

Oct. 8, 1940.

W. F. COURT

2,217,360

HYDRAULIC DISRUPTION OF SOLIDS

Filed May 18, 1938

3 Sheets-Sheet 1

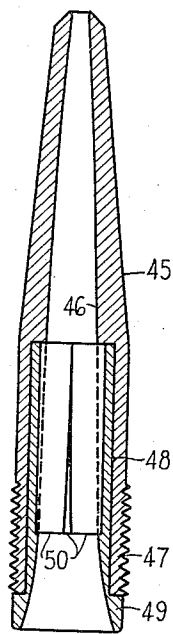


FIG. 3

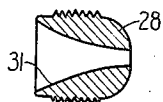


FIG. 4

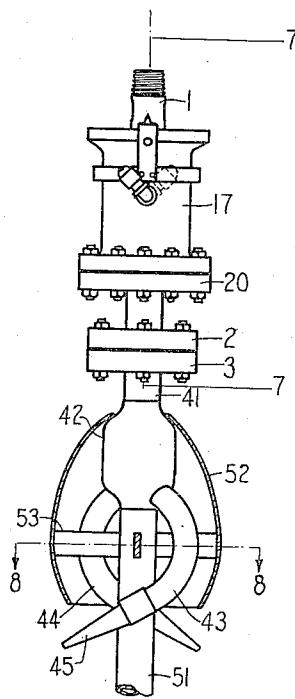
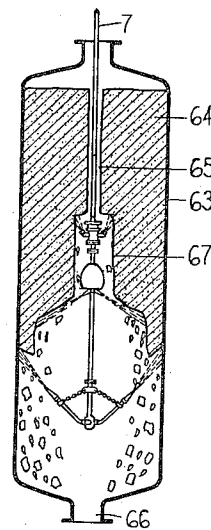


FIG. 6

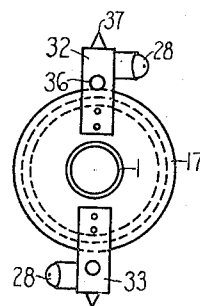


FIG. 2

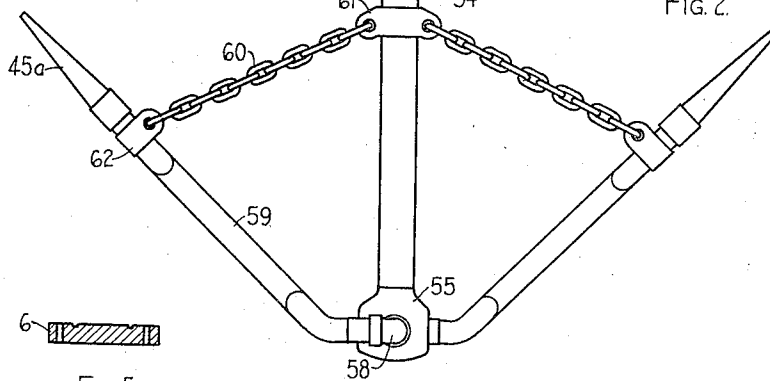


FIG. 5

FIG. 1

Inventor: William Frederick Court

By his Attorney: *[Signature]*

Oct. 8, 1940.

W. F. COURT

2,217,360

HYDRAULIC DISRUPTION OF SOLIDS

Filed May 18, 1938

3 Sheets-Sheet 2

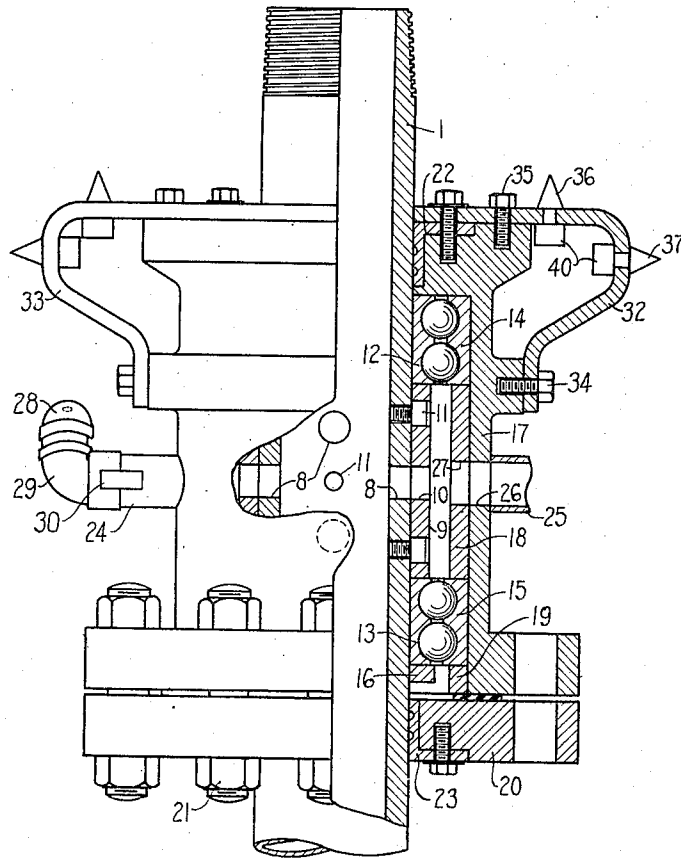


FIG. 7

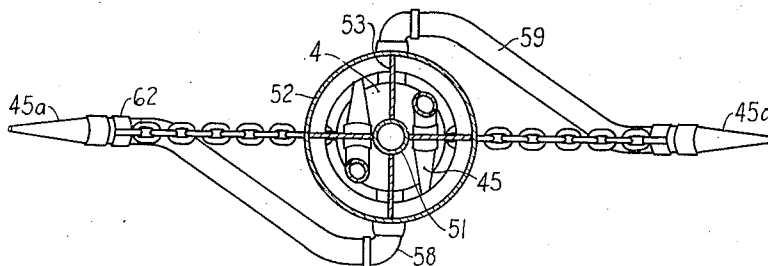


FIG. 8

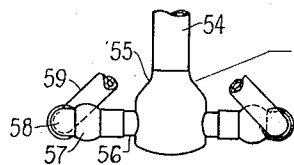


FIG. 9

Inventor: William Frederick Court

By his Attorney: *[Signature]*

Oct. 8, 1940.

W. F. COURT

2,217,360

HYDRAULIC DISRUPTION OF SOLIDS

Filed May 18, 1938

3 Sheets-Sheet 3

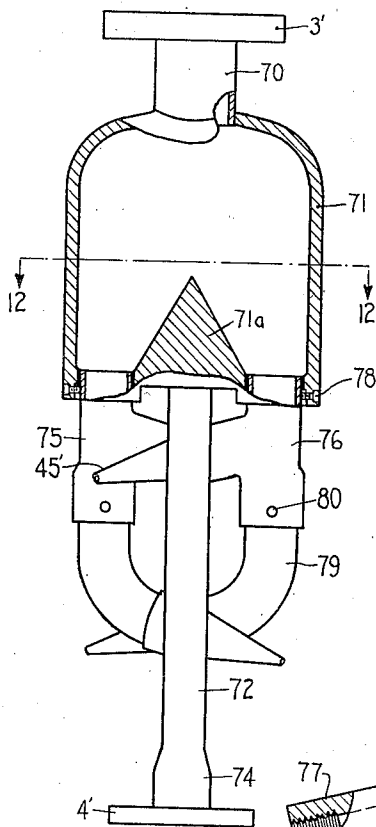


Fig. 10

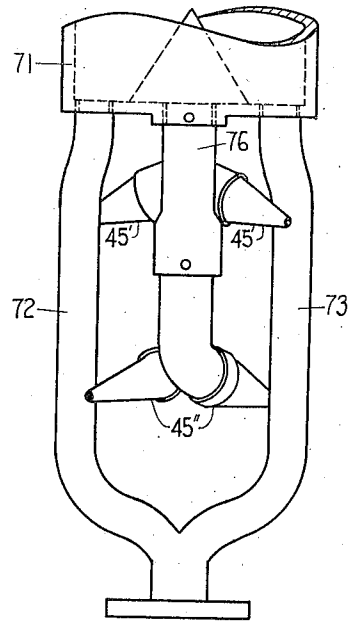


Fig. 11

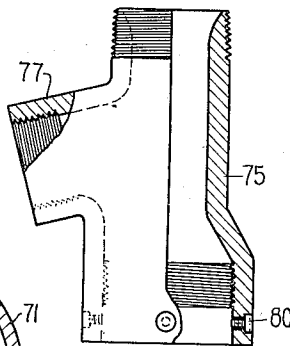


Fig. 13

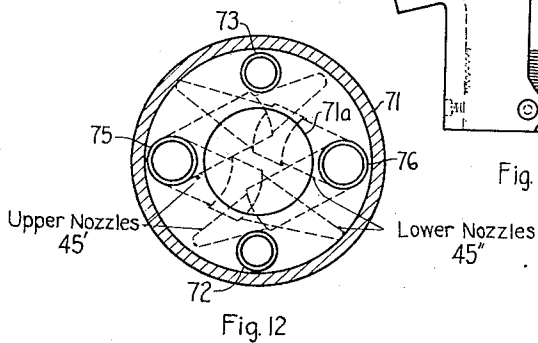


Fig. 12

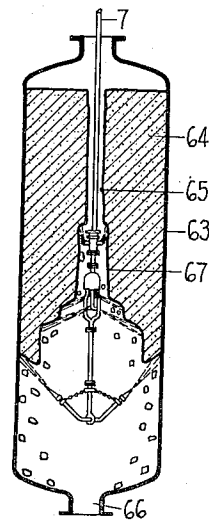


Fig. 14

Inventor: William Frederick Court.

By his Attorney: *[Signature]*

UNITED STATES PATENT OFFICE

2,217,360

HYDRAULIC DISRUPTION OF SOLIDS

William Frederick Court, Webster Groves, Mo.,
assignor to Shell Development Company, San
Francisco, Calif., a corporation of Delaware

Application May 18, 1938, Serial No. 208,711

11 Claims. (Cl. 15—4)

This invention relates to the hydraulic disruption of solid masses by means of water jets which are directed substantially radially outwardly from a well in the mass, and is particularly concerned with an improved nozzle head which is suitable for that purpose. Such a nozzle head is useful in the removal of solids, like coke, from vessels, but may be employed for other purposes.

In my copending application, Serial No. 191,685, filed February 21, 1938, of which this is a continuation-in-part, I have described particularly a process for cleaning vessels which contain solids, like carbonaceous material, particularly deposits of coke produced by the carbonization of hydrocarbon oils, such as reaction and coking chambers employed in petroleum cracking plants and the like, and asphaltic material, especially the solid, brittle kind, by means of water jets. According to one embodiment of the process the body of material to be removed, such as coke in a vertical cylindrical coking chamber, is acted upon in three operations:

In the first step, after opening the top and bottom manholes and cooling the coke by means of steam followed by water, the body of coke is cannulated vertically, either by drilling or by means of a vertically, preferably downwardly, directed jet of water, such as, for example, a jet discharged from a spear nozzle with a $\frac{3}{8}$ or one inch diameter orifice, supported by and supplied through a vertical water feed pipe, and discharging water at between 400 and 750 gallons per minute. When water is used, the fine particles of coke displaced are diffused into the body of the coke bed, and the water drains through the coke, discharging through the lower manhole. In this step a vertical hole from one to several inches in diameter is formed through the coke bed at the axis of the chamber. The purpose of this step is to provide a tubular opening or well to permit a water feed pipe, which is suspended and supplied with water at its upper end, and supports the nozzle head employed in the subsequent steps, to be lowered through the body of the coke.

In the second step the opening is reamed to increase the size of the initial opening to about 18 to 24 inches in diameter so that the nozzle head employed in the last step may be used without fouling the coke bed. For this purpose the water feed pipe, which after the jetting in the first step is suspended within the coke bed, is lowered to extend through the lower manhole, and a reaming nozzle head is attached to the lower end in place of the spear nozzle. The assembly is then raised gradually or step-wise with the water pres-

sure turned on. The reaming nozzle head comprises a rotor, rotatable about the axis of the water feed pipe and is a relatively small radial dimension, having about twice to three times the diameter of the initial hole. It is provided with a plurality of reaction nozzles, which impart a relatively high rotary speed, such as about 1000 revolutions per minute to the head, and with a scraper on top. The nozzles discharge jets of water tending upwardly which cut an enlarged well into the solid material. The second step is completed when the nozzle head has reached the top of the coke bed. Coke which is cut away or loosened by the nozzle head drops down through the opening into dump cars located beneath the coke chamber, and water is collected by means of a pair of inclined aprons, which direct it into a trough, from which it flows into a settling basin, for recirculation through the water feed pipe.

In the third step (which may be begun before the completion of the second step), the main body of the coke is disrupted and completely removed from the chamber. The water feed pipe is again lowered to extend beneath the coking chamber, the reaming nozzle head is disconnected, and the main nozzle head is attached in its stead. Alternatively, the main nozzle head may be coupled beneath the reaming nozzle head. The main nozzle head is nonrotatably connected to the water feed pipe, and is provided with a plurality of upwardly and with a plurality of downwardly directed nozzles which direct jets of water radially outwardly to disrupt and completely remove the coke from the chamber when the water supply is turned on and the nozzle head is raised into the enlarged well. Some of the nozzles on the main nozzle head are arranged to impart a rotary motion to the nozzle head, whereby the nozzles assume a plurality of successive orientations, the rate of rotation being usually regulated by means of a brake operating on the water feed pipe so as not to exceed 2 to 4 revolutions per minute. If desired, the rotation may be effected by applying an external rotating force on the feed pipe, it being in this case unnecessary to arrange the cutting nozzles to impart a turning moment to the nozzle head.

An object of the present invention is to provide nozzle heads which may be employed for carrying out the second and third steps of the process as outlined above. While the nozzle heads described in the present application are particularly adapted for the removal of carbonaceous material by the process of the said parent application, they may be employed for any operation in which it is

desired to form an opening through a mass of solid material, either continuous or packed, and irrespective of whether the operation results in the complete removal of the solid material from the container or merely in the cutting through of an opening. Another and distinct object is to provide a composite nozzle head which will permit the second and third steps of the process to be effected simultaneously, with a single movement of the water feed pipe through the coke bed. Such a nozzle head comprises a plurality of sections of successively larger radial extent, each section cutting away a portion of the solid material to permit the following section to operate without fouling. While it is preferred, for purposes of convenience, and to simplify the mechanical arrangement for guiding the water feed pipe, to effect the above described second and third steps by an upward movement of the nozzle head which is suspended by the water feed pipe, whereby the rotor section functions as a reamer, it should be noted that it is not necessary to suspend the nozzle head; it being also possible to support it and to supply it with water from the bottom and push it upwardly, in which case the first or cannulating steps may, if desired, be omitted and no reaming action, but a direct hydraulic boring action is effected by the rotor; or the cannulating may be effected simultaneously by a drill secured to the leading end of the rapidly rotating head. Finally, the nozzle may be moved downwardly, horizontally, or in an inclined direction, depending upon the material being worked upon or upon the shape and position of the container, with slight mechanical modifications, which will be obvious, to permit the pivoted nozzles on the second cutting section to be in the proper angular position when the nozzle head is inclined or inverted, as by attaching springs to urge the nozzles away from the axis of the feed pipe, and/or changing the point of attachment of the suspending cable to the supporting pipe.

The invention resides in the construction and combination of parts described and claimed herein, considered together with the accompanying drawings, in which:

Figure 1 is an elevation view, partly in section, of the composite nozzle head, broken to reduce the vertical dimension, the lowest section being turned through at an angle of 90° for clarity;

Figure 2 is an enlarged plan view of the rotor section of the nozzle head;

Figures 3 and 4 longitudinal sectional views of nozzles shown in Figure 1;

Figure 5 is a vertical sectional view of a blind flange;

Figure 6 is a schematic vertical sectional view, partly in elevation, illustrating one method of using the composite nozzle head of Figure 1;

Figure 7 is an enlarged vertical sectional view of the rotor section of the nozzle head, taken on line 7—7 of Figure 1, the left half of Figure 7 being in elevation;

Figure 8 is a horizontal sectional view taken on line 8—8 of Figure 1 showing the relationship between the downwardly and upwardly disposed nozzle on the first and second cutting sections of the nozzle head;

Figure 9 is a fragmental side elevation view of the bottom of the nozzle head;

Figure 10 is an elevation view partly in section of the modified form of the first cutting section;

Figure 11 is a fragmental elevation view taken at right angles to Figure 10;

Figure 12 is a horizontal sectional view taken on line 12—12 of Figure 10;

Figure 13 is a detail view of a special Y-fitting or manifold forming a part of the device shown in Figure 10; and

Figure 14 is a schematic view, similar to Figure 6, illustrating the method of using the nozzle head embodying the modifications shown in Figures 10 to 13.

Referring to Figure 1, the composite nozzle head comprises three axially juxtaposed sections: a rotor or uppermost section extending from the threaded upper end of a pipe 1 to a union flange 2; a first cutting or intermediate section extending from the union flange 3 to the union flange 4, and a second cutting or lowermost section extending from the union flange 5 to the bottom of the nozzle head. The flanges, which are attached to the adjacent pipes in a suitable manner, for example by welding or by means of threads, are provided with tongue and groove faces, and held together by vertical studs, permitting the facile separation and assembly of the sections. The three sections, when assembled as shown, form a rigid conduit, adapted for attachment at its upper end to a source of fluid under pressure, and support the rotor and the first and second main cutting nozzles. When the intermediate or lowermost section is disconnected the blind flange 6, shown in Figure 5, is affixed to flange 2 or 4, respectively, to close the downwardly facing opening. Clamp or bolt couplings, or other coupling arrangements may be employed in place of the flanges shown.

The rotor section (Figures 1, 2, 4 and 7)

The function of the rotor section is to cut a well into the body of solid material of sufficient size to permit the first or leading cutting nozzles to enter the well and cut the material by jets which tend away from the axis of the nozzle head. In the embodiment shown herein, it functions as a reamer, by enlarging the initial hole which contains the water feed pipe; the action may, however, be mere cutting, as when the nozzle head is supported from the bottom, and no preliminary hole has been formed.

The pipe 1 is provided with external drill pipe threads at its upper end, adapted for connection with a water feed pipe 7 (Figure 6), and carries the union flange 2 at its lower end. A plurality of ports 8, staggered at different levels, permit the radial flow of water from the pipe 1. A sleeve 9, provided with a plurality of ports 10 in registration with ports 8, is secured to the pipe 1 by means of set screws 11. A pair of ball bearing nests, attached above and below the sleeve 9, comprises inner races 12, 13, fixed with respect to the pipe 1, and outer races 14, 15, rotatable with respect thereto. A hoop 16, secured to the pipe 1, lends vertical support to the inner race 13. The bearings are packed with water proof grease.

A rotatable housing 17 is secured to the outer races 14 and 15 by means of a sleeve 18 and a spacing ring 19, held together by a retaining ring 20, which is bolted to the housing 17 by studs 21. A gasket may be interposed between the bottom of the housing 17 and the retaining ring. Bronze sleeves 22 and 23 are bolted to the housing 17 and to the retaining ring 20, respectively; they are provided with annular grooves on their inner faces adjacent the pipe 1 and coat therewith to prevent the escape of water and bearing lubricant.

Nipples 24 and 25, secured to the wall of the

housing 17 by welding at diametrically opposite points, are in communication with the interior of the housing by means of ports 26 and 27, formed through the housing and the sleeve 18, whereby they may be supplied with water from the pipe 1. Each nipple carries a stub nozzle 28, a 90° L fitting 29 being interposed to permit the angular elevation of the nozzle axis to be selected as desired. By this means the jets emitted from the nozzles 28 may tend either substantially only in an upward direction (a slight radial component being necessary for at least certain jets to obtain a turning moment); or they may tend substantially only tangentially outward from the pipe 1 (this being feasible only when the preliminary well is large enough to permit the rotor to enter the same); or they may tend both upwardly and outwardly, as shown. In the embodiment illustrated, this elevation is 45° of arc above the horizontal, the nozzle axis being in a plane substantially tangential to the path of the nozzle axis as the nozzle and housing 17 rotate about the pipe 1. A short bar of metal 30 may be tack welded to prevent the loosening or accidental disturbance of the position of the nozzle. The stub nozzle tip 28, as shown more particularly in Figure 4, has a smooth tapering bore 31 of gradually diminishing convergence, the convergence being about 2° at the orifice, to emit a powerful, confined jet of water.

A pair of scrapers 32 and 33, is bolted to the housing 17 by cap screws 34, 35. Each scraper is provided with a plurality of pyramidal tips 36, 37, preferably made of tool steel and heat treated for maximum hardness, and secured to the scrapers by welding their shanks to circular nuts 40. It will be noted that the lateral tips 37 extend radially beyond the radial dimension of the stub nozzles, whereby the fouling of the nozzles on solid material which is not cut away by the action of the hydraulic jet is prevented. Similarly, the vertical tips 36 cut away solids which bridge the opening and would prevent the rotation of the housing. The scrapers are provided only for the purpose of preventing the solids from interfering with the action of the rotor, the primary cutting action being effected by the hydraulic jets.

The first cutting section (Figures 1, 3 and 8)

This section supports the first main cutting nozzles, which are the "leading main cutting nozzles" when the nozzle head is moved axially into the body of the solid material.

The seamless pipe 41, welded or otherwise attached to the union flange 3 is in communication with the pipe 1 and with an enlargement 42. A pair of curved pipes 43 and 44 is welded to the lower converging portion of enlargement 42. Each curved pipe carries a long gradually converging nozzle 45 having its axis inclined downwardly at any desired angle, an angle of about 30° below the horizontal, as shown, having been found suitable for cleaning coke chambers, and preferably skew with respect to the axis of the water feed pipe (Figure 8) whereby the action of the water will impart a turning movement to the pipes 1 and 41. The nozzles 45 constitute the first main cutting nozzles; as shown in Figure 3, each of them comprises a tapering body portion with a converging bore 46 and an externally threaded coupling portion 47 at its base, having a cylindrical recess 48 shaped to retain a bushing 49 carrying axially extending straightening vanes 50. It is in most cases important to design these

nozzles, as well as the nozzles 45a, so as to produce a jet which will not substantially break up in striking the mass of solid material, such as coke, whereby the cutting action will be at a maximum, since a nozzle head is intended primarily for cutting the solid material as distinguished from eroding it. A pipe 51 connects the enlargement 42 with the union flange 4.

A shield plate 52 of elliptical shape is welded to the upper inclined surface of the enlargement 42 and secured to the pipe 51 by a plurality of radially extending plates 53. The maximum radial external dimension of the shield plate exceeds slightly the radial distance of the tips of the nozzles 45 from the axis of the pipe 51, to prevent solid material which may not have been removed by the rotor from fouling the nozzles 45 and to deflect solid material cut away by the rotor away from the nozzle.

The second cutting section (Figures 1, 3, 8 and 9)

This section supports the second main cutting nozzles, which are the "trailing main cutting nozzles" when the nozzle head is moved axially into the body of the solid material.

A downwardly extending pipe 54 is secured at its upper end to the union flange 5 and at its lower end to an enlargement 55, carrying on each side thereof a nipple 56 secured to a swivel L joint 58 at 57. The swivel L joint 58 is attached to a curved pipe 59, shaped as shown in Figures 1 and 8. Nozzles 45a, constituting the second main cutting nozzles, similar to nozzles 45 of Figure 3 but longer, are mounted on the ends of the pipes 59 so as to lie in a vertical plane including the axis of the pipe 54. The pipes 59 may, if desired, each be supported by a Y-connection provided with a pair of swivels, as is well known in the art.

The pipes 59, which may thus be swung about the horizontal axis of the nipples 56 by the action of the joint 58, are normally supported by a collapsible tension stay, such as a chain 60 secured to pipe clamps 61 and 62 to cause the axis of the nozzle 45a to be inclined upwardly at any desired angle, such as about 45° above the horizontal as shown. The nozzles 45 and 45a, are preferably oriented 90° apart as shown in Figure 8 (Figure 1 showing the nozzles 45a at an angle of 90° from the correct orientations, for clarity), and the length of the pipe 51 is preferably selected to cause the jets of water from the nozzle 45a to impinge the wall of the container being cleaned at approximately three feet below the point of intersection of the axes of the downwardly directed jets from the nozzles 45 with the wall of the container, as shown in Figure 6. Thus, the jets from the nozzles 45 and those from the nozzles 45a, lie substantially in imaginary surfaces of revolutions which intersect in a closed curve, the curve being a circle outside of the wall of the container in the specific embodiment shown in Figure 6. The point of impact of the jets from the nozzle 45a to have substantially the same elevation as points of intersection of the axes of nozzles 45 with the container.

Operation (Figure 6)

Although the nozzle may be used for other purposes, its use will be described in connection with the cleaning of a coke or reaction chamber. Referring to Figure 6, 63 represents a vertical cylindrical coke chamber of the usual cracking installation which may, for example be 40 feet in

height and 10 feet in diameter. 64 represents a body of coke which has been deposited therein and which has been previously cannulated by forming a small vertical well 65 therein. The water feed pipe 7 is lowered through the well 65 and the bottom manhole 66, and attached to the pipe 1, the cutting sections being detached and the opening closed by attaching the blind flange 6 to the union flange 2. The water feed pipe and the rotor section are then raised through the lower manhole 66 and full water pressure is supplied to the pipe 7 from the top, causing upwardly directed jets of water to flow from the stub nozzles 28 and the housing 17 to rotate at a high speed such as, for example, 1000 revolutions per minute. The water jets cut away the coke above the rotor, forming an opening or well 67 somewhat larger than the size of the shield plate 52, usually about 18 to 24 inches in diameter. The pipe and nozzle head are then raised steadily until approximately 3 feet of the well 65 have been reamed.

The water is shut off, the feed pipe and rotor section are then lowered, the first cutting section is attached to the union flange 2, the blind flange 6 is secured to the union flange 4, the assembly is raised to bring the nozzle 45 above the neck of the manhole, and water pressure is turned on. The housing 17 continues to rotate and reaming is continued as described above. At the same time confined jets of water issue from the nozzles 45, causing the first cutting section to rotate independently of the rotor section, thereby turning the water feed pipe 7 to which it is non-rotatably secured. The rate of turning of the cutting section is preferably regulated by means of a brake shoe (not shown) acting on the water feed pipe 7 at a point above the coke chamber so as to cause the rate of turning not to exceed about 2 to 4 revolutions per minute. The rate of turning, however, depends upon the size of the chamber being cleaned, it being desirable to regulate the rotation so that one complete circular cut into the body of the coke will be made in each rotation. For example, a frustro-conical cut 6 or 7 inches in depth, extending to or almost to the wall of the chamber, may be made in one revolution. This procedure is followed until approximately 5 feet of coke have been removed from the bottom of the chamber.

The water is then shut off, the assembly is lowered through the lower manhole, the lowermost or second cutting section is coupled to the union flange 4 and the pipes 59 are folded upwardly. The assembly is then raised, the arms 59 assuming the position shown in Figures 1 and 6 after having entered the coke chamber. The complete assembly is raised to a position at which the frustro-conical surface of revolution defined by the axis of the nozzles 45 is just below the frustro-conical bottom of the coke body, as shown in Figure 6, full water pressure is applied and jetting restarted. The rotor section continues to rotate at a relatively high speed, and the two cutting sections rotate at a slower rotary speed, as described above for the first cutting section. The nozzles 45 and 45a emit strong jets which cut away the coke, which drops down, usually in lump form, through the lower manhole, the nozzles 45a completing the cut of the coke as shown.

It is not necessary to add the sections successively as described above, it being possible to begin with the two upper sections or with all three sections.

The modified first cutting section (Figures 10, 11, 12 and 13)

The first cutting or intermediate section, extending from the union flange 3 to the union flange 4 or equivalent coupling means, may be constructed as illustrated in Figures 10 to 13, so as to provide several vertically spaced series of jets. This arrangement permits the first cutting head to be considerably smaller in diameter than the head shown in Figure 1, and permits several layers of coke or similar material to be removed in a single cutting, thereby reducing the time required to empty the chamber.

Referring to these figures, a short seamless pipe 70, secured to the flange 3' (corresponding to the flange 3 of Figure 1) is welded to and in flow communication with an enlarged hollow housing 71 having a smooth, upwardly convex outside surface, which may be made of cast steel. A cone 71a is formed on the floor of the housing. Two conduits 72 and 73, located at diametrically opposite points, eccentrically located with respect to the axis of the housing are secured to the bottom of the housing, being joined to a pipe 74, welded or otherwise secured to the flange 4' (corresponding to the flange 4 of Figure 1) and constructed so as to conduct water from the pipe 74 to the pipe 74.

A pair of manifolds, in the form of Y-fittings 75, 76 (see Figure 13) are threadedly mounted at the bottom of the housing, circumferentially spaced intermediate to the conduits 72, 73, as indicated in Figure 12. The lateral branch 77 of each Y-fitting (which constitutes the upper outlet of the manifold) is downwardly inclined about 15° below the horizontal, and the Y-fittings are oriented as shown in Figure 12, i. e., to lie in a vertical plane making an angle of about 32° with the line joining the manifolds or Y-fittings. Each lateral branch 77 carries a nozzle 45', which may be constructed similarly to the nozzle 45 of Figure 3, of such a length as to terminate within the vertical projection of the exterior of the housing 71, and between the conduits 72, 73, which are bulged outwardly slightly to accommodate the nozzles. The Y-fittings are secured in the desired orientation by means of set screws 78.

Each Y-fitting carries a threadedly secured pipe bend 79, surved and oriented to cause the axis of the lower end to be inclined downwardly about 15° below the horizontal and to lie in a vertical plane making an angle of about 27° with the line joining the Y-fittings, as shown in Figure 12. A nozzle 45'', similar to the nozzle 45', is attached to each pipe bend 79. The orientation of the nozzles 45'' and the supporting pipe bends 79 is maintained by means of set screws 80.

As a consequence of the orientations of the nozzles, the upper pair of nozzles 45' will impart a counter-clockwise turning moment (as viewed in Figure 12) to the nozzle head, while the lower pair of nozzles 45'' will impart a clockwise turning moment to the head. Since, however, the axes of the upper nozzles are further apart, due to the greater angular displacement thereof with respect to the line joining the Y-fittings, their action will be greater than that of the lower nozzles, and the resultant force will rotate the head 70 in a counterclockwise sense. This arrangement makes it possible to adjust the magnitude of the turning moment, while providing a considerable latitude in the orientations of the nozzles, since it is possible to change the orientations of all the

nozzles without affecting the resultant turning moment.

The intermediate cutting section according to Figures 10 to 13 may be operated in the manner described above for Figure 1, with the exception that two cuts into the solid material to be removed are made simultaneously, as indicated schematically in Figure 14. In this figure, reference characters are similar to those appearing in Figure 6. It will be noted that the housing 71 acts as a shield plate to protect the nozzles 45' and 45'' from falling material. The length of the pipe 74 is preferably selected so that the relationship between the lower nozzles 45'' and the nozzles 45a is as described heretofore for the nozzles 45 and 45a.

The sizes of the nozzles and rates of discharge may be varied with the size of the installation and the particular purpose to be effected. By way of example, it may be stated that for cleaning a coke chamber of the type and size described above, the external diameters of the rotor section including the scrapers, and of the shield plate 52 may be 14 inches, and it is desirable to employ stub nozzles 28 with $\frac{1}{4}$ inch diameter orifices, about $1\frac{1}{2}$ to 2 inches in length; nozzles 45 with $\frac{3}{8}$ inch diameter orifices, about 8 inches long; and nozzles 45a with $\frac{3}{8}$ inch diameter orifices, about 12 inches long. In the modified form shown in Figures 10 to 13, the external diameter of the housing 71 may be $10\frac{3}{4}$ inches, and the nozzles 45' and 45'' may be $6\frac{3}{8}$ inches long, with $\frac{3}{8}$ inch orifices. Sufficient water pressure is then supplied to cause the total rate of discharge to be between about 400 and 900 gallons per minute.

With regard to the design of the nozzles, and especially of the main cutting nozzles 45, 45', 45'' and 45a, particularly when working on porous or carbonaceous material, it may be stated that the disruption and removal of the solid matter is preferably brought about primarily by the cutting action of the jets. This cutting action is effected by directing the water jet so as to cause a great impact or reaction on the body of solid material over as small an area as possible. In this manner the primary action of the water is to cut the solid material into lumps, and erosion is minimized. For the main cutting action, I prefer to employ water jets which have velocities of more than about 200 feet per second, best results being obtained with velocities of about 300 to 500 feet per second and higher, and which jets are confined. By "confined" jets, I mean jets which do not substantially break up or spread prior to impact. It is, moreover, desirable to employ jets of sufficient size to cause an impact of more than 100 lbs., best results being obtained with jets having impacts between 200 and 300 lbs. or greater. When lower velocities are employed, or when the design of the nozzle is such as to cause the jet to break up or spread the cutting action is materially reduced and erosion is increased. This materially increases the time required for the removal of the solid and is, moreover, often undesirable, since it is frequently advantageous to produce maximum lump and egg size coke. As an example, I may employ a jet of water from a $\frac{3}{8}$ inch diameter nozzle, with a velocity of 380 feet per second. Such a jet will cause an impact of about 212 lbs. over an area only slightly larger than 0.11 sq. in., the diameter of the nozzle orifice. I am, however, not restricted to the use of the specific dimensions, orientations, inclinations, and velocities, or to the

use of the nozzles which produce confined jets, as previously described.

I claim as my invention:

1. In a nozzle head for cutting into a body of solid material, the combination of conduit means adapted for axial connection with a source of liquid under pressure, a rotor rotatably mounted on said conduit means near a first end thereof, reaction nozzle means on said rotor in flow communication with said conduit means and disposed to impart a turning motion to said rotor, one or more leading main cutting nozzles and one or more trailing main cutting nozzles in flow communication with and mounted on said conduit means towards the other end of the conduit means from said rotor and disposed and constructed to discharge substantially confined jets of liquid, each jet tending outwardly from the axis of the nozzle head, the trailing main cutting nozzles being radially more distant from the said axis and axially further away from the rotor than the leading main cutting nozzles, said nozzle means on the rotor being arranged to discharge liquid in jet form tending in a direction to cut a well into said material of a diameter sufficient to permit said leading main cutting nozzles to enter the well without fouling, when the nozzle head is moved axially into the body of solid material in the direction of said first end.

2. In a nozzle head for cutting into a body of solid material, the combination of a conduit means adapted for axial connection with a source of liquid under pressure, comprising three axially juxtaposed sections, coupling means connecting said sections, a rotor on the first end section rotatable with respect to the other sections, reaction nozzle means on said rotor in flow communication with said conduit means and disposed to impart a turning motion to said rotor, one or more first main cutting nozzles in flow communication with and mounted on the intermediate section constructed and disposed to discharge jets of liquid, each jet tending outwardly from the axis of the nozzle head, said nozzle means on the rotor being arranged to discharge water in jet form tending in a direction to cut a well into said material of sufficient diameter to permit said first main cutting nozzles to enter the well without fouling when the nozzle head is moved axially into the body of solid material in the direction of said first end, one or more second main cutting nozzles in flow communication with and supported by the second end section, said second main cutting nozzles being normally radially more distant from the said axis than the first main cutting nozzles, and constructed and disposed to discharge jets of liquid, each jet tending outwardly from the said axis, and pivot means having a substantial horizontal pivotal axis and interposed between the second main cutting nozzles and the second end section of the conduit means, permitting the nozzle to be swung toward said axis.

3. In a nozzle head for cutting through a body of solid material, the combination of a conduit means adapted for axial connection with a source of liquid under pressure, said conduit means comprising two axially juxtaposed sections, coupling means connecting said sections, the upper section comprising a housing, a plurality of spaced, eccentrically located supports extending from the bottom of said housing connecting the housing to said coupling and arranged to establish flow communication between said housing and the lower section, one or more eccentrically located manifolds depending from said housing, a plurality

of first cutting nozzles on each manifold spaced in the direction of the axis of the nozzle head, said nozzles being located between said supports and being constructed and disposed to discharge substantially confined jets of liquid tending outwards from the axis of the nozzle head, at least some nozzles being skew with respect to the axis, whereby a turning moment is imparted to said nozzle head, one or more inclined pipes pivotally connected at their lower ends to the lower section, non-rotatable with respect to the said lower section and in flow communication with the conduit means, collapsible means to limit the outward pivotal movement of said inclined pipes away from said axis, a second cutting nozzle on each pipe constructed and disposed to discharge a substantially confined jet of liquid tending outwards from the said axis.

4. In a nozzle head for cutting through a body of solid material, the combination of a housing adapted for connection with a source of liquid under pressure, a plurality of conduits in communication therewith extending axially from one end of the housing and located eccentrically with respect to the axis of the housing, and nozzles on said conduits disposed generally radially inwardly from said eccentric conduits to discharge jets of water tending away from said axis.

5. The nozzle head according to claim 4 in which the nozzles lie entirely within the axially projected area of the housing.

6. In a nozzle head for cutting through a body of solid material, the combination of a housing adapted for connection with a source of liquid under pressure, a pair of manifolds in communication therewith extending axially from one end of the housing and located eccentrically with respect to the axis of the housing and at diametrically opposite points, a first pair of substantially parallel elongated nozzles mounted one on each manifold near the housing disposed generally radially inwardly from said eccentric manifolds but making an angle greater than zero with an axial plane containing the line joining said manifolds to discharge jets of water tending away from said axis, and a second pair of elongated nozzles mounted one on each manifold further away from the housing than said first pair of nozzles disposed generally inwardly from said eccentric manifolds to discharge jets of water tending away from said axis.

7. The nozzle head according to claim 6 in which the nozzles of the second pair are substantially parallel to one another, and the second nozzles are disposed in a different direction from the angle between the first pair of nozzles and an axial plane containing the line joining said manifolds, whereby a turning moment will be imparted to said nozzle head upon the flow of liquid through the nozzles.

8. In a nozzle head for cutting into a body of solid material, the combination of a conduit means adapted for axial connection with a source of liquid under pressure, a rotor rotatably mounted on said conduit means near a first end thereof, reaction nozzle means on said rotor in flow communication with said conduit means and disposed to impart a turning motion to said rotor, one or more leading main cutting nozzles and one or more trailing mean cutting nozzles mounted on and in flow communication with said conduit means towards the other end of the conduit means from said rotor and arranged and constructed to discharge substantially confined jets of liquid, each jet tending

outwardly from the axis of the nozzle head, the said nozzle means on the rotor being arranged to discharge liquid in jet form in a direction to cut a well into said body of a diameter sufficient to permit at least the leading main nozzles nearest to said well to enter the well without fouling when the nozzle head is moved axially into the body of solid material.

9. In a nozzle head for cutting into a body of solid material which contains a vertical opening therethrough, the combination of a conduit means adapted for axial connection at its upper end with a liquid feed pipe suspended through said vertical opening, said conduit means comprising three axially juxtaposed sections, coupling means connecting said sections, a hollow rotor rotatably mounted on and housing a portion of the upper section, ports in the upper section located to permit liquid to flow from the conduit into the rotor, a plurality of reaction nozzles mounted on said rotor and in flow communication therewith, each nozzle being disposed to direct a jet of liquid away from the axis of the nozzle head and upwardly, whereby the flow of liquid therethrough will cause the rotation of the rotor and the enlargement of said vertical opening above the rotor, a scraper mounted on top of said rotor and extending radially at least as far as the radial extent of said reaction nozzles; a plurality of elongated first main cutting nozzles mounted on and non-rotatable with respect to the intermediate section of said conduit means, shield means above said first cutting nozzles extending radially at least as far as the radial extent of the first cutting nozzles and being small enough to enter a well formed into the body of solid material by the rotor and a plurality of second main cutting nozzles mounted on and non-rotatable with respect to the lower section of said conduit means.

10. In a nozzle head for cutting into a body of solid material, the combination of a conduit means adapted for axial connection with a source of liquid under pressure, comprising three axially juxtaposed sections, coupling means connecting said sections, a rotor on the first end section rotatable with respect to the other sections, reaction nozzle means on said rotor in flow communication with said conduit means and disposed to impart a turning motion to said rotor; the intermediate section comprising an enlarged hollow housing, a plurality of spaced, eccentrically located conduits extending from the bottom of said housing connecting the housing to the coupling between the intermediate and the lower section, a plurality of eccentrically located manifolds depending from said housing, a plurality of vertically spaced elongated first main cutting nozzles on each of said manifolds, said nozzles being located between said conduits, at least some of said nozzles being constructed and disposed to discharge substantially confined jets of liquid tending downwards and outwards from the axis of the nozzle head and skew with respect thereto, whereby a turning moment is imparted to said conduit means by the flow of liquid through said first cutting nozzles, the housing extending radially at least as far as the radial extent of the first cutting nozzles and being small enough to enter a well formed into the body of solid material by the rotor; a plurality of inclined pipes freely pivotable about a substantially horizontal axis and having means to limit the radial swing to a predetermined position connected at their lower ends to the lower

section, non-rotatable with respect to and in flow communication with the conduit means, and an elongated second main cutting nozzle on each pipe constructed and disposed to discharge a substantially confined jet of liquid tending upwards and outwards from the said axis.

11. In a nozzle head for cutting through a body of solid material the combination of a conduit means adapted for axial connection with a source of liquid under pressure, one or more first cutting nozzles non-rotatable with respect to and mounted on said conduit in flow communication therewith, constructed and disposed to discharge substantially confined jets of liquid outwardly from the axis of the nozzle head, and one or more second cutting nozzles freely pivot-

able about a substantially horizontal axis and having means to limit the radial swing to a predetermined position, non-rotatable with respect to and mounted on said conduit in flow communication therewith, said second cutting nozzles being radially more distant from the said axis than the first cutting nozzles, being spaced axially therefrom, and being constructed and disposed to discharge substantially confined jets of liquid outwardly and upwardly from the said axis and lying substantially in a surface of revolution which intersects the surface of revolution containing the jets of at least some of the first cutting nozzles in a closed curve spaced from and surrounding said axis.

WILLIAM FREDERICK COURT.