Sept. 17, 1968 A. D. WHITE 3,401,759

HEEL PACK ROCK BIT

Filed Oct. 12, 1966 4 Sheets-Sheet 1

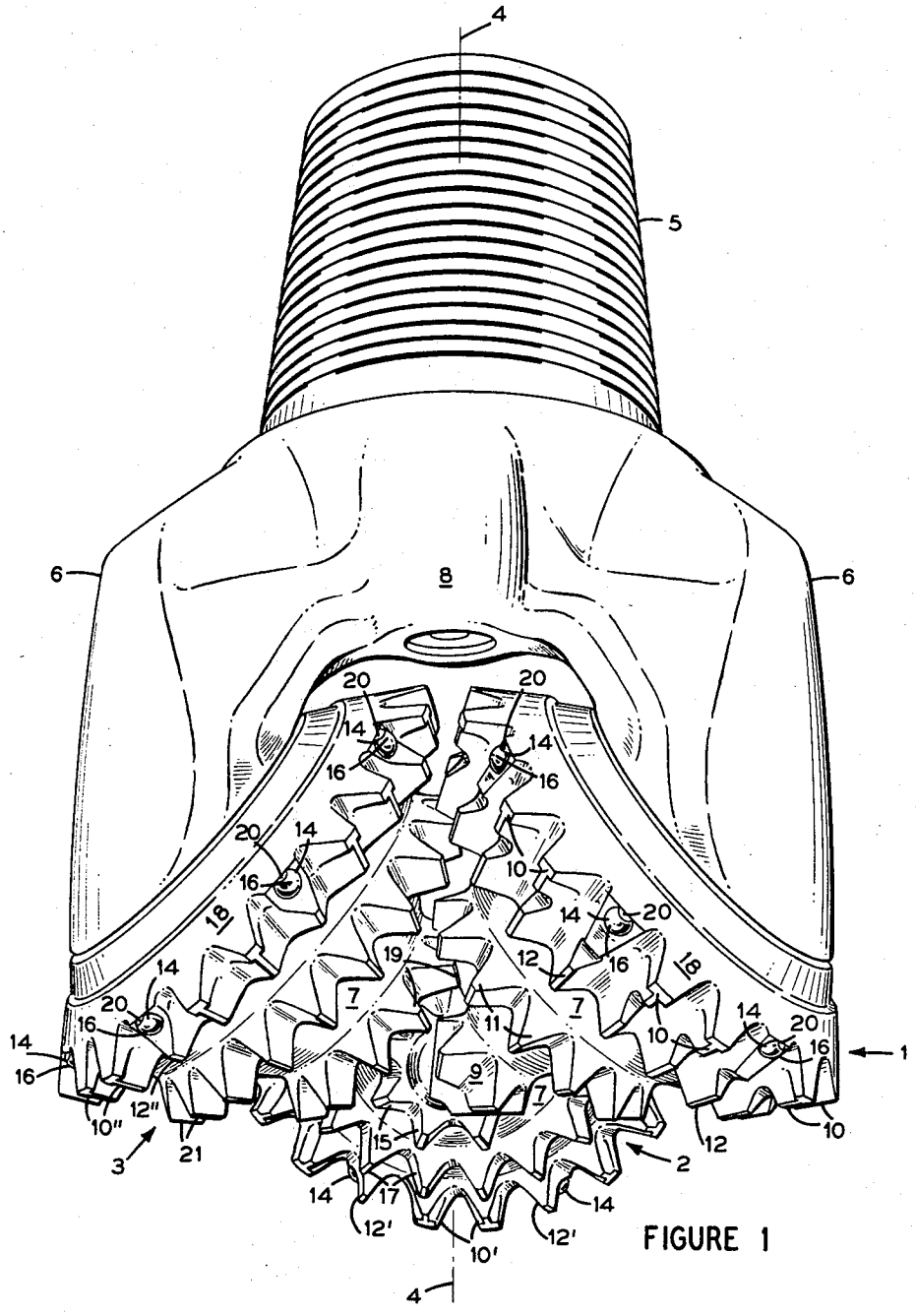


FIGURE 1

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HEEL PACK ROCK BIT

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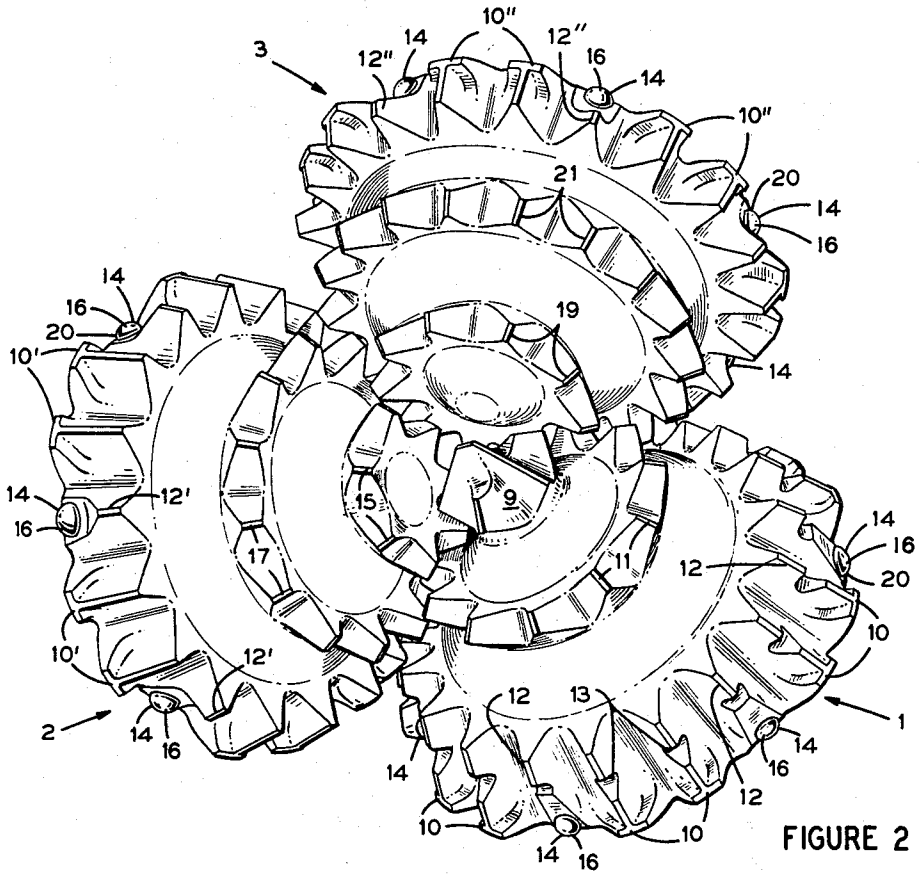


FIGURE 2

FIGURE 3

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HEEL PACK ROCK BIT

Filed Oct. 12, 1966 4 Sheets-Sheet 3

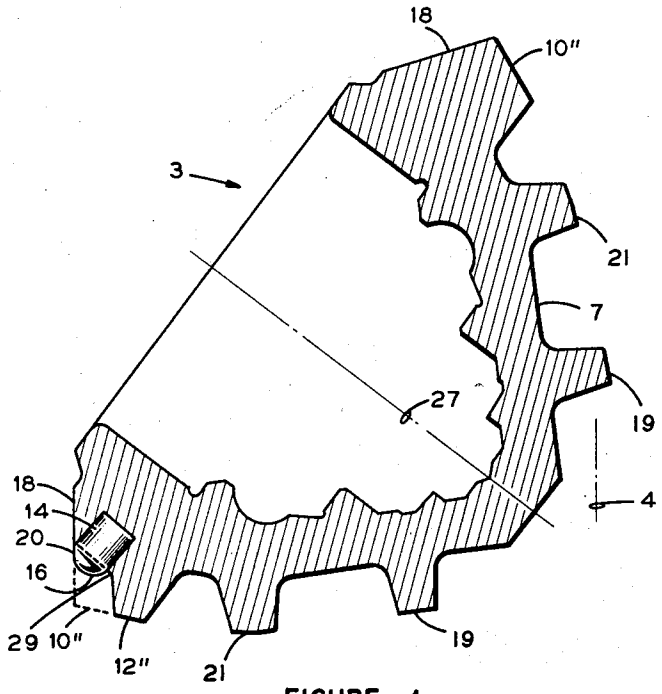


FIGURE 4

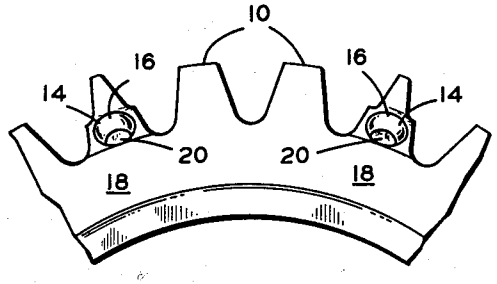


FIGURE 5

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HEEL PACK ROCK BIT

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FIGURE 6

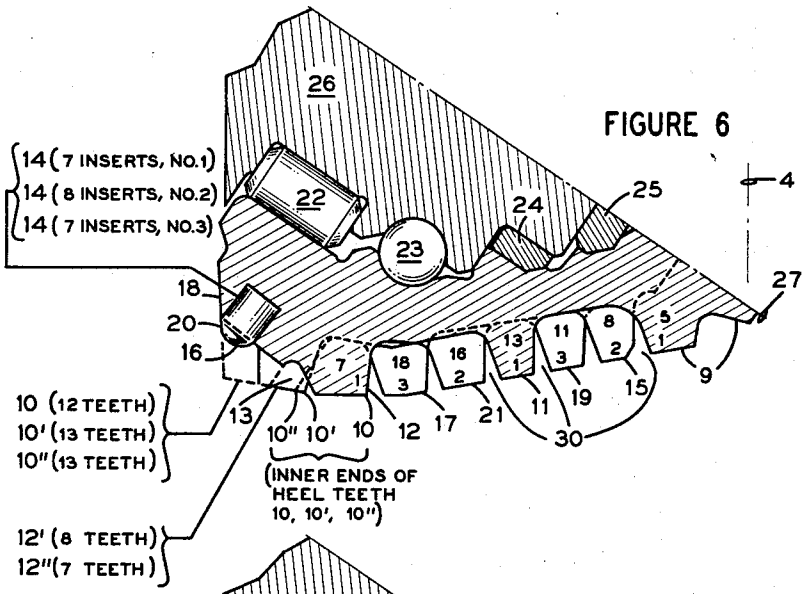


FIGURE 7

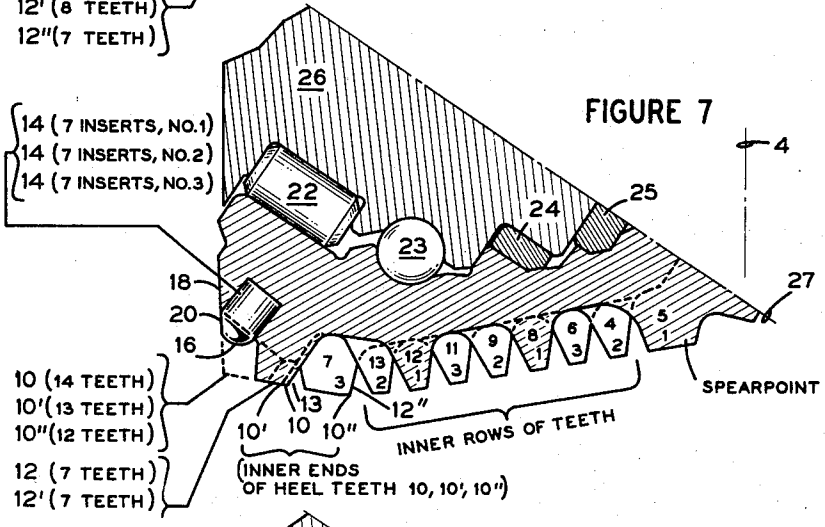
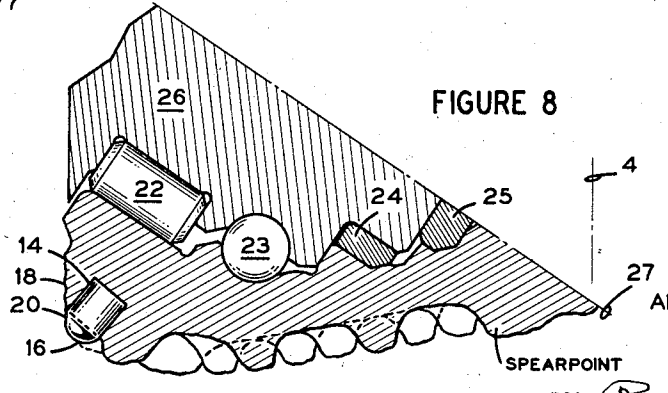


FIGURE 8



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United States Patent Office 3,401,759 Patented Sept. 17, 1968

3,401,759

HEEL PACK ROCK BIT

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Filed Oct. 12, 1966, Ser. No. 586,251
10 Claims. (Cl. 175—341)

The present invention lies in the field of rolling cutter rock bits adapted to drill holes in abrasive rock formations, and is useful in such drilling even though the strength of the rock varies considerably, e.g., from the relatively weak sandstone and sandy shales to the much stronger limestone, chert and quartzite. Furthermore, such bits are particularly useful in drilling areas laden with stringers of abrasive rock which cause heel rounding and severe gage wear before the balance of the cutting structure has worn to the same extent. In some of these instances the gage wear may be uniform while in others the wear is mostly near the intersection of the gage surface and the heel teeth. Sometimes the heel teeth may be worn as severely as the gage surface, while at other times the deep wear is confined to the gage and the heel teeth are worn only about the same as the other rows of teeth.

The bit of the invention is primarily a steel-toothed or milled cutter bit fortified with wear-resistant material such as tungsten carbide on those areas of the cutters where the abrasive formation is most likely to cause premature wear, specifically on the gage surface and the heel teeth. The cutting structure inwardly from the heels of the cutters is not affected, and consists of the hardened alloy steel teeth known in the prior art, such teeth being either elementally crested or circumferentially crested. The heel teeth, however, are modified to prevent rounding in a manner presently to be described.

One prior art attempt to solve the above-mentioned problem was by completely eliminating all of the steel heel teeth and replacing them with a row of heel inserts made of wear resistant material such as tungsten carbide, such inserts being formed of tungsten carbide granules cemented or sintered together with a binder of the iron group family, usually cobalt, in the form of quite small cylinders, e.g., ¼ inch–⅝ inch diameter. Since the process for making these inserts involves compacting the carbide and binder granules together to form the green, presintered shapes, they have come to be known as "compacts," or, more briefly, "pacs." These heel inserts were mounted at an angle to both the bottom of the hole and the sidewall, with their flat inner ends buried in the cutter metal and their blunt cutting tips protruding from the cutter to approximately bisect the angle between its heel conical surface and its gage conical surface, much in the manner of the heel inserts of the first compact bits, as shown in the original patent to Woods et al., U.S. Patent 2,687,875.

Such structure did not constitute a satisfactory answer to the problem. Compact bits are sensitive to the formation they are drilling, more so than milled cutter bits, doing their fastest work in hard formations that respond to the chipping-crushing action of their cutting structure but slowing down to an uneconomical rate in soft formations like shale that are drilled best by a gouging-scraping type of cutting action. The milled cutter bits modified so that compacts replaced all of the heel teeth exhibited this same slow drilling rate in soft formations, and such use did not make for profitable drilling. (Both types of bits also exhibited a similar drilling rate dependence on mud weight, the rate being best in low weight muds like 8½–9½ pounds per gallon (p.p.g.) but decreasing to a rate slower than that of milled cutter bits when the mud weight was increased to the 10–22 p.p.g. range.)

Another disadvantage observed with the prior art bits

was that some of them allowed a large uncut rim of rock to form in the bottom of the hole just inwardly from the heel compacts, and such rim grew in radial thickness as drilling continued. Such a rim further reduces the drilling rate.

Another prior art structure which may have been aimed in part at the rounding problem is illustrated in Schumacher, U.S. Patent 3,126,067. Schumacher teaches a 3-cone rolling cutter bit in which the primary cutting structure of each cone consists of a multiplicity of circumferentially crested steel teeth. There are no elementally crested steel teeth, not even in the heel row. Between adjacent circumferential ends of such steel teeth in each row there is a small gap, and in each such gap Schumacher mounts a small tungsten carbide insert, deeply recessing it so that the crests of the adjacent steel teeth extend well beyond the cutting tips of his compacts. Schumacher uses such inserts with all of his inner and nose rows of teeth as well as his heel teeth, and carries the principle of recessing them so that they terminate short of the crests of his steel teeth to a logical extreme by spacing his cocked heel inserts so that they do not intersect his gage surface. See FIGURE 3 of the reference.

Thus Schumacher teaches a steel toothed-compact bit in which the wear resistant inserts do no work whatsoever as long as the steel teeth retain their original contours, and it may be assumed that his bit does a satisfactory amount of drilling so long as no troublesome abrasive formations are encountered. When abrasive rock is encountered, however, the steel teeth are worn away to expose the cutting tips of the tungsten carbide inserts, and thereafter the bit purportedly will operate in somewhat the same manner as the original compact bits disclosed in the aforementioned U.S. patent of Woods et al., No. 2,687,875.

While Schumacher's bit may serve its intended functions well enough, it will be apparent that its utility is limited by some of the same considerations that limited the usefulness of the aforementioned prior art bit with inserts substituted for all heel teeth. There must necessarily be a finite spacing between Schumacher's heel teeth and his first inner row of teeth, both of which are circumferentially crested and are not made overlapping, and in this space there will be an uncut rim of bottom which will grow in size in an abrasive formation and slow the drilling rate of the bit to an uneconomical level.

In addition, Schumacher's heel inserts will not cut gage until part of the steel gage surface has been worn away, and by that time the bit will already be drilling an undersize hole. By contrast, the bit of the present invention is operable without permitting the growth of a large uncut rim of rock, and the limited number of heel inserts assist the bit in drilling a full gage hole from the time the bit is new, being particularly useful in prolonging the life of the bit in those situations where prior art steel toothed bits become rounded at the heel and lost gage.

In addition to such prior bits, the present inventor and his colleagues experimented with a milled cutter fortified with wear resistant inserts secured in each cutter so that they extended normally out to the gage surface and were there ground flush. Such bits thus had the gage compacts disclosed in Cunningham, U.S. Pat. 2,774,570, but otherwise had cutting structure in the form of steel teeth, including all of the heel teeth. They did not solve the problem of heel rounding in the described troublesome abrasive formations, but rather permitted the heel teeth to wear inwardly and upwardly from the gage point (intersection of gage surface and crests of heel teeth). A rock ridge or rim grew up from bottom in this area which made the bit slow down to an uneconomical drilling rate. The gage inserts worked well enough to prevent excessive

gage wear, but these inserts did not help the bit drill a sharp corner.

In the present invention the disadvantages of the prior art bits have been overcome by retaining most of the steel cutting teeth, including the heel teeth, and partially replacing the others with a limited number of cocked heel inserts disposed in a recessed fashion so that they cut no bottom during the early part of the bit life but rub against the sidewall of the hole to serve a gage-maintaining function from the very outset, when the bit is brand new. At the same time, the retained steel heel teeth are all of elemental form to assure a full cutting of that part of the bottom adjacent the sidewall of the hole and to eliminate any interrow gaps which could serve as nuclei for uncut rims, even in forms of the invention in which the inner rows of steel teeth are circumferentially rather than elementally crested, such elementally crested heel teeth sometimes being connected by circumferential webbing and sometimes not. In addition, the retained steel heel teeth are liberally protected on their gage surfaces by a generous application of welded-on and ground hardfacing, one preferred form being that disclosed by the undersigned inventor in his co-pending United States application S.N. 515,603, filed Dec. 22, 1965.

The present invention may become more clear by considering the following detailed description of it in conjunction with the accompanying drawing in which:

FIGURE 1 is a side view of an embodiment of a Hughes Tool Company 7⅞" diameter WD7 "Tricone" rolling cutter bit in which all of the steel teeth are elementally crested and the adjacent heel teeth are not connected by circumferential webbing, but rather the outer end of each heel tooth extends circumferentially a short distance each way from center so that the tooth crest as a whole takes the form of a T,

FIGURE 2 is a bottom view of the bit of FIGURE 1,

FIGURES 3 and 4 are cross-sections of two of the cone cutters of the same embodiment, respectively of the No. **1** cone and No. **3** cone, viewed in normal drilling position, the section being taken through one of the heel inserts,

FIGURE 5 is an enlarged fragmentary view of the gage surface of one of the cutters of the same embodiment, looking along the axis of rotation of the cutter,

FIGURE 6 is a "bottom hole section" of the same embodiment, i.e., a vertical section through the axis of one of the cutters (No. **1**) disposed in operative position, showing in half section through one of the heel inserts the cutting structure of that cutter and also the cutting structure of the other two cutters coaxially disposed with cutter No. **1** and rotated into the same plane, the number at the upper part of each tooth indicating the number of teeth in the circumferential row and the number in the bottom part indicating the cutter on which that row is mounted,

FIGURE 7 is a bottom hole section, similar to that of FIGURE 6, of a somewhat different bit, a new 7⅞ inch diameter "Hughes" WDR "Tricone" bit, one having circumferentially crested inner and nose rows of teeth and elementally crested heel teeth, some of the latter being connected by circumferential webbing, and

FIGURE 8 is a bottom hole section of a bit which when new was identical to that of FIGURE 7, the FIGURE 8 bit having been run in the field until its cutting structure was partially worn, as illustrated.

Turning to the FIGURES 1–6 embodiment, which illustrates a 7⅞ inch WD7 bit, it will be seen that the general organization of the bit, except for the cutters, is similar to prior art 3-cone rolling cutter bits. Three head sections (not shown separately) are welded together to form an upstanding tapered and threaded shank **5** symmetric about an axis of rotation **4**, and three bit legs **6** are integrally connected to shank **5** and extend downwardly therefrom and out to a somewhat larger diameter. The bit legs **6** are evenly spaced about bit axis **4**, and between each adjacent pair of legs a jet nozzle **8** may be

provided to direct a high velocity stream of drilling fluid to the bottom of the hole (although centralized water courses located nearer the bit axis may also be used, if desired). From each leg **6** a bearing pin in the form of a short cantilever shaft **26** (see FIGURE 6) extends downwardly and inwardly toward bit axis **4**, and it is on these shafts that cutters **1**, **2** and **3** are rotatably mounted so that they rotate about the individual shaft axes **27** and roll over the bottom of the hole as weight and torque are applied to the bit. Bearings for the cutters are illustrated in FIGURE 6 as consisting of rollers **22**, balls **23**, a nose bushing **24** and a thrust button **25**, but the bearings form no part of the present invention and it is to be understood that any suitable combination of journal and non-friction bearings found suitable with prior art bits may be employed, and may or may not be provided with any of several lubricating systems, sealed or unsealed.

The cutters themselves have cutting structure not appreciably different from that heretofore known except at the heel and gage. Thus No. **1** cone has a spearpoint **9** and an annular inner row **11** of elemental steel teeth discretely spaced from one another, No. **2** cone has a nose row **15** and an inner row **17** of similar teeth which follow the corresponding rows of the No. **1** cone, and No. **3** cone has a nose row **19** and an inner row **21** which follow rows **15** and **17** of the No. **2** cone, the distribution being such that, as best seen in FIGURE 6, the teeth in rolling over the bottom form tracks lying between the tracks formed by the teeth on the other cutters and thus cooperate to cut the entire bottom except for the very narrow upwardly converging rims **30** which disintegrate readily under normal drilling conditions. The crests of these nose and inner rows of teeth collectively form a conical surface generally referred to by bit designers as the "main" or "bottom" cutting surface, while the crests of the heel teeth on all cutters is known as the "heel" cutting surface.

The structure of the invention lies entirely in the heel or outermost row of teeth and the gage surface of the cutters, and by again referring to FIGURES 1–6 it will be seen that the heel cutting structure comprises full length or retained T heel teeth **10**, **10'** and **10"** on cutter No. **1**, No. **2** and No. **3**, respectively, and partially cutaway heel teeth **12**, **12'** and **12"** which were originally of the same full crest lengths as teeth **10**, **10'** and **10"**, respectively, but have had their outermost portions cut away to leave spaces adjacent the gage surface in which inserts **14** are mounted. In some cases, when an original tooth has only a short length of crest, it may be completely eliminated to make room for an insert. (This condition is not shown in the drawing, wherein the heel teeth of the different cones vary in crest length, No. **1** cone having the longest crests which are so long that they are relieved by notches **13** to divide heel teeth **10** into inner parts and outer parts, as shown. The shortened heel teeth **12** simply have these outer parts removed.) The general plan in the design illustrated was to leave two of teeth **10** (or **10'** and **10"** on the other cones) intact and modify every third one for the mounting of an insert **14**. Such inserts are inclined with respect to both the gage surface **18** and the heel conical cutting surface of the cutter defined by the crests of the heel teeth, and it will be apparent that inserts **14** are disposed with their cutting tips **16** extending downwardly from the cutter toward the heel conical surface and the bottom of the hole a considerably lesser distance than steel heel teeth **10** (or **10'** or **10"**), and thus that they cut no bottom while such teeth are new. It will also be apparent from the sectional view that the inserts extend to gage surface **18** and are ground flush at **20** with such surface, and thus that they bear against the sidewall of the hole and help drill it to a predetermined diameter even when the bit is new. The surface of the cutter body through which insert **14** extends is preferably flat and normal to the longitudinal dimension of the insert, as shown at **28** and **29** for cutters No. **1** and No. **3**,

respectively, (FIGS. 3 and 4) to equalize stresses on the insert and minimize the likelihood of breakage.

The gage surfaces **18** of retained heel teeth **10**, **10'** and **10"** are provided with a welded-on tungsten carbide hardfacing (not visible), desirable forms thereof being disclosed in the abovementioned co-pending application of the present inventor. This surface hardfacing supplements inserts **14** in bearing against the sidewall of the hole and keeping it dressed to a uniform diameter.

The manner in which bits of the present invention prevent cutting a bottom pattern to leave an uncut rim adjacent the sidewall of the hole will be evident from FIGURE 6, and this same figure illustrates why it is desirable to retain some of the heel teeth intact and make such teeth with elemental crests rather than circumferential crests. In the illustration the retained heel teeth **10**, **10'** and **10"** are shown in phantom to avoid confusing them with modified or stub heel teeth **12**, **12'** and **12"**, but they extend radially inwardly (toward the right in the drawing) so that they terminate at the locations marked on the drawing. These rows of heel teeth overlap one another so there is no gap in the bottom cutting structure, and thus no uncut rim is allowed to be formed. It can be appreciated that if all heel teeth were modified and replaced with inserts, such a rim could be started between inserts **14** and the stub heel teeth **12**, **12'** and **12"**, especially in one of the aforementioned abrasive formations that promote gage wear and heel rounding. What would make this particularly likely to happen is the fact that there would be no teeth directly under inserts **14**, the bottom pattern of the rock would curve around the modified heel teeth to a raised step cut by the inserts, and the outer ends of heel teeth **12**, **12'** and **12"** would be exposed to erosion. By the same token, a bit in which the heel row of each cutter consisted entirely of inserts would have nothing but these inserts drilling on the outermost ring of the bottom at all times, and would drill the softer formations only at slow and uneconomical rates.

FIGURES 7 and 8 are bottom hole sections similar to that of FIGURE 6 but differing therefrom in that the bit of FIGURE 7 is a new bit in which all of the inner and nose rows of teeth are circumferentially crested, and most of the adjacent retained heel teeth are joined by circumferential webbing at the gage surface (the latter detail not being apparent in FIGURE 7). The bit of FIGURE 8 is identical with that of FIGURE 7 except for the fact that it has been used in drilling hole to such an extent that all of the steel teeth are partially dulled.

These two figures illustrate the effectiveness of the invention because they show that the partially dulled bit of FIGURE 8 is still capable of drilling a full-gage hole despite its worn condition. This bit, Serial No. DS171, had drilled 144 feet of hole during 8¾ operating hours at the time it was pulled and used for the drawing illustration, most of the drilling taking place through abrasive limestone which included a gage problem section of Kansas City lime, the drilling having taken place in the Camrick field of Beaver County, Okla. (PSR 1482). Prior art bits having no inserts **14** and being like that of FIGURES 7–8 except that all steel heel teeth are retained are likely to drill somewhat less footage when used in the same location, and when pulled are highly likely to show evidence of heel rounding, excessive gear wear, or both. This may require the following bit to ream a considerable portion of the hole before touching bottom.

A comparison of FIGURES 7 and 8 will show that maximum wear has taken place on the heel teeth, as the spearpoint and inner rows of teeth are worn to a considerably lesser extent. Inserts **14** have barely begun to drill the bottom of the hole, and there is thus considerable life remaining to the bit. Despite the extended use, the same field report (PSR 1482) mentioned above discloses that the diameter of the bit gage 7.850 inches after use.

Another bit like that in FIGURE 7 was used in drilling abrasive limestone in the Caprock field of Lea County, N.Mex., and drilled 114 feet in nine hours through a formation which included a zone of cherty limestone known as the Wolfcamp without loss of gage. (Bit No. HT 148, or PSR Report 1520.) At this same location and depth milled cutter bits without the features of the invention normally make less than 100 feet and lose gage.

As yet another example, a bit like that in FIGURES 1–6 drilled the abrasive and gage-wearing Kansas City lime in Grant County, Kans., drilling 200 feet in 11 hours to maintain a full gage hole. Average runs for milled cutter bits in the same formation of this area are 160 feet in 12¼ hours, with loss of gage.

There has thus been disclosed an improved steel-toothed bit having elemental heel teeth in which the drilling performance in abrasive formations is improved by at least partially removing the outer portions of some of the heel teeth and substituting for them inserts of wear-resistant material disposed so that their cutting tips extend to the gage surface but extend only slightly toward the heel conical surface of the cutter, terminating well below the crests of the adjacent heel teeth. While the work has involved thus modifying only ⅓ of the heel teeth, nothing critical about such number is known, and it can probably vary widely so long as a substantial number are retained intact. Similarly, there appears to be nothing critical about the relative protrusions of the inserts and the adjacent heel teeth from the body of the rolling cutter, so long as the cutting tips are exposed to bottom cutting action at the time the adjacent heel teeth are close to the ends of their useful lives.

What is claimed is:

1. A rolling cone cutter having a body with a gage surface and annular rows of crested steel cutting teeth protruding from the body so that the crests will cut the bottom of a hole, the outermost or heel row thereof being modified so that a part of the teeth therein are at least partially removed and replaced with inserts of hard, wear-resistant material disposed so that their cutting tips extend all the way to the gage surface of the cutter but lie closer to the cutter body than the crests of adjacent heel teeth.

2. A rolling cutter for rock bits having a body, a conical heel cutting surface and a conical gage surface intersecting and coaxial with said heel cutting surface, an annular row of circumferentially spaced elementally crested steel cutting teeth defining said heel cutting surface, some of said heel teeth being unmodified and extending to said gage surface while the others are modified so that their gage portions are cut away, and a heel insert mounted in the space left by said cutaway portion, said insert being mounted with its base portion secured in said cutter spaced from both said conical surfaces and its cutting tip protruding from the cutter to intersect said gage surface but to lie closer to the cutter body than the crests of said steel teeth.

3. A rolling cutter comprising a body having a conical main cutting surface, a conical heel cutting surface and a conical gage surface, said conical surfaces being coaxial about a common axis and said heel and gage surfaces intersecting each other, said main and heel cutting surfaces being defined by the crests of a number of annular rows of cutting teeth extending outwardly from said cutter body, said rows including an outermost or heel row of elementally crested teeth of which a substantial number extend to said gage surface and the remainder are separated from said gage surface by spaces, and a wear resistant insert secured in the cutter body inclined with respect to said heel and gage surfaces and with its cutting tip protruding therefrom in each said space adjacent the intersection of the surfaces, and spaced above the heel surface, said insert terminating flush with said gage surface and extending from said cutter body less than the crests of the adjacent heel teeth.

4. A rolling cutter having a body with a comparatively

elongated conical bottom cutting surface, a shorter conical heel cutting surface and a shorter conical gage surface, said conical surfaces being coaxial about a common axis of rotation and said heel and gage surfaces intersecting one another approximately at a right angle, annular rows of cutting teeth integral with said body and extending from said body so that their crests define said bottom and heel cutting surfaces, said rows of teeth being coaxial with said axis of rotation and spaced from one another along said axis, said rows including an outermost or heel row of teeth of which a substantial number extend to said gage surface and are there provided with a wear-resistant hardfacing ground flush with said gage surface, the balance of the teeth in said heel row being modified by removing at least the outer portions thereof to leave spaces adjacent said gage surface, and wear resistant insert secured in the cutter body at each such space, said insert being disposed to approximately bisect the angle between said gage surface and said heel cutting surface, said heel teeth extending from said bottom surface beyond the cutting tips of said inserts.

5. A rolling cone cutter for rock bits comprising a body with a conical bottom cutting surface, a conical heel cutting surface and a conical gage surface intersecting said heel surface, a multiplicity of rows of steel teeth extending from said body with their crests forming said bottom and heel cutting surfaces, said rows including a heel row of elementally crested teeth of which a substantial number extend to said gage surface and are there provided with a welded-on hard facing of tungsten carbide ground flush with said gage surface, some of said substantial number of heel teeth being separated from one another by circumferential spaces, and an insert secured in the cutter body at each such space so that its cutting tip protrudes therefrom and extends all the way to said gage surface but lies closer to the body than the crests of the adjacent heel teeth.

6. In a rolling cone cutter for rock bits having annular rows of steel teeth protruding from the cutter body, including a row of elementally crested heel teeth extending to the gage surface thereof, the improvement comprising a substantial number of said heel teeth having at least their outer portions cut away to define spaces adjacent said gage surface and a wear resistant insert secured in the cutter body at each said space with its cutting tip intersecting said gage surface, said cutting tip being ground flush with said gage surface and extending from the cutter body less than the adjacent heel teeth.

7. In a steel-toothed rolling cone cutter for rock bits in which the heel teeth are elementally crested, the improvement in which the number of said heel teeth extending completely to the gage surface is substantially reduced and some of such heel teeth are separated from each other by spaces, and an insert secured in the cutter at each said space so that its cutting tip lies closer to the body than the adjacent heel teeth and extends to and is flush with the gage surface of the cutter.

8. In a rolling cone cutter for rock bits having a conical main-bottom cutting surface, a conical heel cutting surface and a conical gage surface, and annular rows of steel teeth extending from the cutter with their crests forming said cutting surfaces, including a row of elementally crested heel teeth, the improvement comprising dividing said heel teeth into a first substantial number which extend to said gage surface and are there provided with a welded-on hardfacing of tungsten carbide, and a second substantial number having at least their portions adjacent said gage surface cut away to define spaces adjacent such surface, and wear resistant inserts of tungsten carbide secured in the cutter at such spaces so that their cutting tips extend toward said gage and heel surfaces, said cutting tips extending from the cutter and terminating short of said heel cutting surface and being ground flush with the gage surface.

9. In a rolling cone cutter for a rock bit, such cutter having a body with a conical heel cutting surface and a conical gage surface, such surfaces being coaxial and intersecting each other at about a right angle, said cutter having cutting structure extending from said body to define said heel cutting surface, said cutting structure consisting of an annular row of steel cutting teeth, the improvement in which said row of heel cutting teeth consists in part of a substantial number of elementally crested steel teeth which extend to and intersect said gage surface and are there provided with a hardfacing of tungsten carbide, said heel teeth being circumferentially spaced from one another to define spaces adjacent said gage surface, and consisting in part of a substantial number of wear resistant inserts secured in the cutter body at such spaces, each said insert having a cutting tip protruding from the bit body and being ground flush with said gage surface, the elemental crests of said heel teeth being spaced further from said cutter body than said cutting tips of the inserts.

10. In a steel-toothed rolling cone cutter having a gage surface and an intersecting heel cutting surface defined by the crests of an annular row of elementally crested steel cutting teeth protruding outwardly from said cutter, the improvement comprising fortifying said heel teeth with a number of wear resistant inserts by terminating a substantial number of said heel teeth short of said gage surface to leave spaces adjacent said surfaces, said inserts being mounted in the cutter at such spaces so that their cutting tips protrude from the cutter a lesser extent than the heel teeth and extend to and are ground flush with said gage surface.

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NILE C. BYERS, JR., *Primary Examiner.*