May 25, 1965 J. L. KELLY, JR 3,185,228

ROTARY-PERCUSSION DRILL BIT WITH HEEL ROW INSERTS TO PREVENT WEDGING

Filed Jan. 21, 1963 2 Sheets-Sheet 1

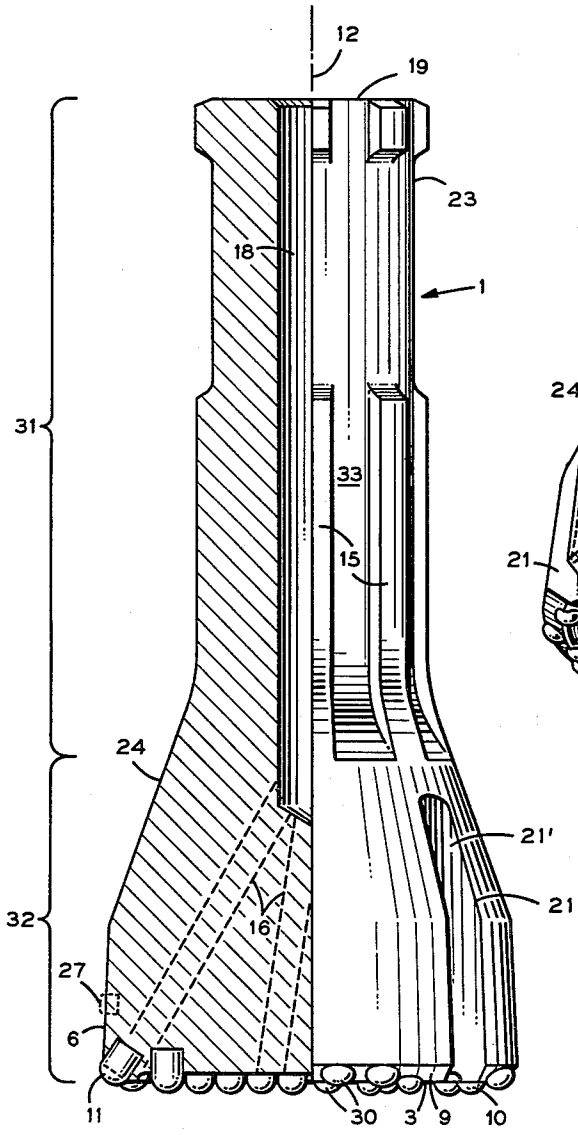


FIGURE 1

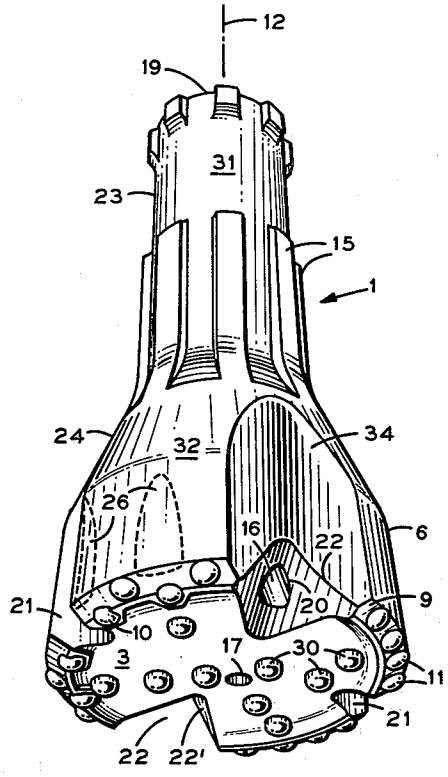


FIGURE 2

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ROTARY-PERCUSSION DRILL BIT WITH HEEL ROW INSERTS TO PREVENT WEDGING

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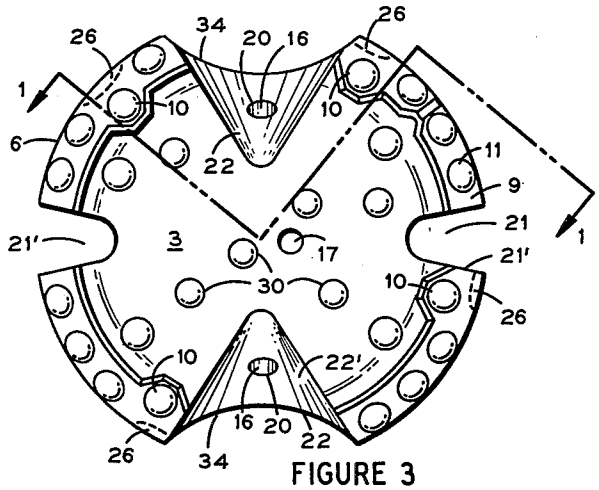


FIGURE 3

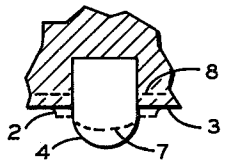


FIGURE 5

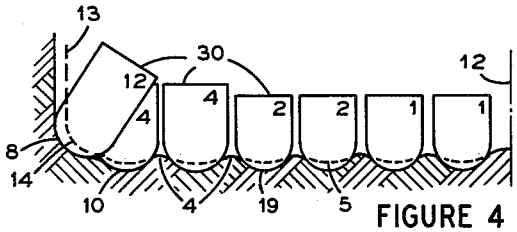


FIGURE 4

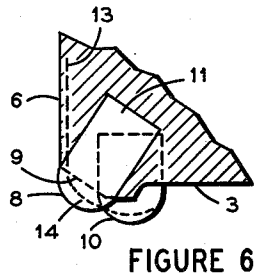


FIGURE 6

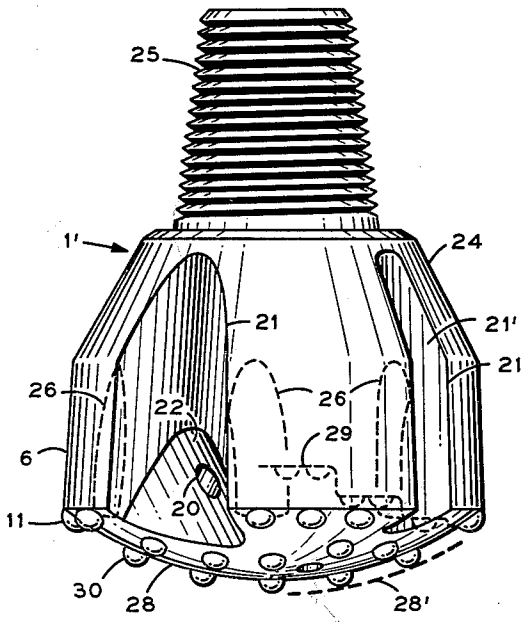


FIGURE 7

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ROTARY-PERCUSSION DRILL BIT WITH HEEL ROW INSERTS TO PREVENT WEDGING

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7 Claims. (Cl. 175—410)

The present invention relates to a new and useful earth boring bit, and more particularly concerns a drill bit suitable for use with percussion drilling equipment. Its more specific aspects are directed to providing a drill bit with a good wear resistance, ability to withstand the large fluctuating forces which accompany percussion drilling, fast drilling rate even when dull, efficient removal of cuttings from the bottom of the hole, and a tendency to wear after long usage to an "anti-wedging" configuration.

Percussion drilling is a technique of old origin. Use of this method is widespread, but perhaps most important is its application to the drilling of blast holes in mining and quarrying. Numerous holes are drilled in the earth formation, and explosive charges are placed in these holes. Detonation of the explosive breaks up the formation, and permits removal of the resulting manageable pieces.

Portable earth boring machines capable of rotating a drilling bit are commonly used. A percussion tool capable of exerting several hundred blows per minute is inserted just above the bit, and is typically actuated by the fluid circulated through the drill pipe. The forces and stresses transferred to the bit are extremely large. Many attempts have been made to invent a drilling tool capable of withstanding these severe operating conditions. Some have succeeded commercially, but the need for a better drilling device continues in order to lower the cost of this important mining method.

A popular bit type used in percussion drilling of blast holes has a cutting structure of massive pieces of tungsten carbide extending radially from a point proximate the bit center of rotation to the periphery of the bit, each such piece having a protruding portion of triangular cross-section which converges downwardly to a chisel-shaped cutting edge. These pieces are brazed into slots on the lower face of the bit, and are sharpened at the lowest extremity. Such devices have been commercially successful in recent years, but have definite limitations.

For example, the provision of radial cutting members extending like spokes from a point proximate the center of rotation of the bit to the gage is undesirable because it ignores the fact that the work expended per unit volume of rock removed is much greater near the wall of the hole than it is near the center. As the bit with massive chisels has the same amount of cutting structure at the outer and inner diameters, it necessarily wears faster at the outer diameter because of the larger peripheral speeds, larger volume of rock removed, and larger work per unit volume of rock removed. Frequent sharpenings are required to maintain an economical penetration rate, and also to avoid breakage of the cutting elements.

The problem of cutting element breakage is related to both wear and load distribution. The cutting elements of the chisel type bit are made of a wear resistant, hard and brittle material, usually tungsten carbide. Such materials have poor resistance to bending. Because of their disposition in the bit, the cutting elements are equivalent to beams resting on an elastic foundation (the more resilient metal of the bit body). The uneven load distribution across the bottom of the hole creates bending stresses in the cutting elements. The load on

the cutting elements increases as their cutting edges dull and it becomes more difficult to drive them into the formation. The greatest increase occurs near the wall of the hole where the bit dulls most rapidly. Eventually, the resulting increase in bending stresses can become large enough to produce transverse fracture.

To alleviate this problem (and also to maintain an economical penetration rate), sharpening of the cutting elements is periodically required—at a considerable expense. For example, in one quarry, where the bits drill 450 to 500 feet, 20 to 25 sharpenings are required at a cost of at least $5.00 each. This is a serious detriment to economic drilling.

Time consuming and costly sharpening is also required to eliminate another wear problem. The tungsten carbide inserts are initially relatively sharp at the outer diameter, and extend upwardly and inwardly with a slight taper. This provides some clearance between the wall of the hole and the carbide extending up on the side of the bit. As the bit wears, however, a large radius begins to form at the lower, outer corners of the inserts. This process continues until the inserts are worn to a taper extending upwardly and outwardly. Thus, a slightly conical shape is formed in the earth formation, tending to wedge the bit. The penetration rate decreases due to the increase in axial force and torque requirements needed to drive and turn the bit in this wedge. Sharpening or replacement is eventually necessary to recoup the lost penetration rate.

It is an object of this invention to provide a bit having a cutting structure capable of withstanding the severe, fluctuating forces of rotary-percussion drilling. Another object is to provide a cutting structure which will maintain substantially the initial penetration rate even when dull, and thereby eliminate the necessity of frequent and expensive sharpenings. A further object is to increase the efficiency of energy transfer by using small inserts of hard, wear resistant material disposed in the relatively elastic body metal. Another object is to avoid the long-standing wedging effect of dulling at gage. Still another object is to effectuate faster removal of the cuttings from the bottom of the hole by optimum use of the fluid circulated through the drill pipe and the bit. A still further object is to use the abrasive laden fluid flowing across bottom to maintain a large insert protrusion by wearing away the body metal as fast as the protruding inserts are worn away in cutting formation. A kindred object to the last named is to provide a bit adapted to cut the hole bottom adjacent the sidewall so that the body material in that area and the cutting structure thereat wear in such manner as not to assume a wedging configuration.

Other objects and advantages of this invention will further become apparent hereinafter and in the drawing in which:

FIGURE 1 is a side elevation view, half in section, showing one preferred embodiment of the invention, as seen in looking in the direction of the arrows 1—1 of FIGURE 3,

FIGURE 2 is a view in perspective of such preferred embodiment showing with more clarity the external structural details,

FIGURE 3 is a bottom view of the (preferred) embodiment of FIGURES 1 and 2 indicating the location of wear resistant inserts and other structural details of the bottom portion of the bit,

FIGURE 4 is a side elevation view of the bottom of the hole in half section with the wear resistant inserts on all rows rotated into the plane of the paper. This illustration shows the pattern the inserts make in the bottom of

the hole, and the wear pattern of the inserts in the preferred embodiment of the invention,

FIGURE 5 is a side elevation view of one form of insert with its supporting body metal in fragmentary section,

FIGURE 6 is a side elevation view of a heel insert, together with an insert of the adjacent row rotated into the plane of the paper. The supporting body metal is shown in fragmentary section. Both the initial positions and the wear patterns of inserts and body metal are illustrated, and

FIGURE 7 is another side elevation view showing a second embodiment with a threaded connector at the upper end, and alternative constructions at the bottom.

In describing the preferred embodiment of the invention illustrated in the drawing, specific terminology will be resorted to for the sake of clarity. It is not intended, however, to be limited to the specific terms, but should include all technical equivalents which operate in a similar manner to accomplish a similar purpose.

Turning now to the preferred embodiment selected for illustration in the drawings, the numeral **1** designates the bit as a whole, consisting of an upper shank portion **31**, and a lower body portion **32** integral with such shank. At the top of shank portion **31**, horizontal end surface **19** serves as an anvil whereon the severe, fluctuating, axial forces provided by the impact or percussion tool (not shown) are delivered to the bit. The outer surface of shank portion **31** is machined to provide splines **15** and intermediate grooves **33** parallel to the longitudinal axis **12** of the bit, such splines and grooves extending to top surface **19**. These elements engage matching splines and grooves in the lower end of the precussion tool, and are used to transmit the circumferential forces which rotate the bit. A wide circumferential groove **23** is machined below the upper end of the bit **19** to form an annular space between the bit body and the percussion tool. A split ring (not shown) is inserted therein to retain the bit on the percussion tool.

Body portion **32** and shank portion **31** are actually a single massive piece of steel, and it is to be understood that the designations employed are used merely for their convenience in discussing the various functions of the bit **1**, its manner of cooperation with the percussion tool and its manner of penetrating the formation being drilled. While the body portion may be thought of as providing support for the cutting elements and as providing the bulk of the mass of the bit, and the shank portion as furnishing the means for transmitting impacts and rotation to the body portion, it is apparent that the shank itself must be sufficiently strong to withstand the blows delivered by the impact tool. In FIGURE 1, these two portions are illustrated as smoothly joined through the conical section **24**.

The body portion **32** is substantially a solid cylinder having an outer surface **6** in the form of a cylinder or a cone tapering slightly inwardly and upwardly, except as relieved by the various openings to be described. In the preferred embodiment of FIGURES 1–6, the bottom of the bit is defined by lower surface **3** of the body portion, preferably normal to longitudinal axis **12**. This lower surface **3** intersects side surface **6** at its outer periphery, and such intersection is slightly chamfered as at **9** to provide a space for the protruding ends of the heel row inserts **11**.

Cuttings formed by the action of bit **1** are removed by a fluid passageway system which includes a central passageway **18** in shank **31** adapted to join a like passageway in the percussion tool and one or more passageways **16** in body **32** joining the lower end of passageway **18** and extending through lower surface **3** at port **17**. Cuttings entrained by the flushing fluid are removed from the hole bottom and carried upwardly past body **32** through return passageways **21** and **22**. These passageways may be formed either with vertical sides **21'** or with sidewalls **22'** flaring upwardly and outwardly from a point near the center of lower surface **3** to a shallow recess **34** in side surface **6**, the combination of a pair of each type having worked quite satisfactorily for the 7 1/16-inch bit illustrated. Additional passageways **16** in bit body **32** may be provided to discharge through walls **22** at the ports **20** illustrated.

The inserts shown are cylindrical compacts of wear resistant material, preferably tungsten carbide (sometimes called "cemented" tungsten carbide), such inserts being familiar to users of the rolling cone rotary bits introduced to the trade by the Hughes Tool Company and popularized under its trademark as "Hugheset" rock bits. While various shapes and sizes of such inserts may be used, the illustrated cylindrical type having hemispherical cutting ends, an overall length slightly greater than the diameter, and diametrial sizes of from 1/4 to 3/4 inch have been found eminently practicable. They are most simply force fitted into holes drilled into the bit body.

The arrangement of inserts **30** across bottom is governed by the required work of the inserts at the various radii. The greatest work in fracturing rock is expended at the juncture of the wall and the bottom of the hole. Wear is also greater at this point due to the large distance traveled by the inserts. Large numbers of inserts are therefor required at this location. Hence, the heel row **11** of this particular embodiment has twelve inserts for the bit illustrated, 7 1/16-inch diameter. The adjacent inner circumferential row **10** requires only four inserts. The number of inserts per circumferential row decreases with decreasing radius until only one is required at the two innermost rows, as indicated, by the numerals appearing in the upper right hand corners of the inserts **30** shown in FIGURE 4. This arrangement must be varied to accommodate the various formations. Other variations are required to accommodate the different sizes of bits used in rotary-percussion drilling. The compacts, for example, sometimes require optional support metal, as shown in phantom by numeral **2** in FIGURE 5. This enables use of large projections, and at the same time, the provision of adequate supporting structure.

The disposition of inserts is such that if rotated into one plane, as in FIGURE 4, there are upstanding rims or rings **4** of uncut bottom which are disintegrated by fracturing. The uncut bottom should not be too great, for if so, the formation will not fracture across these rings, and premature wear occurs. It is preferable to have fracture across the uncut bottom, for when this condition occurs, the wear pattern of inserts **30** is as shown by numeral **5** in FIGURE 4.

The individual compacts wear to a generally flat shape **7**, as shown in phantom in FIGURE 5. Quite unexpectedly, the penetration rate does not decrease much from the initial rate even when the inserts are thus dulled flat. The drilling rate apparently depends on the energy transfer efficiency, and is not related to any large degree to insert sharpness. Evidently the energy transfer efficiency is not radically altered by a change in insert shape from spherical to flat. For this reason, the inserts could initially be flat as numeral **7** indicates in FIGURE 5, or have any other dull lower surface. The preferred spherical surface is thought best, however, because there are no stress raising sharp corners which might cause the inserts to fracture. Also, the spherical ends may aid in localizing the stress in the rock, because there is some, but amazingly small, decrease in penetration rate when the inserts dull.

Another result flowing from the structure described which is believed to be unobvious and unexpected is the elimination of wedging at the outer and lower edge of the bit. As previously indicated, prior art bits require sharpening after not too extensive periods of use because either the gage surface (side surface **6** of bit body just above the heel cutting structure) or the cutting structure, or both, become worn into a wedging configuration, i.e., a taper extending down and in from side surface to lower surface or a rounded corner joining such surfaces. Where prior art attempts to avoid such wear-induced configurations have been directed largely to increasing the wear

resistance of the side surface 6, the present invention embodies the completely opposite concept of decreasing the wear resistance of such surface so that it wears at least as fast as the portions of the inserts of heel row 11 contacting the sidewall of the hole.

This is accomplished largely by disposing heel row inserts 11 at an acute angle with respect to both side surface 6 and lower surface 3 (and also longitudinal axis 12), thus burying the inner ends of such inserts in the body metal and obtaining support therefrom which would not be available if the inserts were otherwise disposed with some portion protruding to contact both the bottom and sidewall of the hole, e.g., with their longitudinal axes parallel to either the side surface or the lower surface. With such disposition, heel inserts 11 are assured of adequate support despite wearing of both the side surface and the bottom surface, while in the other disposition postulated the metal worn away would cause the inserts to be undermined and washed out as the thin supporting metal became thinner and cracked out.

As illustrated in FIGURES 4 and 6, heel inserts 11 have the initial radius 8, the arc at such radius also connecting the sidewall and bottom of the hole. As the bit wears, inserts 11 wear to the shape indicated by phantom line 14 while side surface 6 wears to phantom line 13. Wedging is thus prevented because no wear-induced wedging configuration is allowed to develop.

In some sizes of bits and in some formations, it may prove necessary to provide such means as longitudinal slots 26 between heel inserts 11 to insure that the balance of surface 6 will wear at least as fast as the outer portions of the inserts. It will be understood that the ideal condition of equal rates of wear will vary with the hardnesses and wear resistances of the sidewall and the heel inserts, the areas of each contacting the side wall of the hole, and the type of formation being drilled. In rare instances, it may even be necessary to add some gage inserts of wear resistant material, as indicated at 27 in FIGURE 1.

Another unexpected result obtained with the structure described is produced by the flow of flushing fluid and the cuttings it carries. As fluid exits from port or outlet 17, it becomes impregnated with abrasive particles from the formation, causing erosion of the bit bottom 3. This phenomenon is utilized to promote sustained, fast penetration rates. The inserts of the preferred embodiment initially projected about 7/32 of an inch from the bit bottom surface 3. The inserts penetrate the earth formation only slightly during each revolution of the bit. Hence, there is a space by which the formation cuttings can escape from the bottom. As the inserts wear with use the phantom line 7 of FIGURE 5, for example, the projection of the insert decreases. The cuttings cannot escape as easily through this small space, and the penetration rate would be expected to decrease as the cuttings accumulated on the bottom. Unexpectedly, it was found that the fluid laden with abrasive particles prevents such an undesirable development. This is accomplished by forming the bit bottom 3 parallel to the bottom of the hole over a substantial area, as shown in FIGURES 4 and 7, i.e., by making surface 6, 28, etc., a surface of revolution and disposing the inserts to protrude equally therefrom. The abrasive particles in the fluid erode the bit bottom surface 3 to the phantom line indicated by numeral 8 in FIGURE 5 while the inserts are wearing to line 7. The initial projection of the inserts can thereby be maintained.

The preferred embodiment heretofore described in connection with FIGURES 1–6 utilizes a flat lower surface 3 on bit body 32. Other bottom or lower surface shapes are indicated in the bit 1' of FIGURE 7, which also shows a shank in the form of a tapered threaded connector 25. This figure indicates a convex lower surface 28 (convex downward) in which inserts may be disposed in the same general manner as described for the preferred embodiment to define a similarly shaped bit bottom 28'. A lower bit surface which is concave downward (not shown) would have the advantage of keeping the bit rotating about its centerline on the core thus formed. The inwardly and upwardly stepped surface 29 would serve the same purpose, and an inwardly and downwardly stepped surface also appears feasible. Any such surface should preferably be a surface of revolution defined by rotation about bit axis 12 and have the inserts except at gage protruding normally from the surface approximately the same distance. With any configuration of bottom surface, it is also preferable that the heel row of inserts define a relatively abrupt surface connecting the bottom and sidewall of the hole, as at 8 in FIGURES 4 and 6, to avoid wedging.

An example of the method of manufacturing a successful test bit of the embodiment of FIGURE 1 is as follows:

A large piece of bar stock of high quality, 5 percent nickel steel was turned to roughly the finished diameters. Carburizing stock 3/16-inch thick was left over the lower surface 3 and side surface 6 in order to keep high percentages of carbon from this area, for it is well known that if the metal proximate the inserts has too great a hardness it is prone to fatigue failures. The lower end of the central air course 18 was similarly protected from carburization for the same reason.

The upper portion of the bit 31 was machined to its finished dimensions by milling the splines 15 and turning the split ring groove 23. The structure was then placed in a furnace where the unprotected surfaces was carburized from .090 to .110 inch case depth with approximately 50 percent surface carbon. After removal from the furnace, the bottom surface 3 was machined to its final dimensions including an outside diameter of 7 1/32 inch, a 2° taper on side surface 6, and the drilling of the insert holes.

Five air courses were drilled, the four outside holes being 21/32-inch diameter, and the inside hole being 5/8-inch diameter, as is generally shown in FIGURE 1. The return flow passageways 21, 22, and 34 were then milled with circular cutters. The structure was hardened by placing it in a furnace with an atmosphere in equilibrium with .10 to .15 percent carbon steel with the carburized area painted with a high temperature paint to prevent decarburization. The structure was then oil quenched from 1430° to 1440° F. and drawn immediately at 325° to 325° F., giving the carburized surface area a Rockwell "C" hardness of about 56 and the uncarburized surfaces hardness of about 38 Rockwell "C."

The insert holes were reamed after heat treatment to remove distortions, and to prepare these surfaces for receiving the inserts. The heel and first two inner rows contained ½-inch diameter inserts, and the remaining inner rows contained 7/16-inch diameter inserts, both sies being pressed into holes having .001 to .0028 inch smaller diameter, the variation resulting from machining tolerances. Insert projection of 3/16-inch was used and in addition, insert support metal 2 as shown in FIGURE 5 of ⅛-inch was used on the inner rows, resulting in a total projection about surface of 5/16-inch, this being found sufficient to provide clearance for the cuttings. Other test bits were manufactured having 9/16-inch diameter inserts which projected 5/16-inch from the lower surface metal 3 with no additional support metal 2, and were found satisfactory. The buried ends of the 7/16-inch diameter inserts were 13/32-inch below insert support metal 2, and the ½-inch diameter inserts were buried 11/16-inch. These dimensions were found to produce satisfactory holding force between the inserts and the body metal. The heel row inserts 11 were inserted to protrude approximately 1/32-inch beyond the outer diameter of side surface 6 in order to provide some initial clearance between the wall of the hole and this side surface. This feature will allow cuttings and fluid to escape in this area, and promote some initial wear of side surface 6.

The advantages of the invention are numerous, but of primary importance is the removal of the expensive re-

quirement of periodic sharpening. The penetration rate is substantially constant even after the inserts are worn flat. The elimination of the wedging problem accompanying wear is another great advantage. The provision of a bottom configuration which maintains efficient removal of the cuttings by promoting erosion of the bit body metal is particularly advantageous.

It should be understood that the forms of the invention herein shown and described is to be taken only as illustrative. Various changes may be made in the size, shape and arrangement of parts. For example, the bit described above was 7 1/16-inches in diameter. This invention would probably operate successfully in ranges of diameter from 2 inches up. Other sizes would require a substantial rearrangement of inserts, and placement and size of air courses. The number of inserts in each row can be varied to adapt the invention to drill specific earth formations. Some formations require more inserts and applied force to overcome the compressive strength of the particular rock. The particular angle of inclination of heel inserts used in the test bits described above varied from 30–38 degrees from vertical but this angle will also vary with the type formation drilled. Considerable variation in the body metal and heat treatment may be necessary for the same reason.

What is claimed is:

1. A rotary-percussion bit which does not require repeated dressing to maintain its usefulness throughout its life, comprising

a metallic body portion having an outer peripheral surface and a lower surface extending generally transverse the longitudinal axis of said bit,

a plurality of discrete, wear resistant inserts rigidly secured in said body with cutting tips protruding beyond said lower surface, said inserts being disposed in spaced apart relationship in circumferential rows each containing at least one insert to disintegrate the borehole bottom during rotation and percussion,

the inserts in the outermost of said circumferential rows being disposed at an acute angle with the longitudinal axis of the bit so that the inner ends of such inserts are buried within the body in spaced relationship to said peripheral surface and the protruding cutting tips extend beyond both said peripheral surface and said lower surface at about the intersection thereof, whereby the wedging which would otherwise occur in subjecting said outer peripheral surface to abrasive contact with the borewall of the hole is avoided.

2. The rotary-percussion bit of claim 1 in which said outermost row of inserts and the adjacent inner row are overlapping, whereby such rows are disposed to drill a hole bottom meeting the sidewall of the hole at a relatively sharp corner.

3. The rotary-percussion bit of claim 1 in which the outer peripheral surface of said bit body has a plurality of longitudinal slots to promote wearing of said surface by flushing fluid and cuttings at least as fast as the rate of wear of the outer portions of said outermost row of inserts.

4. The rotary-percussion bit of claim 1 in which said lower surface over a substantial area is a surface of revolution generally symmetric about the longitudinal axis of the bit and said cutting tips protrude an equal distance from said lower surface, whereby flushing fluid and entrained cuttings erode said lower surface to maintain the initial projection of the inserts as they wear during drilling.

5. The rotary-percussion bit of claim 4 in which the downward portions of said cutting tips are generally flat and parallel to said lower surface.

6. In a rotary-percussion bit comprising a bit body having a generally flat bottom surface and a generally cylindrical gage surface relieved by longitudinal grooves, a multiplicity of wear resistant inserts secured in said body with cutting tips protruding from said bottom surface and spaced apart in circumferential rows, and a flushing fluid passageway system which includes interconnected internal passages extending longitudinally from the top to the bottom of the bit body, the improvement comprising disposing the inserts of the outermost of said circumferential rows at an acute angle with respect to the longitudinal axis of the bit so that the inner ends of such inserts are buried within the body in spaced relation from both the bottom and gage surfaces and the cutting tips extend beyond both said surfaces at about the intersection thereof.

7. A rotary-percussion bit comprising a body having an outer peripheral surface and a lower surface extending generally transverse the longitudinal axis of said bit, said bit body having an internal flushing fluid passageway system which includes at least one longitudinal passage extending from the top of the body and terminating in a port in one of said surfaces, the intersection of said surfaces being slightly chamfered by a surface making an acute angle with each of said outer peripheral surface and said bottom surface, a plurality of discrete, wear resistant inserts rigidly secured in said body with cutting tips protruding below said lower surface, said inserts being disposed in spaced apart relationship in circumferential rows each containing at least one insert to disintegrate the borehole bottom during rotation and percussion, the inserts of the outermost of said rows being disposed at an angle with the longitudinal axis of the bit so that the inner ends of the inserts are buried within the body in spaced relation from both of said bottom and outer peripheral surfaces and the cutting tips protrude from said chamfered surface, said outermost row being thus disposed to protrude both axially and radially of the bit body to cut the outermost portion of the hole bottom and to prevent the bit from wearing into a wedging configuration.

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