the efficiency of drilling is lowered by the staying of the cuttings between the bit edge and the solid rock and consume the energy of the bit stroke in being pulverized. 3/

3. Taper of Wings of the Bit. - The excess of the diametrical length of the cutting edge over any other part of the bit or steel, is a factor affecting the freedom of movement of the bit in the drill hole. If the extremities of the cutting edge of the bit are making a circle of larger diameter than any other part of the body of the bit, the bit remains free to move in the hole and does not consume any energy while turning. Now this condition has to be maintained all through the drilling life of the bit, i.e., until it is dulled at
its cutting edge. The cutting edge goes on wearing and thus cuts circles of decreasing diameter continually, and yet this decreased diameter has at all times to be the largest diameter in the whole bit body. It is evident, therefore, that enough allowance has been made for this decrease in gage while designing the bit. This is achieved by giving the wings a taper of 1 in 4, or 1 in 5, and not smaller. Otherwise, the shoulders of the bit would soon become equal in diameter to the cutting edge itself and thus give a very long reaming surface rubbing against the walls of the hole. This taper of the wings is also affected by factors like the size of the bit as compared to the size of the drill steel, the force of blow and the character of the rock being drilled.

4. Length of the Cutting Edge.- The length of the cutting, meaning the combined length of all the cutting edges, is a factor affecting the drilling speed, and the length of the life of the drill steel and the machine. As long as the cutting edge is sharp, a greater length gives a faster rate of cutting, but the effect is exactly reversed when the edge is dulled. This could be explained by saying that the cushioning effect of a blunt or dulled cutting edge gives a rebounding to the steel, and causes not only the slowing down of cutting speed but also a good deal of strain on the steel and the machine.\footnote{11/}

5. Reaming and Gaging Qualities of Bits.- The drill bit, in its downward motion during drilling, besides cutting the
rock at the bottom of the hole, also cuts loose particles of rock from the sidewalls of the hole. This necessitates provision of an edge or surface for reaming the sides of the hole and thus balances the heavy duty put on the extremities of the cutting edge. A reaming edge is provided if the rock drilled is tough and close grained but not very abrasive; and a reaming surface is provided where the rock drilled is abrasive and easily fractured. The provision of a reaming edge insures the maintenance of the required clearance of the bit. A reaming surface, curved concentric with the axis of the bit and varying in area with rock conditions, is of great advantage in an abrasive rock.

In drilling, the bouncing of the bit and its rotation wear the walls of the hole away, and produce a hole of a bigger diameter than the gage of the bit, a procedure called "overdrilling". The amount of overdrilling primarily depends upon the type of the rock being drilled. Sometimes this overdrilling may be sufficient to allow the drilling of the whole depth of a hole with the same bit and yet result in the bottom of the hole having the required diameter. If, however, the overdrilling is less than the loss in the bit gage, then a bit of next smaller diameter has to be used to drill that hole further.

In bit design, the first requisite for reducing the loss of gage is to have the points and corners of the wings of the bit cut circles of same diameters, and so produce a reaming surface with continuous bearing on the walls.
of the hole. Theoretically the greater the reaming surface, the smaller the loss in gage; on the other hand, the disadvantage of making too large a reaming surface is the impeding of the rotation of the bit due to greater friction and the consequent lowering of the speed of cutting. This principle seems to have been kept in mind in designing a double-tapered cross bit. If the bit is properly made, the reaming edge of that bit cuts a circle of the same diameter throughout its curved length, whereas if the reaming edge is formed as a part of the surface of a cone, concentric with the axis of the bit, the side corners of the reaming edge cut a circle of smaller diameter than the middle corners situated on the extremities of the cutting edge. This difference in the diameters of the circles cut, increases with an increase in the taper and width of the wings and a decrease in the angle at the cutting edge. Taking an example of a bit with 5/8 inch width of the wings, an angle of 90 degrees at the cutting edge, and a taper of the reamer at 5 degrees, the difference in the diameters of the two circles referred to above could be calculated as follows:

$$\frac{5}{8} \times \tan 5^\circ = \frac{1}{20}$$

Thus, before the outer or the side corners of the bit would have any part to play in reaming the hole, the middle reaming point at the corner of the cutting edge would have to be worn to an amount equal to 1/40 of an inch on each side, resulting in a total gage loss of 1/20 of an inch. If, however, the reaming edge was originally designed
as a part of a cylinder rather than a cone surface, that is without the second taper of 5 degrees at all, then this gage loss of 1/20 of an inch would be avoided, because then the whole of the reaming edge instead of merely its middle point would take part in reaming the hole. Another way of making the whole of the reaming edge cut a single circle, is to increase the radius of curvature of the reaming edges.

This practice of having all the points on the reaming edge cut circles of the same diameter has been very common in churn-drill bit design for quite a long time, but its incorporation in the design of percussion drill bits is comparatively recent. Another advantage of this design is that during the regrinding of the cutting edges, the gage of the bit does not have to be touched.

As has been previously said, the area of the cylindrical reaming surface at the end of each wing varies with the type of the rock being drilled; and the determination of the value of this area is best done by experimentation. After the wear of the gage of a bit, it may so happen that the length and hence area of the reaming surface increase more than desired; then in that case, the area could be decreased by grinding off a smaller second taper on the wings. This grinding, of course, would of necessity be done in special grinders.

The main advantage in maintaining the gage of a bit is that of a higher overall drilling speed.

The area of the reaming face exposed to the rubbing
action against the side of the hole has been found to control the depth to which a bit can drill efficiently, without binding. The bit usually commences to bind when the reaming face has lengthened approximately from 30 to 40 per cent over its original length. This lengthening of the reaming face can be checked by either grinding a taper as described above or providing originally an offset shoulder in the wing. The gage of the bit would then have to be reduced equal to this offset before any appreciable lengthening of the reamer could take place. The corners of the reaming edge have to be sufficiently strong to resist any tendency toward the reversal of the reaming angle, at least while the cutting edge is not dulled and is capable of drilling deeper.

6. Shape of the Cutting Edge.- To a certain extent, the shape of the cutting edge determines the wearing qualities of a bit. The various convex and concave shapes of the cutting edge are mainly a matter of individual choice, though partly affected by the characteristics of the rock being drilled.

It has been found that a convex cutting edge with a raised center, is more desirable for starting the holes, while the proper maintenance of hole alignment is better achieved through the use of a concave cutting edge. In a number of tests conducted by various engineers from time to time and also in practice, very little if any difference has been noticed in the results obtained by the curved types of bit edges on the one hand and the flat types on
the other. In modern designs no appreciable importance is attached to this consideration of the cutting edge shapes.

7. Other Considerations. - Care has to be taken while designing the shape of the bit, to make it simple enough for the purposes of tempering, forging, sharpening and so forth. Close attention has also to be given to the heat treating and forging of the bits. The various temperatures of hardening and tempering and so forth should be accurately determined by experimentation. Forging and tempering operations should never be carried on the same heat.

As far as practicable, the diameter of the hole and thus of the bit, should be the minimum possible value, as the speed of drilling varies inversely as the square of the diameter of the bit or the hole being drilled.

All the extreme corners on the cutting edges of the bit should be symmetrically placed from the vertical axis of the bit, in order to insure uniform wear and to prevent any rifling of the hole, which may result from one edge of the bit's being larger than the other.

If the rock is much fractured and has alternate hard and soft bands, the drill steel may get stuck in the hole and the hole may be lost. A fracture plane or a soft clay streak in the rock, cutting across the line of the drill hole at an angle gives great trouble so far as the alignment of the hole is concerned. Because the soft rock, as it comes into the hole, offers much less resistance to the cutting edge the bit has a tendency to divert from the
straight line course along the path of least resistance. This deviation of the bit from the straight course causes the binding of the steel in the hole. This may result in loss of time while the steel is withdrawn or even in loss of the hole. Another trouble encountered in soft streaks in a hard rock is due to the swelling of soft rock like talc or clay on coming in contact with water; such swelling jams the steel in the hole. Also the clay and talc cuttings, which cannot be completely washed out of the hole, may also bind or pack behind the bit.

Mining engineers vary in their opinion about the ratio of the diameter of the bit to the rod. A variation of from 30 to 100 per cent in the excess of the diameter of the bit over the diameter of the rod, according to the hardness of the rock, is allowable. The bit shoulder has to be greater in harder rock.

Straight-edged drills have been found to blunt quickly; edges with too sharp a curve blunt at the center first; and edges with light curves are best adapted to hard rock and those with sharp curves to softer rock. It is apparent that a rounded cutting edge is especially desirable in starting hand-drilled holes, because it ensures effectiveness of the first few blows by concentrating the work upon a smaller area of contact between the bit and the rock. Another advantage of a longitudinally rounded cutting edge is that any slight tilting of the drill does not mean any concentration of the blows on any one of the ears, which,
being the weakest part in a bit, are easily broken. This consideration is not so important in the design of the construction of drill bits for use with machine drills.

Comparing the reaming qualities of a single-edge or a chisel bit with a cross bit, it may be seen that even though the chisel design is faster drilling, it is much more susceptible to rifling the hole than a cross type, which has a larger reaming edge or surface, as the case may be. Besides the advantage of decreasing the possibility of a rifled hole, there is another point in favor of a larger reaming area; that is, the cross bit can drill a longer footage before reaming edges are worn off than a chisel bit can.

Special Considerations for Detachable Bits

The idea of using detachable rock drill bits is by no means a recent one. Its conception and a limited application may be traced as far back as the mechanical drilling itself. As two examples, Major Derby's bit and Anderson's detachable bit may be cited. Both of these belong to the last century.

The original idea of introducing a detachable type of drill bit into the mining practice seems to have been derived from the observation of the fact that two entirely contrasted properties and characteristics are required in the drill rod and in the drill bit. The cutting edge of a drill steel should resist abrasion, while the main part of the steel must transmit power to the cutting bit and
therefore should resist fatigue and shock. In short, the cutting end must be hard and the other part of the steel must be tough. It is clear that if the bit and the rod are of the same piece of steel, it is impossible to have two parts of the same steel of different compositions and therefore equally impossible to develop different properties in one piece. This in brief is the birth of the idea of a detachable bit.31/

Within only the past fifteen years, a distinct change over has been made from the use of the conventional steel to the new detachable bit, by almost all the major mining companies of the world.1/ Advantages:-

(1) The bit and the steel can be made of alloying materials proper for developing the qualities required by the work to be done by each, namely hardness for bit and toughness for steel or rod.

(2) Much saving is made in the tremendous amount of labor and expense necessarily incurred in the transportation of large weights of steel from the steel shop on the surface to the working faces underground, and back again to the steel shops for sharpening. A number of mine operators have, from time to time, collected data of such costs, which amount to a figure much larger than is normally realized.

(3) Besides the actual cost of transportation, another incidental item of cost is incurred. The use of the hoisting shaft for hoisting steel and lowering it takes
quite a long time; thus the ore hoisting capacity of the shaft is cut. A number of time studies have been made by mining engineers in Canada and the United States, and it is reported that as much as 25 per cent of the entire shift time is consumed in handling drill steel. The example of Witwaters Rand in 1930, is worthy of citing, where 10,000 to 11,000 drills were handled per shift of eight hours at one shop alone. This amounted to a transport and handling of 170 tons.

(4) A detachable bit made by any large manufacturing plant can be forged and fabricated under ideal and controlled conditions. Burning and cracking bits can be eliminated, and also any decarburized material can be removed from the cutting edges of the bits.

(5) The detachable bit can be heat-treated to uniform temper, hardness, and size specifications.

(6) More rigid inspection of the bits is possible, eliminating passing into the mine of any defective bit, which may have to be rejected underground, causing shortage and the like.

(7) The investment in hollow drill steel and other accessory equipment is very considerably reduced.

Design.—Almost all designs of bits prevalent in the conventional steel also find their copy in the detachable types.

The original Carr bit had an angle of 120 degrees at its cutting edge, which, for a detachable bit, could be
considered too large. For a rock which is hard and is
drilled by crushing rather than cutting, a 105-degree
angle is considered suitable.6/

The relation between the length and the diameter
of a detachable bit as well as the optimum wing tapers are
factors directly governed by the relation between the wear
of the cutting edge and the loss of gage. If the gage loss
is so rapid that the bit has to be discarded before the
cutting edges have been used up to their depth of hardening,
then the bit length has been greater than was desired; and
vice versa. Thus for a rapid gage loss, the bit should be
short and wide, whereas for a slow gage loss, it should be
slimmer and longer. The main advantage in maintaining the
gage is the speed of drilling.

It has been found by experience that a detachable
cross bit should be at least 1/4 inch larger in diameter
than the steel.

A hole in the center of the bit is found to in-
crease the drilling speed by as much as 20 per cent. In
brittle ground, the central hole may be 1/2 inch or even
more in diameter, but in tough ground, it has to be much
smaller. A fine example of this, is drilling through
native copper. If the hole is bigger than 1/4 inch, a
strong plug of copper will spike up into the hole and com-
pletely choke it. Often even a very small central hole is
thus plugged by native copper; therefore a diagonal or side
hole must be provided, so that even when the front hole is
choked, water circulation may continue through the side hole.

Greater depth of hardening on the cutting edges of the bit is a very important factor, since it determines the number of regrinds that can be made on one bit.6/

It has been found that providing an offset at the back of the reaming edge brings about an increase in the rate of drilling and power of penetration of the bit. As an example, comparison may be made between two cross bits of the following descriptions:

**Bit with an Offset:**

- Taper of the reaming surface . . . . 2 degrees
- Depth of the reaming surface . . . 1/2 inch
- Taper of the Offset . . . . . . . . . 45 degrees
- Vertical depth of the offset . . . . 1/8 inch
- Taper of the rest of the wing . . . 20 degrees

**Bit without an Offset:**

- Taper of the reaming surface . . . . 7 degrees
- Depth of the reaming surface . . . 9/16 inch
- Taper of the rest of the wing . . . 15 degrees

The above comparison would show that the bit with an offset drills 10 to 15 per cent faster than the other bit.
CHAPTER II

VARIOUS TYPES OF BITS

The various types of drill bits and drill steel that have been used from time to time during the past, could be classified in a number of ways, taking any one of the following items as the basis for classification.

- Hand drills vs Machine drills
- Hand Sharpening vs Power Sharpening
- Solid Steel vs Hollow Steel
- Conventional Steel vs Detachable Bits
- Steel Bits vs Hard Metal Bits

Most of these classifications would, of course, overlap when examined in sequence of time, but each of the above items has brought about a change in the drill bit design and drilling practice, distinct from previous practice.

Even in the above broad classification, there is ample scope for further sub-classification; for example, in the machine drill bits, there are two distinct eras, one of piston type of machine and its bits and the other of hammer type of machine and its bits. It may be added that the 'high center bit', which became obsolete for the piston type of drills, regained its ground and popularity in drilling practice with the increasing use of hammer drill machines. In the hollow drill steel again, there have been two stages of development. In the bits of earlier designs only one center hole was provided for flushing
water, while later on, when clogging or choking of the front hole became more troublesome, side flushing holes were provided on bits of recent design.

Plate 1-A
Showing Conventional Steel:
6 - heavy steel with lugs
7 - water hole lining
8 - one inch hollow hexagonal steel
9 - one of the earlier types of steel
10 - collared shank steel
11 - collared shank steel

The following are the types of bits, named either after the designer or after their peculiar shape or even after the place of use.
Conventional Bits

Square Cross Bits.-

This bit has long been acclaimed the standard for American drilling practice. It may be made from round, hexagonal or octagonal steel. In the copper mines in Michigan, it was usually made on a round steel. This bit satisfies quite reasonably the three requirements of a bit; namely, (a) to chisel, (b) to keep the hole free and unrifled, and (c) to mud freely. In fact, a fourth advantage to be had by the use of this bit is the drilling of the maximum possible footage before resharpening. The reaming edges of this bit may be rounded or flat, and also the cutting edge may be formed flat or in an arc.10/ Simon's Bit.-

This bit was used and developed at the Champion Mine at Beacon, Michigan. Two wings in this bit are devoted entirely to reaming the hole and keeping it round and free from rifles. The other two wings form a cutting
A test made at the above mine in some of its hardest ground was reported to have shown a speed two and one-half times the cutting speed of an ordinary cross bit.\textsuperscript{10}/

**Brunton Bit.**

This bit was invented by D. W. Brunton in the early years of this century and was long used in Idaho. The four cutting edges are not concurrent but are in an improved x-form. The bit incorporates the advantages of an x-bit minus the sharpening trouble encountered with the latter type. The resharpening of this bit is as easy as that of a cross bit.\textsuperscript{10}/

The four cutting edges of this bit are not concurrent at the center; the peculiar shape often gives trouble during resharpening. The only advantage claimed by this design is that of avoiding rifled holes better than a hand-sharpened cross bit, but with the advent of the power sharpening machines, a cross bit could
be sharpened so accurately that the difficult shape of the x-bit soon began to be abandoned.10/

**High-Center Bit.**

![High-Center Bit Diagram]

This bit has special advantages for starting a hole, because the high center at once makes an impression on the rock, while the square or flat-faced bit requires a perfectly flat-faced rock for starting. With the greater and greater popularity of the hammer drills, this bit also gained ground as a starter. The center of the cutting edge is raised by making

**High-Corner Bit.**

![High-Corner Bit Diagram]

This is a four-wing bit having its corners projecting ahead of its central and flat cutting edges. This is claimed to be a fast cutting type of bit, the corners breaking up the rock in an outer circle and the flat cutting edges doing the major part of
the work. The advantage of this bit is that the drill does not follow any seams or cracks it comes across, it drills a round hole, and it does not strain the machine excessively. The drawback is that the corners, if tempered too hard, are apt to break off.10/

Round Edge Bit.

This bit does not have reaming edges; it has a reaming surface instead. It is good only for drilling in soft rock and may rifle the hole if used in hard rock.10/

Plate 7

The Round Edge Bit

Y-Bit.

This is a bit with three cutting edges. It claims the advantage of incorporating the features of a cross bit in reaming and of having greater speed than the four-wing bit. It will not follow any cracks or fractures in the rock and it provides a large clearance space for the cuttings to be ejected.
The bull bit has a blunt-angled, single cutting edge and possesses greater crushing than wedging strength. It is especially suited to drilling in very hard rocks like flint, where drilling is more dependent on crushing by sheer force of impact than on cutting through. The reaming surface of this bit has no angular edge, but is made round, concentric with the axis of the bit. The advent of the power sharpener threw this bit into the background, as the sharpening difficulties of the American standard cross bit were overcome. The use of this bit is hard on the machine.

Plate 9
The Bull Bit

Z-Bit.

This bit has been used quite extensively in the lead districts of the United States and also in Germany.
This bit also belongs to the era of hand sharpening and has been neglected since the advent of the power sharpeners. It is a composite bit made by incorporating the advantages of the single cutting edge and the predominating features of the bull bit. The arc-shaped cutting edges, which are made diagonal terminals, provide sufficient reaming surface, besides providing the bit gage. The arc-shaped cutting edges also cut a channel around the periphery of the hole, and thus reducing the work of the diagonal edge by rendering the rock inside the circular channel easily broken.

**Six Wing Rosette Bit.**—This bit has long been used with hammer drills in Spanish mines. It is a typical example of the radial-cutting edge type of bit. The advantages claimed by this bit are the starting qualities and the avoiding of any rifling of holes, because of ample area of reaming surfaces.10/7/

**Double Cross Bit.**—The cutting edges of a double cross bit are not positioned radially, but are offset in such a way that as the bit revolves in the hole, the depressions made by the various cutting edges intersect and cross each other, so that the work done is more evenly distributed over the
entire length of the cutting edge, and the overall breaking effect on the rock is both diagonal and radial. As long as the bit is sharp, the greater length of the cutting edges brings the advantage of higher cutting speed, but as soon as the edge is a little dulled, the length of cutting edge
definitely becomes a handicap and starts giving rebounding
effect on the machine, often bringing disastrous results
to steel and machine, besides a slow rate of
cutting. The reaming
qualities of this bit are better than those
of a regular cross bit. In shape it is two crosses offset
from each other. The main objections to the use of this bit are the difficulties in making it, and then in resharpening and tempering it uniformly. If any negligence is shown in the tempering operation, the heat from the center of the bit runs down and draws the temper of the cutting edges at the center so much that before any appreciable wear has taken place at the extremes, the center of the edges becomes battered.  

Double Chisel Bit. - The comparison between a cross and a double cross bit is very similar to that between a chisel and a double chisel bit, which has two parallel cutting edges.

H-Bit. - In the double chisel bit, there is a disadvantage that the axial hole in the steel may get choked by a cone of
the rock left at center. This difficulty is overcome in an H bit by providing an intersecting transverse cutting edge. When sharp, this bit is quite fast drilling, but the two dead corners of the cutting edges do not allow a rapid penetration.

**Double Arc Bit.**—This bit has two arcs of cutting edges, the convex sides towards the center. It was developed to incorporate as many as possible of the advantages of its predecessor bits. Much experimentation was done under a variety of conditions of ground, force and frequency of blow, and speed and strength of rotation. It is claimed that this bit is fairly easy to machine-sharpen and that it is possible to draw quite a uniform temper on its cutting edges. After a series of very elaborate tests made with this and other types of bits, it was found that a double arc bit possesses greater stamina for cutting and reaming, i.e. it gives a greater footage before requiring resharpending; that it has the same cutting capacity as a cross; that its cutting speed does not decrease with depth so much as the other types; and that the wear of cutting edges and the gage reduction are small. A transverse edge connecting the two main arc edges gives properties similar to those of an H bit.

**Tippet Drill Bit.**—This drill was invented by an Australian
named Tippet. It is a hollow drill bit with a side channel for ejecting sludge. The drill has a hollow chamber running longitudinally through the center of the shank, where it has a curved outlet to the side just below the chuck. Through this outlet the cuttings or sludge are ejected. On the down stroke, the sludge enters the hollow steel, and the inertia, being not quite overcome on the up stroke, the sludge keeps the hollow channel filled and thus keeps moving out.10/

Lug Drill Bit.- This drill steel manufactured by Wood Drill Works has lugs on its sides, which, acting as scrapers, remove a little dirt on each up stroke.

Derby Tabular Drill Bit.- This is an old time bit, belonging to the nineteenth century. From the literature, it appears that this bit was patented by Ingersoll-Rand Company but was not put on the market for reasons not obvious. The bit was invented by one Major Derby, and could as well be classed with the detachable type. The drill steel and bit were both hollow, and the bit had six teeth. The bit was fastened to the end of a wrought iron drill rod with a steel pin or an expanding copper ring. This detachable quality saved the transportation costs of the rods. The cuttings were washed out by a current of water, which was introduced through a sleeve surrounding the piston rod. It was noticed during tests that the pieces of rock were washed out whole instead of being reduced to dust, thus the work done by the drill was reduced.10/
Carr Bit.— This bit was patented by Ingersoll-Rand Company. It has a single cutting edge and is uniform and symmetrical in shape. The special feature of this bit is a transverse recess cut across the center of the bit. In solid steel, the recess goes into the bit about half an inch from the edge and in hollow steel it is tapered back to join the hole in the steel. The aim of providing this recess is to make it act as a pilot and also to reduce the contact of the cutting surface with the rock. The length of the bit is equal to the bit gage and the thickness equals the short diameter of the steel. The sides of the bit are parallel in a solid steel and at 5 degrees taper in a hollow steel. The main advantages claimed for this type of bit may be enumerated as follows: It holds gage better than most of the other bits, and so drills a greater footage before steel change. It drills a round hole and has good turning qualities. Only 1/16 of an inch difference between the successive gages is required, so the diameter of the starter is decreased for a particular size of finished hole. The bit is easy to form, sharpen and so forth. 10/

The Carr bit helped a great deal in drilling a hole of uniform diameter, i.e., a hole without change of steel. The shape of the bit was such that it cut a round hole and the shoulders provided allowed for possible wear. The angle at the cutting edge being blunt gave a faster rate of cutting, which was also enhanced by the central recess. This bit proved to be suitable for a larger variety
Plate 16

The Carr Bit
of conditions than its predecessors.

The disadvantages of the bit are that there is always the difficulty of starting; there is a tendency of the bit to go crooked in the hole and produce a fitchered hole; and the punching of the big central recess is difficult -- it may even cause splitting of the bit.

Mohawk Bit.- In the earlier years of this century this bit was quite popular in the Lake Superior copper region, especially in the Mohawk and Wolverine areas. It gets its name from the mine at which it was first used. The bit has a projecting central cutting edge acting as a pilot and cutting the rock in advance of the regular four edges of cross pattern. The special advantage claimed for this bit is that there is less danger of the bits slipping to one side and thus giving a fitchered hole. The projecting edge acts as a centering device, and so maintains the body of the bit in line with its course. The only difference between this bit and the regular cross type is that the stepped form of the bit does the cutting work in two planes. The bit cannot, however, be used in very hard ground because of the danger of the advance cutting edge being smashed.25/

Leyner Drill.- The Leyner drills are used with the Ingersoll-Rand Company's Leyner machines. The shanks have lugs which provide the rotation of the drill steel while in operation.25/

Murphy Drill.- The difference between this and the previous
type is that a collar is forged on the shank to prevent the entering of the drill steel into the cylinder of the machine.

25/

Detachable Bits

The Anaconda Mining Company, one of the largest mining companies of the United States, took definite steps in the direction of the development of detachable bits, as early as 1917. Around the years 1922 and 1923, the company came out with a detachable bit which has ever since been used by the company at their various mines.

What is required in the mining industry at present, is the design and manufacture of a detachable bit which combines all the elements of simplicity, i.e., one that is capable of being readily attached and detached, is of sufficient strength to perform the required job, and is sufficiently low in cost that it can be thrown away when blunted beyond further useful life.31/

Below are briefly discussed the old and recent types of detachable bits:

Anderson's Bit. - This bit seems to have been one of the earliest types of detachable bits. It was made at the works of Messrs Thomas Firth and Sons, Sheffield, England. The weight of this bit was only 6-3/4 ounces. Fifty bits could be easily carried by a miner by passing a string through the center hole of each bit. A tie rod with a triangular head was passed through the center of the bit and the shank end was secured by a nut at the rear end.
The cutting end of the bit was hardened and the rest was left soft, particularly that portion which bore against the shank. Tests performed on the bit, however, showed that its removal from the shank was quite difficult and the bit had a tendency to seize.28/

Hawkesworth Bit. The Hawkesworth bit was invented and made at the shops of the Anaconda Copper Mining Company by one Mr. Hawkesworth and his associates. A patent on the design of this bit was obtained in 1922. Until recently, the bit, with minor modifications now and then, has been used at the mines of the above company. The attachment of the bit to the steel is through a peculiar connection described below. The bit is a double-tapered, regular cross bit, with 7 and 14 degree tapers. The reaming surface is about 1/2 inch long.

Plate 17

The Hawkesworth Bit
A forging and milling operation on the bit end of the steel leaves two projecting edges with a groove, the edges being at an angle to each other and not parallel. The two edges have bevels cut under them to hold the projecting flaps corresponding to them on the bit. The thread end of the bit, after a similar treatment, assumes a counter shape to the steel. The attachment is reported to have been satisfactory.

There are six sizes of the bit, including the starter, varying from 1-7/8 inch, being the diameter of the starter, down to 1-3/8 inch, being the diameter of the fifth. The officials of the Anaconda Copper Mining Company have reported that the use of this bit has resulted in considerable cost savings and that the bit has been used steadily for quite a number of years.

Riley-Rip Bit. - This bit was designed about 1932 by one George C. Riley of Canada and was patented by Messrs. Padley and Venables, Ltd. It is claimed that the bit drilled very successfully in some of the very hard rocks found at the Frood Mine of the International Nickel Company of Canada, Ltd. The special feature of this cross bit was the attachment to the steel by a threaded stud squeezed into the steel.

"Copper Country" Bit. - This bit was developed in the copper country of Michigan. A special feature is the presence of native or "mass" copper in the amygdaloidal rock of this country. The loss of gage is not severe, but consideration
has to be given to drilling through native copper. Comparatively much smaller holes are drilled in this country, the starter being only 1-5/8 inch in diameter. To certain limits, the smaller gage bit permits a very fast drilling rate. The typical feature of this copper country bit is the provision of a diagonal side hole, not smaller than 1/4 inch in diameter, coming out between the wings. When the front hole is plugged by mass copper, the side hole keeps open by virtue of its eccentric position.

**Bedford "Simplon" Bit.** The two peculiarities of this type of bit are that the bit is very long, about 6½ inches, and that it is fitted on to the stem of the steel without any threads, i.e., it has a driving fit on the steel. For detaching, special detaching blocks with vise to hold the stem and block to hammer out the bit must be used. 12/

In 1937, this bit was introduced at the Witwatersrand Mines and ever since it has been used in drilling there successfully. The stem end of the steel is of the following description. About 6½ inches of the stem is tapered slightly in the same direction as the stocket inside it. The socket, which makes a driving fit with the bit extends about 1-11/32 inches into the stem and has a total taper of 6 degrees. The mouth of the socket on stem fits the part of the bit which has the same diameter as the mouth. A copper lining, about .03 inch thick, is deposited electrolytically inside the socket to give a firm grip to the bit. The stem is made of 7/8 inch hexagonal
steel and is normally 54 inches long. The bit is 6\(\frac{1}{2}\) inches long and is made of a slug cut from a bar 1 inch in diameter and 1\(\frac{1}{2}\) pounds in weight. Drilling life of the bit, measured in terms of length is 3\(\frac{1}{2}\) to 3\(\frac{3}{4}\) inches. When the bit is discarded, the residual length is 3 to 3\(\frac{3}{4}\) inches. Roughly 28 to 30 sharpenings can be given to one bit, losing about 1/8 inch per sharpening.\[12/\]

Once the bit is placed in the stem, a few blows of the drill machine give a tight fit to the two components, which can then be separated only by force of several tons.

If a stem breaks, it can be used in the shop for holding the bit while the bit is being forged or sharpened. Repairing the taper of the stem is costly because of the precision required in the work. After subjecting the stem to a roughing process, the precise taper is given by a lathe equipped with a taper-turning attachment.

**Padley and Morgan Bit.**\[12/\] This is a "one-pass" bit, i.e., it is discarded after one use. The bit was patented in England in 1938 by Rip Bits, Ltd., and has been manufactured in South Africa, under license, by the Union Steel Corporation of South Africa, since 1939. In English money, the original sale price of this bit was 3\(\frac{1}{2}\) d. per bit, but has since been
increased to 4-3/4 d. per bit. This bit is also used in the Witwatersrand Mines.

The bit weighs 2/75 to 3.54 oz. It has a diameter of 11/16 to 1-3/8 inch, and 1-1/8 to 1-1/4 inch overall length. The tapered socket (2 1/4 degrees) is 7/16 inch deep with a thickness of "skirt" between 7/64 and 10/64 inch. A special type of bit detacher has to be used for disconnecting bits from steel. The stems are 7/8 inch Chrome-Molybdenum hexagonal steel with 1/4 inch water hole, of variable length but usually 63 inches long. A firm driving fit is obtained by the difference in taper between the stem and the bit, the former being tapered at 4 degrees and the later at 2 1/2 degrees. The stem stretches the bit a little because of the difference in tapers, and a tight fit is obtained. A reconditioning of the bit has also been tried at a more recent date. Two reconditionings were successfully obtained after one original use.

Jack Bits.- The Ingersoll-Rand Company has been making a vast variety of drilling bits of various sizes and shapes, varying in number of cutting edges from one to six. They are all double-taper bits, with variations in the values of the tapers. There are Carr and Cross types, and also side holes and center holes. The earlier types of all the Jack bits had thread connection to the steel, but recently the new "Stud Jack Bit", having a stud connection, has been put on the market. A threaded stud is drilled by a sharpening machine into the bit end of the steel, and on this
stud is screwed the bit. This new bit is claimed to have much extra metal in its skirt. The short stud is made of the best possible alloy steel and is threaded on the bit with an improved reverse buttress thread, and is machined on the steel end to give a cone of undulating surface instead of plane taper, for better grip.\textsuperscript{15, 20, 34}

**Timken Bit.** The Timken bit is the present rival of the Jack bit, and is made by the Rock Bit Division of the Timken Roller Bearing Company of this country. In 1943, the company evolved five series of bits out of the original design having screw connection and shoulder butt between the bit and the steel. A large depth of hardening on the cutting edge is claimed for the new bit. The shoulder (collar-like) of the steel butts directly against the skirt of the bit, and saves minimum strain on the threads by absorbing all shocks.\textsuperscript{1}
The main trouble experienced by the engineers of the Calumet and Hecla Consolidated Copper Company mines is that because the clearance angle is small, the clearance between reamers and wings becomes too small after some wear of the reamers and results in a lack of freedom of movement of the bit in the hole.

Craig Bit.- The Craig bit is one of the new types that have recently been put on the market. The bit and steel connection is threadless. The bit end of the steel has an Archimedean spiral, also the cross section of the bit socket is spiral shaped. These spirals help in locking the bit firmly to the steel.

The objection to this connection, presented by one of the mining engineers who has examined the bit, is that when the skirt on one side becomes much thinner than that on the other side, an inconsistency in the uniformity of the skirt strength results, and also the bit becomes somewhat eccentric. The locking also sometimes becomes too tight, and the bit is therefore difficult to detach.

Redington Bit.- This is a bit built more or less on the design of the Craig bit, only it has two spirals instead of one, i.e., the cross section of the bit end of the steel is
of a cam shape, fitting into a bit socket having two spirals. This bit has recently been designed by the engineers of the Britannia Mining and Smelting Company of Canada. The four-wing Timco bits were all forged from conventional steel, but the detachable type of the bit has been made in the three-wing design. The investigations that led to this design were started to discover a solution to excessive wing breakage, when it was observed that a bit with a broken wing often drilled faster than the undamaged bit. The main advantages were, first, a greater clearance for escape of cuttings and second, a decrease of total area of reaming sur-
face without affecting wing strength. This bit has flattened cutting faces, steep reamers with offsets, and thin wings.24/ Tri-State Three-Wing Bit.- This bit was designed in the tri-state district and was manufactured by both Ingersoll-Rand and Timken Companies. The country rock of the sheet ground deposits of zinc and lead is chert, which, being very abrasive, results in a high loss of gage.

Plate 25

The Tristate 3-wing Bit
& The Tristate 4-wing Bit

The bit had to be discarded after one use, because not much metal was left on the edges for any resharpening. Rate of cutting and gage loss were found to be improved by using Carr and bull bits, the only trouble being deflection of hole on meeting nodules of chert. The three-wing bit theory was put forth as a compromise between the speed and anti-
gage-loss qualities of single bits and non-deflection and reaming qualities of cross bits. Experiments were conducted by converting six-wing bits into three-wing ones. Larger cuttings, broken with less energy, could escape through greater wing clearance of a three-point bit. The bit had the following dimensions:

- Diameter of the cutting edge: 2-5/8 inches
- Thickness of wings: 3/4 inches
- Diameter of skirt: 1.39 inches
- Height of bit: 1-3/4 inches
- Diameter of circle joining wings: 1-9/16 inches
- Taper of the reamer: 1 degree

**Liddicoat Type B Bit.** This bit was designed and patented by Mr. Liddicoat, foreman of the Steel Shops of the Hollinger Consolidated Gold Mines, Ltd., Timmins, Ontario, Canada. It is a full-reaming, center-hole cross bit, made of 0.9 to 0.95 per cent straight carbon steel.
The following are the operations for making the bit. The slugs are first heated and then forged in a die press; the flashings are then trimmed off in a punch press. The cutting edges of the bit are retouched by grinding, and the bit is finally hardened.

The bit is attached to the rod by a driving fit, the bit end of steel having four flaps milled on its round end. The round socket of the bit has four corresponding projections, which fit on the flaps and arrest any tendency of the bit to turn on the rod.

The lower taper on the bit is left in annealed form, so that after receiving blows in drilling, it drives back on the rod, flattening the skirt a little and making its grip tighter on the rod. This grip insures against any possibility of the bit's being lost in the hole during drilling.
CHAPTER III

TUNGSTEN CARBIDE BITS

Tests. - The German mining industry has been far ahead in the use of hard metal bits in percussive drilling underground, as compared with the American mining industry.

In Germany, hard-metal bits have been used at Rammelsberg mine at Goslar in the Harz mountains for over ten years. In reports put out in 1941, it is claimed that the hard bits cut down the cost of drilling by about 50 per cent. In reports of 1942, it has been stated that 30 per cent of the entire drilling was done by hard-metal bits. Bits used with "Borstag", a special steel, gave a drilling performance of 172 m. per bit, and other tests using normal "Rochberg" hollow steel gave a drilling of 250 m. per bit. After World War II, this mine started using the hard-metal bits both in stoping and development.26/

Tests conducted by Holman Brothers of Camborne, Wales, England, showed a footage of values between 80 and 300 feet per bit use. A single bit drilled 800 feet in Cornish granite and 2,300 feet in sandstone. Tests conducted by various bit manufacturing companies, like Ingersoll-Rand, have indeed been encouraging. It has often been reported that 250 feet of hole have been drilled with a gage loss not exceeding 1/40 inch; and, speaking comparatively, the standard bit had to be discarded after a mere two feet of drilling in this ground. The United States Vanadium
Corporation conducted tests with two types of tungsten carbide bits, namely the single or the two-point and the cross or the four-point type.26/

The chisel bit was made by putting the carbide insert into a groove forged at the end of a steel; the insert had 90 per cent tungsten carbide and 10 per cent cobalt. This bit was used with a hammer drill delivering a large number of light blows. The same type of bit was manufactured in Sweden and tested with a special light drill, operating at 70 pounds per square inch of air pressure. The tests conducted by the Vanadium Corporation at Rifle, Colorado, indicated an average life expectancy of 350 to 500 feet per bit. The gauge loss in the entire life of the bit does not exceed 1/8 inch. In hard ground, reconditioning of the bit was done five times by silicon carbide wheels of 40 to 60 mesh. These were used on a portable air grinder, the operation being conducted very near the face, and the finishing grind was given by a short hand honing, to remove the grind marks and so forth. Tests showed the speed of drilling with the carbide bits to be 2 to 3 times faster than the speed by regular detachable bits of steel. The carbide bits were used with light jackhammers and the steel bits with heavy drifters.

The four-point bit tested by this company was developed by Ingersoll-Rand, Carbaloy Company, Alleghany-Ludlum Steel Company, Sullivan Division of Joy Manufacturing Company, Chicago Pneumatic Tools Company, Firth Sterling
Steel Company, Haynes Stellite Company, Kennametal Inc., and others. The tests were conducted at the United States Vanadium Corporation, Pine Creek Mine. Two types of attachments of bits to steel were made, one the "screw-on" type and the other the pressure-welded type (welded by Linde Air Products' pressure-welding process).

Machines used were standard Ingersoll-Rand 3½ and 3 inch drifters and 2-5/8 inch jack-hammers. Steel used was 1-1/4 inch hollow-round lug shank and 1 inch hollow hexagonal. Jack rods were made of high-Nichrome alloy drill steel. The life expectancy of the bit, obtained by estimates of these tests, was 78 feet per bit. The ratio with a steel bit was 76:1. For the life of the carbide bit, the average speed increase over steel bits was 35 to 50 per cent. Loss in gage never exceeded 3/32 inch. The bits, to be used for block holing in the future, might be predicted to have a gage of 1/2 inch.21/

Advantages. — The special use of the tungsten carbide insert bits will be in hard ground where the present-day equipment fails because of heavy strain. The use of these bits may be expected to eliminate, to a large extent, the use of steel of various lengths. Also, if a special alloy steel is developed, which will be necessary with these bits, the steel breakage may also be reduced to a new low. In mines where the working places are remotely situated from the shaft, the cost of transportation of drilling equipment will be substantially cut down. Besides the above, there
are a number of other diversified advantages of the tungsten-carbide insert bits; the uniform-sized drill holes are easy to load uniformly and give a proper contact between the explosive and the rock. The amount of explosive used per ton of rock broken may also decrease and thus lessen the chance of a big "blast". The air consumption of the lighter drill (which will be universally used) will also decrease, possibly by one third of its present value. There will be longer periods of actual drilling without wasting any time in bit changes. A longer feed per drill hole (longer drill holes in one steel feed) will be possible.26,32/

Making the Tungsten-Carbide Inserts. 3/ First, tungsten carbide has to be produced. There are two methods for the production of tungsten carbide. In the first, the mixture of tungsten, carbon, and some binding material is cold pressed and then sintered. In the other, the above mixture is hot pressed.

Tungsten is mixed with lampblack and heated to 1400° C. for some hours. The tungsten carbide produced is ground in ball mills to minus 15 microns. A binder, cobalt, is then added in ball mills. After addition of a little lubricant (paraffin), the mixture is pressed under several hundred tons pressure. The final sintering is done at 1500° C., in a reducing atmosphere (hydrogen).

Hot pressing is performed in small graphite molds, heated by being connected to electrodes, utilizing tungsten carbide as resistor, or by high frequency methods. Allow-
ance must be made for a little loss of cobalt, because of its being squeezed out when pressure is applied. Because tungsten-carbide shrinks considerably, getting small tolerances in the bit sizes is a problem. Allowance has to be made for this shrinkage before heating. If, however, very accurate size is required, diamond-impregnated wheels may be employed for grinding accurately to the required size.

By the addition of 5 to 12 per cent cobalt, strength to withstand shock (i.e., toughness) is developed in tungsten carbide, though it is at the sacrifice of some hardness. The property of hardness also depends upon the grain size of the tungsten carbide after grinding. A mixture having coarser grains gives more strength to the insert, whereas fine-grained material gives hardness. To withstand the strong pounding during drilling, the material used should have sufficient shock-resisting qualities.

The use of iron or nickel has also been suggested as binding material in tungsten carbide, but cobalt has been found to have a definite advantage, namely, the filling of any shrinkage pores after cooling. The whole content of cobalt is rejected on cooling, whereas some iron is left in solution even on cooling. The cobalt thus gives proper density and compactness to the tungsten carbide.

Brazing. — For brazing tungsten carbide inserts to the grooves or slots in the steel bit, a silver solder consisting of silver, copper, and zinc is employed. The solder flows
easily at brazing temperature of 1,100°F. According to the recommendations of the Firth Steel Company, there should be no chromium present in the steel, since the former contaminates the solder. The bits and inserts must be thoroughly cleaned before brazing.

The thickness of the solder joint is said to play a very important part in the tensile strength, which decreases considerably with a very minute increase in the thickness of the joint. The silver solder may be first tinned to the slot, or sandwich brazing may be done by inserting into the slot, silver solder strip of 0.005 inch thickness.

Care must be taken to use a proper flux, which melts at the brazing temperature, covers the joint, and prevents any oxidation. A reducing or neutral flame should be used for heating the joint. A slight pressure during cooling results in the proper seating of the inserts in the slots.

**Types of Commercial Bits.**—Tungsten carbide is one of the hardest metals in industrial use, its hardness varying between 9.0 and 9.2 on Moh's scale.

Germans made use of Shore Sceleroscope to determine hardness of various rocks and also to obtain an estimate of the rebound the bit would actually receive from any rock so tested. The selection of the tungsten carbide, of the drill machine and of the design of the bit, were all made on the basis of results of these tests.

General construction features of the hard-metal
insert bits are very much the same as those of the other steel bits. The main difference is in the angle at cutting edge, which, for hard metal, is between 100 to 110 degrees as against 90 degrees for steel. A difference between the continental and the American bits is the shaping of the cutting edge. In the former, it is common practice to grind the edge on a radius, whereas in the latter the cutting edge is flat.

**Bertl Bit.** - One Erhard Bertl in Germany designed the bit in which the inserts were not placed radially from the center but were offset, with one insert extending up to the center. The advantage of this was that it destroyed the wedge of rock which forms under the center of a regular bit, slows down the cutting speed, and causes excessive abrasion.8/

**Cormant Bit.** - This chisel bit is manufactured in Sweden. The insert is mounted on a single slot, forged at the end of a steel. The Swedish light drill, called Jackleg, is used with this bit. Three companies in Sweden are manufacturing this bit today. 8,13,34/

**Plate 27**

**Cormant Bit**

**Stud Carset.** - This is an Ingersoll-Rand bit interchangeable on a jack rod with the stud jack bit. The reaming corners only have to be ground round before putting the bit to service; otherwise, no sharpening on edges is required. There are four inserts
Stud Carset Bit

Kennenmetal Bit. - These are rotary and percussive types of hard-metal insert bits. The rotary bit may be coring or non-coring, whereas the percussive bit is generally a chisel type. This bit has no clearance grooves.34/

Rip Bit. - This is an English bit, manufactured by the Rip Bit Ltd. The bit has side water holes. The male threaded part is on the bit rather than the rod.3/

Sulmet Bit. - This bit can be resharpened. It has a central water hole and is of the double tapered cross type.34/

Holbit. - The cross bit of this type has a central water hole and use is made of a tapered socket for connection to the steel.3/
Plate 30
Rip Bit

Plate 31
Sulmet Bit
Firth Sterling Bits

Firth Sterling Bits.—There are various types of bits, including the chisel and cross bits, having two or more flushing water holes and clearance grooves. It is claimed that a special method of forging is employed in making these bits, to avoid any edge cracking. There are mostly small gage bits, used for drilling secondary blast holes.

Plate 32

Firth Sterling Bits
CHAPTER IV

MAKING, SHARPENING, HEAT TREATMENT AND TESTING OF BITS

Making.—Since the detachable-bit manufacture is fundamentally different from the ordinary conventional bit manufacture, it is necessary to give some idea of the major operations involved in detachable-bit making. The following is the practice followed by one of the largest rock bit manufacturing companies of this country, The Timken Bit Company.¹

The rods are first heated in gas furnace to 2000°F, and then pass through an upsetting machine, where slugs of predetermined length are cut. In this operation, the bit is partially formed in a special die. These blanks are then forged in a press, to the finished size. A trimming press then trims the excess flash metal. The bits then pass on to a gas-fired annealing furnace having automatic temperature control where the bits are annealed in four hours. Here, atmosphere is carefully controlled to avoid decarburisation, and special grain structure is developed to bring better machining properties.

The bits then pass on to a battery of five spindle automatics, here the bits are bored to thread size, the center hole is drilled, and the back face of the bit is faced and chambered. A drill then counter bores the holes. The bits go to special broaching machines for finishing the flutes and making cutting edges on the bits. In smaller bits, extra clearance is given by grinding. Multiple-
spindle machines drill the side holes if desired.

The final operation is milling the outside of bit skirt to proper diameter. The bits are then sent for heat treatment (described on later pages).

In earlier days the conventional bits were forged and sharpened by hand.

There were two methods of hand sharpening. The first, called the set-hammer system, consists of hammering the steel in a set hammer. The second, called the fuller and dollie system, comprised of drawing the stock sharp at the corners and then setting it back in the center with a dolly.

Then came the age of machine sharpening. This again has been of two types; the first method is called hot milling, and second is called cold grinding. In the former method, steel is heated to a certain temperature to make it easy to work on, and then with the help of dies and dollies, the cutting edges are sharpened.

Various types of furnaces for heating the steel and different machines for forging or sharpening the bit have been developed from time to time. There have been machines of different design and different capacity but all utilized the same principle and even the same type of swaging tools and dies and dollies, and the like. Furnace temperature controls have been used from time to time; base metal thermo-couples and so forth.11/

Heating Treating.- Steel, when heated to specific tempera-
ture, depending on its composition, dissolves carbon into solid solution and also attains a definite grain size and structure, different from that which it had before being heated. These conditions give different hardness and toughness properties to steel, at different stages. The idea of heat treatment of steel, therefore, is to develop the required qualities. The process usually consists of heating to a precalculated temperature, cooling at a predetermined rate, and then drawing at a previously set temperature for a definite amount of time, to relax the strains due to cooling, and to bring the hardness to required value.

Within certain limitations, the higher the carbon content, the easier the steel is to harden; but the high carbon content of steel would "burn" or oxidize at a lower temperature than if the content were low. A high carbon steel must be heated much more exactly than low carbon steel.

23/ A great effort has been made by the engineers to design furnaces with better temperature controls. Chronologically they were coke fired furnaces, gas fired furnaces, liquid heating baths and then electric furnaces. The Gilman automatic electric heat treating machine is one of the latest designs for heat-treating furnaces. Similarly, since the quenching must be uniform and at constant temperature, many designs of quenching tanks have been evolved. To control the rate of quenching, different media have been used like cold water, hot water, oil, air, mica, or mixtures of water with rapeseed oil, coal tar, salt or acid.
The composition of most of the bit steel used in this country varies within the following limits.\textsuperscript{14}

- Carbon: 0.75 to 0.90 per cent
- Manganese: 0.25 to 0.40 per cent
- Silicon: 0.20 to 0.25 per cent
- Phosphorus: Under 0.02 per cent
- Sulphur: Under 0.02 per cent

Alloy steel of chrome-molybdenum type must be forged between 1900 and 1800°F and hardened between 1500 and 1450°F, by quenching in oil bath at a temperature of 100 to 120°F.

The shanks of alloy steel have a hardness of 380 Brinell, while a hard rock may require a shank of 440 Brinell. To achieve this, the shank could be heated to 1800°F and laid to cool in air.

By lightly dollying the steel, heated to 1950°F, sufficient hardness can be produced. Oil quenching of alloy steels gives a Brinell value 80 to 90 points higher than air cooling.\textsuperscript{14}

\textbf{Sharpening and Heat Treatment Practice at C & H Shops.}—Before the detachable bits were introduced, the conventional steel was sharpened in the Ingersoll-Rand dolly and die type of forging machine. When the bit started cracking, it was sheared off, a new portion of the steel was properly heated and another bit was forged with the above machine. One man, heating his own steel, sharpened about 300 bits a day.
The dolly used was of large size and the bit was pushed right through the die. The dolly worked on the bit in this position outside the die. The dolly had both a forward and backward action on the bit, also on its free sides. This practice gave sharper cutting edges. The Calumet and Hecla Company shops were the first to sharpen bits outside a die, even though the machine manufacturers had advised otherwise.

In June 1940, for the first time detachable bits were put to service, and then the above hot-milling practice was abandoned and the bits were sharpened by grinding. The Timken bits are ground five to six times. Grinding is done by flute or bevel edged emery wheels, and gaging is done by flat-edged wheels, i.e., wheels used for touching reamers on bits. There are two sharpening shops, each having two Masco 38 rock bit grinding machines. Two emery wheels are

Plate 33
Showing the emery wheel grinding machine for Timken detachable bits
mounted on each machine. One of the two machines has both grinding wheels, the other machine has one grinding and one gaging wheel, i.e., there are three grinding wheels to one gaging wheel, since it takes longer to sharpen the edges than it does to touch the reamers.

The bits from underground are cleaned and taken to the gaging wheel; after gaging, their edges are ground; and then one man tests them for gage size and sorts them. They are then mounted on carriers. If the bit is not of any exact gage, it is termed the short of a particular gage number, which it approaches in size. The supply men carry 2 to 4 carriers, each having 22 bits; and the bits are distributed to miners on each level station.

Hardening of the bits is not done too often; only if a bit, which is in good condition, becomes soft and starts turning at its cutting edge is heat-treatment given. The bit is kept at 1450°F for one hour in an electric furnace, and then it is stood up on a screen placed under water at a depth of 1/4 inch. The water is at 100°F, and is kept in circulation to avoid developing a plane of weakness on the bit edge, which might occur if the water were stationary; hot water is used to avoid any cracking of the bit.

The heat treatment of steel is as follows:

20 foot rods of high quality crucible steel of 7/8 inch quarter-octagon section, are cut off to required sizes in Ingersoll-Rand cut-off machine. (Previously, 1 inch hexagonal steel was used). The cutting machine has an emery
wheel of 3/32-inch thickness. These rods of 2 to 10-foot lengths, are then shanked on one end. The corners are bevelled and tested for a fitting size of the chuck of the machine. One inch of the shank end is then heated to 1450° F. It is then quenched for a period of six seconds in cold running water, up to a depth of 1/4 inch from the ends. This quenching brings the structure of the steel to martensite. After this operation, 18 inches of the rod are then plunged into a bath containing Houghton No. 2 quenching oil.

After the shank end of the rod, the thread end is heated to 1900° F in a coke-fired furnace. A length of 1-3/8 inch on this end is then upset in an upsetting machine. After some machining, this length is reduced to 1-1/4 inch. The thread portion is 1 inch in diameter and

Plate 34
Showing upsetting machine for putting threads on Timken rods.
5/8 inch in length. (Plate 2) The rod thus upset is allowed to cool in air. It is again heated to 1450°F in an electric furnace, after it has attained this temperature, it is withdrawn and placed in cold powdered or flake mica and allowed to cool, for softening. The thread end is then annealed at 1600°F for a period of 1 hour and then allowed to cool in air. The thread end is again heated to a temperature of 1540°F in a furnace for one hour and then quenched in cold oil and left in the oil only long enough to bring down the temperature to about 400°F, so that the rod is self-drawing or tempering, when allowed to cool in air.

Testing. The following seems to be a correct procedure specification for testing efficiency and cutting speed, and so forth, of drill bits:

(1) All testing should be done by the same machine and by the same operator.

(2) Holes should be drilled across the structure and spaced so as to eliminate as many inconsistent results as possible.

(3) All holes should be collared with separate bits and collar distances measured and recorded before insertion of the test steel.

(4) With few exceptions in cases of special tests, each test should be done for about 20 seconds; that is, after every 20 seconds, drilling should be stopped and readings taken.
(5) Constant air pressure of about 90 pounds per square inch should be maintained.

(6) Records should be kept of all chipped corners, broken wings, and tight steel.

Tests conducted at the Mount Weather Testing Adit of the United States Bureau of Mines showed that, in general, a gage reduction from 2.077 inch to 1.826 inch, i.e., a difference of 0.025 inch, gave a drilling speed increase of 65 per cent. A full reaming bit of 1-15/32 inch diameter drilled 164 per cent faster than a standard cross bit of 2-1/16 inch diameter.

C & H Company Tests.—Tests conducted by Calumet and Hecla Company with Timken detachable bits and conventional bits gave the following results:

<table>
<thead>
<tr>
<th></th>
<th>Conventional Bit</th>
<th>Detachable Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet drilled</td>
<td>52.0</td>
<td>52.7</td>
</tr>
<tr>
<td>Number of bits used</td>
<td>17.</td>
<td>10.</td>
</tr>
<tr>
<td>Inches per minute (actual cutting time)</td>
<td>8.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Breakage of rods or shanks</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feet drilled per bit dulled</td>
<td>3.06</td>
<td>5.28</td>
</tr>
<tr>
<td>Gages (in inches)</td>
<td>1-5/8 to 1-5/8</td>
<td>1-3/4 to 1-5/8</td>
</tr>
<tr>
<td>Gage change (in inches)</td>
<td>1/16</td>
<td>1/16</td>
</tr>
<tr>
<td>Cost per bit sharpened (in cents)</td>
<td>8.0</td>
<td>-</td>
</tr>
<tr>
<td>Cost per foot of hole (in cents)</td>
<td>2.85</td>
<td>-</td>
</tr>
</tbody>
</table>
Steel Testing Machine. - The bit shop of the Calumet and Hecla Company has a steel testing machine, in which all new steel samples are tested. It consists of two drilling machines (Chicago Pneumatic type drifters) and two special hard steel blocks with holes cut to fit the steel gage. The steel is put on the machine run at 90 pounds per square inch air pressure. The special steel blocks serving as the rock to be drilled. The number of minutes the steel is on before finally failing is a comparative measure of its strength and quality.
CHAPTER V

HISTORY, GEOLOGY AND MINING PRACTICES
OF CALUMET, MICHIGAN

History.-22/ The copper country of the Michigan state is in the extreme north of the Northern peninsula. The copper-bearing lodes occur in a belt roughly 2 to 4 miles wide and 100 miles long.

Dr. Douglas Houghton, Michigan State Geologist, reported on copper deposits in 1837, and regular mining operations were started in 1844.

Five of the biggest six ore bodies lie in the amydaloids, the sixth being in the Calumet and Hecla conglomerates. The ore mineral is all native copper, though in earlier days, some native silver was also encountered in the upper horizons.

The Calumet conglomerate ore body occurs in a felsitic conglomerate which has a thickness of 10 to 12 feet in Calumet, widening with depth to a maximum of 20 feet. The copper content of ore in the upper levels until 20 years after commencement of mining, was 90 pounds to a ton, which gradually dwindled down to 40 or 30 and now is a low of 25 pounds to a ton.

Geology.-22/ The Keweenaw formation of Michigan is made up of many basic lava flows, interbedded with acidic conglomerates and sandstones. Almost all through the series, a major fault and innumerable minor faults have
cut the formations, which are many thousand feet thick, consisting of several hundred lava flows.

The copper-bearing lodes occur in the control parts of these thick formations, which had often been intruded by felsitic porphyries.

During the cooling of lavas, gases escaped and formed vesicular cappings all along the upper flows, which later had some of their minerals replaced by native copper, forming what are called the amygdaloidal veins of this district. In the intervals between flows, the felsitic rocks of previous eruptions, were eroded and redeposited, giving rise to the conglomerate deposits of today. The copper, in both the amygdaloidal and the conglomerate deposits, appears to have been deposited from hot solutions, which sometimes replaced the cementing material of pebbles also, with copper.

Physical Characteristics. Thick beds of trap lie over and under the Calumet Conglomerate, which is 10 to 20 feet thick. The lode is made up of quartz, porphyry, and felsitic pebbles, cemented by native copper, calcite, quartz, and rock particles of the same composition as pebbles.

The rock is very tough and highly abrasive, with an average hardness of 7. The fillings contain massive copper; and there are abundant pebbles, particularly replaced by copper or having copper inside.

Sandstone lenticules are quite common in the conglomerates. These sandstones do not contain any metal
but because of their interposed position with the mineralized zones, must be mined out. The well defined parting of sandstones from the other rocks, makes support difficult. The whole of the trap above the back is crisscrossed by dry and tight joints or slips, being quite shattered in some zones. The floor has a broken capping over trap, which contains softer minerals like calcite and chlorite, offering a contrast with the hard conglomerate.

Mining.-28/ The earlier method of mining was advanced in a haphazard manner. Increasing roof pressure and frequent occurrence of rock bursts changed the method of stoping into a retreating one, using heavy amounts of timber and practicing square-set mining in thick vein areas.

Drilling.-22/ Various types of machines have been in use at these mines, from time to time. Leyner type of drills, with 3-1/2 inch pistons and mounted on 3 inch single jackpots were used for drifting and stoping since 1930 while jack hammers were used for trimming and blockholing work. A more recent machine used is the Chicago Pneumatic hammer drill. Hollow hexagonal steel of a cross section of 1 inch across flats, was used first and then 7/8 inch quarter-octagon hollow steel was introduced. These steels have been bought mostly from the Crucible Steel Company. Because the rocks are faulted and seamy, single-edge bits could not be successfully employed, because they would jam in cracks and seams.
Showing drilling machine (Chicago Pneumatic) using Liddicoat bit in stopes encountered in holes. Cross bits have therefore been used for quite a long time.

In all drifting operations, pyramidal downcut was the standard round drilled, requiring drilling of 13 to 20 holes and pulling out 4½ feet of rock per break. The powder sticks were 1-1/4 inch round and 8 inches long.

In stoping operations, the spacing of drill holes varied a great deal, because of both the changing nature of the face and the pressure slabbing or jointing.

In recent practice, the holes are started to a gage of 1-5/8 inch with 2 foot starter and the following sizes were used:
<table>
<thead>
<tr>
<th>Rod Length</th>
<th>Bit Gage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 feet</td>
<td>1-9/16</td>
</tr>
<tr>
<td>6 feet</td>
<td>1-1/2</td>
</tr>
<tr>
<td>8 feet</td>
<td>1-7/16</td>
</tr>
<tr>
<td>10 feet</td>
<td>1-3/8</td>
</tr>
<tr>
<td>12 feet</td>
<td>1-1/4</td>
</tr>
</tbody>
</table>

As may be noticed, the loss of gage in a 12 foot depth of hole is only 3/8 inch, and gage reduction per bit change is 1/16 inch.
CHAPTER VI

DESCRIPTIONS OF CALUMET BITS WITH PLATES

In the words of an eminent mining engineer, writing the history of the drill bit development of a particular area is like trying to write a continuous history of the human race by collecting facts from the lives of a few individuals. This is true because the various design features of all the bits used at a mine may not be explainable in a continuous history of the development of each of them.

Bits from the Old Collection

Below is the brief discussion of the various bits present in the collection in the Calumet and Hecla Consolidated Copper Company bit shops.

The numbers in parentheses used in the following text correspond to the bit numbers in the photographs attached on later pages.

Conventional Bits.— (1) This is a single-edge bit made at the end of a 1 inch hexagonal solid steel, used before and up to about 1900, for hand drilling, before the introduction of the Carr bit. The cutting edge was resharpened by hand hammering.

(2) This is cross bit formed on a 1 inch solid octagonal steel used with the two-man piston type heavy drill machine around 1907. The drill hole was watered by hand. The chuck was rotated by holding it with a wrench. The bit had flat wings and reaming edges and had a gage of
Showing: 1 - Single edge bit  
2 - Cross bit  
3 - Simon's type bit  
2-3/16 inches. The steel was 4 feet long and was used with a piston machine.

(3) This bit, forged at the end of a 1 inch steel, had one cutting edge and two flattened ends on the other wings. The bit combined the cutting action of a single bit and the reaming qualities of a cross bit. It was used around 1900 in the iron mines of Michigan, and also in the copper country at Kearsarge mine, with a piston-type machine.

(4), (5), (6) These bits were forged at the end of 1 inch round steel and used with a piston type machine around 1907. Sharpening was done by hand hammering. The bit (4) shows rough protruding edges at four corners. These
Showing: 4 - Cross Bit with projecting corners

5 - Cross Bit

6 - Cross Bit

acted as pilots in drilling. They helped keep the hole round and cut the rock along the periphery, which was followed by main cutting action of the flat edges.

(7) This is Mohawk bit, used at the Calumet and Hacla property between 1905 and 1910. It was developed at the Mohawk mine in the copper country. The bit, forged on a round steel, had a single cutting edge acting as pilot in the middle, and flat reaming edges. According to records, it was made of black-diamond type of quality steel.

(8) This single bit indicates a definite step in the development of drill steel, showing the use of hollow steel with a central water hole for wet drilling. This was
PLATE 39

Showing Mohawk Bit

used with Leyner type heavy drill around 1911 and 1912. It was a full reaming bit and was originally forged at the end of 1 inch round steel, but after about 1920, 1 inch hexagonal steel was employed.

(2) This bit had 12 cutting edges and was 2-1/8 inches in gage. It was used as a starter for the Carr bit, so that the bit to follow may remain steady in the hole. The 12 edges gave a steady starting quality, even so that it could start a hole at an angle. The steel was only 2 or 3 feet long.

(10) This is a 4 foot cross bit, used with a big shank and a No. 18 Leyner drill machine. It was forged at the end of a 1-1/4 inch round steel and was in use up to the year 1920.
PLATE 40
Showing: 8 - Single Bit on round hollow steel
9 - Starter Bit for Carr bit
10 - Cross Bit on steel with lug shanks

PLATE 41
Showing battered bit on Imperial Steel after 308 feet
of drilling in 183 holes and sharpening 56 times
(11) This is the final condition of a bit made at the end of Imperial drill No. 7, imported from England. This cross bit was tested for drilling until its destruction. It drilled a total of 308 feet 5 inches, being used in 183 holes and sharpened 56 times, giving an average of 5-1/2 feet per sharpening. The good quality of the steel is shown by the above tests.

(12) This bit was mostly used at the Mohawk mine and sometimes at the Calumet and Hecla's mines, for drilling a burn-cut hole. The drilling was done in two different operations. First a small hole, equal to the gage of the pilot guide was drilled and then, by keeping the guide in this small hole, the bigger hole is drilled. The bit was
kept steady by the guide fitting in the small hole. One inch hexagon steel was used. This bit was used up to about 1930.

(13) This is a Rose bit, having six cutting edges, forged at the end of 1 inch hexagon steel; and used around 1920. The main application of this bit was either in starting holes or in drilling in softer rocks.

(14) and (15) These bits were only tested to demonstrate the efficiency of cutting in two planes. They incorporated some of the qualities of both single and cross bits. The main chisel edge cuts in advance of the other two arc-shaped edges, made on the other wings in line with reamers. These edges help keep the hole round, cut part of the peripheral rock in advance, and provide greater clearance for escape of cuttings than the cross type. The bit was only experimented with in 1930 and never was employed in
PLATE 44
Showing bits with a single cutting edge and two following reaming and cutting edges regular drilling. It was made on a 1 inch hollow hexagonal steel.

PLATE 45
Showing two Cross Bits used at the C & H mines from 1925 until 1940
(16) and (17) These cross bits were used at these mines from 1925 to 1940, just before the introduction of the detachable type there. They were made on 1 inch hollow hexagon steel and were used with Chicago Pneumatic hammer drill machine. They were sharpened in the Ingersoll-Rand No. 5 dolly and die type of forging machine. The bit had a smaller gage than its predecessors. The starters were just 1-5/8 inch. Bit No. (16) was on a standard drill steel No. 4, and No. (17) was on FAC RST No. drill steel.

PLATE 46
Showing conditions of Cross Bits at various stages of use

(18), (19) and (20) These bits are the same type as (16) and (17), showing here their condition at various stages of use. One trouble with these bits was that massive copper would spike up into the holes and clog them.
The bit would then have to be heated so that the melted copper could be blown out of the hole.

PLATE 47

Showing a Carr Bit and hexagonal steel

(21) and (22) This is a regular Carr bit formed on a 1 inch hexagonal hollow steel and used at the Calumet and Hecla property up to 1938. Ten foot lengths of steel were used. The only trouble with this bit was that it entered any seam or crack that crossed the hole, and produced a fitchered hole.

Detachable Bits.— (23) and (24) These are the Timken detachable bits, used with 1 inch hexagonal hollow steel. The bit end of the steel has a shoulder that butts against the skirt of the bit, and prevents much shock being received by the threads. The Timken bits have a much smaller skirt than the jack bits, because the walls of the skirt
are thicker in the former bit.

PLATE 48
Showing two Timken detachable bits

PLATE 49
Showing a Jack Bit
(25) This is a Jack bit with a central water hole and also a side hole. This bit was never used at the Calumet and Hecla mines; it was only tested in 1938. It was used with 1 inch hexagonal hollow steel.

(26) and (27) This is a Hokanson bit, which was just experimented with but was never actually used in underground mining. The bit uses a 7/8 inch round steel with shoulder on the thread end of steel. The bit utilizes the principle of cutting in two stages or planes. The inner pilot of smaller diameter has a single cutting edge, and has two grooves cut on sides for water. The pilot has a driving fit into the socket of a bit, having two arc-shaped cutting edges. The shape of this bit in plan is rectangular, the longer side providing clearance from
the hole walls, for the escape of cuttings. The advance cutting is done by the pilot and the second plane cutting by curved edges is more or less a reaming action of making the hole round. The pilot insert has the shape of a round file, with its grooves inclined to the direction opposite to rotation.

PLATE 51

Showing a six-edge Timken Bit

(28) This is a six-edged Timken detachable bit, and was tested for its starting qualities, for collaring holes for the following cross bit. The bit was, however, never used in practice.

(29) This bit is a Timken special No. 13 bit of a larger gage (2-1/8 inch). It was meant to be used for drilling burn cut holes, but in actual practice it was used for drilling the eye pin holes for air lifts and other machinery requiring support at the back or sides underground.
PLATE 52

Showing: 29 - Timken Special No. 13 Bit
30 - Large size Jack Bit

(30) This is a large-size Jack bit. The clearance for escape of cuttings in this type is provided by milling the sides.

(31) and (32) The bit (31) is a regular Timken bit shown with the bit end of the steel. This bit shows the position of a side hole. Bit (32) was an experimental bit made out of a regular Timken, by grinding off the wings behind the reamers up to the round diameter of the skirt. The idea was to provide greater clearance to the reamers after they had worn off somewhat and to make the bit more free to move inside the hole.

(33) through (40) These are Liddicoat bits as developed at the Calumet and Hecla's bit shops. The details
PLATE 53

Showing: 31 - Regular Timken Bit and Thread End of Steel

32 - Timken Bit with Wings ground off

PLATE 54

Showing two views of the new Liddicoat Bit Type L
PLATE 55
Showing the driving fit connection of Liddicoat Type L Bit on a 7/8 inch Steel

PLATE 56
Showing five sizes of Liddicoat L Bit
of the history, development, design, manufacture, heat treatment and use are briefly discussed in the following text:

History: In November and December of 1945, a detachable rock bit of Canadian manufacture, the Liddicoat Type L, was tested exhaustively at one of the Calumet and Hecla Mines. The tests proved that this "one-use" bit could be successfully employed for regular underground drilling operations, but for the customs and freight rates, which would be quite high for bringing the bits from across the border. The Calumet and Hecla Company negotiated with Thompson Products Ltd., (Canadian manufacturers) and Thompson Products Inc., of Ohio, U.S.A., for permission to manufacture bits at Calumet, Michigan, on a royalty basis.

Under the supervision of Mr. Percivall Liddicoat, the designer of the bit, a plant was constructed at Calumet, having adequate capacity to produce the bits for sale besides meeting the company's own requirements. The company secured exclusive rights to sell the bits in western United States, from the Pacific Coast up to a line joining the Dakotas and Texas. During the month of October 1947, the company sold 37,000 bits to the Anaconda Copper Mining Company. The Anaconda Company is now erecting another plant in Salt Lake City after an agreement with the Calumet and Hecla Company.

The Calumet and Hecla Copper Company has switched over four of its eight mines from the Timken to the Liddicoat bit. The remaining four are still consuming the large
stocks of Timken bits in the company's stores.

Design: The cutting end of the bit is designed to give greater resistance to abrasive wear and also to minimize friction during rotation. The cutting edges are so designed that the rock is cut in three planes, giving the effect of maximum chipping and minimum grinding. The following are the elements cutting in three stages:

(i) A pilot, having two edges.

(ii) Two cutting edges opposite each other, with the edges inclined away from the center of the bit and having acute cutting angles, and

(iii) Two cutting edges opposite each other, with the edges inclined toward the center of the bit and having obtuse cutting angles, forming the cutting plane at third level.

An offset shoulder is also provided on the wings to expedite ejection of the cuttings and to minimize the drag on the rotation of the machine. The attachment of bit to steel is the "push-on" type, making a driving fit. The tolerance allowed is $\pm 1/2000$ inch. Four flats are milled on the round bit-end of rod and these engage with four corresponding projections in the bit socket, to prevent any rotation of bit on rod.

Regarding the water hole in the bit, it was found that punching a side or diagonal hole, would require much extra special press and die machinery entailing large costs. So after experimentation it was decided to give
some eccentricity to the front hole, by making it a half or a semi-circular hole. The choking of the hole by massive copper was successfully avoided to a very large extent.

Manufacturing Plant: The bit is a forged extrusion of light weight and needing no machining. All the heating for cutting, forging, hardening and draw tempering is done electrically; thus oxidation and formation of scale are minimized. A Tocco high-frequency 75 kW generator supplies current to two Tocco remote control stations, handling bar stock or slug cutting.

One and one-sixteenth inch diameter round bars of Park quality crucible steel, 12 to 14 feet long, are placed on a steel rack near the first Tocco station. The automatic feeder puts one bar at a time into a high-frequency induction heater, which heats it to 1450°F. The bar then passes on to a shear press, which cuts it into slugs of predetermined length, roughly at the rate of 34 slugs per minute. These slugs, 3,000 at a time, go to a tumbler (24 inch pipe), which rotates and removes any rough burrs and scale. A reciprocating plunger then feeds these slugs into another induction coil heater, which heats them to 1900°F and discharges about 9 pieces per minute near a 400-ton Hamilton press. The operators drop these slugs, one by one, into a split die and on the downstroke of the press, the bit is rough forged to approximate gage size, without the central hole. On the upstroke, the bit is drawn out of this special collapsible die and blown.
PLATE 57

Showing Slug Cutting Machine

PLATE 58

Showing 400-ton Hamilton Press
through an air tube to the Thomas Trimming Press.

Here the bit is trimmed, the hole is punched, and the gage and flats in the socket are checked. The bit is allowed to cool slowly to relieve any forging stresses. The bits are then heated to 1450°F in a rotary hearth Lindberg electric furnace. They are then withdrawn and placed on a Link belt conveyor, submerged in running cold water up to 3/16 to 1/4 inch. After this hardening, the bits are tempered in a Lindberg draw furnace at 324°F for one hour. They are then painted according to gage size in five colors, starting from bigger to smaller size in red, blue, black, yellow and green. Only one size is made at a time, and four men working one shift can turn out 500 bits per hour. The following are the sizes made:
PLATE 60

Showing rotary hearth Lindberg Electric Furnace

Rods for Liddicoat Bit: Seven-eighth inch quarter-octagon hollow crucible drill steel, is used for making rods. After upsetting, rounding, and tapering the bit end, flats are ground on the four positions 90° apart, by emery grind-
ing wheels.

For heat treatment, the bit end of the rod is pre-heated to 800°F and then heated to 1550°F in Houghton N.D. liquid heat for 45 minutes. It is then quenched in Houghton No. 2 soluble quenching oil. The end is then drawn at 550°F in Houghton No. 275 draw-temper salts and then laid to cool in the air. The draw-temper heat on the rod end is about 3 inches more than the hardening heat.

The shank end of the rod is heated in an open furnace to 1650°F to about 2 inches and then quenched in No. 2 soluble quenching oil.27/
Sketches showing heat treatment of shank end of steel for use with Liddicoat bit
BIBLIOGRAPHY


