United States Patent

Kelly, Jr. et al.

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[54] ROTARY-PERCUSSION GANG DRILL WITH CIRCUMFERENTIALLY FLOATING OFFSET BITS

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[73] Assignee: **Hughes Tool Company,** Houston, Tex.

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[52] **U.S. Cl.**.....**175/96,** 175/410

[51] **Int. Cl.**.....**E21b 1/06,** E21b 3/12, E21b 5/00

[58] **Field of Search**....175/96, 95, 53, 108, 389, 390, 175/415, 416, 410

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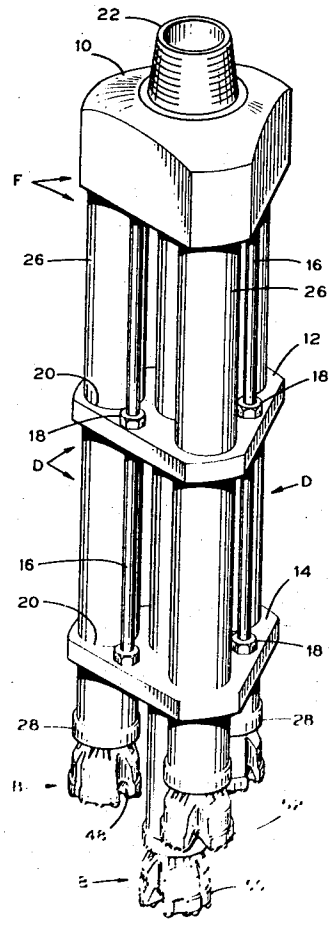
Primary Examiner—David H. Brown

Attorney—Robert A. Felsman

[57] **ABSTRACT**

A big hole drill in which a multiplicity of parallel downhole percussion drills are secured to a common framework for joint rotation therewith. The drills may be supplied with operating fluid from a common manifold, but each drill hammers independently of the others. The individual drill has a percussion bit secured to and depending from its forward end, the bit being mounted for limited axial movement relative to the drill so that the hammering action of the drill on the bit drives it forward into a rock formation. The improvement lies in mounting those bits which are offset from the axis of rotation of the assembly so that each bit is circumferentially floating with respect to its associated drill. In operation each such offset bit is rotated relative to its drill to bring different portions of its peripheral cutting structure into contact with the sidewall of the kerf formed by the row of bits in which it is located. The inventors have discovered that the offset bits thus mounted are rotated by contact with the formation as the entire assembly is rotated, distributing the wear on the bits and causing them to drill a full size hole.

5 Claims, 11 Drawing Figures



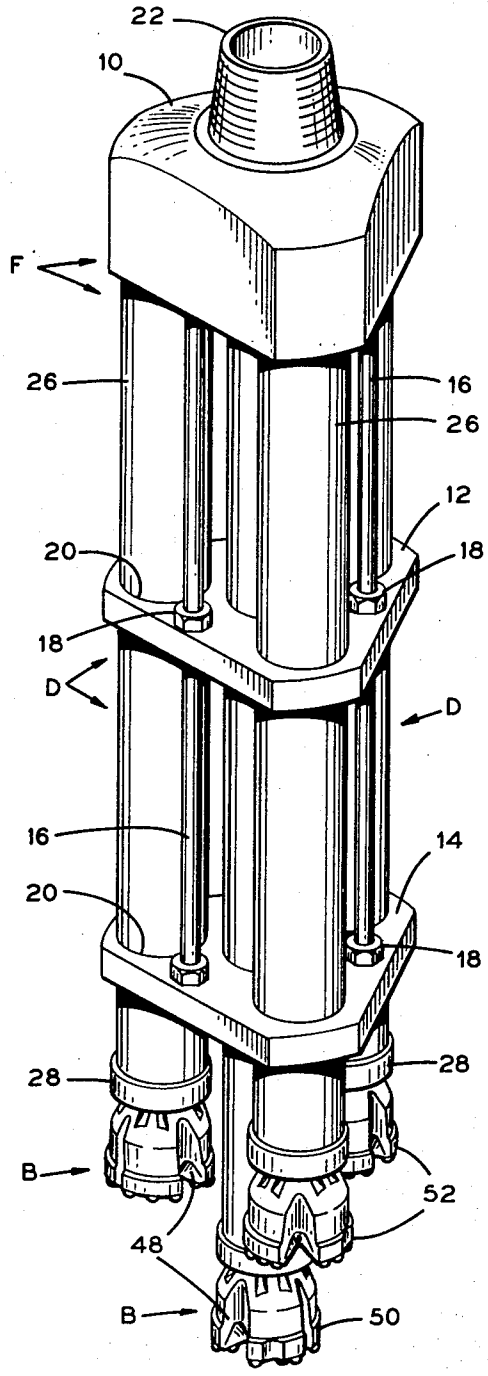


FIGURE 1

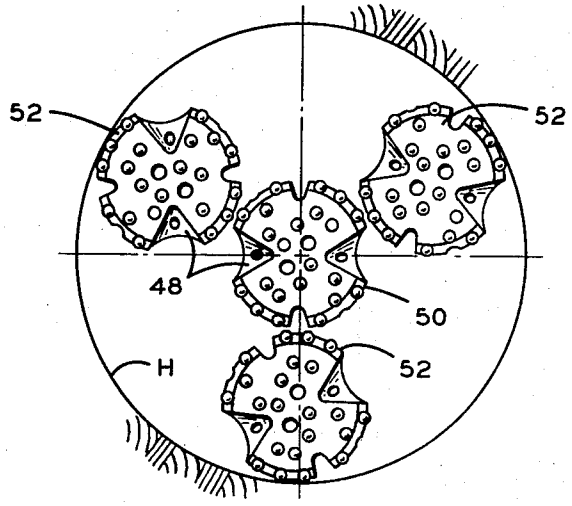


FIGURE 2

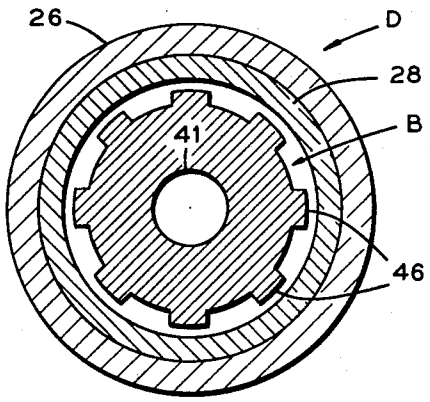


FIGURE 4

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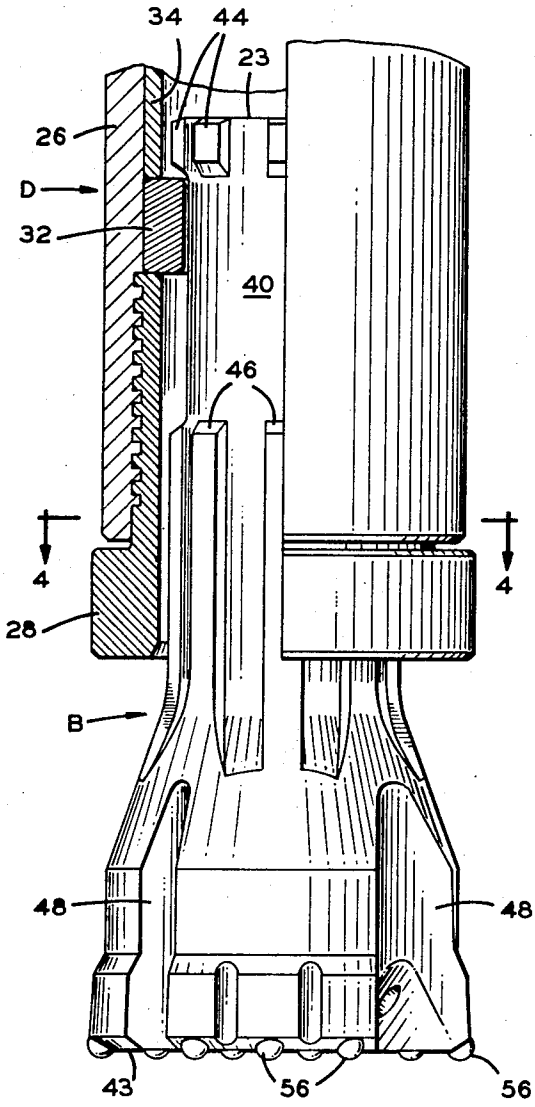


FIGURE 3

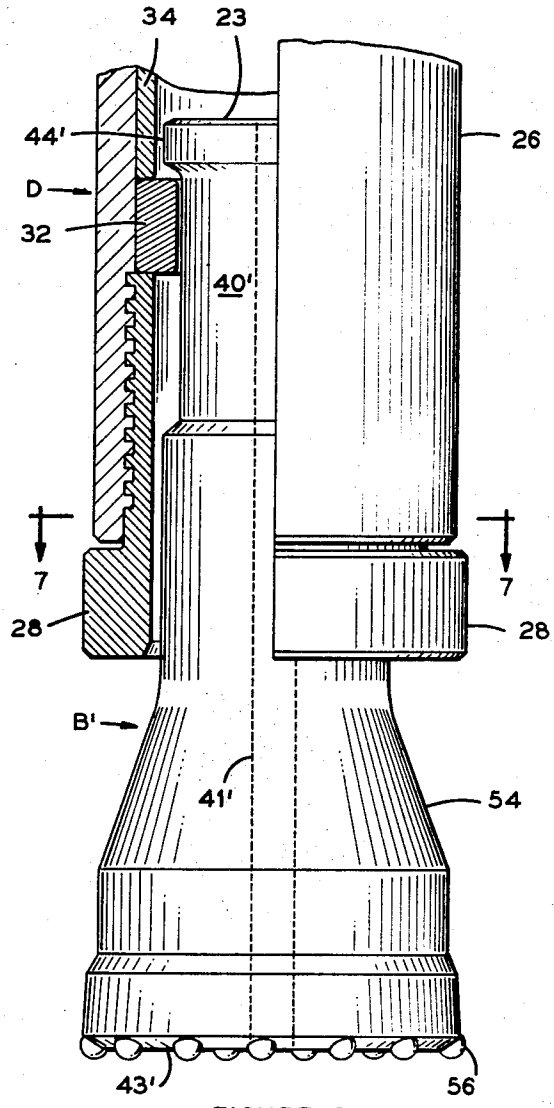


FIGURE 6

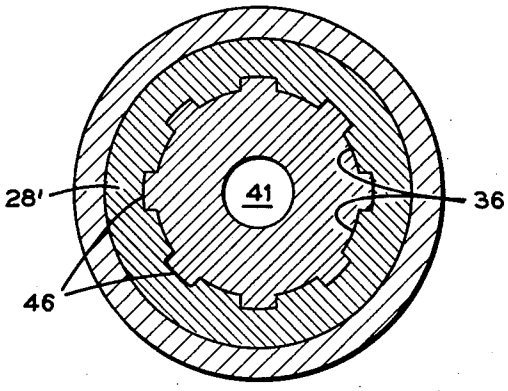


FIGURE 5
PRIOR ART

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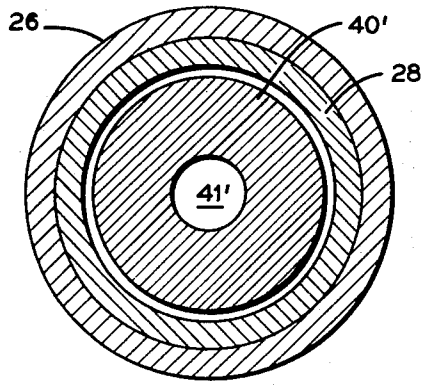


FIGURE 7

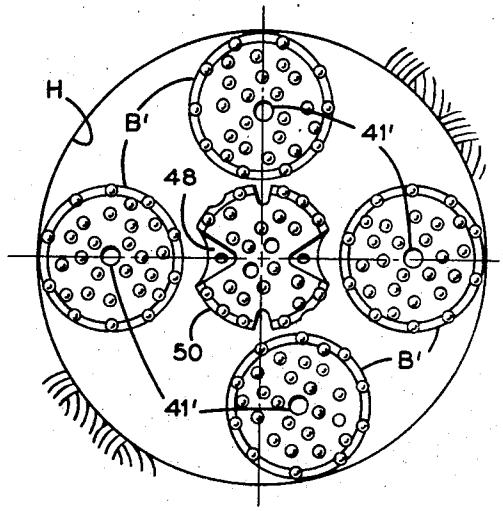


FIGURE 8

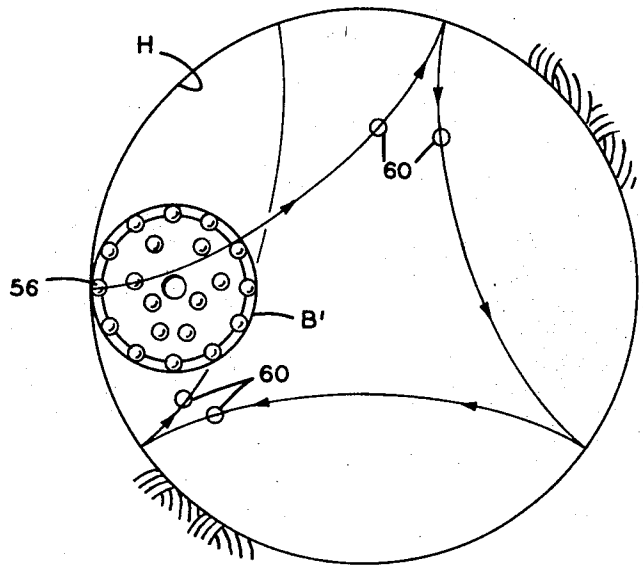


FIGURE 9

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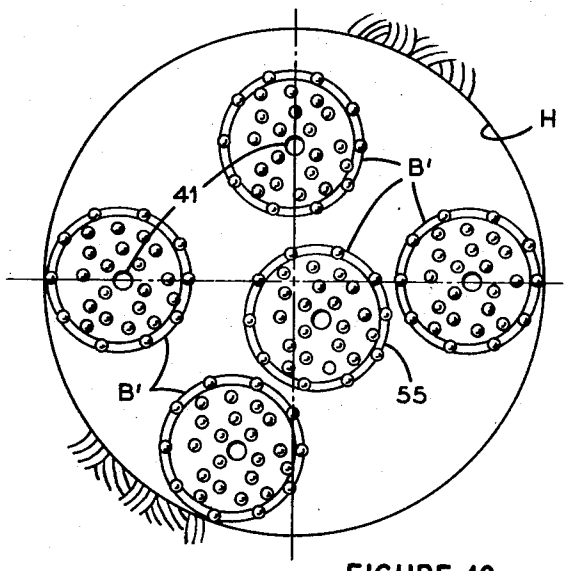


FIGURE 10

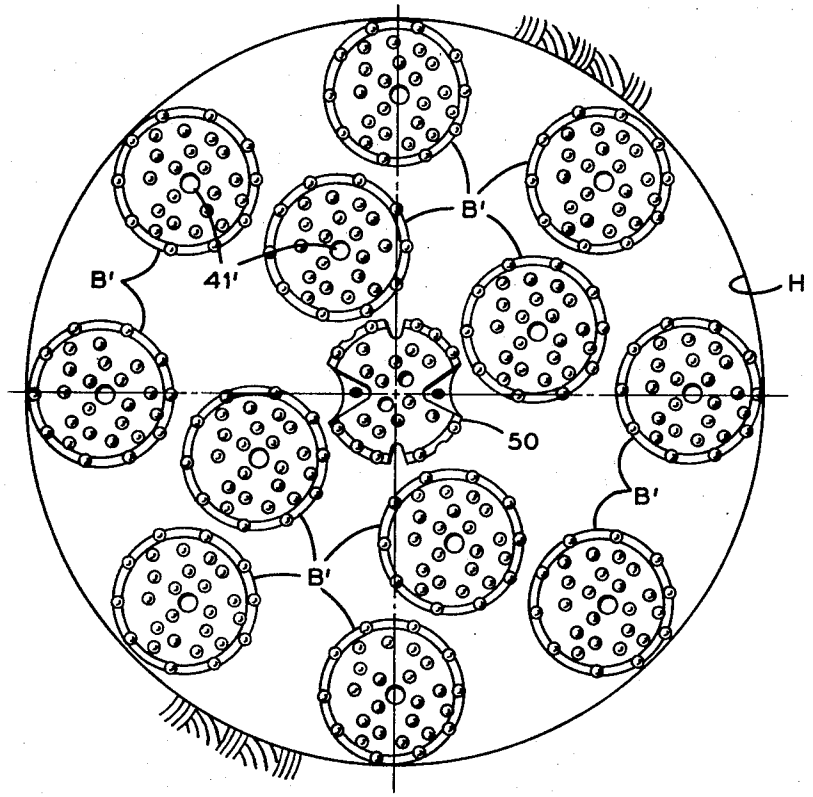


FIGURE 11

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ROTARY-PERCUSSION GANG DRILL WITH CIRCUMFERENTIALLY FLOATING OFFSET BITS

The subject matter of the present invention is gang drills, and more particularly gang drills of the type wherein several downhole percussion drills are disposed in parallel fashion about the axis of rotation of a rotary framework, each drill receiving at its lower end a percussion bit of the type designed to receive hammer blows delivered on its upper end by the axially reciprocating hammer of the drill to drive the bit into a rock formation and disintegrate it. At the same time, the entire gang or assembly is rotated about a longitudinal axis so that the bits act on the entire face of the rock formation to cut a complete hole. The common framework also serves as a means for manifolding the downhole drills together to a common source of power, typically an operating fluid which not only operates the downhole drill to produce axial reciprocation of its hammer but also serves as a means for carrying away the cuttings from the bottom of the hole so that the cutters act only on virgin rock.

Such gang drills are known in the prior art, e.g., Kurt et al., U.S. Pat. No. 3,144,086 and Thompson, 3,387,673. However, such prior art gang drills teach the necessity for securing each bit to its associated drill so that it has only one degree of freedom with respect thereto, specifically in that the bit may move axially, to a limited extent, relative to the drill body or casing. No rotation of the bit relative to the drill body is permitted, and indeed common rotation of the two is insured by providing the outer surface of the bit shank with alternating circumferential lands and grooves, and similar lands and grooves are provided on the inner surface of a chuck constituting the lowermost member of the drill body. In other words, the prior art arrangement is one of interfitting longitudinal splines on the two members, permitting the bit to slide up and down relative to the drill but preventing the bit from independently rotating about its own axis.

Thus, if a prior art drill and bit are mounted as one of the outermost peripheral members of the gang drill, to cut the corner of the hole where the bottom and side wall come together, the same portion of the drill bit is always in contact with the corner of the hole where these two surfaces intersect. Since this corner has the largest surface and is hardest to drill by comparison with inner portions of the hole, the drill bit inserts or other cutting structure thus in constant contact with the corner will wear more rapidly than the other parts of the cutting structure, and some adjustment must be made to equalize the wear. In Kurt et al., the patentees teach a structure in which the clamping means holding an offset drill to the common framework is loosened, the drill and its depending bit are re-oriented to bring a different bit cutting edge into contact with the sidewall of the hole, and the drill is then re-clamped to the framework. This sequence of operations requires that the entire gang drill be taken out of action until the changeover can be completed.

In Thompson, on the other hand, use is made of a pair of rigid percussion bits which have a larger area of cutting surface contacting the corner of the hole than do their inner parts, and Thompson also teaches the use of rolling cone cutters disposed with the bases of the cones contacting the corner of the hole. Thompson stresses the use of cutters especially adapted to be fixed against rotation relative to their associated drills, and makes no use of the stop-and-adjust concept of Kurt et al. Like Kurt, however, Thompson teaches that the shank of each bit body should be splined to its associated percussion drill so that each bit can move axially but not circumferentially with respect to its drill.

The primary object of the present invention is to provide a gang percussion drill utilizing percussion bits secured to their respective drills in such manner that each bit which is offset from the center of the assembly rotates, during operation, in such a manner as to equalize the wear on its peripheral cutting structure and thus obviate the need for any down time to re-orient the bit with respect to its drill. An associated object is to provide a gang percussion drill utilizing percussion bits secured to their downhole drills to reduce wear on the cutting structure of the various bits.

Another object is to provide such a gang percussion drill in various sizes, disposing the various drills in one or more circumferential rows spaced radially between the axis of rotation and the periphery of the assembly, with or without a drill disposed on the axis of rotation. Yet another object is to provide such a gang percussion drill utilizing existing designs of individual single hole percussion drills and percussion bits, modifying the bits or drills only as necessary to permit rotation of individual bits relative to their associated drills (signifying by "single hole" that the drill or bit is one designed for individual use in boring a single hole).

In developing their discovery, the present inventors also discovered that improvements may be made in the conventional single hole percussion bits when utilizing them in groups in a gang drill like that of the present invention. Specifically, they have found that in solid head bits the external longitudinal slots and grooves found necessary in a single hole bit to permit the upward flow of circulating fluid and cuttings are unnecessary when the bit is used in a gang drill, because each bit has ample space around it for upward flow. Similarly, they have discovered that the multiple air passages of single bits used in the present gang drills may be simplified to a single axial passage extending from top to bottom of the bit body. In addition, of course, percussion bits manufactured expressly for gang drill use need not have splines formed on their shank portions, and the same is true of the drills. Thus it is an object of the present invention to provide a gang percussion drill using single hole drills and bits modified to eliminate unnecessary features and therefore being lower in cost.

The principal aspect of the present invention may be summarized by saying that it is a gang percussion drill improved by a novel connection between one or more of the gang of percussion bits and the associated percussion drills, a connection in which the bit is secured to its drill so that the bit is circumferentially floating with respect to the drill. The usual arrangement is provided whereby the bit may move axially to a limited extent in response to hammer blows delivered on its upper surface by the drill, and the drill itself is rigidly secured to a framework of a gang drill so that it, together with a number of similar drills, must move axially with the framework and must also rotate with the framework when the entire assembly is rotated. The bit, however, will rotate with respect to its associated drill in response to frictional forces exerted by anything

with which the cutting structure end of the bit is in contact.

Typically the bit is made with a shank which projects up into the hollow lower end of the drill, and circumferential floating is achieved by the type of geometry provided on the confronting faces of the two members, the outer surface of the bit shank and the inner surface of the chuck or other lowermost member of the drill. These two confronting surfaces are dimensioned for a comparatively loose fit, and one or both of them is provided with a surface of revolution, usually a cylindrical surface, which is free of lands and grooves or other forms of projection which might fit into corresponding grooves in the other member to compel a common rotary relationship. By comparison with the prior art structures in which both the bit shank and the drill chuck were provided with splines, the present invention takes the form of eliminating the lands (splines) from one of the confronting surfaces, i.e., machining them off so that the resultant surface is a smooth right cylindrical surface. In actual practice it is preferable to manufacture the drill bit and chuck so that each of them has a smooth bore cylindrical surface, thereby eliminating the machining operation of the prior art which was necessary to form alternating lands and grooves.

Another feature of the invention lies in the body and cutting structure end of the percussion bits used in such gang drills. While prior art bits which are used singly to form small holes may be employed in the gang drills of the present invention by modifying only their interfit with their associated downhole drills, as discussed above, the present inventors have also found it unnecessary to preserve other aspects of the prior art single hole bits. Such bits when used singly must be provided with longitudinal grooves and passageways whereby the flushing fluid ported through the bit at the bottom of the hole may pick up the cuttings and carry them up around the bit to the surface. In gang drills, however, a hole considerably larger than that drilled by a single bit is formed and there is ample room between the bits for the flushing fluid to carry the cuttings upwardly. No peripheral longitudinal grooves are needed on each bit, so the lower end of the bit, on which the cutting structure is provided, may be made full circle and equipped with cutting structure distributed evenly thereover.

The invention also provides a simplified and less expensive fluid delivery system (usually air) inside the bits. Conventional bits used singly in small hole drilling require one or more air passages to deliver the circulating fluid to the bottom of the hole for cuttings removal. These air courses cannot discharge at the center of the hole because cutting elements must be provided at that location. In the offset bits of the present invention no such requirement exists and a single, through air course can be provided along the axis of the bit.

The present invention may perhaps be more readily understood by the following detailed description of some preferred embodiments, taken together with the accompanying drawing in which:

FIG. 1 is an isometric view of a complete gang drill in one preferred form,

FIG. 2 is a bottom view of only the drill bits of FIG. 1,

FIG. 3 is an elevation of one of the offset drills and associated bits of FIG. 1, a quarter of the lower end of the drill being sectioned away to show the interfit of its chuck with the shank of the bit,

FIG. 4 is a cross-section of the same drill and bit, as indicated by the sectioning lines and arrows in FIG. 3 labeled "4—4,"

FIG. 5 is a cross-section like that of FIG 4, but showing the prior art interfit of drill chuck and bit shank,

FIG. 6 is a side elevation similar to that of FIG. 3, but showing another preferred embodiment in which splines have been eliminated from both drill chuck and bit shank, and also using a bit of the present invention in which longitudinal gaps and passageways have been eliminated from the cutting structure end of the percussion bit,

FIG. 7 is a cross-section of the drill and drill bit of FIG. 6 (similar to that of FIG. 4), on the sectioning lines and arrows of FIG. 6 marked "7—7,"

FIG. 8 is a bottom view of the drill bits of a gang drill similar to that shown in FIG. 1, utilizing offset drills and bits like those shown in FIG. 6 but departing from the type shown in FIG. 1 in using a larger number of drill bit sub-assemblies, in using a non-uniform circumferential spacing between the offset sub-assemblies and in using only a single air course in each offset bit,

FIG. 9 is a view looking down into the borehole created by a gang drill built according to the present invention, this plan view showing a single offset bit in an arbitrary starting position and following the progress of a single heel insert or tooth of such bit as the gang drill is rotated about its longitudinal axis (assuming no slippage between the bit and the wall of the hole),

FIG. 10 is a bottom view of the percussion bits of a gang drill similar to that shown in FIG. 8, but differing therefrom in the disposition of the various bits including disposing the bit which cuts the center of the hole in an offset position relative to the center line of the hole (and thus the axis of rotation of the overall gang drill), and

FIG. 11 is another bottom view of the percussion bits of a gang drill of the invention, the particular gang drill illustrated having an intermediate circumferential row of bits as well as a peripheral row and a center or pilot bit.

As shown in FIG. 1, a complete gang drill consists of a basic framework F, a number of parallel downhole percussion drills D, and a like number of percussion drill bits B. The framework F may vary widely in construction, the one illustrated comprising a manifold or header 10, the center supporting and spacing plate 12, and the lower supporting plate 14. Plates 12 and 14 are secured to header 10 and to each other by the vertical tie rods 16, which pass through center plate 12 and are threaded into header 10 and are fastened to lower plate 14 and center plate 12 by nuts 18. Each of plates 12 and 14 is provided with appropriate vertical openings 20 to receive the drills D so that the drills extend through each plate and protrude below the forward or lower surface of bottom plate 14. To accommodate the upper ends or backheads of drills D, header 10 is also provided with a number of openings (not shown) which do not extend completely through the header. Each backhead of a drill D is received in that opening not shown in header 10 which registers with a correspond-

ing pair of holes in the plates **12** and **14**, and such opening may be tapped to receive a threaded connection that forms a leak-tight joint and also prevents the drill from rotating with respect to the framework, but any arrangement may be used which insures the same result. The header or manifold **10** includes a hollow center pin or shank **22** for connecting the gang drill to a hollow pipe used to rotate the gang drill and also to supply operating fluid which flows through pin **22** and into connecting passageways leading into each of the drills D.

The drills D shown in the drawing may be any conventional downhole percussion drill. A preferred type is one in which the operating elements are contained within an elongated casing **26** and in which a percussion hammer (not shown) reciprocates axially within such housing or casing **26**. Any operating fluid may be used, a preferred form being air which is exhausted below the hammer and into the drill bit, exiting from the lower end or bottom face of the drill bit so that it can remove loose cuttings from the bottom of the hole, carry them up around and between the bits and plates and up the bore hole in the annulus between the side wall of the hole and the hollow drill string.

Typically, as shown in FIGS. **3** and **6**, the forward or lower end of the drill D terminates in a sleevelike chuck **28** which is threaded into the body **26** of the drill. As chuck **28** is screwed into position, it contacts a ring **32** and clamps it against an inwardly extending portion **34** of the drill body **26**. Ring **32** is thus clamped against axial movement so long as chuck **28** is threaded into the assembly position shown in FIG. **3**, and the ring in turn prevents bit B from falling out of the bottom of the drill D by virtue of the outwardly turned flange **44** at the top of bit shank **40**. Ring **32** also controls the extent to which bit B can move upwardly into drill D, as upward motion will be halted at the time the lands or splines **46** on bit shank **40** come into contact with the lower surface of ring **32**.

The connection feature of the invention can be best appreciated by examining FIGS. **3** and **4**, and by comparing the latter figure with FIG. **5**. FIGS. **3** and **4** show the present invention as used with a conventional single hole percussion bit of the type adapted for cutting a small hole having a diameter essentially equal to the maximum diameter of the lower end of the bit, e.g., as shown in the U.S. Pat. No. to J. L. Kelly, Jr., 3,185,228, and FIG. **5** shows the splined interfit of such a bit to the chuck of a drill bit as in the prior art (and also as used for the center drill bit **50** of the FIGS. **1–4** embodiment, about which more below). The modification to the assembly to accomplish the purposes of the present invention lies in eliminating the inwardly projecting splines or lands **36** of chuck **28'**, as in prior art assemblies of the type shown in FIG. **5**. As shown in FIG. **4**, in the present invention the inner surface of chuck **28** is a smooth right cylinder free of any longitudinal splines or lands. The bit B may be freely rotated with respect to chuck **28** and drill D, either by hand when the bit is held out of contact with any surface or by interaction with the bottom and side wall of a hole when the drill has been lowered until the forward face of the bit contacts the bottom of the hole.

It will be apparent that the gang drill of FIGS. **1–4** has the advantage of permitting a prior art gang drill to be modified to accomplish the purposes of the invention with very little cost. Stock bits as manufactured for drilling small holes each equal to the diameter of the bit may be employed, and all that is necessary, for mounting each offset or peripheral bit **52** shown in FIG. **2**, is to replace the prior art chuck **28'** of FIG. **5** with a smooth bore chuck **28** as shown in FIG. **4**. In the FIGS. **1–4** embodiment, it should be noted that the center or pilot bit **50** and its associated drill are disposed co-axially with respect to the axis of rotation of the entire gang drill, and that the only feasible connection of such center bit **50** to its drill is of the splined type shown in FIG. **5** as exemplifying the prior art. This means that center bit **50** must rotate as its drill and the entire gang drill assembly is rotated, but such common rotation is necessary if the bit is to do any cutting. If bit **50** were circumferentially floating in the same manner as the offset bits **52**, it would very probably not rotate at all and would prevent the entire assembly from progressing forward satisfactorily.

In the preferred embodiment illustrated in FIGS. **6–8**, the drill bit B' has as its outer surface a smooth right cylinder, free of the splines of prior art bits and center bit **50**. The outer surface of bit shank **40'** faces a similar surface of chuck **28** across a small radial gap, just sufficient to permit ready axial movement of the bit. Bit B' also differs from prior art bits in that its lowermost body portions, just above the lower face **43'**, are free of the longitudinal gaps and grooves **48** of the bits shown in FIGS. **1–4** (and center bit **50**). Such gaps and grooves are not necessary where there is ample room between bits for the flow of cuttings.

FIGS. **6–8** also illustrate that the offset bits B' of the invention, when manufactured specifically for the gang drills of the invention, may have a vastly simplified flushing fluid system. As shown in the figures, this takes the form of a central air course **41'** extending with uniform bore from the anvil surface **23** at the top of the bit to the bottom surface **43'**.

The bottom view of FIG. **8** shows, among other things, that bits B' of the type shown in FIGS. **6** and **7** may be used as offset or peripheral bits in a gang drill assembly. As compared with FIG. **2**, FIG. **8** also shows that the number of peripheral bits may be varied according to the size of the hole and the toughness of the formation being cut, drilling practices employed, etc. It also shows that it is not necessary to use a uniform circumferential spacing between the peripheral bits B'. In the illustrated arrangement, the spacing between bits starting with the top center bit and proceeding clockwise is 90°, 15°, 105°, and 90°, but various other asymetrical spacings may be employed. Such nonsymetrical spacings have the advantage of reducing the likelihood of the gang drill producing an oversize hole, result in a smoother running drill, and reduce the shock loading transmitted through the bits and drills to the surface equipment.

The schematic view of FIG. **9** may be thought of as one obtained by looking down the borehole formed by a gang drill of the invention with all equipment rendered invisible except the bottom of a single drill bit B'. If it is assumed that the frictional resistance of the formation causes bit B' to rotate with true rolling action at the wall of the hole, like a wheel that doesn't slip, then a single insert **56** will follow the cycloidal

paths 60 indicated in the figure. For a particular size configuration, a big hole H of 20 inches diameter using bit B' of 6 inch diameter, the single heel or peripheral insert 56 of bit B' will contact the corner of the hole being drilled approximately three and a half times per revolution of the gang drill assembly. It will be apparent that each other heel insert 56 will similarly be rotating into contact with the hole, with the result that wear is distributed uniformly over all such heel inserts 56. It is not essential that the bit always rotate with true rolling action to get such distributed wear, as a much slower and non-uniform rate of rotation still insures equally distributed wear to obtain the desired results.

As noted above, when the gang drills of the invention include a center drill and a pilot bit 50 disposed co-axially with the axis of revolution of the entire assembly, such drill and bit must necessarily be connected so that each of them rotates in unison with the assembly and each other. However, it is not essential that the cluster of drills and bits include one disposed directly on the axis of the gang drill, and the present invention embraces within its scope an arrangement in which all drills and percussion bits are offset to some extent from the axis of rotation. Such an arrangement is shown in FIG. 10, wherein even the bit 55 closest to the center is somewhat offset therefrom. No splining for common rotation is necessary, and all bits may be connected to their drills in the manner illustrated in the drawing, either as in FIGS. 3 and 4 or as in FIGS. 6 and 7.

FIG. 11 is a bottom view of an embodiment of the invention in which more percussion drills and bits are added to drill a larger diameter hole. While the figure shows a center bit 50, an intermediate row of bits B' and an outer or peripheral circumferential row of bits B', it will be apparent that 4, 5 or more rows may be added with increasing diameter. Of course, the on-center bit 50 could be replaced by a slightly off-center bit B', by making the appropriate shifts in the intermediate row of bits B'. The bits are preferably disposed in a stepped arrangement similar to that illustrated in FIG. 1, i.e., in elevation the pilot bit 50 would lead all the others, the intermediate row of bits B' would follow, and the peripheral row B' would follow after the intermediate row, but alternately all of the bits shown in FIG. 11 may be arranged to drill on essentially a common plane.

Broadly, the present invention embraces any gang drill or assembly of downhole percussion drills mounted parallel to each other to deliver percussion blows to a cluster of percussion drill bits which are also mounted parallel to one another and are disposed in spaced relationship so that, when the entire assembly is rotated and the drills are activated to hammer on the bits, a large hole is formed. The drills may be activated to hammer on the bits in any feasible manner, using not only the drilling fluids of the prior art but any other suitable motive power such as electrical power delivered to a solenoid coil which causes axial reciprocation of a hammer. Some or all of the drills and bits may be offset from the axis of rotation, and any or all of them which are thus offset may be connected so that the drill bit which is associated with a downhole percussion drill is free to rotate with respect to its drill. In addition, all such bits which are offset from the axis of rotation may have shank portions which require no splines, preferably being simple right cylinders of revolution. The lower or body portion of each bit which is thus free to rotate may be free of circumferential gaps and passageways employed with single such bits used to drill a hole equal in diameter to the diameter of the bit, and in their place may have such body portions made with peripheral surfaces which are also cylinders of revolution. In addition, all such bits may have a simple, single internal fluid passageway formed coaxially with the longitudinal axis of the bit.

What is claimed is:

1. A gang percussion drill assembly which comprises:
a framework adapted to be secured to and rotated by a drill string member;
a plurality of percussion drill means supported by the framework, and having reciprocating hammer elements driven by an operating fluid at a frequency independent of the rotational speed of the assembly;
an anvil bit connected with each percussion drill means to communicate periodically with a hammer element;
one end of the outermost of said bits including a wheel-like circumferential cutting edge that contains a plurality of wear resistant inserts;
said bit being free to rotate circumferentially and freely.

2. The percussion drill assembly of claim 1 wherein the freely rotatable bit includes a shank end formed of a surface of revolution secured by retainer means inside the percussion drill means.

3. A gang percussion drill assembly which comprises:
a framework adapted to be secured to and rotated by a drill string member;
a plurality of percussion drill means supported by the framework, and having reciprocating hammer elements driven by an operating fluid at a frequency independent of the rotational speed of the assembly;
an anvil bit connected with each percussion drill means to communicate periodically with a hammer element;
one end of the outermost of said bits including a wheel-like, circumferential cutting edge that contains a plurality of wear resistant inserts;
said bit being rotatable circumferentially during drilling by frictional engagement with a borehole surface;
retainer means securing said bit to the associated percussion drill means to enable unrestricted engagement of the bit against a borehole bottom during drilling.

4. The percussion drill assembly of claim 3 wherein said retainer means comprises a ring secured in the percussion drill means to protrude into an elongated, circumferential slot to permit selected axial movement of said bit.

5. A gang percussion drill assembly which comprises:
a framework adapted to be secured to and rotated by a drill string member;
a plurality of percussion drill means supported by the framework, and having reciprocating hammer elements driven by an operating fluid at a frequency independent of the rotational speed of the assembly;

an anvil bit connected with each percussion drill means to communicate periodically with a hammer element;

one end of the outermost of said bits including a wheel-like, circumferential cutting edge that contains a multiplicity of wear resistant inserts having cylindrical bodies received in apertures in said bit, and additional such apertures spaced across the end of the bit;

said bit being rotatable circumferentially during drilling by frictional engagement with a borehole surface, the rotation thus being independent of the rotational speed of the drill assembly; and

retainer means securing said bit to the associated percussion drill means to enable unrestricted engagement of the bit against a borehole bottom during drilling.

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