ABRASIVE WATERJET CUTTING SYSTEM FOR SUBSEA OPERATIONS

Applicants: Paul L. Miller, Harvest, AL (US); Ian Roberts, Houston, TX (US)

Inventors: Paul L. Miller, Harvest, AL (US); Ian Roberts, Houston, TX (US)

Appl. No.: 14/036,658

Filed: Sep. 25, 2013

Publication Classification

Int. Cl.
B24C 3/00 (2006.01)

U.S. Cl.
CPC ........................................ B24C 3/00 (2013.01)
USPC .................................................. 451/91

ABSTRACT

An abrasive entrainment waterjet cutting system capable of cutting objects located underwater, particularly in deep subsea environments, wherein the abrasive system is comprised of an abrasive component suspended in a hydrophobic matrix component.
ABRASIVE WATERJET CUTTING SYSTEM FOR SUBSEA OPERATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD OF THE INVENTION

[0002] This invention relates to an abrasive entrainment waterjet cutting system capable of cutting objects located under a body of water, particularly in deep subsea environments, wherein the abrasive material is comprised of an abrasive component suspended in a hydrophobic matrix component.

BACKGROUND OF THE INVENTION

[0003] There is a demand for underwater cutting of metals, stone, and other hard materials for such things as mining, salvage, rescue work, offshore platform removal, nuclear plant service, deep ocean rock sampling, infrastructure development, petroleum exploration and development, disposal of discarded military munitions, as well as environmental remediation. Underwater work environments are among the most difficult and dangerous operating areas for cutting objects. The development of manned subservices and remotely operated vehicles (ROVs) has extended the maximum working depth for underwater operations, thereby magnifying the shortcomings of conventional underwater cutting techniques.

[0004] Problems relating to hydrostatic pressure, high liquid viscosity (compared to air), waters’ high thermal and electrical conductivity, and the lack of visibility all hamper conventional cutting technologies. Oxy-arc, oxy-fuel, oxy-hydrogen, and waterjet are cutting can be used to cut steels underwater at limited depths. Mechanical drills and cutting tools, such as circular, ring, band, wire, and abrasive saws, are also used underwater with varying degrees of success. None of these methods are easy to perform underwater and all have limitations that restrict their use. They are also generally dangerous to use around hazardous and explosive materials that are all too frequently found in subsea environments.

[0005] One conventional method for disposing of underwater structures is to sever them in-situ using highly skilled divers to place the necessary explosive charges. Unfortunately, fish and marine mammals such as whales, dolphins, and porpoises can be killed or seriously injured up to several kilometers from an underwater detonation owing to the effects of explosive shock overpressure. Abrasive entrainment waterjets have the potential of providing a safe and environmentally friendly alternative to conventional underwater cutting technologies if certain obstacles can be addressed. Such obstacles include being able to feed a substantially steady flow of abrasive material to the waterjet cutting head.

[0006] The term “waterjet” does not limit the application’s use to only pure water as the fluid in the waterjet. In this context the word “water” can infer any fluid, any solution, and any solid material that will flow through an orifice under pressure, or any gas that liquefies under pressure, such as ammonia, to form what should more precisely be termed a “fluid” jet but by convention is defined in the trade as a “waterjet.”

[0007] Waterjets are fast, flexible, reasonably precise, and have recently become relatively easy to use. They use the technology of high-pressure water being forced through a small hole (typically called the “orifice” or “jet”) to concentrate an extreme amount of energy through a small area. The restriction of the small orifice converts the high pressure water into a high-velocity waterjet. The inlet (process) water for a pure waterjet is typically pressurized between 20,000 psi (138 MPa) and 150,000 psi (414 MPa). This is forced through the orifice, which is typically about 0.007″ to 0.020″ in diameter (0.18 to 0.4 mm). The result is a very high-velocity, very thin jet of water traveling in excess of the speed of sound in air.

[0008] Abrasive slurry waterjet, also known as an abrasive suspension jet, typically uses a hopper filled with abrasive, water, and a slurrying or suspension agent. This combined mixture is then pressurized and forced through the orifice of the cutting head. An abrasive slurry waterjet system must maintain the abrasive in suspension. This is typically done by the use of chemical additives and/or mechanical means, in order to prevent the abrasive from dropping out of suspension in the piping which can result in plugging and disabling of the system. Likewise, the flow of a pressurized abrasive and water slurry mix is highly erosive to piping, valves, and fittings used in the system. In addition, one or more large pressure vessels must be used to contain a sufficient amount of abrasive slurry for cutting. Consequently, an abrasive slurry waterjet system is typically limited in pressure to approximately 140 MPa, and normally operates at pressures closer to about 70 MPa.

[0009] Abrasive entrainment waterjet uses a high velocity waterjet, formed by pressurized water passing through an orifice (jewel) of the cutting head resulting in a partial vacuum in a mixing chamber downstream of the orifice that aspirates and entrains abrasive particles that are introduced into the mixing chamber. Although transport and delivery of abrasive particles is typically performed by vacuum aspiration, the abrasive transport can also be performed by pneumatic conveyance, or by a fluid conveyance as an abrasive suspension, as taught in Xu, et al., U.S. Pat. No. 6,200,203, which is incorporated herein by reference.

[0010] Abrasive entrainment waterjet technology has several advantages over abrasive slurry waterjet technology. For example, it is more reliable; it requires less maintenance; it is able to operate at internal system pressures up to about 1,000 MPa or more; it can operate in a continuous mode rather than in a batch mode; it does not require expensive chemical additives; and it is able to operate with significantly lower abrasive consumption.

[0011] Waterjet technology has been used underwater for cutting metals and stone. For example, waterjets were taught as being effective in underwater mining operations. See Borkowski, P. and Borkowski, J. (2011). “Basis of High-pressure Water Jet Implementation for Poly-metallic Concretes Output from the Ocean’s Bottom,” Rocznik Ochrony Środowiska Selected full texts, 13, pgs. 65-82. An abrasive slurry system is taught as being capable of operating under-
water as long as the internal fluid pressure is substantially higher than the surrounding hydrostatic pressure.

While the art teaches the possibility of using waterjet technology for underwater cutting, serious problems still exist that must be overcome before such technology can successfully be used commercially, especially in deep water.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an abrasive entrainment waterjet cutting system comprised of:

a source of process water for the waterjet;

a waterjet pump in fluid communication with the source of process water, which waterjet pump is capable of delivering a jet of water at a pressure of at least 280 MPa;

a stored supply of abrasive material comprised of a particulate abrasive component at least partially suspended in a hydrophobic matrix component;

an entrainment abrasive waterjet cutting head in fluid communication with said waterjet pump and said stored supply of abrasive cutting material; and

a means for feeding said abrasive material to said cutting head in a controlled manner.

In a preferred embodiment of the present invention the hydrophobic matrix component is a liquid selected from the group consisting of aliphatic hydrocarbons having a carbon number between about 6 and about 20, petroleum oils, animal oils, and plant oils.

In another preferred embodiment, the hydrophobic matrix component is a gel.

In yet another preferred embodiment of the present invention the hydrophobic matrix component is a wax selected from the group consisting of plant waxes, animal waxes, and mineral waxes.

In still another preferred embodiment of the present invention the ratio of abrasive to hydrophobic matrix component is about 20:80 to about 80:20.

In another preferred embodiment of the present invention the abrasive material is conducted to the waterjet cutting head by use of a pump that is powered by the electrical power from an umbilical cord from a surface vessel to an underwater remotely operated vehicle.

In still another preferred embodiment of the present invention the pump used to conduct the abrasive material to the waterjet cutting head is powered by the hydraulic system of a subsea remotely operated vehicle.

DETAILED DESCRIPTION OF THE INVENTION

By underwater, or under a body of water, we mean that the object to be cut is found resting or part of a structure secured to the bottom of a body of water. Non-limiting examples of bodies of water include oceans, seas, bays, rivers, as well as man-made bodies of water such as reservoirs and lakes. For purposes of the present invention the object to be cut will typically be at depths from about 30 ft (10 meters) to about 20,000 ft (6100 meters), preferably from about 300 ft (91 meters to 1500 meters) 300 ft to 5,000 ft.

An abrasive entrainment waterjet has a distinct disadvantage as compared to abrasive slurry jet when used underwater because the abrasive transport and feed system is severely hampered, if not completely disrupted, by the hydrostatic backpressure of the surrounding water forcing its way under pressure into the abrasive system. Water entering the abrasive feed system will wet the abrasive. A wet abrasive mix will become a relatively coarse mud that can plug the system, similar to what happens to an abrasive slurry jet when the aqueous suspension fails. Hydrostatic backpressure increases underwater at the rate of about 9.8 kPa/ft (0.432 psi/ft.) of depth in freshwater and at roughly the rate of 10 kPa/m (0.445 psi/ft.) of depth in seawater. Consequently, the problem is rapidly exacerbated by depth. In addition, the cold temperature of the surrounding seawater as depth increases can cause both moisture to be precipitated in the abrasive feed system and the hydrostatic backpressure to increase with an increase in likelihood of forcing water into the abrasive feed system.

In order to utilize the advantages of abrasive entrainment waterjet technology over abrasive slurry waterjet technology, and to be able to successfully commercially operate underwater, the following problems must be solved: supplying water at a pressure of at least about 280 MPa to the waterjet cutting head; supplying a measured and substantially continuous stream of abrasive material to the abrasive waterjet cutting head; and preventing plugging or jamming from the reservoir of abrasive material to the abrasive waterjet cutting head.

The type of waterjet cutting head used in the practice of the present invention will be an abrasive entrainment waterjet cutting head that is generally comprised of: a metal body having an outer cylindrical surface and a central bore substantially parallel to the cylindrical surface, with an upstream direction and a downstream direction. It will have a jewel orifice mounted in the bore in the metal body. A portion of the central bore will typically be downstream of the jewel forming a mixing chamber. An inclined bore for abrasive material passes from the outer cylindrical surface to the central bore, preferably inclined and joining the central bore downstream of the jewel at the mixing chamber. There is also typically provided a nozzle wherein the waterjet containing the abrasive further mixes and exits.

Any type of waterjet pump can be used in the practice of the present invention as long as it is capable of delivering a jet of water, with entrained abrasive material, at a pressure of at least about 280 MPa to about 1000 MPa. A referred type of waterjet pumps suitable for use in the present invention is an intensifier pump. Waterjet intensifier pumps are well known in the art and utilize the so-called “intensification” principle. A waterjet intensifier pump typically operates by having pressurized hydraulic oil flow into one side of a centrally located hydraulic piston having double ended piston rods extending into the high pressure water cylinders at each end. The central hydraulic piston of the intensifier pump is typically 20 times the area of each piston rod giving a 20:1 intensification ratio. The piston rods, in turn, form the high pressure water pistons. Consequently, an application of 14 MPa hydraulic oil to the central hydraulic piston results in a twenty-fold intensification of pressure in the water cylinder and yields an outlet water pressure of 280 MPa. The outlet pressure of the water can be controlled by adjusting the inlet hydraulic oil pressure. When the centrally located hydraulic piston reaches the end of its stroke, a hydraulic valve body switches the flow of oil to the opposite side of the hydraulic piston and the process continues with the opposite water piston. The depressurized oil from the central cylinder is exhausted via the control valves to an exhaust port connected with an oil return to an oil reservoir, which can be underwater or at the surface. High-pressure water can be provided to the
waterjet cutting head by any suitable means, such as by locating the waterjet pump at the surface and conducting the pressurized water to a submerged waterjet cutting head by use of a high pressure hose. One major drawback with this method is that using a high-pressure hose to supply water from the surface to an abrasive entrainment waterjet cutting head underwater is a problem that increases with increasing depth. For example, high pressure hoses are expensive, heavy, and have a pressure drop due to internal fluid friction. It is known in the art that submerged hose lengths of at least about 2.5 times the water depth are required for efficient operations. Working at depths of 400 m (1300 ft) would require about 1,000 m (3,300 ft.) of hose with over 1.8 tons (4,000 lb.) of line tension pulling on the hose just from its own weight.

A preferred method of supplying high pressure water is to use pressurized hydraulic oil fed by hydraulic hoses from pumps on the surface, typically operating at pressures from about 14 MPa to 105 MPa, preferably from about 14 MPa to 35 MPa, to a waterjet intensifier pump located underwater and returning the resulting depressurized hydraulic oil to the surface. A hydraulic feed hose and return hose are significantly lighter and less expensive than high-pressure waterjet hoses. The exhaust pressure alone will be sufficient to pump the oil up a return line back to the surface. As an alternative, a supplementary pump can be added to assist in pumping the oil to the surface for reuse.

High pressure hydraulic fluid can also be powered by the ROV’s on-board hydraulic system and used to power a submerged high pressure waterjet intensifier pump. Submerged operations require the use of an electrical umbilical power line from the surface to the ROV, as described by the U.S. Naval Oceana Systems Command’s Technical Document 1530, dated April 1989. A hydraulic power attachment can be made through a standard ROV “hot-stab” port conforming to ISO 13628-8, titled “Remotely operated tools and interfaces on subsea production systems,” or through standard quick-disconnect fittings, such as Parker FH Series Couplings, or similar hydraulic connections know to those skilled in the art. The waterjet pump can be mounted on the ROV or mounted as an accessory unit as a separate fixture that the ROV can pick up and put down as required. A subsea hot-stab is known in the art to be a high pressure sub-sea connector that is typically used to connect into a fluid system for intervention/emergency operations. It is typically designed to be ROV activated. A subsea hot-stab basically comprises two parts; a valve, and a tool that connects to the valve and functions it.

In order to provide high pressures with reduced wear and increased reliability it is preferred to demineralize the process water that is used at high pressures. By process water we mean the water that is pressurized by the waterjet pump and used for cutting. It is preferred that the process water contain no more than about 350 parts per million total dissolved solids. In comparison, seawater is typically in the range of about 35 parts per thousand of dissolved solids. The approximate distribution of dissolved minerals is: 55% chloride; 30.6% sodium; 7.7% sulfate; 3.7% magnesium; 1.2% calcium; and 1.1% potassium ions. In addition to the dissolved minerals, the water can contain suspended materials such as algae, plankton, and finely dispersed solids. Process water from a surface ship can be supplied as part of an umbilical cord along with power and control cable. It is also within the scope of this invention that the process water be obtained from a process water holding tank stored underwater and within the vicinity of the object to be cut. The process water can also be generated by the filtering of seawater either at the surface or by a subsea operation.

Filtration of the seawater greatly increases the reliability of the high pressure waterjet equipment. Filtration can be provided by one or more stages of mechanical filtration using increasingly finer meshes to mechanically capture the suspended materials. These mechanical filters can be provided with pleating, caused by alternate folding patterns, to increase the surface area of the filter media. These mechanical filters can also be fitted with manual or automatic backwash capabilities to allow a counter current flow pressurized water to remove surface contamination that can occlude the filter media, known as “blinding.” In addition, a secondary set of one or more containers of solid or particulate materials with a high degree of porosity can be used to increase the efficiency of suspended material removal by use of tortuous pathways, such as in a packed filter using crushed quartz, or by adsorption mechanisms, such as by the use of activated carbon or diatomaceous earth.

An abrasive entrainment waterjet starts out the same as a pure waterjet, but with an abrasive entrainment waterjet, as the high pressure stream of water leaves the orifice abrasive is added to the stream at a mixing chamber. The high-velocity jet of water exiting the orifice creates a vacuum that pulls abrasive from an abrasive line, which then mixes with the jet of water in the mixing chamber of the cutting head and is jetted out of a nozzle. The jet of water accelerates the abrasive particles to speeds fast enough to cut through very hard materials. The cutting action of an abrasive waterjet is two-fold. The force of the water and abrasive erodes the material, even if the jet is held stationary (which is how an object is initially pierced). The cutting action is greatly enhanced when the abrasive waterjet stream is moved across the intended cutting path of the object. The ideal speed of cutting depends on a variety of factors, including the hardness of the object being cut, the shape of the object, the waterjet pressure, and the type of abrasive. Controlling the speed of the abrasive waterjet cutting head is crucial to efficient and economical cutting.

Non-limiting examples of abrasive materials that are suitable for use in the present invention include glass, silica, alumina, silicon carbide, aluminum-based materials, garnet, as well as elemental metal and metal alloy slags and grits. Preferred are garnet and aluminum-based materials. It is also preferred that the abrasive particles have either sharp edges or that they be capable of fracturing into pieces having sharp cutting edges, such as for example, octahedron or dodecahedron shaped particles. The size of the abrasive particles may be any suitable effective size. By effective size, is meant a size that will not plug the cutting head and that will be effective for removing the material of which the targeted object to be cut is made from (typically a metal alloy, such as steel) and which is effective for forming a substantially homogeneous mixture with the fluid carrier. Useful particle sizes for the abrasive material will range from about 3 mm to 55 microns, preferably from about 15 mm to 105 microns, and most preferably from about 125 microns to about 250 microns.

It is important that the abrasive material be delivered to the waterjet cutting head without jamming or plugging. In shallow water, a surface vessel can supply dry abrasive via a hose down to the waterjet cutting head. A braided metal hose is recommended to prevent the hose from crushing under hydrostatic pressure. The aspiration of the mixing chamber in the entrainment abrasive waterjet cutting head will preferably...
provide sufficient suction at depths to approximately 90 m (300 ft.). At greater depths the delivery of the abrasive material becomes more of a problem.

[0037] It is preferred, for the practice of the present invention, that a hydrophobic material be used as a matrix for forming a pumpable slurry with the abrasive component. Non-limiting examples of such matrix materials suitable for use herein include aliphatic hydrocarbons having a carbon number between about 6 and about 20, preferably between about 10 and 14, petroleum oils, animal oils, and plant oils, preferred are hydrophobic oils, more preferred are petroleum oils. The hydrophobic matrix is incorporated with the abrasive to form a slurry that is capable of being mechanically injected into the abrasive waterjet cutting head at a controlled rate. This can be determined by an abrasive feed control system using a conventional piston, gear, or peristaltic pump, auger, etc. A piston pump is preferably used for conducting the abrasive slurry into the cutting head by compressing the slurry with a piston using pressure supplied by a hydraulic piston, an electrically driven rack or threaded shaft, or a hydraulically driven rack or threaded shaft.

[0038] The discharge rate of the piston pump can be controlled by the abrasive feed control system by varying the duty cycle or by varying the electricity or the hydraulic pressure applied to the piston pump motor. The ratio of abrasive to hydrophobic material will be an effective ratio. By effective ratio we mean at a ratio that will enable the abrasive to become and stay substantially suspended in the hydrophobic matrix material and that can be conducted, without substantial plugging, to the abrasive waterjet cutting head. It is preferred that the suspension be a substantially homogeneous suspension. Such a ratio of abrasive to hydrophobic matrix material, by volume, will be about 20:80 to about 80:20. An excess amount of abrasive, known as a “rich” mixture, is undesirable because it will create too much pressure on the slurry delivery system, while an excess of the hydrophobic matrix, known as a “lean” mixture, can cause the abrasive waterjet cutting head to be inefficient during cutting. The liquid hydrophobic matrix is dispersed by the high pressure jet of water along with the abrasive in the mixing chamber of the abrasive waterjet cutting head and will form a solid-liquid-liquid jet upon exiting the abrasive waterjet nozzle with the abrasive, hydrophobic material, and water, respectively.

[0039] It is within the scope of this invention that the hydrophobic material be a solid or high viscosity liquid selected from greases, and waxy materials, such as, but not limited to, paraffin wax or beeswax. These solid materials incorporate the abrasive so that a flexible solid or semi-solid strip, tube, or rod, etc., of abrasive and binder matrix (solid material) can be mechanically fed into the abrasive waterjet cutting head at a controlled rate, under the control of the abrasive feed control system, by plastic deformation. Other non-limiting examples of such solids suitable for use herein include plant waxes, animal waxes, mineral jellys, mineral waxes, mineral soaps, mineral greases, and animal greases or mixtures thereof. The binder matrix is dispersed by the high pressure jet of water along with the abrasive in the mixing chamber of the abrasive waterjet cutting head and would form a solid-liquid-liquid jet upon exiting the abrasive waterjet nozzle with the abrasive, hydrophobic matrix, and water, respectively.

[0040] Hydrophobic gels can also be used for the matrix for the suspension of the abrasives. Gels are comprised of a solid three-dimensional network that spans the volume of a liquid medium and ensnares it through surface tension effects. Non-limiting examples of hydrophobic gels suitable for use herein include hydrophobic silica gels modified with trimethylsilyl and long-chain alkyl (C6-C18) groups; hydroxypropyl beaded dextran that has been substituted with long chain (C13-C18) alkyl ethers; and polyethylene glycol (PEG) end-capped with fluoroalkyl groups.

[0041] The above abrasive and hydrophobic matrix can be mechanically fed into the abrasive waterjet cutting head at a controlled rate. This can be done by any suitable means, such as by heating the hydrophobic matrix material until it is in a plastic or liquid state, using heat, preferably by electric resistance elements or heated process fluids, for example, from the ROV’s hydraulic pump. The abrasive/hydrophobic matrix can then be pumped to the waterjet cutting head using any suitable conventional pump, such as a piston, gear, or peristaltic pump, auger, etc. The liquefied matrix is dispersed by the high pressure jet of water along with the abrasive in the mixing chamber of the abrasive waterjet cutting head and forms a solid-liquid-liquid jet upon exiting the abrasive waterjet nozzle with the abrasive, liquefied hydrophobic matrix, and water, respectively.

[0042] The abrasive mix can be metered using a programmable electronic or mechanical device, known as the abrasive feed control system that will allow precise control over the quantity of abrasive mix being fed to the abrasive waterjet cutting head. In one preferred embodiment a microprocessor-based system is used. A mechanical logic control system likewise can use fluidic, pneumatic, or mechanical logic processing to regulate the flow of the abrasive mix.

[0043] The abrasive feed and metering system for the abrasive mix can use a number of types of feed systems, such as incremental piston feed systems or increment feeders, such as belt feed, bucket feed, reciprocating feed, or oscillating feed, etc., powered by electrical, mechanical, hydraulic, or pneumatic means under fixed control or under the control of the abrasive control system. Also, the abrasive feed and metering system will monitor the seawater hydrostatic backpressure at the abrasive waterjet cutting head to maintain the internal pressure in the abrasive system, particularly in the abrasive reser voir, at a higher pressure, preferably about 125 Pa to 7 kPa higher, than the surrounding water pressure by means of a differential pressure sensor.

What is claimed is:
1. An abrasive waterjet cutting system comprised of:
   a) a source of process water for the waterjet;
   b) a waterjet pump in fluid communication with the source of process water, which waterjet pump is capable of delivering a jet of water at a pressure of at least 280 MPa;
   c) a stored supply of abrasive cutting material comprised of a particulate abrasive component at least partially suspended in a hydrophobic matrix component;
   d) an entrainment abrasive waterjet cutting head in fluid communication with said waterjet pump and said stored supply of abrasive cutting material; and
   e) a means for feeding said abrasive cutting material to said cutting head in a controlled manner.

2. The abrasive waterjet cutting system of claim 1 wherein the hydrophobic matrix is a liquid.

3. The abrasive waterjet cutting system of claim 2 wherein the liquid is selected from the group consisting of aliphatic hydrocarbons having a carbon number between about 6 and 20, aromatic hydrocarbons having a carbon number between about 6 and 20, petroleum oils, animal oils, and plant oils.
4. The abrasive waterjet cutting system of claim 3 wherein the liquid is a petroleum oil.

5. The abrasive waterjet cutting system of claim 1 wherein the hydrophobic matrix component is a semi-solid or solid material.

6. The abrasive waterjet cutting system of claim 5 wherein the hydrophobic matrix component is selected from the group consisting of greases, waxes, gel-like materials, and soaps.

7. The abrasive waterjet cutting system of claim 6 wherein the hydrophobic matrix is a wax selected from plant waxes, animal waxes, and mineral waxes.

8. The abrasive waterjet cutting system of claim 6 wherein the hydrophobic matrix is a gel.

9. The abrasive waterjet cutting system of claim 8 wherein the gel is selected from the group consisting of silica gels, silica gels modified with trimethylsilyl and C6-C18 alkyl groups; hydroxypropyl beaded dextran; hydroxypropyl beaded dextran substituted with C13-C18 alkyl ethers; and polyethylene glycol (PEG) end-capped with a fluoroalkyl group.

10. The abrasive waterjet cutting system of claim 1 wherein the ratio of abrasive to hydrophobic matrix component, by volume percent, is from about 20:80 to 80:20.

11. The abrasive waterjet cutting system of claim 10 wherein the ratio of abrasive to hydrophobic matrix component, by volume percent, is from about 40:60 to 60:40.

12. The abrasive waterjet cutting system of claim 1 wherein the abrasive material is conducted to the waterjet cutting head by use of a piston pump.

13. The abrasive waterjet cutting system of claim 2 wherein the piston pump is driven by electrical power.

14. The abrasive waterjet cutting system of claim 13 wherein the electrical power is obtained from an umbilical cord from a surface vessel to a remotely operated vehicle.

15. The abrasive waterjet cutting system of claim 14 wherein the piston pump is driven by hydraulic power.

16. The abrasive waterjet cutting system of claim 15 wherein the hydraulic power is obtained from the hydraulic system of a remotely operated vehicle.

17. The abrasive waterjet cutting system of claim 11 wherein the piston pump has a microprocessor control system.

18. The abrasive waterjet cutting system of claim 1 wherein the process water has less than about 350 parts per million of dissolved solids.

* * * * *