This invention relates to a reamer for use in a string of drill pipe employed in the rotary drilling of bore holes into earth formations.

For example, it often becomes necessary to enlarge the diameter of a bore hole being drilled, in order to run a casing which has an inner diameter at least conforming to the diameter of the bore hole being drilled. Also, in drilling bore holes through earth formations, it is difficult to maintain a straight hole, consequently, it is desirable to ream out and straighten portions of a bore hole at different depths while the drilling continues, to prevent binding and excessive wear of the drill pipe caused by rubbing thereof on the wall of the bore hole.

It is obvious that for economy and speed of drilling, the reamer must be capable of passage through diameters corresponding to the diameter of the hole being drilled, and at the same time be capable of reaming to larger diameters at places where reaming is required.

It is, therefore, an object of the present invention to provide a reamer for connection anywhere along the length of the drilling string and which may be run with the drill pipe to depths in the bore hole where the reaming operation is to start, and which is capable of being withdrawn through the diameters of the bore hole corresponding with the diameter of the drill bit being used.

In accomplishing this object, a reamer is provided having a reaming face projecting from one side only of the drill pipe, so that the total diameter thereof is such that it may pass through the diameters corresponding with the diameter of the bore hole produced by the drill bit that is attached to the lower end of the drilling string.

Further objects of the invention are to provide a reamer of this character having a reaming face composed of a plurality of cutting elements such as diamonds, bortz, and similar hard substances; to provide an adequate fluid supply for cooling the cutting elements and removing the cuttings; to provide a reamer which permits the drill pipe to yield for absorbing shock upon the cutting elements; to provide the face of the reamer with flow channels intermediate rows of cutting elements to accommodate the cuttings therein; to provide the reamer with a cutting face that is generated on a true arc about the axis of rotation, so that all of the cutting elements are in contact with the wall of the bore hole and to assure distribution of the drilling fluid to all of the flow channels; and to provide a reamer with an advance side that forms a wiper to clear the wall of the bore hole in advance of the cutting elements.

In accomplishing these and other objects of the invention, I have provided improved structure, the preferred forms of which are illustrated in the accompanying drawings, wherein:

FIG. 1 is a vertical section through the lower portion of a bore hole, and showing a drilling string therein having a drill bit on the lower end thereof, and provided with one or more reamers constructed in accordance with the present invention.

FIG. 2 is an enlarged longitudinal section through a reamer and the portions of the drilling string that connect therewith.

FIG. 3 is a perspective view of one of the reamers, particularly illustrating the reaming face thereof.

FIG. 4 is a cross section on the line 4-4 of FIG. 2, and showing the discharge port and transverse channel for supplying drilling fluid to the longitudinal channels of the reaming face of the reamer.

FIG. 5 is a similar section, taken on the line 5-5 of FIG. 2.

FIG. 6 is a cross section through the bore hole produced by the bit, and showing the casing and reamer passing therethrough to a reaming position.

FIG. 7 is a section similar to FIG. 4, but showing a modified supply of drilling fluid to the reaming face of the reamer.

FIG. 8 is a cross section through the reaming face of the reamer, to better illustrate the vertical grooves or channels and the setting of the diamonds or cutting elements in the ridges between the grooves.

FIG. 9 is a similar section through a modified arrangement of cutting elements.

FIG. 10 is a still further modified form wherein single cutting elements are set in the ridges between the grooves or channels.

Referring more in detail to the drawings:

1 designates a bore hole being drilled through earth formation by a drill bit 2 which is rotated by a string of drill pipe 3. The string of drill pipe 3 is made up of stands of pipe sections 4 that are connected together by tool joints 5. The tool joints 5 include an internally threaded box 6 (FIG. 2) on one section that usually connects with an externally threaded pin 7 on the next lower section.

In drilling the bore hole 1, it may be necessary to case off certain of the formations. This is accomplished by running a reamer into the bore hole to enlarge the diameter thereof to accommodate a casing (not shown) having an inner diameter near that of the bore hole. In many instances it is desirable to follow the reamer with the casing, in which case the reamer must be capable of being withdrawn through the casing.

Also, in drilling bore holes it is difficult to drill a straight hole, because the drill bit, due to the character of the formations, tends to lead off in various directions, consequently, the drill pipe 3 rotates in a crooked hole and is subject to wear where the tool joints rub on the walls of the bore hole in attempting to follow the curvature of the crooked hole. For example, the bore hole shown in FIG. 1 curves toward the right, so that the drill pipe rubs with greater pressure on that side of the bore hole. This places the drill pipe under greater stress and results in failures of the drill pipe, caving of the wall, and wedging of the drill pipe in the bore hole. Therefore, it is desirable to ream the bore hole at such places to straighten the hole and ease bending conditions of the drill pipe.

To accomplish a reaming operation for running in a casing, the drill pipe is provided with a reamer 8 constructed in accordance with the present invention, to ream out the bore hole and be removed through the casing when the casing follows the reamer into the bore hole.

In straightening a bore hole, one or more of the reamers 8 may be connected into the drilling string and lowered through the bore hole to the place that the reaming operation is to be started.

The reamer 8 includes a generally cylindrical body 9, having a diameter substantially conforming to the outer diameter of the drill pipe sections. The upper end of the cylindrical body has an externally threaded pin 10, conforming to the pins 7 of the drill pipe sections, to couple the reamer into the box 6 of the stand of drill pipe. The lower end of the body has an internally threaded box 11, conforming to the boxes 6 of the stands of drill pipe sections, to connect with the pin 7 of a lower drill pipe sec-
tion, as shown in FIG. 2. The cylindrical body 9 has an axial bore 13 extending therethrough and through the pin 10 to 11, to provide a continuation for the flow of drilling fluid through the string of drill pipe.

Extending from only one side of the cylindrical body is a lateral projection 13, having a reaming face 14 of arcuate cross section, a radial advance face 15 in the direction of rotation, and a trailing side face 16 tangential with the cylindrical body 9. The upper portion 17 of the reaming face is substantially cylindrical, while the lower portion 18 of the reaming face slopes inwardly and downwardly toward the end of the cylindrical body, as best shown in FIGS. 2 and 3. The upper end of the lateral projection is made inwardly and upwardly from the upper portion 17, to join with the cylindrical body, as indicated at 20.

In order that the reamer may be passed through the bore hole 1 that is made by the drill bit 2, the overall distance between the upper portion 17 of the reaming face and the opposite side of the cylindrical body is slightly less than the diameter of the bore hole 1. Also, the reaming face 14 has a width less than one-half the circumference of the bore hole to be reamed, as is shown in FIG. 6.

The upper and lower portions 17 and 18 of the arcuate reaming face have a plurality of laterally spaced apart longitudinal channels or grooves 21, forming ridges 22 therebetween. The upper and lower ends of the grooves or channels 21 have terminals 23 and 24, respectively, that continue through upper and lower marginal portions of the reaming face. The grooves 21 are inset from the forward and trailing marginal sides of the reaming face, as indicated at 25 and 26. The ridges 22 and grooves 21 may be of a shape, as shown in the large cross section illustrated in FIG. 8, to provide teeth 27 having forward faces 28 and outer faces 29 that are relieved from the wall of the bore hole to facilitate movement of cutting tools from the forward faces into the grooves following the ridges. The terminals 23 at the upper ends of the grooves are of less flow capacity than the terminals 24 at the lower ends, to better control the flow of drilling fluid and to provide outlets for the cuttings when the reamer is in use. To facilitate cutting, a plurality of diamonds or similar hard cutting elements 30 are inset into the forward edges of the teeth or ridges, as illustrated in FIG. 8.

Another arrangement of grooves 31 and ridges 32 is shown in FIG. 9, wherein the leading and trailing faces 33 and 34 are parallel and the outer faces 35 are arcuate, having substantially the same curvature as the general curvature of the reaming face of the reamer. In this form of the invention, a plurality of diamonds or similar hard cutting elements 36 are inset in rows into the outer faces 35.

Another arrangement may consist of alternate grooves and ridges 38 having the general shape of the grooves 31 and ridges 32 of FIG. 9. In this form of the invention, single rows of larger diamonds or like cutting elements 39 are used, as shown in FIG. 10.

In order to supply drilling fluid to the reaming face for cooling the diamonds and assist in flow of the cuttings from the grooves 21 are all interconnected by a transverse channel 40 terminating short of the front and rear marginal faces 25 and 26 and having the ends thereof defined by inset slugs 41 and 42 of hard material, such as cast iron, which contact the bore hole wall and resist wear at the ends of the channel and assure distribution and flow of drilling fluid from the transverse channel to all of the longitudinal grooves 21. The drilling fluid is supplied to the transverse channel 40 from the axial bore 12 through a passageway 43 that extends radially from the bore 12 and terminates in a reduced port 44 opening into the transverse channel 40, that forms a check valve to restrict the drilling fluid to the reaming face in the amount desired, and to maintain pressure within the drill pipe so as to supply the drilling fluid to similar reamers located at lower positions in the string of drill pipe and to the drill bit 2.

The leading face 15 joins with the reaming face in an abrupt edge 45 to wipe the wall of the bore hole ahead of the reaming face, and the scrapings are directed by the face 15 into the stream of drilling fluid which flows upwardly in the space 47 between the drill pipe and wall of the bore hole to the top of the bore hole. The edge 45 may be provided with spaced hard metal slugs 46, to resist wear and assist in scraping the wall of the bore hole.

In the illustrated instances, the lateral projection 13 is preferably formed of powdered metal compacted with suitable binders, to facilitate formation of the grooves 21 and ridges 22 in the cutting face and to facilitate setting of the diamonds or similar cutting elements 30. In order to retain the powdered metal material, the lower portion 48 of the cylindrical body of the reamer is of reduced diameter, to form an upper shoulder 49 at the upper end of the bevel 20. The powdered metal material is extended around the reduced portion 48 of the cylindrical body in the form of a sleeve 50, which is integral with the projecting portion 13 of the reamer. To insure a bond between the cylindrical body and the powdered metal material, the reduced portion 48 of the cylindrical body may be equipped with a plurality of protuberances 51, such as pins 52, that extend outwardly into the powdered metal material, as shown in FIGS. 2 and 4. The pins 52 may be inset tightly within sockets 53 drilled into the portions 48 of the cylindrical body.

The modified form of the invention shown in FIG. 7 conforms to the structure just described, with the exception that the passageway 54 is of sufficiently reduced diameter so as to eliminate the necessity of the choke formed by the reduced port in the first described form of the invention.

In using the reamer constructed as described for enlarging a bore hole to accommodate a casing (not shown) having an inside diameter conforming to the original diameter of the bore hole, a reamer 8 is connected above the drill bit 2 between any two adjoining stands 4 of drill pipe, and started into the bore hole 1. The drill pipe is rotated in the usual manner, while drilling fluid is circulated downwardly through the drill pipe for discharge through the drill bit to wash cuttings made by the bit to the top of the bore hole by way of the upflow passageway 47. Rotation of the drill pipe grates the reaming face 14 in a circular path about the axis of rotation. The cutting action is started with the leading portion 17 of the reaming face, and continues to the lower sloping portion 18 as the bore hole is enlarged with lowering of the drill pipe, until the diameter of the bore hole corresponds to the circular path of the upper reaming face portion 17.

A portion of the drilling fluid is discharged through the passageway 43 and choke port 44 into the transverse channel 40 for distribution to all of the grooves 21. The cuttings from the striations produced by the diamonds 30 are washed from the ridges 22 into the grooves 21, and are discharged through the upper and lower terminals 23 and 24 into the bore hole and into the upward flow of drilling fluid.

Attention is directed to the ability of the drill pipe to yield, as it provides a shock absorber effect on the diamonds. The reaming face, which includes the leading edges of all of the bore hole ahead of the reaming face, makes all of the diamonds effective in reducing the wall of the bore hole. The leading side 15 of the projection provides a wiper for cleaning the wall of the bore hole ahead of the reaming face and assists the scraping edge 45 in removing any cuttings that may tend to lodge on the wall of the bore hole and carrying them into the upwardly flowing stream of drilling fluid.
the reamer is formed. The casing may be inserted progressively with the reamer, since the reamer may be withdrawn through the casing on shifting the drill pipe to the side opposite the projection 13.

In using the reamers for straightening a crooked hole, as shown in FIG. 1, one or more of the reamers may be inserted in the drill pipe at places where the drill pipe tends to rub on the wall of the bore hole, as, for example, on the inside line of curvature, as indicated at 55. The drill pipe, with one or more reamers thereon, is readily lowered through the bore hole of the diameter made by the drill bit, since the total diametrical width of the reamer from the reaming face to the opposite side of the cylindrical body 9 is such that it may be lowered through the bore hole, as shown in FIG. 6, to the place where the reaming is to be started. Since the drill pipe is riding the side of the bore hole to be straightened, the tension in the drill pipe crowds the reaming face against that side of the bore hole, to start the reaming action when the drill pipe is rotated. The reamers may be inserted in the drill pipe so that they act in successive order in removing the side of the bore hole sufficiently to straighten the bore hole and relieve bending of the drill pipe.

What I claim and desire to secure by Letters Patent is:

1. In a drilling apparatus, a string of drill pipe, a drill bit on the lower end of the drill pipe for drilling a bore hole, a reamer coupled into the string of drill pipe above the drill bit to straighten or enlarge the bore hole made by the drill bit, said reamer having a reaming face of arcuate cross section at one side of the string of drill pipe of less than one-half the circumference of the bore hole to provide upflow passages on trailing and advance sides of the reaming face, and diamond cutting elements set in said reaming face to be forced into cutting contact with the wall of the bore hole by the drill pipe, said drill pipe being yieldable under a reaction thrust of the reaming face for absorbing shock on the diamond cutting elements.

2. In a drilling apparatus, a string of drill pipe, a drill bit on the lower end of the drill pipe for drilling a bore hole, a plurality of reamers coupled into the string of drill pipe at spaced locations above the drill bit to straighten the bore hole made by the drill bit, said reamers each having a reaming face at one side of the string of drill pipe, and diamond cutting elements set in said reaming faces to be forced into cutting contact with the wall of the bore hole, said drill pipe being yieldable under a reaction thrust of the reaming faces for absorbing shock on the diamond cutting elements.

3. In combination, a string of drill pipe, a drill bit on the lower end of the drill pipe for drilling a bore hole, a reamer coupled into the string of drill pipe above the drill bit and having a reaming face of arcuate cross section at one side of the string of drill pipe to enlarge the bore hole upon rotation of the string of drill pipe and to permit yielding of the drill pipe in a direction opposite the reaming face, said reaming face of arcuate cross section having a plurality of diamond cutting elements and channels in which cuttings made by the diamond cutting elements work back into the channels, and means for supplying drilling fluid from the string of drill pipe and opening into to said channels to cool the diamond cutting elements and to wash the cuttings from the channels.

4. A reamer for insertion in a string of drill pipe, said reamer including a generally cylindrical body having connections at the ends thereof for connection into the string of drill pipe, said body having a lateral reaming means projecting from only one side of said body for contact with the wall of a bore hole when the reamer is in use, said body having a passageway connecting with the reaming means for diverting a portion of the drilling fluid from the drill pipe, and a choke in said passageway for controlling flow of drilling fluid to said reaming means.

5. A reamer for insertion in a string of drill pipe, said reamer including a generally cylindrical body having connections at the ends thereof for connection into the string of drill pipe, said body having a lateral projection from only one side thereof to provide a reaming face of arcuate cross section for contact with the wall of a bore hole when the reamer is in use and including an upper arcuate portion and a lower portion sloping downwardly and inwardly toward said body, said reaming face having a plurality of spaced apart longitudinal channels and a transverse channel extending transversely of said longitudinal channels for distributing drilling fluid to said longitudinal channels, said body having a passageway connecting with the transverse channel for diverting a portion of the drilling fluid from the drill pipe to said transverse channel, and cutting elements set in ridges that are formed between the longitudinal channels.

6. A reamer as described in claim 5, wherein said passageway which connects with the transverse channel has a choke for controlling flow of drilling fluid into said transverse channel.

7. A reamer for insertion in a string of drill pipe, said reamer including a generally cylindrical body having means on the ends thereof for connection of the reamer in coaxial alignment with drill pipe sections which make up the drilling string, said body being provided with an axial bore for continuing flow of drilling fluid through the drill pipe, said body having a portion projecting laterally from only one side thereof to provide a reaming face of arcuate cross section for contact with the wall of a bore hole when the reamer is in use and including an upper arcuate portion and a lower portion sloping inwardly toward said body, said reaming face having a plurality of spaced apart longitudinal channels and a transverse channel extending transversely of said longitudinal channels in said upper portion for distributing drilling fluid to said longitudinal channels, a passageway connecting the transverse channel with said bore for diverting a part of the drilling fluid from the drill pipe to said transverse channel, and cutting elements set in ridges that are formed between the longitudinal channels.

8. A reamer as described in claim 7, and including carbide slugs closing ends of the transverse channel.

9. A reamer for insertion between sections of a string of drill pipe, including a generally cylindrical body having means at the ends thereof for connecting with ends of adjacent drill pipe sections, said body being provided with an axial bore for continuing flow of drilling fluid through the drill pipe, said body having a lateral projection from only one
said lateral projection being of a shape to provide a reaming face of arcuate cross section and including an upper arcuate portion and a lower portion sloping inwardly toward said body,
said reaming face having plurality of spaced apart longitudinal channels and a transverse channel extending across the longitudinal channels for distributing drilling fluid to said longitudinal channels,
said body having a passageway connecting the transverse channel with said bore for diverting a part of the drilling fluid from the drill pipe to said transverse channel, and
cutting elements set within the powdered metal along ridges which are formed between the longitudinal channels,
said longitudinal channels having terminals extending through upper and lower ends of said reaming face and having flow outlets for holding pressure of the drilling fluid and to assure distribution of the drilling fluid to all of said channels.

12. A reamer for insertion between sections of a string of drill pipe, including
a generally cylindrical body having means at the ends thereof for connection with sections of adjacent drill pipe sections,
said body being provided with an axial bore for continuing flow of drilling fluid through the drill pipe,
said body having a lateral projection from only one side of said body and provided with a reaming face of arcuate cross section for contact with the wall of a bore hole when the reamer is in use and including an upper arcuate portion and a lower portion sloping inwardly toward said body,
said reaming face having therein a plurality of laterally spaced apart longitudinal channels and a transverse channel extending transversely of said longitudinal channels for distributing drilling fluid to said longitudinal channels,
said body having a passageway connecting the transverse channel with said bore and having a metering orifice for diverting a part of the drilling fluid from the drill pipe to said transverse channel, and
cutting elements set within the powdered metal along ridges which are formed between the longitudinal channels.

11. A reamer for insertion in a string of drill pipe, said reamer including
a generally cylindrical body having means on the ends thereof for connection into coaxial alignment with the drill pipe sections which make up the string of drill pipe,
said body being provided with an axial bore for continuing flow of drilling fluid through the drill pipe,
said body having a reduced circumferential portion,
a powdered metal member encircling the reduced portion and having a portion projecting laterally from only one side of said body,