Dec. 26, 1967 C. R. CANALIZO 3,360,061

LARGE WELL BORE DRILLING APPARATUS

Filed Oct. 8, 1964 2 Sheets-Sheet 1

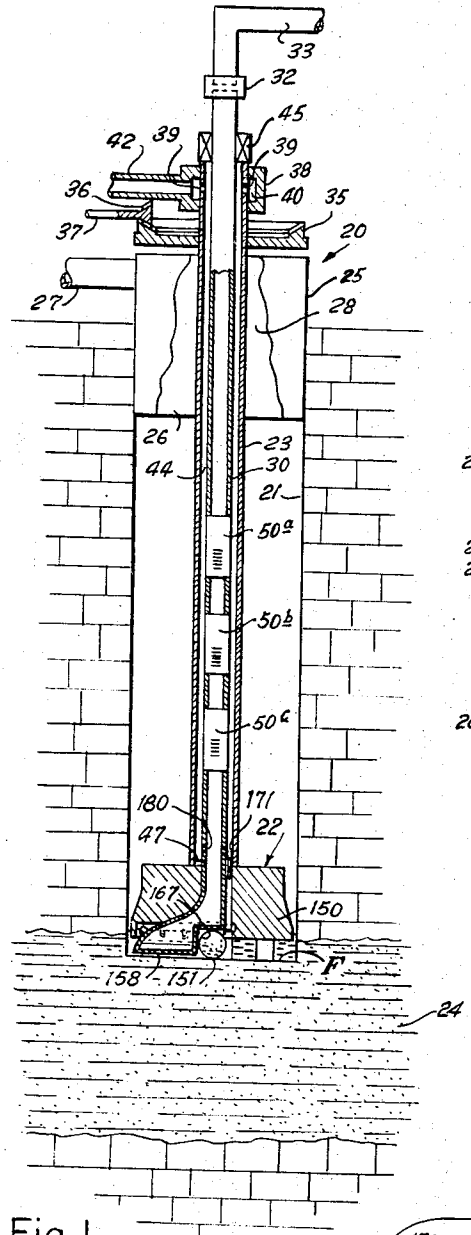

Fig. 1

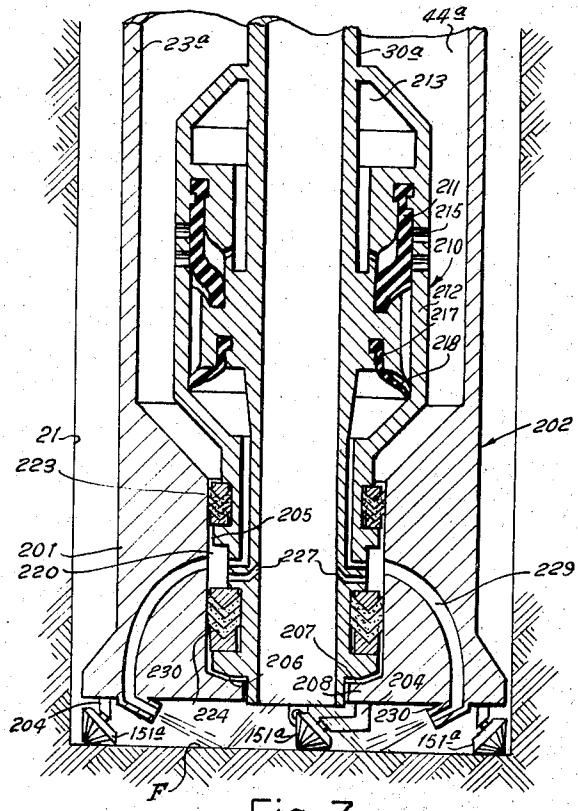

Fig. 7

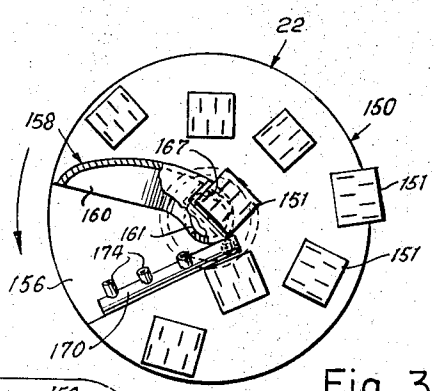

Fig. 3

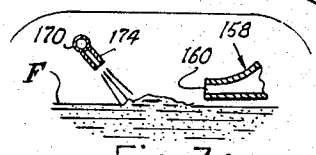

Fig. 3A

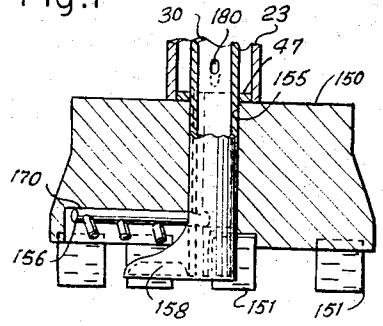

Fig. 2

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Dec. 26, 1967 C. R. CANALIZO 3,360,061

LARGE WELL BORE DRILLING APPARATUS

Filed Oct. 8, 1964 2 Sheets-Sheet 2

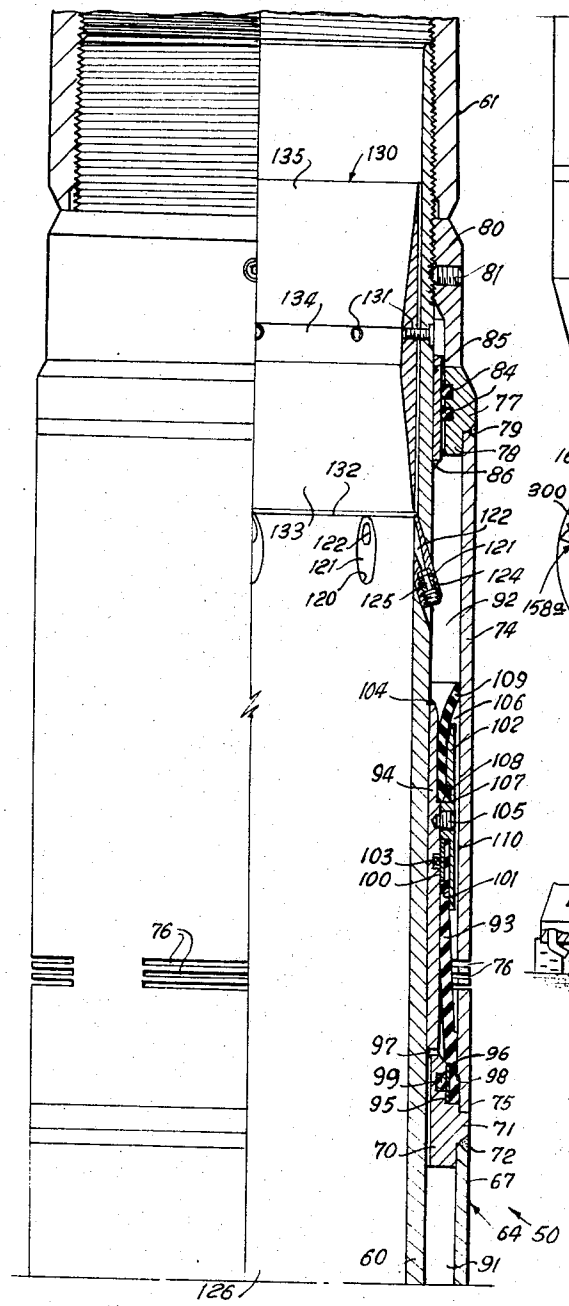

Fig. 5

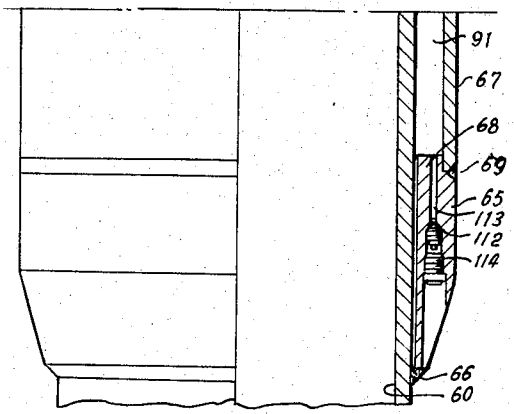

Fig. 6

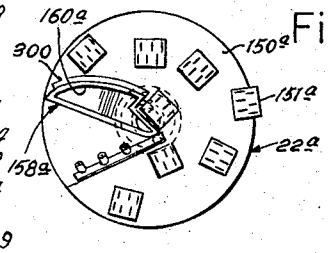

Fig. 8

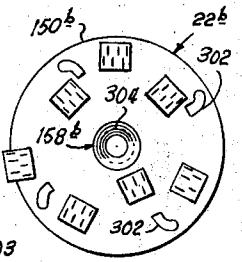

Fig. 10

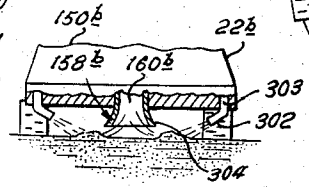

Fig. 11

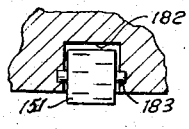

Fig. 4

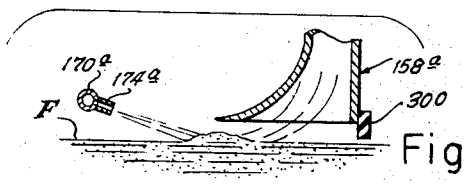

Fig. 9

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3,360,061

LARGE WELL BORE DRILLING APPARATUS

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Filed Oct. 8, 1964, Ser. No. 402,425
17 Claims. (Cl. 175—324)

This invention relates to well apparatus and more particularly to a well apparatus for drilling a well bore and transporting to the surface earth cuttings and liquids flowing into the well bore.

An object of this invention is to provide a new and improved well apparatus for drilling a well bore and transporting to the surface the earth cuttings produced during the drilling and any liquid flowing into the well bore through a tubular member or tubing which extends from the bottom of the well bore to the surface.

Another object is to provide a well apparatus of the type described having means for accelerating the movement of the cuttings and liquids through the longitudinal passage of the tubular member at longitudinally spaced locations along the tubing by introducing or injecting gas at high velocity into the tubing in the direction of longitudinal movement of the fluids therethrough.

Still another object is to provide a well apparatus for drilling a well bore and for transporting cuttings and liquid from the well bore which provides for circulation of low pressure gas into the well bore and then upwardly through the tubing extending through the well bore and for the circulation of high pressure gas from the surface through a passage means extending about the tubing and into the tubing to aid in the transport of the cuttings and liquids to the surface.

A further object is to provide a well apparatus of the type described wherein a drill is secured to the lower end of a drill pipe which provides the passage for the circulation of high pressure gas and wherein means are positioned adjacent the drill for maintaining the liquids and cuttings at the bottom of the well bore in a state of agitation or turbulence to facilitate their movement into the lower end of the tubing.

A still further object is to provide a well apparatus of the type described wherein the agitating means includes a baffle means extending downwardly of the drill adjacent the drill face and means for directing jets of gas at the drill face immediately in front of the baffle means.

Another object is to provide a well apparatus of the type described wherein the tubing is provided at vertically spaced locations with control devices for controlling the flow of the high pressure gas into the tubing from the annular gas passage between the tubing and the drill pipe through which the tubing extends.

Still another object is to provide a well apparatus of the type described wherein high pressure gas from the gas passage is directed against the bottom of the well bore below the drill to agitate the cuttings and liquids in the well bore.

Still another object is to provide a well apparatus of the type described wherein the rate of flow of high pressure gas from the gas passage directed against the bottom of the well bore is controlled by controlling the effective orifices of the passages through which the high pressure gas flows from the gas passage.

Still another object is to provide a well apparatus having the flow control device responsive to the pressure within the gas passage for permitting flow of gas from the gas passage through nozzles adjacent the drill face of the well bore only when the pressure in the gas passage is raised to a predetermined value.

Additional objects and advantages of the invention will

be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, within:

FIGURE 1 is a schematic illustration of a drilling apparatus for drilling a well bore and for transporting liquids and cutting from the well bore;

FIGURE 2 is an enlarged fragmentary schematic view, partly in section, of the drill bit and the means for agitating the cuttings at the drill face of the apparatus illustrated in FIGURE 1;

FIGURE 3 is a bottom schematic view of the apparatus illustrated in FIGURE 2;

FIGURE 3–A is a schematic illustration of the baffle means and the means for directing jets of gas at the drill face;

FIGURE 4 is a schematic fragmentary sectional view of a modified means for mounting the roller bits of the drill bit on the drill bit body;

FIGURE 5 is a vertical, partly sectional view of the upper portion of a flow control device used in the apparatus;

FIGURE 6 is a view similar to FIGURE 5 being a continuation thereof showing the lower portion of the flow control device;

FIGURE 7 is a schematic sectional illustration of a modified form of the drilling and agitating apparatus of the invention;

FIGURE 8 is a bottom schematic view of a drill having a modified form of the baffle;

FIGURE 9 is a schematic illustration of the baffle means and the means for directing jets of gas at the drill face of the drill illustrated in FIGURE 8; and,

FIGURE 10 is a bottom schematic view of drill having a modified form of the means for directing jets at the drill face and agitating the earth cuttings.

Referring now to FIGURE 1 of the drawing, the well apparatus **20** for drilling a large diameter well bore **21** utilizes the circulation of gas to remove the cuttings of the earth formation produced by a usual drill **22** on the bottom end of the usual drill pipe **23**, and any liquid flowing into the well bore as during the drilling of the well bore in locations where the well bore extends through a porous water bearing formation **24**. The drill pipe **23** extends through a suitable casing head **25** secured to the upper end of a casing **26** which extends a short distance into the ground. The casing head has an inlet conduit or pipe **27** which opens to the annulus or gas passage **28** about the drill pipe so that large volumes of air of relatively low pressure may be introduced or pumped into the upper end of the large annulus and flow at relatively low velocity to the bottom of the bore and then upwardly through a string of tubing **30** at an increased velocity to carry the cuttings of the earth formations penetrated by the drill and any liquids flowing into the well bore to the surface. The tubing extends through the drill pipe **23** and is rigidly secured thereto. The upper end portion of the tubing extends upwardly of the upper end of the drill pipe and is secured by a suitable swivel **32** to an outlet conduit or pipe **33** through which the air with the cuttings and liquids carried thereby is transported to a desired location. The drill pipe is rotated at the surface by any suitable means such as the large gear **35**, through which the drill pipe extends vertically slidably but non-rotatably, and a gear **36** on a drive shaft **37** driven by any suitable prime mover.

The drill pipe at its upper end portion extends rotatably through a suitable manifold **38** and is provided with a plurality of ports **39** which open to the annular passage **40** of the manifold. The manifold has an inlet pipe or conduit **42**. Gas under high pressure is introducible into the

upper end of the gas passage **44** between the tubing and the drill pipe by means of the manifold and the ports of the drill pipe. The upper end of the gas passage is closed by a suitable packer or seal **45** which seals between the tubing and the drill pipe. A suitable closure or packing **47** which seals between the string of tubing and the drill pipe closes the bottom end of the gas passage.

The string of tubing has a plurality of flow control devices or ejector pumps **50***a*, *b*, *c*, connected therein at longitudinally spaced locations which control the flow of gas from the gas passage into the string of tubing to aid in transporting cuttings and liquids from the bottom of the well bore through the tubing to the surface. Each of the ejector pumps includes a tubular mandrel **60** threaded as at its upper and lower end portions whereby it may be connected by the usual coupling collars **61** to adjacent ends of adjacent sections of the tubing and may constitute a section of the tubing.

A cylindrical sleeve **64** is disposed about the mandrel intermediate its ends and includes a tubular bottom section **65** rigidly secured to the mandrel in seal tight relationship therewith by a weld **66**. A tubular charge chamber section **67** of the sleeve has a lower end portion telescoped over the reduced end portion **68** of the bottom sleeve section and is rigidly secured thereto in seal tight relationship by a weld **69**. The upper end portion of the chamber sleeve section telescopes over the reduced lower end portion **70** of a connector section **71** of the sleeve and is rigidly secured thereto in seal tight relationship by a weld **72**. A tubular port section **74** of the sleeve is telescoped downwardly over the upper portion of the connector section with its downward movement limited by the engagement of its annular bottom end shoulder surface with the upwardly facing annular shoulder **75** of the connector section. The port sleeve section has a plurality of lateral ports **76** intermediate its ends. The top section **77** of the sleeve has a reduced lower end portion **78** telescoped into the upper end portion of the port sleeve section and rigidly secured thereto in seal tight relationship by the weld **79**. The port and top sections of the sleeve are held against upward movement on the mandrel by a retainer ring **80** threaded on the upper end portion of the mandrel and rigidly secured in any adjusted position against rotation by a set screw **81**. The bottom annular end surface of the retainer ring abuts the upper end surface of the top sleeve section.

The top sleeve section has a pair of internal annular recesses in which are disposed O-rings **84** which seal between the top section and a seal ring **85** rigidly secured to in seal tight relationship with the mandrel by a weld **86**.

The mandrel **60** and the sleeve **64** define an annular space about the mandrel closed at the upper and lower ends by the bottom and top sleeve sections and separated into a lower annular charge chamber **91** and an upper flow passage **92** by a resilient tubular closure or valve member **93**. The valve member is disposed within the sleeve and about the upper inner support portion **94** of the connector sleeve section which is spaced inwardly of a port sleeve section. The lower end portion of the valve member has an internal rigid bottom ring **95**, which may be bonded thereto, which telescopes over the annular external surface **96** of the connector sleeve section below its circumferentially spaced lateral ports **97**. The lower end portion of the valve member is compressed against and sealingly engages the internal annular surface of the port sleeve section below its downwardly facing annular shoulder **98** and is thus held against upward displacement. An O-ring **99** disposed in an external annular recess of the connector sleeve section seals between the bottom ring **95** of the valve member and the connector section.

A top ring **100** is similarly disposed in the upper end portion of the valve member and may be bonded thereto. The upper end portion of the valve member telescopes into the enlarged lower portion **101** of an annular support **102** and is compressed against and sealingly engages the internal surfaces of the outer support member defining the enlarged portion. An O-ring **103** disposed in an external annular recess of the inner support portion **94** seals between the ring **100** and the support portion. The upper end of the support portion of the connector sleeve section is rigidly secured to, and in seal tight relationship with, the mandrel by a weld **104**. The outer support member is secured to the support portion **94**, by any suitable means, as by a set screw **105**.

The inner support portion **94** and the outer support member **102** hold the lower portions of a tubular resilient check valve **106** therebetween, the outer support member having internal annular recess **107** in which is received an external annular flange **108** of the check valve. The upper annular lip portion **109** of the check valve is engageable with the internal surfaces of the port sleeve section to prevent downward flow through the annular flow passage **92** to the ports **76**. The lip portion resiliently flexes inwardly to permit flow of fluids from the ports **76** and through the circumferentially spaced longitudinal slots **110** of the outer support member and thus through the flow passage **92**.

Fluid under pressure is introducible into the charge chamber **91** through a suitable filler valve **112** threaded in an enlarged intermediate portion of the filler passage **113**. A protector plug **114** is threaded in a lower enlarged portion of the passage to protect the valve.

It will be apparent that the force of the charge of compressed gas in the chamber **91**, communicated to the internal surface of the valve member intermediate its ends through the radial ports **97** of the connector sleeve section, biases the valve member **93** outwardly toward expanded position and into sealing engagement with the internal surface of the port sleeve section about its lateral ports **76** to close the ports to inward flow of fluids therethrough, and that the valve member will be moved inwardly to its retracted or open position to open the ports when the pressure exteriorly of the valve member exceeds the pressure in the chamber **91**.

The mandrel **40** above the check valve **106** has a plurality of circumferentially spaced inwardly extending apertures **120** in which are disposed tubular inserts **121**. The upper end portions **122** of the bores or passages of the inserts flare upwardly, i.e., increase in diameter upwardly. The lower enlarged threaded portions of the passages open to the passage **92** above the check valve. Beans **124** having orifices **125** are threaded in the lower portions of the inserts. The orifices of the beans communicate with the passage **92** and the flared upper portions **122** of the passages of the inserts. The rate of flow of gas from the passage **92** into the internal longitudinal passage or bore **126** of the mandrel, at any given pressure of the gas in the flow passage **92**, may be adjusted by providing beans of different orifices. The inserts **121** and the beans **124** are preferably made of a very hard wear resistant substance to minimize their flow cutting by the gas flowing therethrough.

The upper ends of the passages of the inserts open to the inner longitudinal passage **126** of the mandrel below the lower end of an annular passage restricting member **130** rigidly secured by the screws **131** in the enlarged upper end portion of the longitudinal passage. The bottom end of the passage restricting member is disposed immediately above the annular upwardly facing shoulder **132** of the mandrel and the lower upwardly and inwardly extending internal surface **133** of the restricting member at its lower end is of substantially the same diameter and flush with the internal surface of the mandrel defining the passage **126** below its shoulder **132** to minimize turbulence in gases flowing upwardly through the restricting member. The restricting member also has an intermediate central cylindrical surface **134** and an upwardly and outwardly extending upper internal surface **135**.

Due to the restriction of the flow passage of the mandrel above the top ends of the passages of the inserts, gas flowing into the mandrel through the inserts increases in velocity. The pumping or ejector action of the gas injected into the mandrel from the gas passage **44**, whose effect is intensified by the restriction of the mandrel flow passage **126** immediately above the top ends of the flow passages of the inserts **121**, tends to move fluids in the tubing upwardly to the surface. The restricting member **130** is preferably hard surfaced to resist abrasive wear and, since it extends into the passage of the mandrel, it tends to prevent wear of the mandrel since the main flow of fluids bearing earth cuttings is thus spaced inwardly of the internal surfaces of the mandrel. The restricting member is easily replaced when worn to an excessive degree.

If the apparatus is to be used in drilling a well bore through earth formations which produce liquids at relatively great rates which flow into the well bore being drilled by the apparatus, the pressure of the charge of gas in the charge chamber of each of the ejector pumps **50***a*–**50***c* connected in the string of tubing **30** is so selected that the pressure charge in each pump is lower than that in the pump next above it in the well bore **21**, the lowermost ejector pump **50***c* having the lowest charge pressure and the uppermost ejector pump **50***a* having the greatest charge pressure. Thus, as the pressure of the gas in the gas passage **44** rises as it is introduced or pumped into the gas passage through the inlet conduit **42**, the ejector pumps are opened progressively and successively, the bottom ejector pump **50***a* opening first, then the next higher ejector pump **50***b* and then the uppermost ejector pump **50***c*. If the well bore is to penetrate earth formations which produce no or little water, the pressures in the charge chambers of the several ejector pumps are preferably set at equal values.

It will be apparent that while only three ejector pumps have been shown connected in the string of tubing **30**, the number of valves and their spacing is determined by the particular requirements of a particular well bore being drilled, which may vary with the characteristics of the earth formations which the well bore penetrates, the rate of drilling, the rate of flow of liquids into the well bore, and other such factors.

The drill **22** secured to the lower end of the drill pipe **23** may include a suitable body **150** which has suitable support means by means of which the usual earth and fragmenting roller bits **151** are rotatably mounted on the body. The roller bits are arranged below the bottom surface **153** of the body in a suitable pattern to overlap the full area of the well bottom or drill face F of the well bore as the drill is rotated. The lower end of the string of tubing extends downwardly through the closure or packing **47** and through a central downwardly opening bore or aperture **155** of the drill body. The bore **155** opens to a laterally outwardly extending and downwardly opening recess **156** of the body in which is positioned a baffle or scoop **158** rigidly secured to the lower end of the string of tubing and whose elongate opening or throat **160** extends substantially radially across substantially the full radius of the bore hole. The scoop, of course, opens as at **161** to the lower end of the longitudinal passage of the tubing. The scoop is provided with a downwardly opening recess **167** in which is rotatably mounted in any suitable manner, one of the roller bits **151**. The roller bits are so arranged that during each complete rotation of the drill the full area of the drill face F will be engaged by the drill and the earth formation is fragmented thereby in the usual manner.

A substantially horizontal manifold or nozzle duct **170** is also disposed in the recess **156** and is supplied with compressed gas under high pressure from the gas passage **44** by means of the duct **171** which extends through a suitable aperture in the closure or packer **47** and which is rigidly secured to the drill body. The manifold is provided with a plurality of spaced nozzles **174** through

which jets of high velocity gas from the gas passage are directed at the drill face immediately in front of the throat **160** of the scoop **158** in order to maintain any cuttings or other debris at the bottom of the bore hole in a state of turbulence or agitation whereby they are more easily drawn into the throat **160** as the drill rotates. The drill rotates in the direction indicated in FIGURE 3 of the drawing so that the scoop throat opens in the direction of rotation of the drill bit while the jets on the nozzles **174** are directed downwardly in the direction of the scoop.

The tubing immediately above the drill and the closure or packing **47** is provided with a plurality of upwardly convergent passages **180** which may be flared upwardly in the same manner as the passages **122** of the inserts **121**.

In use, when the well apparatus **20** is used to drill a large diameter well bore, for example, four or more feet, large volumes of air under relatively low pressure are introduced into the annulus **28** through the duct or pipe **27** and flow downwardly to the bottom of the well bore at relatively low velocity and then enter into the bottom end of the tubing **30** through the throat **160** of the scoop. The velocity of flow of the gas as it flows into the tubing increases greatly since the effective orifice of the tubing is much smaller than the effective orifice of the annulus **28**. Cuttings from the earth formations being fragmented by the roller bits of the drill as the drill rotates and any small amounts of liquid in the bore are readily transported to the surface through the tubing by such gas introduced under relatively low pressure into the well bore at the surface as long as no appreciable amounts of water flow into the well at the bottom of the well bore, as due to the penetration of the drill through a water bearing formation, such as the water bearing formation **24**, or as long as the rate of production of the earth cuttings does not exceed the transport capacity of the low pressure gas.

If water or cuttings tend to accumulate at the bottom of the well bore, gas under relatively high pressure is introduce into the gas passage **44** at the surface through the pipe **22** and the manifold **38**. As the gas under high pressure is introduced into the gas passage at the surface it commences to flow downwardly through the duct **171** and manifold **170**, and jets of high velocity gas are directed at the drill face or bottom of the well bore to place such cuttings and any water in the bore into agitation or turbulence and therefore flow more readily through the scoop throat **160** into the bottom of the tubing and thence to the surface instead of settling on the bottom of the well bore. At the same time the gas flows upwardly through passages **180** into the tubing immediately above the drill and this gas flow also aids in lifting such cuttings and water to the surface.

If the well bore is to penetrate through earth formations which produce no liquids at relatively low rates the charges of gas in the charge chambers of the several ejector pumps are set at the same pressure and, if cuttings tend to accumulate in the well bore, the pressure of the gas in the gas passage is increased to the value at which the ejector pumps are rendered operative and gas under high pressure, for example 450 p.s.i., flows through the ejector pumps into the flow passage of the tubing to further aid in transporting the cuttings and any small amounts of water to the surface. As the drilling of the well bore is now continued, the operation of the ejector pumps and of the jets of gas from the nozzles **174** in cooperation with the scoop **158** aid in transporting the cuttings and water flowing into the well to the surface through the tubing.

It will be apparent that during the rotation of the drill the scoop causes turbulence at the bottom of the well bore which turbulence is increased by the action of the jets of air from the nozzles **174**.

If the well bore is to penetrate earth formations which

produce liquids at relatively great rates, the pressures of the charges of gas in the charge chambers of the ejector pumps are set at progressively lower values with their depth in the well, the charge pressure of the lowest ejector pump being the smallest.

If water accumulates in the well bore and in the tubing to a height above any of one or more of the ejector pumps, for example, the scecond lowermost ejector pump **50***b*, upon the introduction of gas under high pressure into the gas passage, the pressure in the gas passage is increased first to the value at which the bottom ejector pump **50***c* is rendered operative and gas under high pressure flows through the ejector pump into the flow passage of the tubing and lowers the pressure in the tubing below the location of ejection of the gas into the tubing through the bottom ejector pump. As the pressure in the gas passage continues to increase, the next lower ejector pump **50***b* and then the ejector **50***a* are rendered operative. As the ejector pumps **50***c* and **50***b* are rendered operative, the gas from the gas passage begins to flow into the tubing beneath the column of water in the tubing below the passages **122** of the inserts **120** of the ejector pump **50***c* and then of the pump **50***b* and lifts the column or slug of water thereabove upwardly through the tubing. If necessary, the pressure of the gas in the gas passage is increased to the value at which the top ejector pump is also rendered operative. The gas flowing into the tubing through the ejector pumps then aids in transporting the water and cuttings from the well bore to the surface. The pressure in the gas passage is maintained at such pressure as required to render and then maintain operative the smallest number of ejector pumps necessary to remove any accumulation of water and cuttings from the well bore and then prevent any more accumultaion to minimize the amount of gas which must be pumped into the gas passage. The upward movement of the slug of water is, of course, accelerated by the pump action of the top ejector pump **50***a* until the slug of water flows upwardly and out of the upper end of the tubing. The flow of gas at high velocity through the lowermost ejector passages **180** and through the nozzles **174** also aids in transporting the water to the surface.

When any such water which has accumulated in the well bore and tubing has been removed to the surface, the action of the flow of low pressure gas into the well bore through the pipe **27** at the surface may be effective to transport any water which may continue to flow into the well bore and cuttings as they are produced to the surface in which event the introduction of the high pressure gas may be discontinued or it may be introduced into the gas passage at a relatively low pressure, higher than the pressure which is lower than that necessary to open any of the ejector pumps, but sufficiently great to cause jets of air to flow through the nozzles **174** and the ejector passages **180**. If such combined flow of high pressure gas merely through the ejector passages **180** and the nozzles and of the low pressure gas is not efiective to transport the water and cuttings to the surface through the tubing, the pressure of the gas in the gas passage is increased to the value necessary to cause operation of such number of the ejector pumps **50** as may be necessary to transport the cuttings and the water to the surface.

The turbulence or agitation of the cuttings at the drill face varies, of course, with the rate of flow of gas between the bottom surface **153** of the drill body and the drill face and such agitation increases for a given rate of flow of the low pressure gas into the annulus and of the high pressure gas through the nozzles **174** as the distance between the bottom surface **153** of the drill body and the drill face decreases. As is illustrated in FIGURE 6, this distance may be decreased by providing the bottom of the drill body with relatively deep downwardly facing recesses **183** in which upper portions of the roller bits **151** may be received. The roller bits are, of course, rotatably mounted, as by means of pinions or shafts **183** which are journaled in suitable bores of the body which open into the recesses **182**.

The scoop serves as a baffle, as well as a scoop, since it moves over the drill face and also agitates the water and cuttings. In addition it also provides a baffle or barrier to the horizontal flow of the high pressure gas as the jets of gas are deflected from the drill face thus further increasing the turbulence.

In the event that the water flows into the well bore at the same rate as it is being removed from the well bore, a layer of water may form a seal between the well bore and the bottom of the tubing passage in which case, the low pressure gas does not flow from the well bore into the tubing and the pressure in the well bore is then merely maintained at a predetermined low pressure.

In some cases if the cuttings tend to accumulate in a dry well bore, water may be introduced through into the well bore to help wash the cuttings away from the roller bits and toward the passage of the tubing. If desired the viscosity of the water flowing into the well bore from earth formations or introduced thereinto at the surface may be increased by the addition thereto of suitable substances such as gels, soap and the like, to increase the cuttings transportation capability of the water.

The well apparatus **200** illustrated in FIGURE 7 is similar to the apparatus **20** and, accordingly, elements of the well apparatus **200** have been provided with the same reference numerals, to which the subscript *a* has been added, as the corresponding elements of the well apparatus **20**. The body **201** of the drill bit **202** is rigidly secured to the lower end of the drill pipe **23***a* and a plurality of conical drill bits **151***a*, only three of which are shown, are rotatably mounted on the body below its bottom surface **153***a* by means of suitable shafts **204**. The lower end of the tubing **30***a*, in which one or more of the ejector pumps **50** are connected, extends through a reduced bottom portion of the bore of the drill body **201** which provides a seal surface **205**. Downward movement of the tubing in the casing is limited by the engagement of its bottom annular downwardly facing shoulder **206** with the upwardly facing stop shoulder **207** of an internal annular flange **208** of the drill body.

A flow control device **210**, mounted in the string of tubing immediately above the drill, is similar to the flow control devices **50** having a flexible valve member **211** which is biased outwardly into sealing engagement with the internal surfaces of a sleeve **212** by the force of a charge of compressed gas in a charge chamber **213** to close the lateral ports **215** of the sleeve and prevent flow of the gas from the gas passage **44***a* between the string of tubing and the drill pipe into the flow passage **217** and past the tubular check valve **218** to the exterior of the tubing. The passage **217** opens outwardly into an annular passage **220** between the tubing and the drill pipe between the upper and lower packers or seal means **223** and **224** mounted on the tubing and sealingly engaging the internal seal surface **205** of the drill body. The tubing has ejector passages **227** which permit flow of gas from the passage **220** into the string of tubing in an upward direction. The drill body also has passages **229** which open to the passage **220** and to the well bore below the face **153***a* through suitable nozzles **230** which direct jets of the gas inwardly and downwardly at the drill face or bottom of the well bore.

It will be apparent that the well apparatus **200** will function in the same manner as the well apparatus **20** to aid in transporting cuttings and liquids flowing into the well bore to the surface through the tubing **30***a*.

It will be apparent that the flow of the high pressure gas from the gas passage **44***a* is controlled by the flow control device **210**, the pressure of whose charge of gas in its charge chamber **213** may be higher than the pressure in the charge chambers of any of the ejector pumps con-

nected in the tubing **30***a* thereabove. The flow control device **210** will open to permit flow of the high pressure gas into the tubing through the ejector ports or passages **227** and to the well bore through the passages **229** and nozzles **230** only after the ejector pumps in the tubing have successively opened.

As a result, any column of water which may have accumulated in the well bore and in the string of tubing is raised by the successive openings of the ejector pumps connected in the string of tubing **30***a*. When the column or slug of water above each of the ejector pumps has been lifted to the surface, the pressure of the gas in the gas passage **44***a* is increased to the value which exceeds the pressure of the charge of gas in the charge chamber **213** of the flow control device **210**, the valve member **211** is moved to its open position and the high pressure gas flows from the gas passage through the lateral ports **215** and the passage **217** into the annular passage **220** and thence through the ejector ports **227** of the tubing to raise any column or slug of water in the tubing thereabove. At the same time the high pressure gas flows through the nozzles **230**.

It will thus be apparent that one of the main differences between the well apparatus **20** and the well apparatus **200** is that the flow of high pressure gas through the ejector ports **180** and the nozzles **174** of the well apparatus **20** commences whenever gas is introduced into the gas passage **44***a* at the surface whereas in the well apparatus **200** the flow of gas through the lowermost ejector ports **227** and the drill nozzles **230** takes place only after all of the ejector pumps connected in the string of tubing thereabove have opened and the pressure in the gas chamber is increased to a predetermined value.

Alternatively, the pressure of the charge of gas in the charge chamber **213** of the flow control device may be lower than the pressure in the charge chambers of any of the ejector pumps **30***a* connected thereabove. In this case, the flow of high pressure gas through the ejector parts **227** and the nozzles **230** of the apparatus **200** commences when the pressure in its gas passage is raised to a predetermined value and the ejector pumps will be rendered operatively only if the gas pressure in the gas passage is raised above such predetermined value and to the values at which the ejector pumps are rendered operative.

It will now be seen that the new and improved well apparatus for drilling a well bore and transporting from the well bore cutting and liquids flowing into the well bore to the surface includes a string of tubing which extends about the drill pipe on which the drill is mounted, a plurality of ejector pumps connected at longitudinally spaced locations in the string of tubing, a baffle or scoop **158** through whose open throat **160** the cuttings and liquid enter into the bottom end of the tubing, and a means for agitating the cuttings and liquids which may be present between the bottom surface of the drill body and the drill face of the well bore which includes means such as the nozzles **174** or **230** through which a gas from the annulus or gas passage between the tubing and the drill pipe is ejected at high velocity downwardly at an angle at the drill face and in the direction of such baffle or scoop.

It will further be seen that the flow of high velocity gas may take place immediately upon introduction at the surface of the high pressure gas into the gas passage between the tubing and the drill pipe or in the well apparatus **20** if, as in the well apparatus **200**, the apparatus is provided with the flow control device **210** only after the pressure in the gas passage has been raised to a predetermined value.

It will further be seen that the well apparatus **20** as well as the well apparatus **200** has ejector passages opening upwardly into the tubing adjacent its lower end whereby any column of water between such ejector passages and the lowermost ejector pump thereabove may be lifted by the gas flowing through the ejector passages. If desired, a passage restricting member, such as the member **130** of the ejector pumps, may be mounted in the tubing above such ejector passages.

It will further be seen that the rear vertical wall **160***a* of the scoop extends angularly outwardly relative to the radius of its rotation in the direction of rotation whereby its rotation tends to move any cuttings engaged thereby radially inwardly toward the center and toward the lower end of the tubing.

Referring now particularly to FIGURES 8 and 9 of the drawing, the drill **22***a* is substantially similar to the drill **22** and, accordingly, its elements have been provided with the same reference numerals, to which the subscript *a* has been added, as the corresponding elements of the drill **22**. The scoop **158***a* of the drill **22***a* differs from the scoop **158** of the drill **22** in that it is open at the bottom and is provided with a resilient baffle strip **300** rigidly secured as by bonding, or the like to the trailing side of the scoop **158***a* and which extends below the scoop toward the drill face F. The jets of high velocity gas from the nozzles **174***a* tend to agitate and are directed downwardly at such angle toward the drill face that they deflect from the face F in the direction of the bottom open end of the scoop and thus tend to agitate and carry the cuttings into the scoop and thus into the tubing.

Referring now to FIGURES 10 and 11 of the drawing, the drill **22***b* is similar to the drill **22** and accordingly its elements have been provided with the same reference numerals, to which the subscript *b* has been added as the corresponding elements of the drill **22**. The body **150***b* of the drill **22***b* has a plurality of nozzles **302** at circumferentially spaced locations which are supplied with high pressure gas from the gas passage of the well apparatus through suitable passages or ducts **303** which extend through the drill body **150***b*. The jets are inclined downwardly and inwardly toward the lower end of the scoop **158***b* connected to the lower end of tubing. The scoop has a downwardly and outwardly flared annular flange **304** spaced below the bottom surface of the drill body **150***b* so that the velocity of the gas flowing into its lower end is increased due to the narrow spacing therebetween. The jets of high velocity gas from the nozzles **174***b* are directed inwardly and downwardly at such an angle that when deflected from the drill face they are directed towards the open lower end of the scoop and thus also tend to aid in moving the cuttings into the throat **160***b* of the scoop.

The drill bits **151** and **151***a* are each usable with the drill body of either form of the drill.

It will now be apparent that several forms of a drill having a baffle and a means for agitating the cuttings produced by the drill have been illustrated and described.

It will further be seen that while a particular ejector pump has been illustrated and described as being connectable in the string of tubing for controlling the flow of high pressure gas from the gas passage of the apparatus into the tubing through which the cuttings and liquids from the bottom of the well bore are transported to the surface that the tubing may be provided with other types of flow control devices which permit flow of high pressure gas therethrough from the gas passage into the tubing. For example, valves of the type described and illustrated in Patent No. 2,954,043 may be mounted on the exterior of the tubing in the manner described in the patent, in circumferentially spaced relationship, and in the gas passage, at suitable vertically spaced locations therealong for controlling the flow of gas from the gas passage into the tubing through suitable ports thereof.

It will further be seen that while the apparatus is provided with a means, such as the well head **25** and the conduit **27**, for introducing air under relatively low pressure into the well bore, in certain installations the

well bore may be open to the atmosphere at the surface and the transport of the cuttings and liquids from the well bore through the tubing is then effected by the operation of the ejector pumps connected in the tubing.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage; downwardly inclined jet orifice means mounted on said drill for directing jets of gas from said gas passage into the well bore below said drill downwardly toward the bottom of the well bore and toward the longitudinal passage of said tubing; and flow directing means on the drill directing flow of gas and cuttings upwardly into the longitudinal passage of the tubing.

2. A well apparatus for drilling a web bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said tubing having at least one flow control valve device connected thereto for controlling introduction of gas from said gas passage into said longitudinal passage and directing the flow of the gas upwardly into said longitudinal passage to increase the velocity of upward flow of fluids through said longitudinal passage.

3. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; a baffle projecting downwardly of said bottom surface and extending outwardly of the central axis of said drill from a point adjacent and communicating with the lower open end of the tubing; and means on said body for directing jets of gas from said gas passage into the well bore downwardly and in the direction of said baffle and the open end of the tubing.

4. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said tubing having at least one flow control device connected thereto for controlling admission of gas from said gas passage into said longitudinal passage and directing the flow of the gas upwardly into said longitudinal passage to increase the velocity of upward flow of fluids through said longitudinal passage; said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; a baffle projecting downwardly of said bottom surface and extending outwardly of the central axis of said drill from adjacent the lower open end of said tubing; and means on said body for directing jets of gas from said gas passage into the well bore downwardly and in the direction of the baffle to be directed by the baffle into the lower open end of the tubing.

5. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottotm end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well

bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; a baffle projecting downwardly of said bottom surface and extending outwardly of the central axis of said drill from adjacent the lower open end of said tubing; and means on said body for directing jets of gas from said gas passage into the well bore downwardly and in the direction of said baffle to be directed by the baffle into the lower open end of said tubing, said tubing having inlet passages opening upwardly thereinto from said gas passage adjacent the lower end of said tubing and at spaced points thereabove.

6. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said passage; said tubing having inlet passages opening upwardly thereinto adjacent said drill from said gas passage; flow control valve means in said inlet passage controlling admission of gas through said inlet passages into said tubing; and means mounted on said drill for directing jets of gas from said gas passage into the well bore below said drill downwardly toward the bottom of the well bore and toward the lower open end of the tubing.

7. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; and a scoop having an elongate throat opening substantially radially outwardly below said bottom surface, and to said longitudinal passage of said tubing.

8. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquid and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; and a scoop having an elongate throat opening substantially radially outwardly below said bottom surface, and to said longitudinal passage of said tubing; and means on said body for directing jets of gas from said gas passage downwardly of said bottom surface and in the direction of said scoop.

9. A device for use in a well bore drilling apparatus including: a drill having a body securable to a drill pipe, said body having a bottom surface; a plurality of earth engaging and fragmenting means mounted on said body and extending downwardly of said bottom surface; a scoop having a substantially radially opening throat opening below said bottom surface, said body having a central aperture for receiving a bottom end portion of a tubing, said scope communicating with said tubing receivable in said central aperture; and means communicating with an annular passage providable by said tubing and said drill pipe connectable to said body for ejecting jets of gas from said passage below said bottom surface downwardly and in the direction of said throat, said scoop directing said jets of gas into said central aperture.

10. The device of claim 9 wherein said tubing adjacent said body is provided with a plurality of radially spaced inwardly and upwardly opening ejector passages through which gas from said annular passage may flow upwardly into said tubing adjacent said body.

11. The device of claim 10, and means responsive to the pressure in said passage for controlling flow of gas from said passage to said means for ejecting jets of gas and said ejector ports.

12. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; means closing the upper end of the well bore through which the drill pipe extends movably; means for introducing gas under low pressure into the well bore about said drill pipe; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface, said longitudinal passage being of substantially smaller orifice than the annular passage of the well bore about the drill pipe whereby air

introduced at low pressure into the well bore at the surface flows downwardly to the bottom of the well bore at a low velocity and then upwardly at an increased velocity through said longitudinal passage to transport liquids and cuttings of earth formations being penetrated by said drill to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas at relatively high pressure into the upper end of said gas passage, said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engaging the bottom of the well bore; baffle means projecting downwardly of said bottom surface and communicating the lower open end of said tubing and extending outwardly of the central axis of said drill; and means on said body for directing jets of gas from said gas passage into the well bore downwardly and in the direction of said baffle, said tubing having passages opening upwardly thereinto adjacent said drill from said gas passage, for directing gas from said passage into said tubing near said drill; and flow control means responsive to the pressure in said passage for controlling flow of gas from said gas passage to said means for directing jets of gas and to said last mentioned passages.

13. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatablye drill pipe having a drill on its lower end; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to tre surface; means closing the upper and lower ends of said gas passage; means for introducing gas to the upper end of said gas passage; downwardly directed jet means mounted on said drill for directing jets of gas from said gas passage into the well bore below said drill downwardly toward the bottom of the well bore and toward the lower open end of said tubing; and flow directing means on the drill directing flow of gas and cuttings upwardly into the longitudinal passage of the tubing.

14. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface; means closing the upper and lower ends of said gas passage; said tubing having at least one flow control device connected thereto for controlling flow of gas from said gas passage into said longitudinal passage and directing the flow of gas upwardly into said longitudinal passage to increase the velocity of upward flow of fluids through said longitudinal passage; means for introducing gas to the upper end of said gas passage; and means mounted on said drill for directing jets of gas from said gas passage into the well bore below said drill downwardly toward the bottom of the well bore and toward the lower open end of said longitudinal passage.

15. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas to the upper end of said gas passage; said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engagement with the bottom of the well bore; a baffle extending downwardly of said bottom surface and extending outwardly of the central axis of said drill from adjacent the lower end of said tubing and communicating therewith; and means on said body for directing jets of gas from said gas passage into the well bore downwardly and in the direction of said baffle, said baffle having a flexible member extending downwardly thereof toward the bottom of the well bore, said baffle opening upwardly into the lower end of said longitudinal passage of said tubing and downwardly to the bottom of the well bore.

16. A well apparatus for drilling a well bore and transporting cuttings and liquids from the well bore, said apparatus including: a rotatable drill pipe having a drill on its lower end; a tubing extending longitudinally through said drill pipe and spaced therefrom to provide an annular gas passage therebetween, said tubing having a longitudinal passage opening at its bottom end to the well bore below said drill and opening at its upper end to the surface; means closing the upper and lower ends of said gas passage; means for introducing gas to the upper end of said gas passage; said drill including a body having a bottom surface and a plurality of earth fragmenting means mounted on said body below said bottom surface for engagement with the bottom of the well bore; a scoop extending downwardly of said bottom surface and communicating with said longitudinal passage, said scoop opening downwardly, and a plurality of jet means communicating with said gas passage and discharging angularly downwardly for directing jets of gas from said gas passage convergently downwardly and inwardly toward said scoop to be directed thereby into the longitudinal passage of said tubing.

17. A well bore drilling apparatus including: a drill having a body securable to a drill pipe, said body having a bottom surface; a plurality of earth engaging and fragmenting means mounted on said body and extending downwardly of said bottom surface, said body having a central aperture for receiving a tubing extendable downwardly through said drill pipe and securable to said body; a baffle extending downwardly from said bottom surface of said body and communicating at one end with said central aperture and extending substantially radially outwardly therefrom toward the outer edge of the body; and means communicating with an annular passage provided by said tubing and said drill pipe for ejecting jets of gas from such passage below said bottom surface of said body downwardly and in the direction of said baffle, said baffle directing such gas toward said central aperture of said body.

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