MAINTENANCE MANUAL
GARDNER DENVER
WATERBLASTER
For
G.C. ZARNAS & COMPANY

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GENERAL INFORMATION

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GARDNER DENVER

- T-300 FLUID END
- 24 MM PLUNGERS
- T-300 POWER FRAME

3

GARDNER DENVER

- NITROGEN REGULATOR

4

JETSTREAM

- JETSTREAM SHUTOFF HAND LANCE

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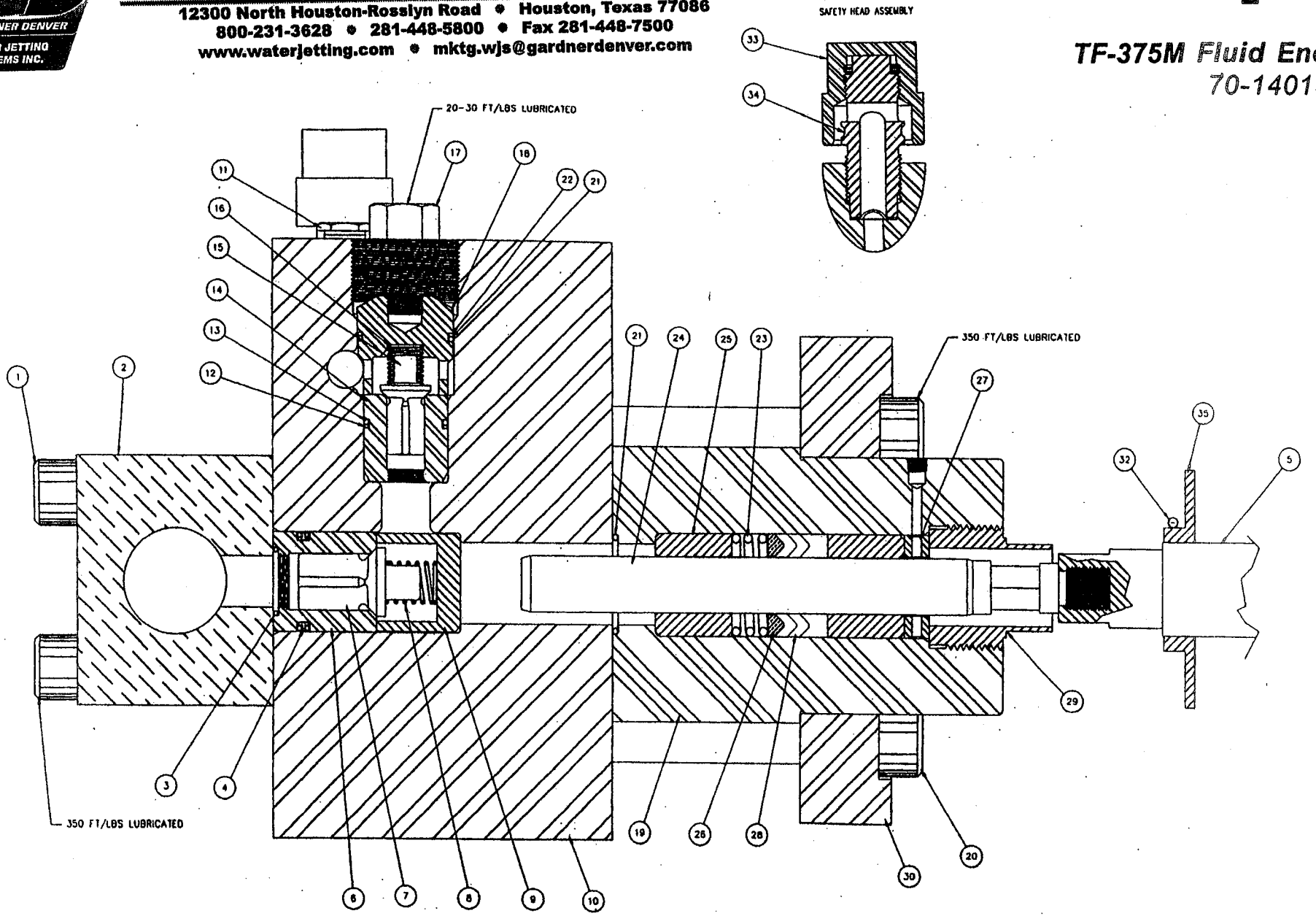
Pumps

TF-375M Fluid End

70-14015



Plunger Options for T-300M

3/4" (19.05mm)

Item	Qty	Part Number	Description
22	3	70-78004-100	RING, LANTERN
24	3	70-74353-346	PLUNGER—COLMONOY COLLET
25	3	70-74009-750	THROAT BUSHING
26	3	70-75343-750	FRONT PACKING RING
27	3	70-78005-100	BUSHING, REAR
28	3	22-80157	PACKING SET

24mm

Item	Qty	Part Number	Description
22	3	70-78004-700	RING, LANTERN
24	3	70-74353-246	PLUNGER—COLMONOY COLLET
25	3	70-74009-024	THROAT BUSHING
26	3	70-75343-024	FRONT PACKING RING
27	3	70-78005-700	BUSHING, REAR
28	3	22-80154	PACKING SET

7/8" (22.225mm)

Item	Qty	Part Number	Description
22	3	70-78004-500	RING, LANTERN
24	3	70-74353-786	PLUNGER—COLMONOY COLLET
25	3	70-74009-875	THROAT BUSHING
26	3	70-75343-780	FRONT PACKING RING
27	3	70-78005-500	BUSHING, REAR
28	3	22-80155	PACKING SET

20mm

Item	Qty	Part Number	Description
22	3	70-78004-300	RING, LANTERN
24	3	70-74353-206	PLUNGER—COLMONOY COLLET
25	3	70-74009-020	THROAT BUSHING
26	3	70-75343-020	FRONT PACKING RING
27	3	70-78005-300	BUSHING, REAR
28	3	22-80156	PACKING SET

1" (24.5mm)

Item	Qty	Part Number	Description
22	3	70-78004-900	RING, LANTERN
24	3	70-74353-106	PLUNGER—COLMONOY COLLET
25	3	70-74009-100	THROAT BUSHING
26	3	70-75343-010	FRONT PACKING RING
27	3	70-78005-900	BUSHING, REAR
28	3	22-80153	PACKING SET

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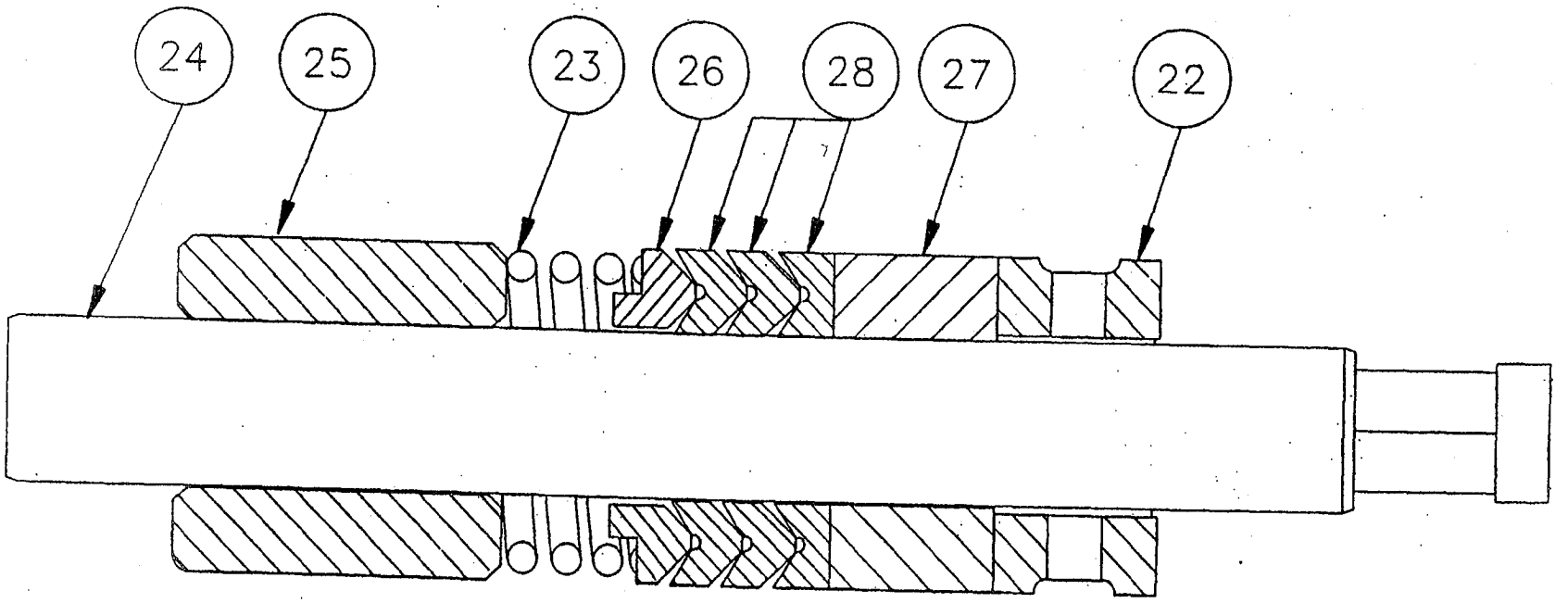
Pumps

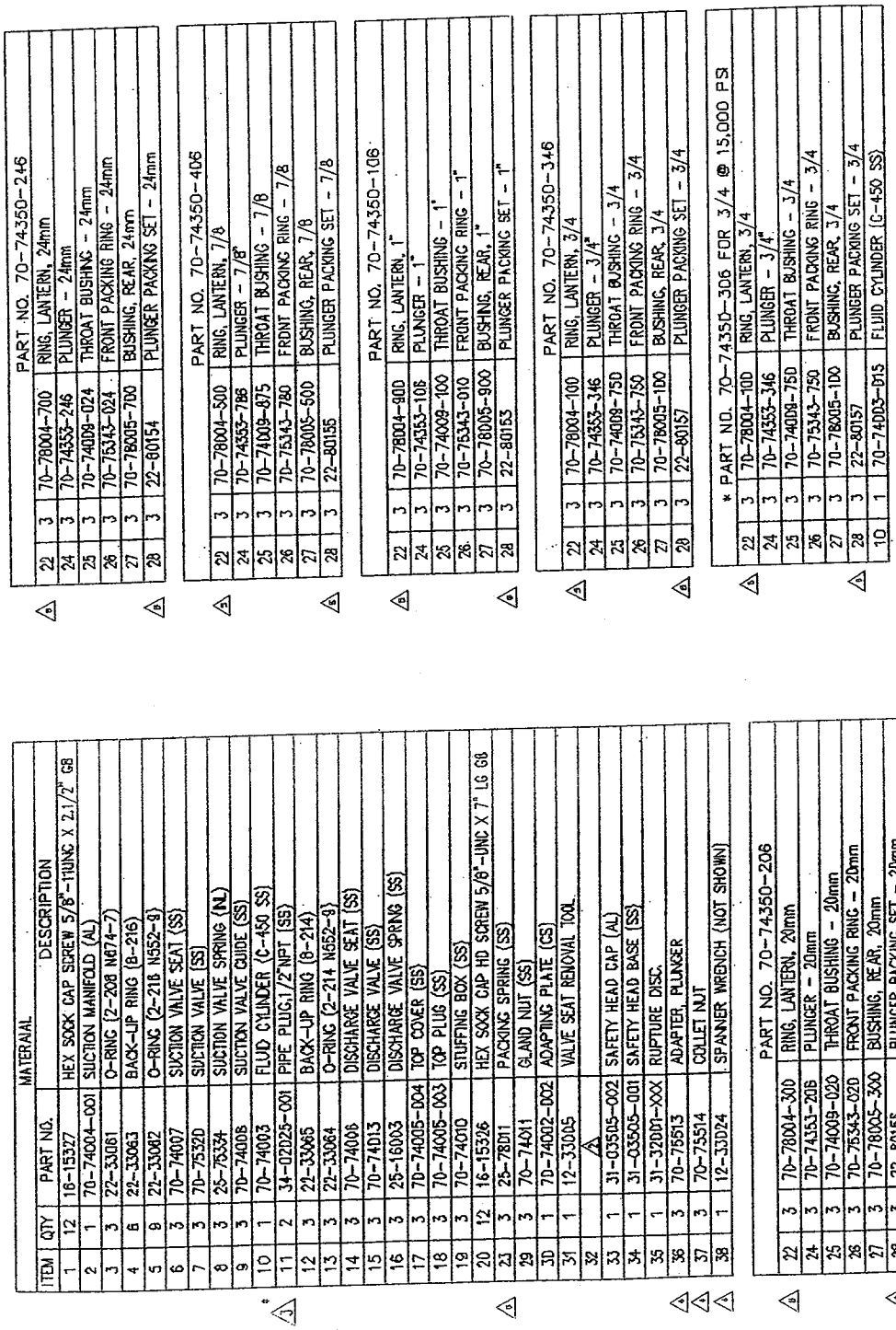
Plunger Options T-300M

70-74350



NOTE: To be used with Packing Spring 25-78011 (Item 23)

Table 2: T-300M Fluid End Parts List



ITEM	QTY	PART NO.	DESCRIPTION
1	12	16-15327	HEX SOCK CAP SCREW 5/8"-11UNC X 2.1/2" GR
2	1	70-74004-001	SUCTION MANIFOLD (AL)
3	3	22-33061	O-RING (2-208 N674-7)
4	6	22-33063	BACK-UP RING (B-216)
5	6	22-33062	O-RING (2-216 N552-9)
6	3	70-74007	SUCTION VALVE SEAT (SS)
7	3	70-75320	SUCTION VALVE (SS)
8	3	25-75334	SUCTION VALVE SPRING (NL)
9	3	70-74008	SUCTION VALVE GUIDE (SS)
10	1	70-74003	FLUID CYLINDER (C-450 SS)
11	2	34-02D25-001	PIPE PLUG,1/2"NPT (SS)
12	3	22-33065	BACK-UP RING (B-214)
13	3	22-33064	O-RING (2-214 N552-9)
14	3	70-74006	DISCHARGE VALVE SEAT (SS)
15	3	70-74013	DISCHARGE VALVE (SS)
16	3	25-16003	DISCHARGE VALVE SPRING (SS)
17	3	70-74005-004	TOP COVER (SS)
18	3	70-74005-003	TOP PLUG (SS)
19	3	70-74010	STUFFING BOX (SS)
20	12	16-15326	HEX SOCK CAP HD SCREW 5/8"-UNC X 7" LG GR
23	3	25-78011	PACKING SPRING (SS)
29	3	70-74011	GLAND NUT (SS)
30	1	70-74002-002	ADAPTING PLATE (CS)
31	1	12-33005	VALVE SEAT REMOVAL TOOL
32			
33	1	31-03505-002	SAFETY HEAD CAP (AL)
34	1	31-03505-001	SAFETY HEAD BASE (SS)
35	1	31-32D01-XXX	RUPTURE DISC.
36	3	70-75513	ADAPTER, PLUNGER
37	3	70-75514	COLLET NUT
38	1	12-33024	SPANNER WRENCH (NOT SHOWN)

PART NO. 70-74350-206			
22	3	70-78004-300	RING, LANTERN, 20mm
24	3	70-74353-206	PLUNGER - 20mm
25	3	70-74009-020	THROAT BUSHING - 20mm
26	3	70-75343-020	FRONT PACKING RING - 20mm
27	3	70-78005-300	BUSHING, REAR, 20mm
28	3	22-80156	PLUNGER PACKING SET - 20mm

PART NO. 70-74350-246			
22	3	70-78004-700	RING, LANTERN, 24mm
24	3	70-74353-246	PLUNGER - 24mm
25	3	70-74009-024	THROAT BUSHING - 24mm
26	3	70-75343-024	FRONT PACKING RING - 24mm
27	3	70-78005-700	BUSHING, REAR, 24mm
28	3	22-80154	PLUNGER PACKING SET - 24mm

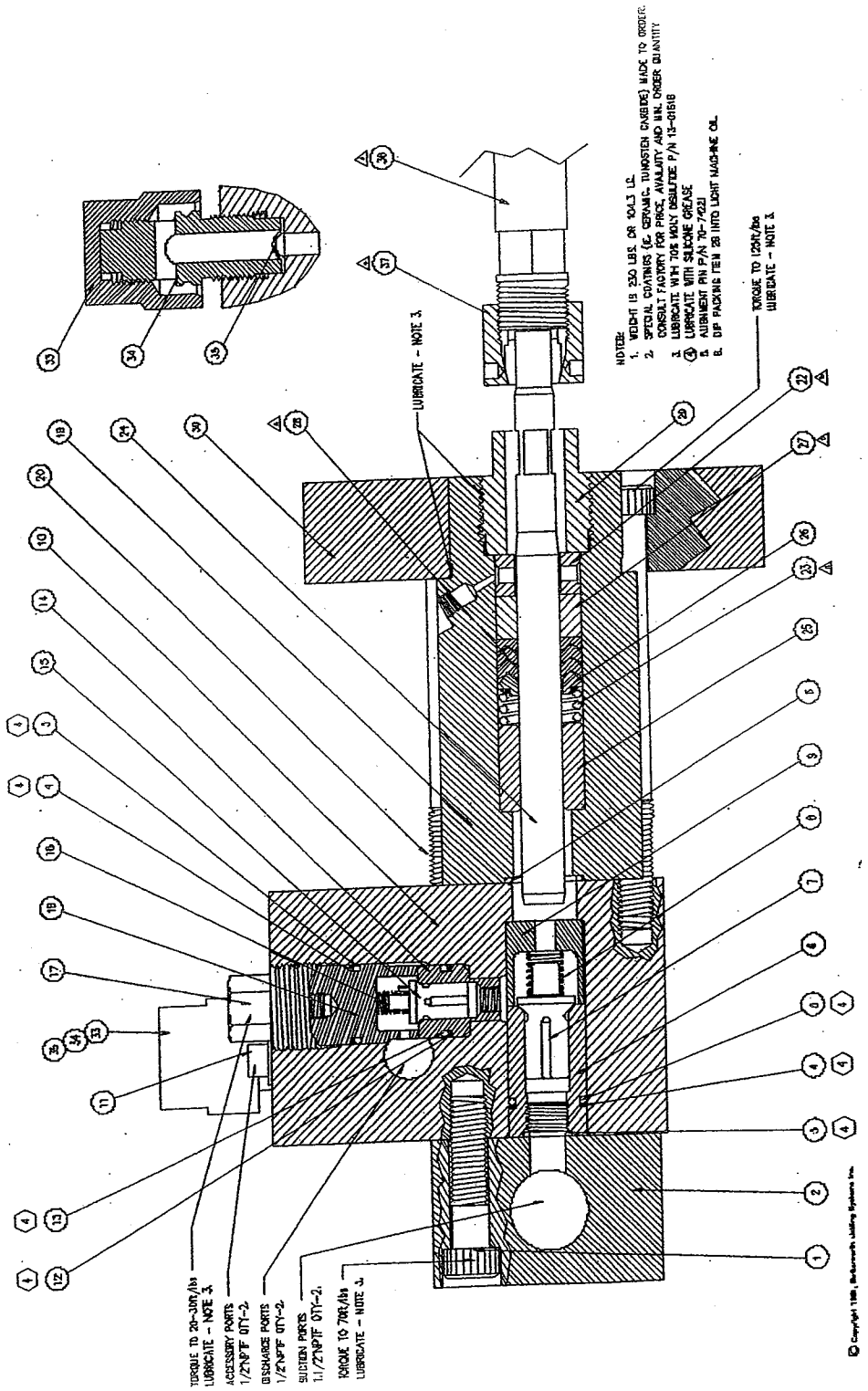
PART NO. 70-74350-406			
22	3	70-78004-500	RING, LANTERN, 7/8
24	3	70-74353-786	PLUNGER - 7/8"
25	3	70-74009-875	THROAT BUSHING - 7/8
26	3	70-75343-780	FRONT PACKING RING - 7/8
27	3	70-78005-500	BUSHING, REAR, 7/8
28	3	22-80155	PLUNGER PACKING SET - 7/8

PART NO. 70-74350-106			
22	3	70-78004-900	RING, LANTERN, 1"
24	3	70-74353-108	PLUNGER - 1"
25	3	70-74009-100	THROAT BUSHING - 1"
26	3	70-75343-010	FRONT PACKING RING - 1"
27	3	70-78005-900	BUSHING, REAR, 1"
28	3	22-80153	PLUNGER PACKING SET - 1"

PART NO. 70-74350-346			
22	3	70-78004-100	RING, LANTERN, 3/4
24	3	70-74353-346	PLUNGER - 3/4"
25	3	70-74009-75D	THROAT BUSHING - 3/4
26	3	70-75343-750	FRONT PACKING RING - 3/4
27	3	70-78005-100	BUSHING, REAR, 3/4
28	3	22-80157	PLUNGER PACKING SET - 3/4

* PART NO. 70-74350-306 FOR 3/4 @ 15,000 PSI			
22	3	70-78004-10D	RING, LANTERN, 3/4
24	3	70-74353-346	PLUNGER - 3/4"
25	3	70-74009-75D	THROAT BUSHING - 3/4
26	3	70-75343-750	FRONT PACKING RING - 3/4
27	3	70-78005-100	BUSHING, REAR, 3/4
28	3	22-80157	PLUNGER PACKING SET - 3/4
10	1	70-74003-015	FLUID CYLINDER (C-450 SS)

Figure 6: T-300M Fluid End Assembly



T-300M Fluid End Maintenance

(Reference Drawing on Page 4-7)

Maintenance

The *fluid end* should be checked regularly for any necessary repairs. See Daily Maintenance Check and Preventive Maintenance Check sections before disassembly. When the problem is found, see the Pump Troubleshooting Chart on page 3-1 for the correct repair solution. When proceeding with the following, ensure that all seals, back-up rings and o-rings are replaced at every disassembly. Refer to the assembly drawing on ***Page 4-7*** and ***Figures 3 & 4*** for the following procedures.

Valve Disassembly & Re-assembly Procedure

Suction Valve Disassembly Procedure

a) With the appropriately sized Allen wrench, remove the twelve cap head screws [1] from the suction manifold [2].

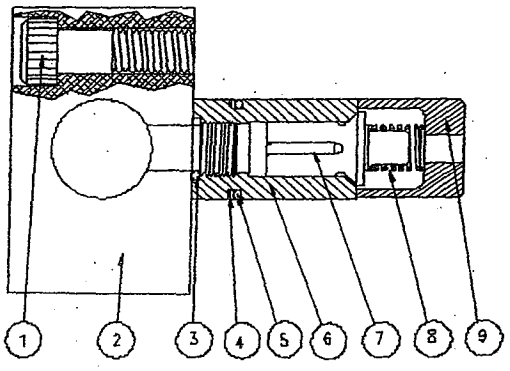


Figure 3: Suction Valve Assembly
Refer to page 4-7 for full assembly drawing

b) Remove the suction manifold [2].

c) Remove the suction valve seats [6] with the valve seat removal tool [31].

d) Remove o-rings [3], [5] and back-up rings [4] and replace.

e) Inspect the valve seating surfaces [6] for wear or erosion and replace if necessary.

f) Inspect the valves [7] for wear or erosion and replace if necessary.

g) If the valve is not seating smoothly, lap with Clover Grade E Lapping Compound, or equivalent. If the seating is still faulty, then replace the valve.

h) Check valve springs [8] for damage, and replace if required.

i) Remove the valve guides [9]. Replace valve guides if valve and valve seat replacement was required.

Re-Assembly Procedure

a) Lubricate all t-seals and o-rings [3], [4], [5] with silicone or 327-C Super C Armor Plate with Moly-D, BJSI P/N 13-33044.

b) Lubricate the threads of the twelve screws [1] with an anti-seize compound such as P/N 13-01516.

c) Push the valve guide [9] into the front bore with the three projections on the guide facing outward toward the suction manifold. Be careful not to bend the three projections on the guide.

d) Place the suction valve [7] into the valve seat [6] and the spring [8] on the valve end and insert into the fluid cylinder. Check that all valves move freely by pressing on the valve.

e) Ensure the suction manifold o-rings [3] are in place and lubricated with silicone or 327-C Super C Armor Plate with Moly-D, BJSI P/N 13-33044.

f) Mount the suction manifold against the valve seats.

Note:
The surface of the suction manifold should be smooth to assure that the valve seat o-rings do not leak.

g) Torque the 12 cap screws according to the specifications on the full drawing; ***Page 4-7.***

Discharge Valves-Disassembly

a) Remove the top plug covers [17] and top plugs [18] with a socket or box-end wrench and inspect o-rings [3] and back-up rings [4]. The top plugs, once loosened, should turn easily. If there is difficulty, STOP. Using force will cause the threads to gall. Hit the Top Plug forcefully with a hammer while trying to turn it in either direction. This will relieve the threads and permit the top plug removal.

b) Remove the discharge valves [15] and the springs [16] with either a magnet or long-nosed pliers.

c) With the valve seat removal tool [31], remove the valve seats [14] by pulling.

d) Remove the backup ring [12] and o-ring [13], and replace. Inspect the valve seating surface [15] and the valve seats [14]. Lap or replace as needed.

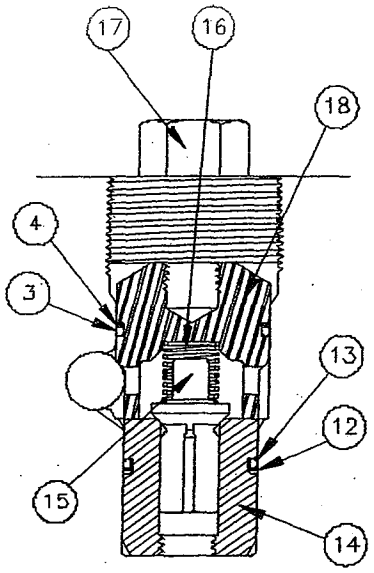


Figure 4: Discharge Valve Assembly
Refer to page 4-7 for full assembly drawing

Note:
An impact wrench should never be used on the top plug covers [17]. Never use an impact wrench to assemble any two parts which are stainless steel.

e) Inspect the valve seating surfaces [14] for wear or erosion and replace if necessary.

f) Inspect the valves [15] for wear or erosion and replace if necessary.

g) If the valve is not seating smoothly, lap with Clover Grade E Lapping Compound, or equivalent. If the seating is still faulty, then replace the valve.

h) Check valve springs [16] for damage, and replace if required.

Discharge Valves-Re-assembly

a) Insert the discharge valve seats [14], discharge valves [15] and the springs [16].

b) Coat the top plug covers [17], top plugs [18] with an anti-seize compound such as BJSI P/N 13-01516.

c) Lubricate o-rings [3],[13] and back-up rings [4], [12] with silicone or 327-C Super C Armor Plate with Moly-D, BJSI P/N 13-33044.

d) Install the top plugs [18], top plug covers [17] and tighten with an open end wrench.

Plunger and Packing Replacement

Refer to the Assembly Drawing on ***Page 4-7*** and ***Figure 5*** for the following procedure.

The plunger removal procedures vary depending upon the plunger size. In all cases, plungers are removed from the rear.

Plunger Removal

a) Ensure the plunger to be removed [24] is as far back as possible into the *fluid end* of the pump

b) *Collet Plunger:* Remove collet nut [37]and bushing.
Threaded Plunger: Unthread plunger [24] from plunger adapter [36].

c) Remove gland nut [29].

d) Place well cover [*Power End* item 40,] over the Power Frame well opening during packing removal

Warning !!!

Keep hands away from plunger/brass removal area during high water pressure packing removal.

e) Block off the discharge line and turn on the suction feed water pressure until the brass and plunger are pushed out. Turn water feed off.

Note: Packing Removal Water Pressure 30 to 50 psi

f) Remove the lantern ring [22], rear throat bushing [27] packing set [28], front packing ring [26], spring [23], front throat bushing [25] and plunger [24].

g) Replace the packing if it appears to be frayed or torn.

h) Inspect the plunger for scoring; replace if necessary.

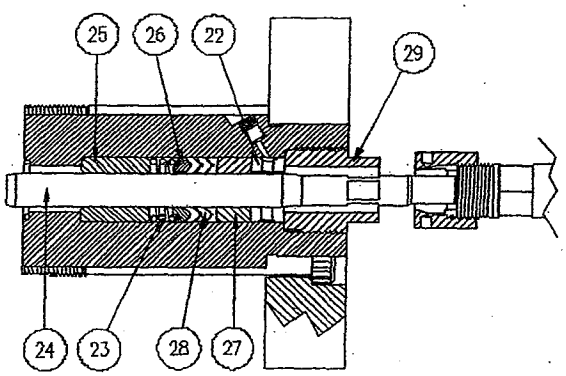


Figure 5: Plunger and Packing Replacement
Refer to page 4-7 for full assembly drawing

Packing Replacement

i) First, insert the plunger [24], then the throat bushing [25], spring [23], front packing ring [26] (snugly into the spring), packing [28] (with taper outward toward incoming pressure), rear throat bushing [27] and lantern ring [22].

j) Insert the gland nut [29] backwards and tap on it with a mallet to compress the packing until only the gland nut threads are showing.

k) Remove the gland nut [29]. Using an anti-seize compound on the threads, replace it in the proper position.

l) *Collet Plunger:* Insert the bushing and collet nut; secure until almost snug. Pull plunger [24] through or use water pressure to drive the plunger toward and into the collet nut. Make sure the plunger is inserted fully into the collet nut. *Threaded Plunger:* Manually drive the plunger toward the plunger adapter. Lubricate threads with Loc-tite 242 compound and screw them into the plunger adapters. Tighten using an open end wrench and tapping it firmly with a rubber mallet.

m) *Collet Plunger:* Tighten the collet nut. Return to Step (a) for next Plunger Removal.

Removal Procedure for Plunger Sizes Above 1 1/16"

a) Drain crankcase oil until the level is below the bottom of the diaphragm seal plate [Power end item 38].

b) Push plunger [*Fluid End* item 24] as far toward the power end as possible.

c) Unbolt the diaphragm seal plate [*Power End* item 38].

d) Unscrew the plunger adapter [*Power End* item 41] and remove it.

e) Rotate the crankshaft [*Power End* item 36] until the crosshead [*Power End* item 37] is as close as possible to the crankshaft,

f) Loosen and remove the gland nut [*Fluid End* item 29],

g) Pull the plunger [24] out from the back end of the stuffing box,

h) Inspect plunger [24] for scoring or damaged threads.

i) Using a wooden or soft metal rod, push the front throat bushing [25], packing springs [23], front packing ring [26], packing [28], rear throat bushing [27] and lantern ring [22] from the front to the rear of the *fluid end.* This requires the suction valves [7] assembly and suction manifold [2] be removed.

Re-assembly procedure

a) Lubricate packing [28] by soaking in light machine oil.

b) Install the front throat bushing [25] in such a manner that the radius, or chamfer, is forward.

c) Install the packing springs [23], the front packing ring [26], the packing [28], the rear throat bushing [27] and the lantern ring [22] in the order shown.

d). Install but do not tighten gland nuts [29].

e) Lubricate the plunger [24] threads with Loc-tite 242 pushing the plunger into the *fluid end* from the back and screwing it into the plunger adapters [36]. Tighten using an open end wrench and tapping it firmly with a rubber mallet.

f) After the plungers are installed, use an open end wrench to tighten the gland nuts [29].

g) Bolt diaphragm seal plate [*Power End item 38*].

h) Refill crankcase oil to the capacity indicated in the Power End Maintenance Manual.

T-300 Power End Maintenance

Minor Maintenance

Cleaning and oil changing should be performed on the pump's *power end* after the initial 100 hours of operation and every 500 hours or three months thereafter. Refer to the Power End Assembly Drawing on ***Page 5-5*** and Power End Lubrication Table on ***Page 6-1*** for the following procedure.

Cleaning and Oil Changing Procedure

a) Remove the *power end* drain plug and drain the oil.

b) Remove the 18 hex head screws [7] securing the crankcase cover [34] to the power frame housing [33].

c) Remove the crankcase cover and the cover gasket [22] It is recommended that the gasket be replaced at this time.

d) Wipe the crankcase clean using a clean cloth soaked in solvent. The magnets glued to the bottom of the power frame should be cleaned of any debris.

e) Check the torque on the connecting rod bolts and tighten if necessary. (See Page ***5-5*** for torque values.)

f) Visually inspect the tapered roller bearings [27] for any signs of excessive wear or overheating. Replace the bearings if this has occurred.

g) Reinstall the crankcase gasket, cover and drain plug.

h) Refill the crankcase with the recommended amount of Exxon Spartan EP-150 motor oil. See *Power End* Lubrication Table, Page 6-1.

Major Maintenance

See Daily and Preventative Maintenance Checks and Troubleshooting sections on before proceeding.

a) Remove the pump from the unit.

b) Remove the oil drain plug and drain the crankcase oil.

c) Remove the hose clamp [44] securing the stub deflector [43].

d) Loosen the plunger in the plunger adapter [41]. This will involve breaking a "Loc-tite" bond on the threaded style plungers. The collet style plungers require the use of a spanner wrench to loosen the collet nut [42].

e) Remove the two bolts [10] securing each of the diaphragm seal plates [38] in their positions in the power frame [33].

f) Remove the diaphragm seal plates [38] (with their seals [21] in place), gaskets and o-rings [23].

g) Remove the oil level sight tube [14], elbows and nipples.

h) Remove the 18 hex head screws [7] securing the crankcase cover [34] to the power frame.

i) Remove the two bolts for each connecting rod assembly [31]. The rod caps are matched to the rod bodies (see stamped ID numbers on sides of rod cap and rod body). Match these components when the *power end* is reassembled.

j) The removal of the connecting rod caps exposes the connecting rod bearings [28]. The rod bearings are wear parts and should be changed every 1000 hours or sooner, if they show signs of wear. The bearings are copper based with a babbitt coating. They contain oil channels and holes designed to align with the holes in the connecting rods. Note the hole placement to allow for exact assembly. The bearings are wearing properly if they are smooth with no ridges or deep grooves. If grooves or uneven wear is obvious, it may indicate that the pump has been overloaded (power output too high) or the oil may be contaminated.

k) Push the crosshead(s) [37] with the connecting rod bodies in place as far forward as required to clear the operating area for the crankshaft [36].

l) Remove both the seal end cap [35] (the flat cast part) and the crankshaft cover [39] (the cast part shaped like a top hat). This is done by removing the six hex head screws [10] securing each of the two covers. Leave the crankshaft shim sets (the multi-colored plastic rings) intact with the caps for assembly.

m) The crankshaft [36] can now be removed from either side by tapping with a hammer and a wood block placed on the crankshaft end. Take care not to allow the crankshaft to drop as it passes through the crankshaft bores in the power frame.

n) With the crankshaft removed, the crosshead [37], the connecting rod body and the crosshead pin [32] can now be removed from each power frame bore as one complete assembly per bore.

o) The crosshead pin(s) [32] can now be removed from the crosshead [37] and connecting rod body by removing the two styles of set screws [9] - dog point (sharp) and [11] - cup point (concave). Then press the wrist pin (crosshead pin) out of the crosshead bore. This can be done by hitting a wood peg placed on the end of the wrist pin or by hydraulic press.

p) The wrist pin (crosshead pin) [32] and wrist pin bushing can now be examined for wear. The wrist pin should be replaced if it shows deep or uneven wear. The wrist pin bushing can be replaced by pressing it out of the connecting rod wrist pin bore. Note any lubrication holes in the wrist pin bushing to allow for proper assembly in the same position in the connecting rod bore.

Assembly Procedure

a) Thoroughly clean the inside of the power frame. High pressure water may be used if available. Wipe all ledges on the inside of the frame to remove any accumulated deposits. Spray all exposed metal surfaces with WD-40 to avoid flash rusting.

b) Remember to perform the following as an integral part of assembly.

c) Position the crossheads in their power frame bores with the lube port in the up position. This will allow lubrication oil to pass through the power frame upper shelf and down to the crosshead where it passes through the crosshead pin bearing. In the 450 series pump, the oil will also pass through a drilled hole through the entire length of the connecting rod.

d) Two styles of set screws are used to secure the wrist pin (crosshead pins) [32] in the connecting rod wrist pin bore. These are dog point (sharpened) and cup end. The dog point goes in first, then the cup point is used following the dog point to lock the two in place. Snugly tighten both with a "T" handle hex screw (Allen) key. The dog point set screw should mate with an indentation in the crosshead pin.

e) If plunger adapters [41] are removed from the crossheads [37], reinstall using Loc-tite 242 (medium strength, semi-permanent). Place a bead of Loc-tite on the adapter threads and screw it into the crosshead until it bottoms out. Threaded plungers are to be secured to the plunger adapters in the same manner. Make certain the shoulder between the plunger adapter and plunger is clear of any obstruction to allow a clean shoulder-to-shoulder match. This avoids any potential alignment problem between the adapter and the plunger.

f) Check the torque and lubrication requirements for proper bolt torque values, type and quantity of crankcase oil (*page 5-5 and 6-1*).

Warning !!!

Dirty oil, low oil level, and improperly torqued bolts can greatly shorten the life of your pump. Bolt torques and other threaded connections should be checked weekly.(See Assembly Drawing on Page 5-5 for torque values.) Check oil level daily. Change oil after the initial 100 hours of operation and every 500 hours (or three months) thereafter. Keep a maintenance log on every pump by serial number.

Table 3: T-300 Power End Parts List

ITEM	QTY	PART NUMBER	DESCRIPTION
			MATERIAL
1	1	SEE CHART	
2			
3	2	16-15007	LOCKWASHER 1/4"
4	4	16-15042	NUT, HEX, 3/4"-10 UNC
5	2	16-15049	SCREW, HEX HEAD, 1/4"-20 UNC X 3/4" LG GRADE 5
6	18	16-15063	LOCKWASHER 3/8"
7	18	16-15212	SCREW, HEX HEAD, 3/8"-16 UNC X 3/4" LG GRADE 5
8	4	16-75207	STUD, 3/4"-10 UNC X 3.1/2" LG.
9	3	16-75246	SCREW, HEX SOCKET SET, 3/8"-16 UNC X 1/2" LG
10	18	16-75658	SCREW, HEX HEAD, 1/2"-13 UNC X 1.1/4" LG GRADE 5
11	3	16-75660	SCREW, HEX SOCKET SET, 3/8"-16 UNC X 5/8" LG
12	2	16-75661	DOWEL PIN, 3/8" DIA X 1" LG.
13			
△3 14	1	37-77063	GAUGE, OIL LEVEL
15			
16			
17			
18	3	19-32031	PIPE PLUG, 1/2" NPT
19			
20	1	19-77014	PIPE PLUG, 1" NPT
21	3	22-33015	GASKET, DIAPHRAM SEAL PLATE
22	1	22-33016	GASKET, CRANKCASE COVER
23	6	22-33028	OIL SEAL, DIAPHRAM PLATE
24	2	22-75630	SEAL, CRANKSHAFT OIL
25		22-75712	SHIM SET (AS REQUIRED)
26			
27	2	52-75107	BEARING, CRANKSHAFT
28	3	70-75116 △3	BEARING, CONNECTING ROD
29			
30	1	70-75515	BREATHER, CRANKCASE
31	3	70-75112	CONNECTING ROD ASSEMBLY
32	3	70-75119	PIN, CROSSHEAD
33	1	70-75501	POWER FRAME
34	1	70-75502	COVER, CRANKCASE
35	1	70-75503	CAP, SEAL END
36	1	70-75504	CRANKSHAFT
37	3	70-75505	CROSSHEAD
38	3	70-75507	PLATE, DIAPHRAM SEAL
39	1	70-75509	CAP, CRANKSHAFT COVER
40	1	70-75512	COVER, WELL
41		SEE CHART	
42		SEE CHART	
43		SEE CHART	
44		SEE CHART	

70-75510-300 L-300 POWER END WITH COLLET PLUNGERS			
1	1	12-33024	SPANNER WRENCH (NOT SHOWN)
41	3	70-75513	ADAPTER, PLUNGER
42	3	70-75514	COLLET NUT

70-75510-004 I-300 POWER END (REFERENCE ONLY)			
41	3	70-74611	ADAPTER, PLUNGER
42	3	70-74615	COLLET NUT

70-75510 L-300 POWER END WITH THREADED PLUNGERS			
41	3	70-75506	ADAPTER, PLUNGER
43	3	22-17061	STUB DEFLECTOR
44	3	16-15250	HOSE CLAMP

70-75510-001 LM & LH-300 POWER END WITH THREADED PLUNGERS			
41	3	70-75506-001	ADAPTER, PLUNGER
43	3	22-17061	STUB DEFLECTOR
44	3	16-15250	HOSE CLAMP

70-75510-002 L-300 POWER END USED ON ELECTRIC HYDRAULIC HYDROSTATIC			
36	1	70-75504-001	CRANKSHAFT

Figure 7: T-300 Power End Assembly

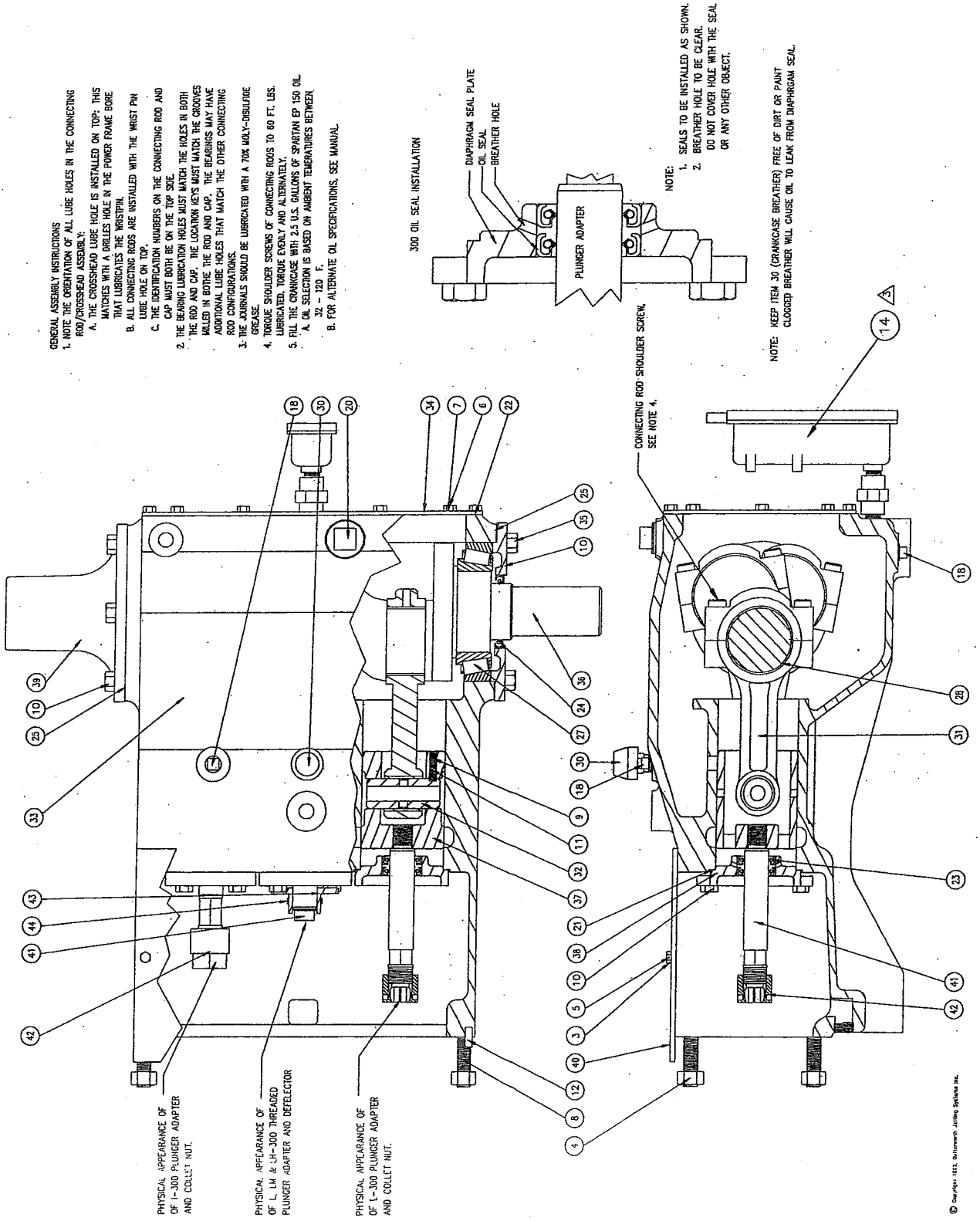


Table 4: Power End Lubrication

Pump Model	Oil Capacity* (U.S. Gallons)	Oil Type
300	2.5	Exxon Spartan EP-150
375	5	"
450	9	"
450X	9	"
Q-450	12	"
Gear Box Assembly	2.5	"

*Oil capacity is given as an approximate figure. Some systems have high capacity oil re-circulation systems. The guide for all power ends is for the roller bearing to be covered and not trip the HIGH LEVEL Alarm.

Oil: API-GL5 80W90

Warning !!!
Oil selection is based on ambient temperature of 32 degrees to 120 degrees Fahrenheit. (0° C to 49° C)

Oil Change Interval:

- Initial change on new pump after 100 hours.
- Every 500 hours or 3 months, which ever comes first, and thereafter.

Maintenance Tips for Maximum Pump Life:

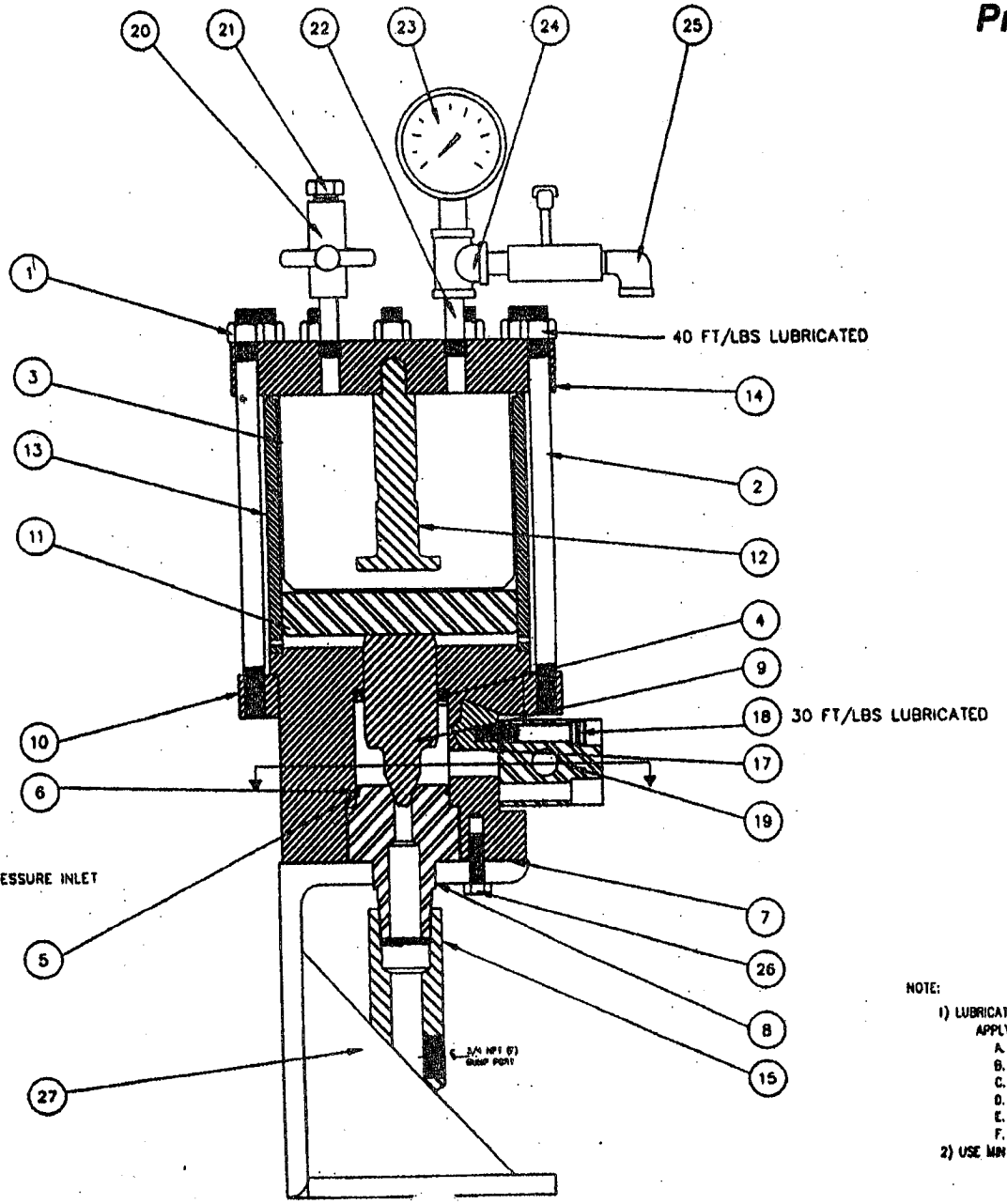
- Keep the oil level full and clean.
- Keep water out of the oil.
- Change oil according to schedule.
- Do not operate the pump on an incline. This may damage certain portions of the pump and will void the warranty.

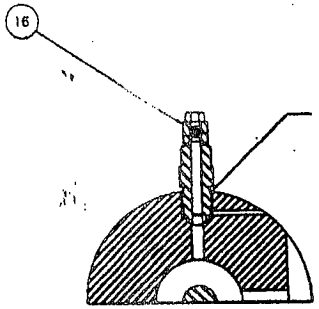
GARDNER DENVER WATER JETTING SYSTEMS, INC.
Partek • Geoquip • CRS Power Flow • Jetting Systems • American Waterblaster
12300 North Houston-Rossiyn Road • Houston, Texas 77086
800-231-3628 • 281-448-5800 • Fax 281-448-7500
www.waterjetting.com • mktg.wjs@gardnerdenver.com

Accessories

Pressure Regulator

31-09720-XXX





SECTION VIEW

NOTE:

1) LUBRICATION INSTRUCTIONS
   APPLY 70% MOLY DISULFIDE GREASE (P/N 13-01516) TO:
   - A. INSIDE SURFACE OF CYLINDER BORE (ITEM 13)
   - B. OUTSIDE OF DIAPHRAGM (ITEM 3)
   - C. O.D. OF PISTON (ITEM 11)
   - D. ALL SCREW THREADS
   - E. O - RINGS
   - F. INSIDE SURFACES OF RING (ITEM 10)
2) USE MIN 1,000 PSI NITROGEN PRESSURE TO TEST FOR LEAKAGE.

Pressure Regulator
31-09720-XXX

Item	Qty	Part Number	Description
1	12	16-15017	NUT, HEX
2	12	16-15530	STUD
3	1	22-09720	DIAPHRAGM
4	1	22-09721*	SEAL
5	1	22-74203*	RING, BACKUP
6	1	22-74204*	O-RING
7	1	31-09773	REGULATOR BODY, 20K
8	1	31-09722*	SEAT, VALVE
9	1	31-09723*	VALVE
10	1	31-09724	RING
11	1	31-09725	PISTON
12	1	31-09726	STOP, PISTON
13	1	31-09727	CYLINDER
14	1	31-09728	COVER
15	1	34-02031	ELBOW
16	1	31-41100-813	BLEEDER VALVE ASSY
17	1	22-17406	O-RING
18	4	16-78544	BOLT
20	2	55-32077	SHUT-OFF VALVE
21	1	34-33047	ADAPTER
22	1	34-33120	TEE
23	1	49-14014	PRESSURE GAUGE
24	1	34-33120	TEE
25	1	19-00330	ELBOW
26	3	16-0106C-016	BOLT
27	1	79-92441	STAND
REF		31-09720-900	REPAIR KIT (INCLUDED IN KIT)*

NOTE: Inlet port 1" MP. Specify required adapter.

31-09720-151, 15,000 psi

Item	Qty	Part Number	Description
19	1	31-09774	MANIFOLD, 15K

31-09720-201, 20,000 psi

Item	Qty	Part Number	Description
19	1	31-09775	MANIFOLD, 20K

PRESSURE REGULATOR SYSTEM

98-3109363

PRESSURE REGULATOR OPERATION AND MAINTENANCE

(Reference Drawing no. 31-09720-200)

DESCRIPTION:

The Butterworth high pressure regulator is designed as a back pressure regulator for high pressure liquids. The regulator can be used for liquid pressures up to 15,000 psi (P/N 31-09720-150), and up to 20,000 psi (P/N 31-09720-200). The pressure regulator is energized by pressurized nitrogen, the regulator does not consume nitrogen unless it is being reset.

The bleeder valve appends the regulator to act as a safety device which prevents static pressure build-up when the high pressure pump is not operating. As it continuously bleeds liquid out of the system at 0.25 - 0.50 GPM, it allows no pressure beyond atmospheric pressure to remain in the system after approximately 10 seconds of turning the pump off.

***** WARNING *****

- Never exceed 2,000 psi nitrogen pressure in the regulator. Exceeding this pressure may result in stud, cylinder, or accessory failure and may cause severe injury.
- Do not operate the regulator without the elbow connected to the valve seat. A high velocity liquid jet coming from the valve could cause severe injury.
- If a stud failure or loose nut is detected, depressurize the nitrogen and repair.
- Never pressurize, plug, or restrict the outlet (bottom of the regulator).

APPLICATIONS:

The pressure regulator may be used in two different ways:

1. As a safety relief valve, the regulator maintains a minimum accuracy of 92%. The set pressure will be 8% above the normal operating pressure.
2. As a pressure regulator, the regulator maintains an accuracy of 98%. The set pressure will be the same as the operating pressure, while allowing the regulator to leak a very small amount of liquid continuously.

PRESSURE REGULATOR SET-UP PROCEDURES

Installation:

1. Connect the inlet port of the regulator body (7) to the proper high pressure hose, to the pump discharge port.

2. Connect the bleeder valve to the regulator outlet. The bleeder valve may then be coupled with a pipe or hose to deliver the dumping liquid to another location. It is not recommended to exceed 10 ft. in hose length to avoid creating a back pressure when discharging higher flow. Do not attempt to plug or restrict this pipe or hose.

3. The nitrogen line is connected to the upper plate (14) of the cylinder (13). The pressurized nitrogen system utilizes two needle valves for pressure adjustment. There are two pressure gauges. The one nearest the nitrogen bottle shows the bottle pressure and indicates when bottle replacement is required. The second gauge is mounted on the liquid regulator and indicates the pre-charge pressure.

Adjustment: Before adjusting the set pressure of the system, check the following:

1. The high pressure discharge hose between the pump and regulator is securely connected.

2. Close the manual valves in the high pressure discharge system on the guns or whatever components are used to shut off the flow.

3. Close the flow control valve if using an electrical unit.

4. Check to see that the nitrogen bottle on the regulator assembly is charged. As furnished from the factory, it will be between 2000-2300 psi.

5. Close the needle valve on the regulator that is used to bleed off the nitrogen pressure. It is mounted directly on top of the regulator.

6. Observe that the regulator pressure is below 100 psi.

Initial Pressure Setting:

1. Turn on the unit; all the flow will dump over the regulator and the pump discharge pressure will be on the system back pressure.

2. Slightly open the bottle shut-off valve and the supply line needle valve, and allow the nitrogen pre-charge pressure in the regulator to slowly rise. Observe the pump discharge pressure gauge, and continue to increase the nitrogen pre-charge until the desired operating pressure is attained.

3. Immediately close both the bottle shut-off valve and the supply line needle valve. The pressure should then be recorded to allow quick adjustment on future settings at the same pressure. If the pump flow rate is changed it will be necessary to repeat this procedure.

Readjustment of Pressure Setting:

1. Decrease operating pressure - Repeat steps 1 - 3 of the system check-out procedure. Start up the pump and operate in the shut-off mode with all the flow dumping over the regulator. Slowly open the needle valve on the regulator and decrease the nitrogen pre-charge pressure. Watch the pump discharge pressure gauge until the desired operating pressure is attained. Close the needle valve completely to maintain the new pre-charge pressure.

2. Increase operating pressure- Check the pressure in the nitrogen bottle; it must be greater than the pre-charge pressure in the regulator. Repeat steps 2 and 3 in Initial Pressure Setting procedure.

Change Nitrogen Bottle:

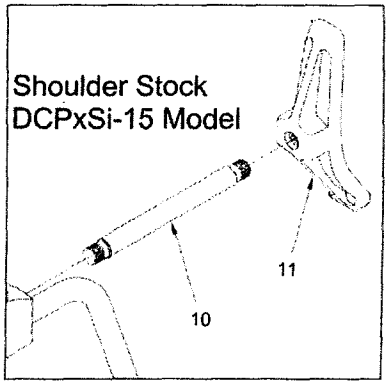
1. When the nitrogen bottle pressure is lower than the pre-charge pressure required in the regulator it must be changed. Close the bottle shut-off valve completely. Open both needle valves in the system venting all pre-charge. Both gauges will read 0 psi. Loosen the nut on the bottle connection (Item 2) and disconnect the tank. Reconnect piping to new bottle. start the system check and proceed to the initial pressure setting section.

*** WARNING ***

- **The temperature of the liquid flowing through the regulator is increased by approximately 3° F per 1,000 psi. It is not recommended to use a small reservoir to recycle the dumping liquid from the regulator.**

- **The temperature of the nitrogen may have an effect on the set pressure. Periodically check for a change of pressure due to temperature variations. It is recommended to shield the top portion of the liquid pressure regulator and to have it thermally insulated in order to prevent excess temperature variations.**

DURASAFE™ HAND GUNS
SHUT-IN STYLE
REPLACEMENT PARTS



Model DCPSi-15
Shown

Item	Part No.	Description
1	26061	Coupling
2	J55620	Handle Assembly
2a	J55614	Handle
2b	J55617	Trigger Assembly
2c	26116	Pin
3	26689	Capscrew
4	52645	DCPSi-15 Body Assembly
	54450	DCPxSi-15 Body Assembly

Item	Part No.	Description
5	52635	CPSi-15 Cartridge
6	52543	Cartridge Plug
7	53304	Body Pad (DCPSi-15)
8	25296	Nut (DCPSi-15)
9	53303	Stud (DCPSi-15)
10	50127	Extension (DCPxSi-15)
11	50124	Shoulder Stock (DCPxSi-15)

Related Items
SHUT-IN REGULATOR VALVE — See page C-14
ORBI-JET NOZZLES — See pages E-1 – E-5
HHTC NOZZLES — See page E-9
SAFETY SHROUDS & WHIP HOSES — See page G-3

Recommended Practices For The Use Of Manually Operated High Pressure Waterjetting Equipment

Prepared by the WaterJet Technology Association (WJTA)

This book may be purchased from:

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PREFACE

This is the third version of the *Recommended Practices* put together by the Safety Committee of the Waterjet Technology Association. From the beginning this group has sought to bring together the views of government, academia and industry in order to make a workable and effective document.

The work of the original committee has been enhanced by numerous suggestions and advice from industrial contractors who have helped develop the cleaning industry which now exists. It is a pleasure to recognize the debt which the industry owes to these individuals and to their employers who have provided the time for them to make this effort. In addition Mark Birenbaum, as part of the management company which helps guide the Association, has significantly contributed to the final appearance of the document, and this effort is recognized gratefully.

Because the industry continues to change, it is important that this document recognize and reflect these developments in the industry. Thus we request that any suggestions for change in these *Recommended Practices* or other consideration be sent to:

The Chairman
Safety Committee
Waterjet Technology Association
917 Locust Street — Suite 1100
St. Louis, MO 63101-1413

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 These *Recommended Practices* apply to the operation of all types of high pressure waterjets as normally used in construction, maintenance, repair, cleaning, cutting and demolition work. Types of waterjet equipment are described, and recommendations are made about how to run the equipment and how to train equipment operators. Reference should also be made to present or proposed industry standards, including those of the U.S. Occupational Safety and Health Administration (OSHA), the American Society of Testing Materials (ASTM), the American National Standards Institute (ANSI), and to equipment manufacturers recommendations, where they are appropriate.

1.2 High pressure waterjet technology for cutting and cleaning is changing rapidly. Therefore, these *Recommended Practices* will be reviewed and revised regularly. The date of this version is shown on the front cover.

1.3 In this document the term "high pressure," unless another description is given, refers to all waterjets.

2.0 GOALS

2.1 These *Recommended Practices* are designed to describe the basic practices for using high pressure waterjets when cleaning or cutting materials.

2.2 These *Recommended Practices* do **NOT** replace the training necessary to operate and maintain high pressure waterjet systems. Trainees must be properly trained by qualified personnel and must be able to demonstrate their knowledge and ability to perform a task before being required to do so.

2.3 Every job and work site has its own special conditions that must be reviewed by the contractor's and owner's representatives, before work begins, to develop for each job and work site a set of written procedures. The written job procedures may be based on these *Recommended Practices*, but they must also include special precautions to be followed on a particular job or at a particular site.

2.4 Waterjet systems are now used at several different operating pressure ranges and can be operated with either liquids or solid particles added to the water. Waterjets at any pressure can be dangerous and can cause injury, so these *Recommended Practices* should be referred to whenever waterjets are used.

2.5 When using different systems at different sites, procedures may need to be changed. However, certain steps are recommended for all operations. In these *Recommended Practices*, where "**shall**" is used rather than "should", the procedure described must be followed to comply with these *Recommended Practices*.

2.6 Since there are many terms used to describe waterjet equipment and the ways to cut or clean, a standardized set of definitions is provided in a glossary at the back of this booklet. These definitions apply to the terms used in these *Recommended Practices* and are recommended for general use.

3.0 RESPONSIBILITY

3.1 **Purpose** - To assist anyone unfamiliar with the use of waterjet equipment to correctly use the equipment.

During any waterjet activity the correct operation and application of the waterjet equipment is the responsibility of the operator, who should be familiar with the identification of high pressure pumps, metal fittings, hoses, guns, and accessories (Figure 1).

The modification of waterjet equipment or accessories is not recommended without the prior written approval of the manufacturer of the equipment.

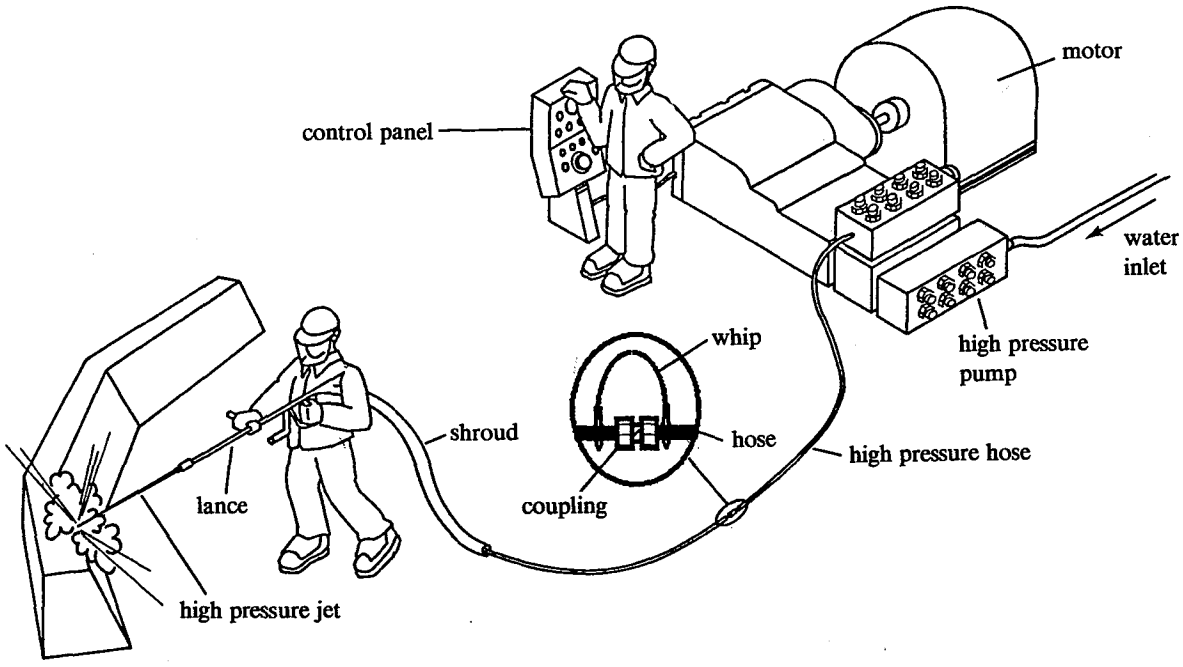
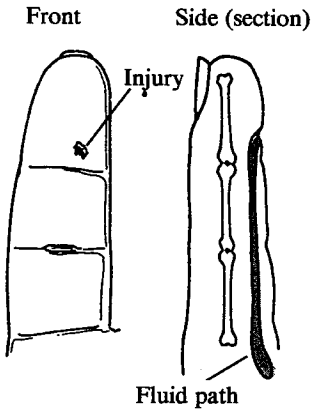


Figure 1. Waterjet Cleaning Operation Showing System Components

Serious harm or injury may result from the misuse of waterjet equipment or the use of improper fittings, hoses, or attachments. The Waterjet Technology Association (WJTA) does not guarantee that the practices described and the recommendations contained in these *Recommended Practices* will prevent harm or injury.

4.0 ACCIDENTS



Figures 2 and 3

4.1 **Personal Injury** - A person injured by being hit with a waterjet will not necessarily see the full extent of the injury, particularly the internal damage and depth of penetration. Even though the surface wound may be small and may not even bleed, it is quite possible that large quantities of water may have punctured the skin, flesh, and internal organs through a very small hole (Figures 2 and 3). The spread of micro-organisms through a wound of this type is a very real concern; the injury should, therefore be carefully monitored for several days.

4.2 **Operator Identification** - In the event of an injury, immediately take the injured person to a hospital and inform the doctor of the cause of the injury. To ensure that the doctor knows and understands the cause of the injury, all waterjet operators should carry a waterproof card that is easily accessible and that outlines the possible nature of the injury. The wording on the card might be as follows:

> *This person has been involved with high pressure waterjets at pressures up to 55,000 psi, (375 MPa, 3,750 bar) with a velocity of up to 2,000 miles per hour (3,300 kph).*
>
> ***Please take this into account when making your diagnosis.***
>
> *Unusual infections have been reported with microaerophilic organisms that tolerate low temperatures. These organisms may be Gram-negative pathogens such as are found in sewage. Bacterial swabs and blood cultures may therefore be helpful.*

4.2.1 **Medical Recommendations** - If an accident should occur and high pressure water penetrates the skin, seek medical attention immediately.

4.3 **Immediate First Aid** - If it is not possible to have the injury treated immediately by a doctor, restrict first aid to dressing the wound and observing the patient until a medical examination has been arranged.

4.4 **Reporting** - If any person or equipment is injured in a waterjet-related accident, a report **must** be made to a responsible party of the employer/customer and of the owner of the equipment.

5.0 EXAMPLE OF A PRESERVICE AND OPERATIONAL CHECKLIST FOR HIGH PRESSURE WATER CLEANING

Date: _____

Location: _____

Equipment being cleaned: _____

1. Is the area, including the other end of the unit being cleaned, adequately barricaded, with proper warning signs posted?
2. Have precautions been taken to protect all electrical equipment?
3. Is there any hazard to personnel from possible damage to equipment, such as release of corrosive chemicals, flammable liquids, or gases?
4. Are all fittings of the correct pressure rating in accordance with 13.12 in the Glossary?
5. Are all hoses of the correct pressure rating in accordance with 13.16 in the Glossary?
6. Are all hoses in good operating condition?
7. Are all fittings in good operating condition?
8. Are all nozzles free from plugging and in good operating condition?
9. Have precautions been taken to prevent line-mole reversal?
10. Is the filter on the pump suction clean and in good operating condition?
11. Is there an adequate water supply?
12. Have precautions been taken against freezing?
13. Do all personnel have the proper equipment for this job?

14. Do all personnel have the proper training for this job?

15. Are all personnel qualified to perform this work?

16. Has the complete hookup been flushed and air removed from the system before installing the nozzle?

17. Has hookup, including pipes, hoses, and connections, been pressure tested with water at the maximum operating pressure?

18. Is the dump system operating properly (will it dump when released)?

19. Are all control systems operational?

20. Is the location of first aid equipment and an emergency medical center known?

21. Has the job site been examined to determine if *Confined Space Entry Requirements* apply?

22. Has all the relevant moving equipment, such as conveyors, choppers, mixers etc., been mechanically or electrically disabled with an appropriate lockout procedure?

23. Has job been examined for environmental considerations, with action as appropriate?

6.0 PROTECTIVE EQUIPMENT FOR PERSONNEL

6.1 **OSHA Compliance** - (for work subject to the rules of federal or state Occupational Safety and Health Administrations or similar agencies in other countries) – All personnel **shall** follow the OSHA regulations for personal protective equipment.

6.2 **Head Protection** - All operators **shall** be issued suitable head protection which **shall** be worn at all times while at the worksite (Figure 4). Where possible, head protection should include a full face shield.

Figure 4. Head Protection Showing Helmet, Goggles With Side Shield and Face Shield

6.2.1 **Eye Protection** - Eye protection must provide the protection needed and must properly fit the person wearing it. Eye protection **shall** be provided to, and worn by, all high

pressure waterjet equipment operators and all visitors to waterjet operations while they are in the working area. (Some states and countries have their own eye protection rules that must be followed.) All eye protection shall meet appropriate ANSI requirements for that type of eye protection.

Note: Side shields to glasses and goggles should prevent liquids from getting through.

In some cases, liquids may be in use that can cause eye damage. In those cases a combination visor and goggles or a full hood with shield should be used (Figures 5 and 6).

Figure 5. Goggles

Figure 6. Face Shield

6.2.2 **Hearing Protection** - Waterjets generate considerable noise, both in air and under water [frequently louder than 90 DB(A)].

Therefore, **all** operators and **all** visitors **shall** be issued and **shall** wear hearing protection while in the working area (Figures 7, 8, and 9). Hearing protectors should be regularly inspected and properly maintained, and should comply with federal and/or state OSHA standards.

All personnel, operators, and others in the vicinity of waterjet equipment should be taught how to fit and properly use ear protectors so that their exposure to noise does not exceed OSHA or other regulatory limits.

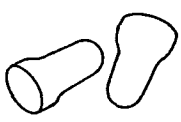


Figure 7. Foam Earplugs

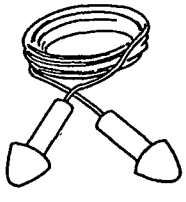


Figure 8. Strap with Plastic Earplugs

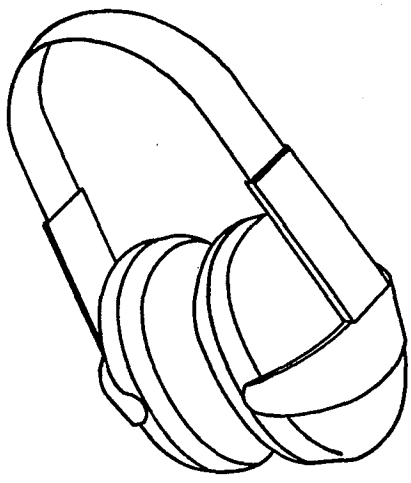


Figure 9. Earmuffs

6.3 **Body Protection** - Waterjets can penetrate clothing, most protective suits, and the skin, and cause serious injury. Therefore, protective clothing should be waterproof and have an outer layer that repels casual rebounding water. Protective clothing should also provide some protection from the impact of rebounding debris from the jet impact point where this may be a hazard to the operator.

Everyone working around a waterjet operation should be provided with, and should wear, sufficient waterproof clothing to provide protection from the type of exposure to water and debris that the work might create. Garments should completely cover the operator, including his/her arms.

Liquid or chemical-resistant suits **shall** be worn when there is a reasonable chance that an injury can be prevented by such equipment (Figure 10).

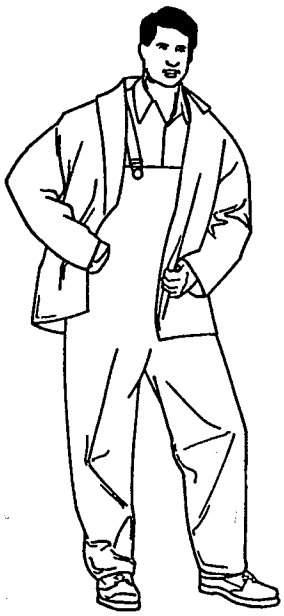


Figure 10. Typical Wet Suit

6.4 **Hand Protection** - All operators should be provided with adequate means to protect their arms and hands, and this protective equipment **shall** be worn when there is a reasonable chance that an injury can be prevented by such equipment. (Figures 11,12,13).

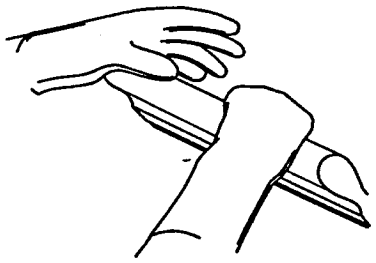


Figure 11. Plastic-Coated Gloves

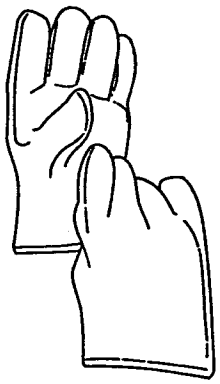


Figure 12. Rubber Gloves

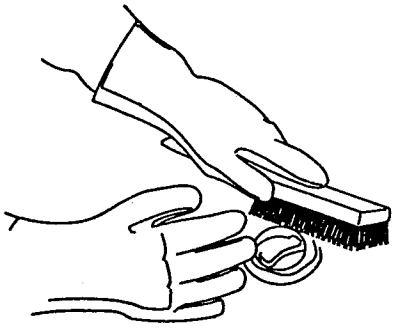


Figure 13. Metal-Mesh Reinforced Gloves

6.5 **Foot Protection** - All operators and workers in the vicinity of a jetting operation should be supplied with, and shall wear, waterproof boots that have been fitted with steel toe caps. A metatarsal guard should also be worn by jetting gun operators (Figures 14 and 15).

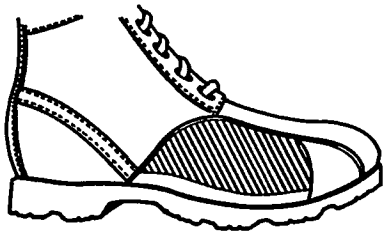


Figure 14. Steel-Toed Boots (sectioned)

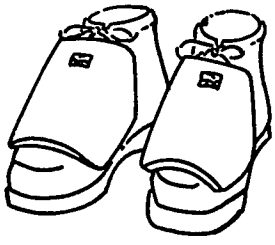


Figure 15. Metatarsal Guards

6.6 **Respiratory Protection** - A respiratory program **shall** be implemented when there is a reasonable chance that an injury can be prevented by such a program (Figures 16, 17).

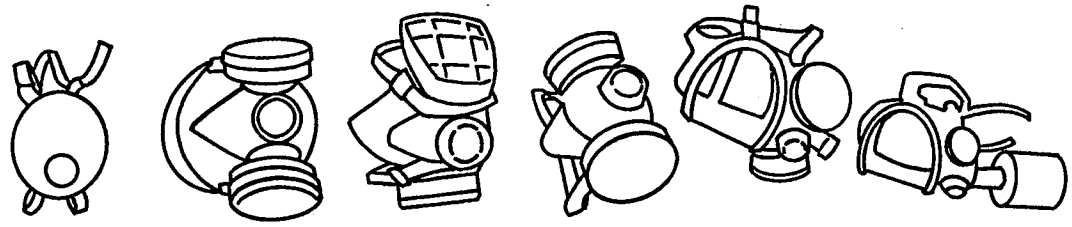


Figure 16. Various Possible Respirators

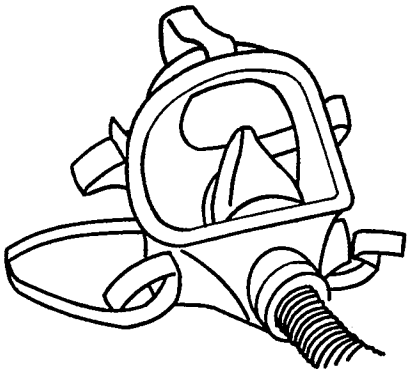


Figure 17. Full Face Protection with Supplied Air

6.7 **Equipment Limitations** - Protective equipment may not prevent injuries to operators and other workers caused by the direct impact of high pressure waterjets or from debris that may be thrown out by the impact of the jet.

7.0 OPERATIONAL AND TRAINING REQUIREMENTS

7.1 **Qualified Operators** - Only personnel who have undergone a proper training program and who have demonstrated the knowledge and skill, and gained the experience to perform all likely assigned tasks **shall** operate high pressure waterjet equipment. They may also supervise the training of new operators.

7.2 **Training** - Before being assigned to their first high pressure waterjet jobs, employees **shall** receive proper training developed by their employer. This training **shall** include, at a minimum, coverage of all items listed in these *Recommended Practices*.

7.3 **Cutting Action** - The cutting action of a high pressure waterjet and the potential hazard it poses to the human body **shall** be demonstrated through the use of audiovisual aids or actual use of equipment (by cutting through a piece of lumber, a concrete block, etc.).

7.4 **Personal Protective Equipment** - The minimum personal protective equipment **shall** be explained. Instructions shall be given as to when and how specific clothing and other types of protective devices **shall** be worn according to the type of work performed, locations, etc.

7.5 **System Operation** - The operation of high pressure waterjet systems **shall** be explained by pointing out potential problems and proper corrective actions.

7.5.1 **Operating Pressure** -The need to operate equipment at or below the manufacturer's recommended working pressure shall be stressed.

7.6 **Control Devices** - The operation of all control devices **shall** be explained. The importance of not tampering with any control devices, as well as the importance of keeping them in proper working order, **shall** be stressed.

7.7 **Equipment Maintenance** - The importance of the proper and timely care and maintenance of high pressure waterjet equipment **shall** be presented. Instructions **shall** be provided on the procedures to follow in maintaining equipment and when the equipment must be returned for care by more qualified employees.

Stress that equipment **shall not** be repaired, or connections tightened, when the unit is in operation or the pump is running.

7.7.1 **Valve Maintenance** - Point out that valves and seating surfaces in pressure regulating devices encounter high wear during high pressure waterjetting. These items require frequent inspections, maintenance, and/or replacement to ensure proper operation.

7.8 **Hose** - The proper method of identifying and connecting hoses, including laying out without kinks, protecting hoses from excessive wear, identifying worn or unsafe hose, and proper tools to use on couplings and fittings, **shall** be explained. Fittings and couplings on hoses should not be tightened or tampered with while the hose is pressurized. Safety connectors (whipchecks) should be used across all hose connections.

7.9 **Stance** - The proper stance for sound footing and how to use the various devices for lancing, shotgunning, and moleing **shall** be demonstrated. The trainee, under close supervision, **shall** be trained to use the various devices while the unit is slowly pressurized and is operating at its normal working capacity.

7.10 **Proficiency** - Personnel **shall** demonstrate knowledge and skill in the proper operation of equipment through practical applications before performing indirectly supervised work.

7.11 **General**

7.11.1 **Depressurizing the System** - High pressure waterjet systems **shall** be depressurized when

(a) not in use;

(b) an unauthorized or inadequately protected person enters the barricaded area;

(c) replacement or repairs are made to the system; and/or

(d) any *Recommended Practices* are violated.

7.12 **Refresher Training** - Operator retraining **should** be on an annual basis or more frequently if needed.

7.13 **Hazards Communication** - All personnel shall have received OSHA-mandated Hazards Communication Training.

8.0 PREOPERATING PROCEDURES

8.1 **Planning** - Each job **shall** be preplanned. Personnel familiar with the equipment to be cleaned or the material to be cut and the work environment **shall** meet with the personnel who will be doing the work and shall outline potential hazards of the work area, environmental problems, safety standards, and emergency aid procedures.

8.1.1 **Corrosive Materials** - Where the jetting operation involves, or the operator may be exposed to, corrosive or toxic material, the owner or the owner's representative **shall** be requested to inform the contractor or the contractor's representative of the special precautions that may be necessary in working around the material, in protecting personnel, and in the collection and disposal of waste materials.

Personnel should be made aware of any chemical reactions which may occur during the waterjetting which may release toxic gases or fumes.

8.1.2 **Operating Pressure and Flow** - The owner and the contractor or their representatives **shall** review the pressures and flow rates required to perform the work to be carried out. Within the limits of any restrictions on flow volume that may arise, the work should be performed at the lowest effective pressure.

8.1.3 **Confined Spaces** - When jetting must be carried out in a confined area or space, a specific written set of procedures and precautions **shall** be prepared by the owner and contractor or their representatives. These procedures **shall** include written certification that the space has been properly cleared. Where applicable, OSHA regulations for confined space entry shall be followed. All persons who may be entering subject space shall be trained and certified in OSHA confined space entry procedures.

8.2 **Work Area** - Where practical, items that are to be jetted should be taken to an area that has been set aside for high pressure waterjetting. Where this is not practical, the item can be cut or cleaned either where it is installed or close to it, provided that the necessary permission and procedures have been obtained and agreed upon with the owner or the owner's representative.

8.3 **Checklist** - A checklist **shall** be used to assure that proper procedures and proper equipment selections are followed (see Section 5.0).

8.4 **Electrical Equipment** - Any electrical equipment in the immediate area of the operation that presents a hazard to the operator **shall** be de-energized, shielded, or otherwise made safe.

8.5 **Dump Valve** - High pressure waterjet systems **shall** include at least one valve that will allow the operator to rapidly shut down the equipment or dump the water to atmosphere, rapidly reducing the pressure within the system to a low level. The Nozzle Operator **shall** have control of a valve that will stop the jet action. This valve should be of the type that will automatically activate if the operator releases the control handle, whether the control handle is operated by hand or foot. The valve **shall** have a guard to prevent accidental activation of the system.

This valve **shall** be checked at the beginning of a jetting operation and, should it be defective, work **shall** not begin until this valve is replaced or repaired.

8.6 **Area Limits** - The area around a work site that will be required for the jetting operation and for the protection of those not involved in the jetting operation **shall** be defined by the owner and contractor or their representative. The boundary of this area **shall** be clearly marked by the waterjet team, providing both a visible and a physical barrier to entry by unauthorized personnel. Notices that state: "DANGER — KEEP CLEAR, HIGH PRESSURE WATERJETS IN OPERATION" or other suitable wording should be posted. Barriers should be of either the warning type or the protective type, depending on the distance at which they are located from the jetting operation.

8.6.1 **Warning Barriers** - Suitable barriers **shall** be erected to restrict access to the hazard area and signs **shall** be posted to warn personnel that they are entering a hazardous area. The barriers should be outside the effective range of the jet, wherever possible. Barriers may be of rope, safety tape, barrels, etc., as long as they give an effective warning and are highly visible. The minimum recommended barrier **shall** be an approved form of hazard warning, which may be either a rope or a tape stretched above ground level (Figures 18 and 19).

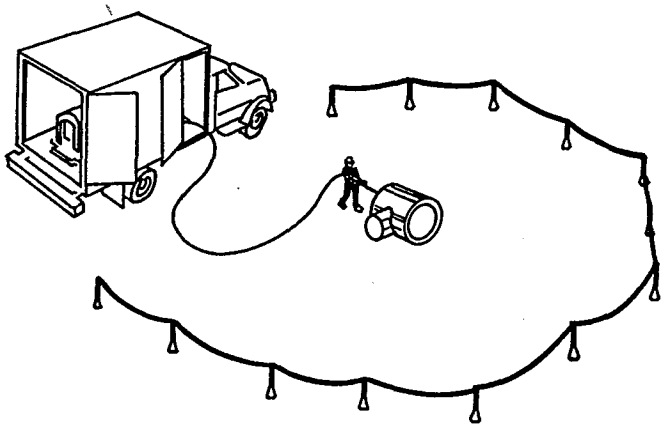


Figure 18. Open Barriers

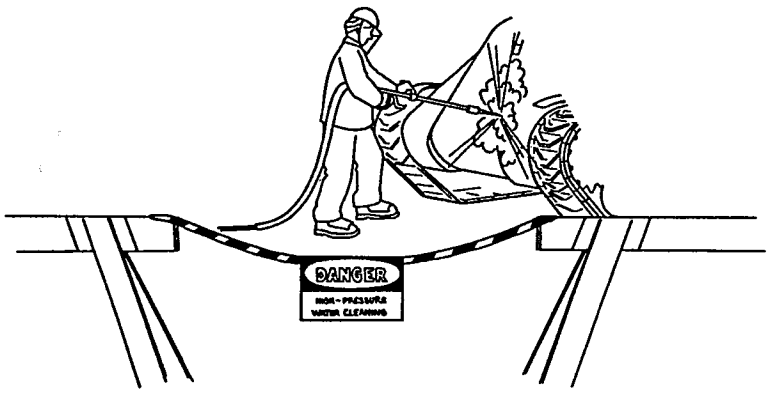


Figure 19. Warning Signs and Barricades

8.6.2 **Protective Barriers** - Where it is not possible to provide barriers beyond the effective range of the jet and any debris or abrasive thrown from the cutting zone, then protective physical barriers should be erected. Protective barriers should be designed to prevent fluids and particles from a waterjet operation from going beyond the barriers.

8.7 **Hook-up**

8.7.1 **Hose Layout and Support** - Hose **shall** be arranged so that workers will not trip over them. Hoses, pipes, and fittings **shall** be supported to prevent excessive sway and/or wear created by vibration or stress on the end connections.

8.7.2 **Hose Protection** - All hoses should be protected from being run over and crushed by vehicles, forklift trucks, etc. A hose **shall not** be operated at a pressure exceeding the working pressure. Hoses should be laid out to avoid or minimize abrasive wear on the hose.

8.7.3 **Fittings** - All fittings **shall** be cleaned before installing in the system. Be sure all fittings are leak free and pressure rated for the purpose.

8.7.4 **Hose Condition** - All hoses **shall** be checked for evidence of damage, wear, or imperfections. The check **shall** be made periodically during the operation. As the system is being assembled for a job, the hose and connections **shall** be checked to ensure that they are rated for use at the pressures to be used.

8.7.5 **Preflushing** - Before installing the nozzle, the system **shall** be completely flushed with sufficient water to remove any contaminants.

8.7.6 **Nozzles** - All orifices in nozzles **shall** be checked for any blockage and/or damage or imperfections before the nozzle is attached to the system. Defects should be corrected before the nozzle is used. Pressurize the system slowly to make sure that nozzle openings are open

and clear. Nozzles should also be checked to ensure that the orifice is properly sized for the flow and pressure to be used.

8.7.7 **Air Systems** - Steel-braided hoses should be used on air-operated fail-safe systems to prevent the system from being accidentally activated by someone stepping on the hose or running over it.

8.8 **Work Surface** - Before beginning work, the operator should ensure that it is possible to jet all the surfaces to be cleaned, and that a stable, secure working platform is available at all times from which to reach those surfaces. The operator should be able to maintain a sound and secure footing at all times. The working area should be checked, before beginning work, to ensure that the hoses and other required equipment do not interfere or pose hazards to the movement of the operator. All loose materials should be removed or securely fastened and the site checked to minimize the risk of slipping or tripping over an obstacle.

8.9 **Procedures for Entering the Working Area** - The owner or the owner's representative **shall** be requested to tell all those who normally work at the site, and especially those who might need access to the working area, that high pressure waterjetting will take place. These workers **shall** also be informed of the procedures to enter the working area.

8.10 **Connection Protection** - The point where the hose connects to the gun **shall** be fitted with a hose shroud, such as a length of heavy duty hose or a shoulder guard, which will act to prevent injury to the operator if the hose, pipe, or fitting breaks open.

8.11 **Material Safety Data Sheets (MSDSs)** - As required by the U.S. Occupational Safety and Health Administration (OSHA), MSDSs shall be available for any and all materials, chemicals, etc. that may be encountered in the course of the job.

8.12 **Disabling of Moving Equipment** - All moving equipment, such as agitators, choppers, conveyors, etc. that are in proximity with the waterjet operation **shall** be mechanically disabled (breaking a chain, coupling, etc.) or electrically disabled with an appropriate lock-tag-try procedure, except where the nature of the waterjet operations require continuous movement.

9.0 WATERJET TEAM

In most jetting operations it is an accepted practice to employ a minimum of two persons as a team. The number of operators required will vary, depending both on the size and nature of the work that must be carried out.

9.1 **Nozzle Operator** - The member of the team who holds a gun, lance, or delivery hose and controls the motion and direction of the jet(s) is known as the Nozzle Operator. The Nozzle Operator **shall** control the jetting operation while waterjet is taking place, ensuring that

a) the group works together as a team;

b) the Preoperating Procedures (Section 8) have been properly carried out;

c) the Operational Procedures (Section 10) are properly carried out;

d) the working area is properly prepared and maintained during waterjet operations; and

e) all necessary permits, permissions, procedures, and agreements have been obtained before work begins.

9.2 **Pump Operator** - The second member of the team, the Pump Operator, monitors and controls the pressurizing pump during the jetting operation. In addition, the Pump Operator **shall** watch the Nozzle Operator at all times to react in the case that any difficulty arises, or if the operator begins to show signs of fatigue. The Pump Operator **shall** monitor the working area and its surroundings in case anyone should try to enter the area or in case a potentially hazardous condition should occur. In either of these circumstances, or as otherwise necessary, the Pump Operator **shall** reduce the pressure in the supply hose to the gun until the condition has been dealt with. Caution **shall** be exercised when reducing pressure rapidly, because this can cause loss of footing by the Nozzle Operator.

9.3 **Additional Operators** - In addition to the Nozzle and Pump Operators, other personnel may be required on the team, depending on the site and nature of the work. For example, assistance may be required in handling a jetting gun if it is fitted with more than one jetting extension or if the hose must be fed forward into the workpiece. Alternately, if the pump is located at some distance, and out of the sight of the Nozzle Operator, a team member may be required to monitor the jetting action and the working area and to communicate between the Nozzle and Pump Operators.

9.4 **Back Thrust** - The back thrust from a jet can be calculated from the equation:

$$Back\ thrust\ (lb) = 0.052 \times Q \times \sqrt{P}$$

where:

Q is the flow rate in U.S. gallons/minute and

P is the jet pressure measured in psi

As an example, an operator working with a jet flowing at 10,000 psi at 10 gpm will experience a force equal to:

$$0.052 \times 10 \sqrt{10{,}000} = 0.052 \times 10 \times 100 = 52\ lb$$

It is not recommended that any one person be required to withstand a back thrust of more than one third (1/3) of his/her body weight for an extended period of time. For the above example, this means that the operator should weigh at least 156 lb in order to operate the nozzle.

9.5 **Rotation of Tasks** - The reaction force and the working environment (for example, spray) from the operation of a jetting gun can tire the gun operator. The Team Supervisor should set up a schedule to regularly change the operator of the gun and to rotate the members of the team to perform different tasks of the jetting operation.

9.6 **Fitness** - The Nozzle Operator and other team members **shall** be physically and mentally capable of performing the required operations.

9.7 **Code of Signals** - The noise that waterjets make and the nature of the protective equipment may limit voice communication. Clear signals for each step in the operation of the equipment (e.g., start the pump; raise the pressure; lower the pressure; shut down the pump) **shall** be agreed upon by the team. The Team Supervisor is responsible for ensuring that each member of the team understands the meaning of each signal before work begins.

9.8 **Single Person Operation** - A single person may operate a waterjet system where the pump pressure does not exceed 4,000 psi (275 bar) and the flow to the gun is less than 10 gallons per minute (38 liters per minute).

9.8.1 **Single Operator Guidelines** - All recommendations pertaining to team operations **shall** hold for single operators, except where exceptions in writing are obtained from the owner or contractor which permit individual operation of a designated waterjet system.

10.0 OPERATIONAL PROCEDURES

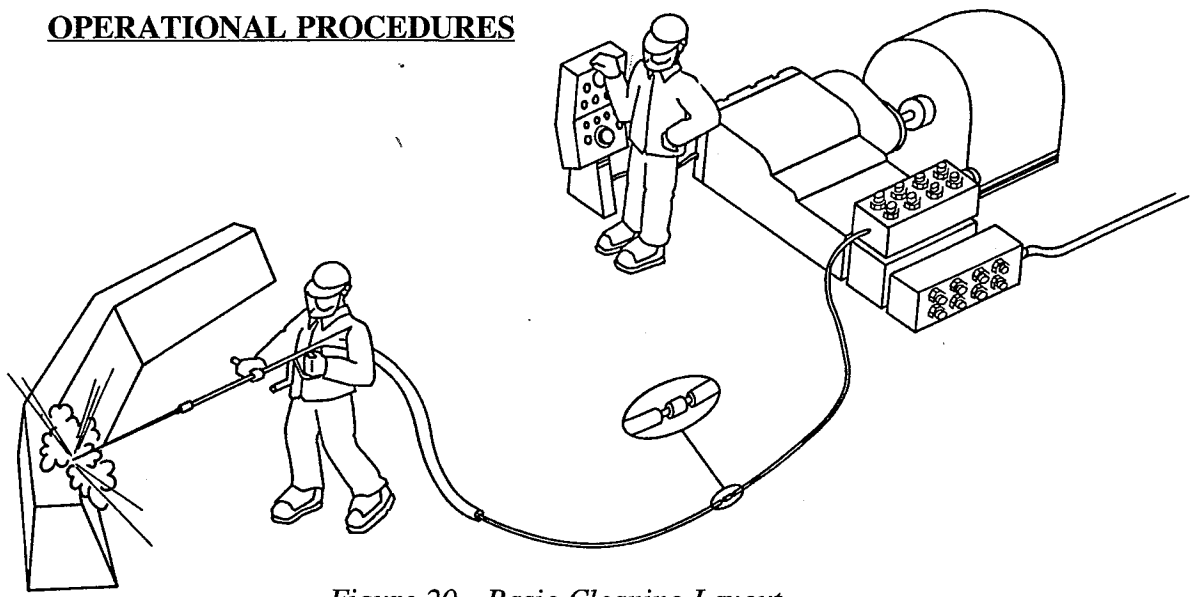


Figure 20. Basic Cleaning Layout

10.1 Proper Operation

10.1.1 **Start up** - The Pump Operator **shall** not start the unit (Figure 20) until told to do so, by word or signal, by the Nozzle Operator. Before bringing the unit up to pressure, on a second signal the Pump Operator **shall** ensure that the jetting nozzle is either directed at, or positioned within, the workpiece; that the Nozzle Operator has a secure stance and control of the nozzle; and that each team member is in the proper position to perform their task.

10.1.2 **Operational Check** - Both before and after bringing the system up to pressure the Pump Operator **shall** visually examine the hose and connections to the jetting gun or nozzle assembly to detect any leaks in the system.

10.1.3 **Tightening and Adjusting Components** - Apart from the normal adjusting of valves and other components required in a standard jetting procedure, no attempt **shall** be made to tighten or otherwise adjust any nut, hose connection, or other fitting or component of a high pressure waterjet system while the system is under pressure. The pumps **shall** be stopped and any pressure in the line discharged before any repair or other adjustment is made.

10.1.4 **Equipment Malfunction** - If any dump valve or pressure relief valve does not work properly when tested at the beginning of an operation, or if the valve fails during operation, then the system **shall** be shut down. The component **shall** then be repaired or replaced by properly trained personnel before the system is restarted.

10.1.5 **Reaction Force** - The Pump Operator **shall** slowly raise the pressure of the system to allow the Nozzle Operator to adjust to the changing reaction force from the nozzle. Once the operating pressure has been reached, then the pressure **shall** not be further adjusted without the operator being aware that an adjustment is to occur. When the pressure is reduced at shutdown, the pressure should also be lowered slowly to prevent the sudden lack of force from causing the operator to lose his/her balance.

10.1.6 **Operating Pressure and Orifice Selection** - The Nozzle and Pump Operators **shall** be told the working pressure for the job to be undertaken. Pump and nozzle orifice sizes **shall** be selected to match these conditions.

10.1.7 **Effect of Pressure Change** - The reaction force experienced by the Nozzle Operator can suddenly change when the trigger on a gun activates a dry shutoff or dump valve. The operator should be familiar with this change in thrust at pressures up to the working pressure for the job. The operator should stand in such a way as to be able to withstand this change. The system may include devices that are designed to reduce this effect.

10.1.8 **Operator Position** - The Pump Operator **shall** monitor the positions of other team members while the system is in operation, and **shall** lower the pressure of the system if any team member approaches a hazardous or potentially hazardous position.

10.1.9 **Use of Balanced Nozzle Orifices** - Particularly when cleaning internal surfaces, nozzle orifices may be used that have jets issuing at some angle to the body of the nozzle. These are often designed so that the reaction forces from opposing jets are equal, reducing the out-of-balance force on the operator. However, if one nozzle orifice should be damaged or blocked, then the flow from such opposing jets may no longer balance. This may throw a sudden and unexpected sideways force on the nozzle that may cause the operator to lose control. These nozzle orifices should, therefore, be checked in particular before operation, and they should only be brought up to pressure when they are located within the work piece.

Where balanced nozzle orifices are used in a shotgunning type of operation, the pressure to the gun should be raised slowly to ensure that the jets from the nozzle are providing equal thrust. The operator should also brace the gun to protect against sudden sideways loading from an instantaneous blockage or failure of a nozzle.

10.1.10 **Work Stoppage** - Waterjet operations **shall** stop

(a) if any unauthorized person enters the working area;

(b) if a hazardous or potentially hazardous condition is detected;

(c) if an alarm is sounded within the plant or works; or

(d) if any of the *Recommended Practices* in this document are not being followed.

10.1.11 **Shutdown** - Care should be taken to release the pressure in the system, especially when a dry shutoff gun is in use. The Nozzle Operator **shall** ensure that no pressure remains in the line or gun after shutdown.

10.2 **Improper Use** - The hose or any other component of a high pressure waterjet system **shall** not be used as a means of support for the operator or to carry the operator's weight, particularly when going up or down into a confined space.

10.3 **Access** - During the time that waterjet is in progress no unauthorized persons **shall** be allowed into the area closed off by the barriers. Warning notices restricting entry into the area **shall** be clearly posted outside the barriers.

10.4 **Procedures for Entering the Working Area** - Access procedures should be agreed upon before work begins, and should include steps to ensure that no person enters the working area while waterjet is in progress and until the operators are aware that entry is required. Those who wish to enter the area, or to have operations stopped, should first gain the attention of a team member other than the Nozzle Operator. The Nozzle Operator **shall** not be distracted while operating the gun until the jet has been shut down.

10.5 **Additional Protection** - Where it is necessary to shield personnel or to protect equipment from water and solid materials removed from, rebounding from, or passing through the workpiece, additional protective barriers or shields **shall** be set up within the working area. Protective barriers should be arranged so as not to interfere with the access of the operator to the working surface.

10.6 **Protective Equipment** - All personnel working or entering the blocked off area while cleaning or cutting is in progress **shall** wear the required protective equipment.

10.7 **Pressurizing the System** - Pressure **shall** be increased slowly while the system is being inspected for leaks and/or faulty components. All leaks or faulty components **shall** be repaired or replaced immediately. The system **shall** be depressurized for repairs.

10.8 **Shotgunning**

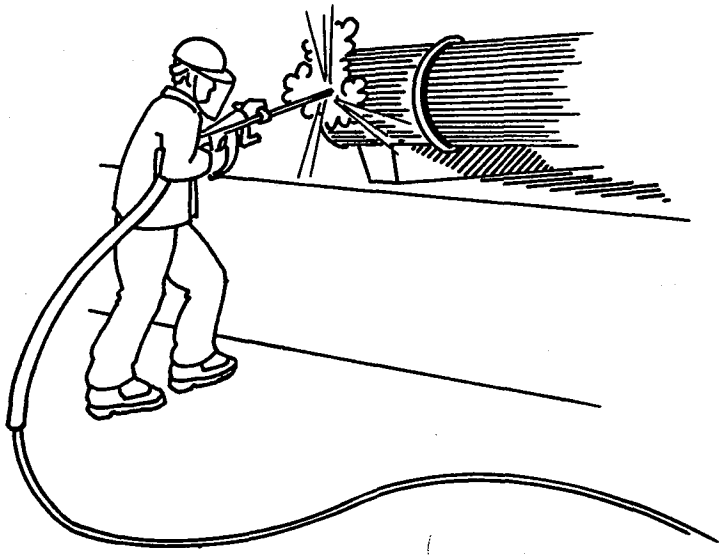


Figure 21. Shotgunning

10.8.1 **Controls** - The jetting gun **shall** be fitted with either a dump system or dry shutoff control valve. The person operating the gun, lance, or nozzle assembly **shall** have direct control of the dump system (Figure 21).

10.8.2 **Attendance** - The system **shall** never be left unattended when pressurized.

10.8.3 **Multiple Operation** - When more than one shotgunning operation is being performed within the same area, a physical barrier **shall** be installed or adequate spacing between operators **shall** be maintained to prevent the possibility of injury from the high pressure water.

10.8.4 **Holding the Target** - Objects to be cleaned **shall never** be held manually.

10.8.5 **Minimum Length** - Users should follow manufacturer's recommendations.

10.8.6 **Maximum Length** - The length of the lance, from the triggering device to the nozzle, **shall** not exceed a length beyond which the operator can maintain control of the lance at all times.

10.9 **Moleing or Flex Lancing**

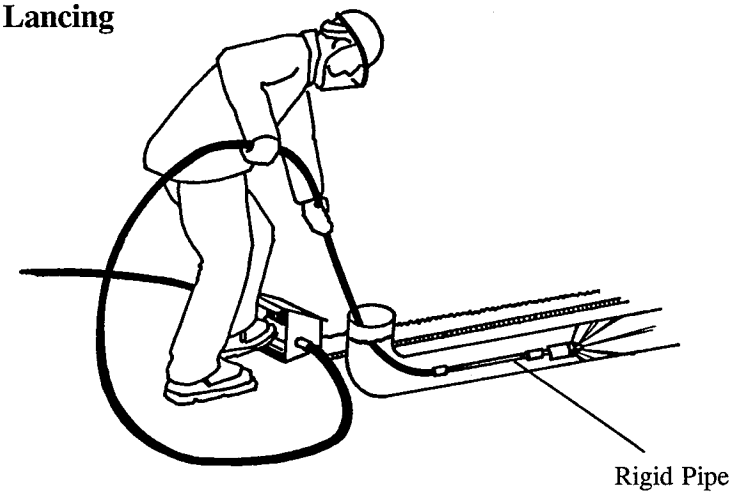


Figure 22. Moleing or Flex Lancing

10.9.1 **Control** - The feed assembly to the flexible lance or hose **shall** be fitted with either a dump system or a dry shutoff control valve. The operator inserting the nozzle **shall** maintain control of the dump system (Figure 22).

10.9.2 **Reversing** - A positive method **shall** be used to prevent the nozzle from reversing direction inside the item being cleaned.

10.9.3 **Retro jet use** - During manual operations, the entrance to a line or pipe **shall** not be cleaned with a nozzle containing backward facing jets without adequate shielding. If this is not available then some other method of cleaning the entrance **shall** be used.

10.9.4 **Clearance** - The clearance between the outside diameter of the hose, lance and nozzle assembly and the inside wall of the item being cleaned **shall** be sufficient to allow adequate washout of water and debris.

10.9.5 **Pressurization** - During manual operations, the nozzle **shall** be inserted into the tube before pressurizing. The nozzle should be far enough into the tube so that any backward facing jets do not pose a hazard to the operator. Conversely, the system **shall** be depressurized before removing the nozzle from the tube.

10.9.6 **End Identification** - Hoses **shall** be conspicuously marked no closer than 2 ft. from the nozzle to warn the operator when the nozzle is getting close to the tube entry.

10.9.7 **Nozzle Support** - Where the length of the nozzle and rigid coupling is less than the inside diameter of the pipe, a length of rigid pipe of not less than the diameter of the pipe being cleaned should be fitted directly behind the nozzle, or a suitable safety shield should be provided to protect the operator. This prevents the nozzle from turning around 180° and doubling back toward the operator.

10.9.8 **Lance Retention Device** – A lance retention device shall be installed on the pipe entrance. This will prevent the mole from being pulled out of the pipe under pressure.

10.10 **Rigid Lancing**

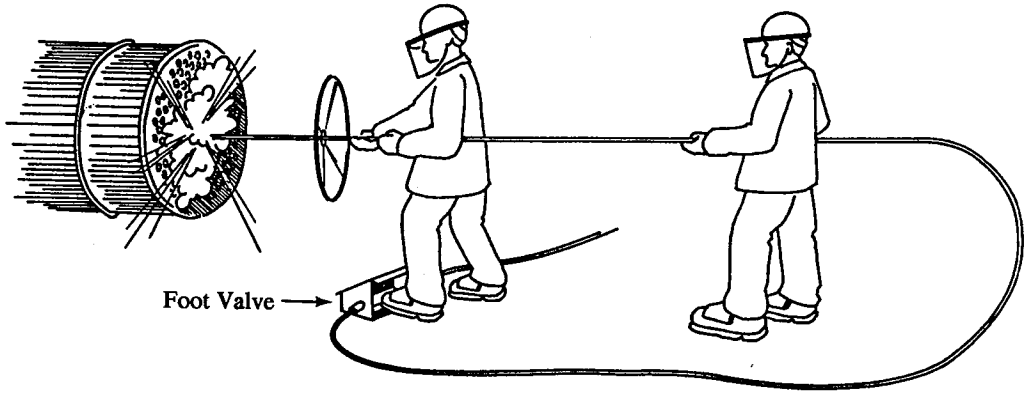


Figure 23. Rigid Lancing

10.10.1 **Control** - The jetting extension or lance **shall** be fitted with either a dump system or a dry shutoff control valve. The operator inserting the nozzle **shall** have direct control of the dump system (Figure 23).

10.10.2 **Lance Length** - The length of a rigid lance or a lance and series of extensions **shall** not be greater than the operator can control at all times. If the lance length required is beyond the control of one operator, then a second operator **shall** be used to assist in controlling the lance.

10.10.3 **Clearance** - The clearance between the outside diameter of the lance and nozzle and the inside wall of the item being cleaned **shall** be sufficient to allow adequate washout of water and debris.

10.10.4 **Shields** - When lancing tubes with a rigid lance a safety shield should be installed, where practicable, around the lance to prevent a lance nozzle from being inadvertently withdrawn and causing injury.

10.11 **Additives** - Any water additive (chemical, detergent, or solid particle) **shall** be used in accordance with the manufacturer's recommendations.

11.0 CARE AND MAINTENANCE OF EQUIPMENT

11.1 **Maintenance, Servicing, and Repair** - Three levels of maintenance should be carried out on the components of high pressure waterjet systems:

a) First is the daily maintenance that **shall** be carried out by the normal equipment operators. This includes a regular check that the components being used are correct for the job, that the connections and parts are in good condition, that the connections are properly made, and that no damage has occurred to the components of the system.

b) Second is the regular checking of the external and internal parts of the valves, fittings, and gun components of the system. Although part of this may be carried out by the operator, it is recommended that this check be a part of a routine scheduled event at a central facility conducted by trained personnel.

c) Third is the servicing of the pump and major components of the system. This maintenance **shall** be performed as scheduled and in the manner recommended by the manufacturer and should only be performed by trained and competent personnel.

11.2 **Maintenance Scheduling** - Equipment care and maintenance scheduling **shall** recognize that parts and equipment naturally wear out during jetting operations. Special care should be taken to examine the components of the jetting system to be sure that they are in fit condition to perform their necessary function. This inspection should be carried out while the system is being assembled before a jetting operation, and also when it is being taken apart. Both of these times allow for the examination of the threads and other internal parts that the operator could not otherwise see. All equipment **shall** be examined, and all necessary or scheduled maintenance performed, at a minimum, as recommended by the manufacturer of that component.

11.3 **Drive Unit** - Where an engine is used to drive the pump, the engine **shall** be checked at least daily, and, at a minimum, at the intervals set by the manufacturer. Such checks **shall** ensure that all necessary fluids, including fuel, oil, hydraulic fluid and cooling water are present, in good condition, and at the recommended levels. All belts will be checked for the correct tension and to be sure that they are in good shape and that they are not peeling, cracked, or otherwise damaged. All guards **shall** be checked to ensure that they are properly secured and undamaged. The control cables and engine controls **shall** be inspected daily to ensure that they are working properly.

11.4 **Pressurizing Pump** - The pump **shall** be examined both when shut down and when operating. To ensure that there are no leaks or loose fittings, both visual and listening checks should be performed. The listening checks alert the operator of any unusual noises coming

from the unit that might indicate an internal problem. Regular visual checks should be made of the plungers and seals while the unit is not operating, and on a schedule at least as often as recommended by the manufacturer. In addition, all the maintenance specified by the manufacturer **shall** be performed on the schedule that has been specified.

11.5 **Water Inlet, Reservoirs, and Booster Pump** - Before the unit is started, a visual check should be performed to determine the condition of the low pressure water line feeding into the pump, any booster pump required to assist in supplying water at the right pressure and flow to the pressurizing pump, and any containers used to store water during the jetting operation. This check should ensure that there is sufficient water to supply the high pressure pump during the operation planned. Tanks should be free of rust and dirt. All the pump maintenance specified by the manufacturer **shall** be performed on the schedule that has been specified.

11.6 **Filters and Strainers** - Regular checks should be made of all fluid filters to ensure that they are not blocked or damaged. Care should be taken when examining, changing, or cleaning the filters to ensure that no solid particles escape into the supply lines to the pump and nozzle. These solid particles can damage the valves and nozzles and make the pump run poorly. All fluid filters should be checked at regular intervals, especially where the supply of water is of poor quality. Filters should be examined at least as frequently and in the manner specified by the pump manufacturer. Filters should be adequately sized to collect any particles which might block the smallest opening in the system.

11.7 **Hose Assemblies** - The condition of all hoses, high pressure tubing, and their connections is critical to the proper operation of the equipment. The outer covering of the hose should be examined for any broken wires, obvious damage from being run over or rubbed against a surface, or places where ballooning of the hose has occurred as a result of internal failure.

Where the hose is stored on a reel, care should be taken to wrap the hose on the reel in a manner that will not lead to pinching or damage. The reel should also be inspected to ensure that it has sufficient lubricating oil for proper operation.

During operation of the equipment, the hose and all other components of the system **shall** be periodically examined to ensure that no damage has developed. The pump **shall** be shut down, and repairs carried out, whenever damage such as that identified above is seen.

11.8 **Nozzles, Nozzle Holders, and Lance Connections** - The system should be flushed with water before installing the nozzle. The nozzles should be checked to ensure that they are not blocked or damaged and that they seat properly in the holder or manifold. The condition of the threads holding the nozzle in place should be checked to ensure that they are in good condition and not worn. All damage **shall** be repaired, or the parts replaced, before jetting begins.

11.9 **Trigger and Valve Controls** - Each hand-operated and foot-operated valve **shall** be manually checked before a unit is put into operation to ensure that it is clean and properly functioning. The valves should be periodically disassembled to examine the condition of the internal components and to replace worn parts. Valve guards should also be inspected and any defects, such as bent plates, that might interfere with the proper operation of the unit **shall** be corrected.

11.10 **Electrical Equipment** - Special precautions should be maintained when operating high pressure waterjet systems around electrical components. Before using the equipment, and on at least a daily basis, all electrical boxes, connections, switches, cables, and fittings **shall** be checked for damage. Precautions should be taken to ensure that water cannot enter these components and that they are not liable to be damaged by the entry of water or abrasive from the jetting process. Any connections made **shall** be placed in such a manner that they cannot fall or lie in a pool of water created by the jetting operation. The correct direction of rotation of the electric motor should be checked on initial installation and after every reconnection to a power supply.

11.11 **Trailers** - When using a trailer-mounted unit, the unit should be inspected each time it is moved. This examination should include brakes, lights, jacks and connections for stabilizing the unit in place, the tow bar connection including safety chains, and the tires.

Trailers should only be towed by vehicles that are capable of towing the load and that are properly connected.

11.12 **Use of Recommended Tools** - **IMPORTANT**: provide and use only tools recommended by the manufacturer for assembling and disassembling high pressure components. Any tool that can cut into a part, such as a pipe wrench, can create a weak point that can lead to a hazardous condition and serious part failure. Such tools are not recommended for use.

11.13 **Compatibility** - All the components of a high pressure waterjet system should be checked to make sure that they are of the correct size, thread, and pressure rating for the use intended.

11.14 **Freeze Precautions** - When it is likely that a high pressure waterjet system will be exposed to freezing conditions, the unit should be protected. Equipment manufacturers' recommendations should be followed, and the procedures should include steps to circulate antifreeze through the water lines of the system. This can be carried out by removing the gun from the delivery line and then directing the flow from the hose back to the supply reservoir. Once the correct amount of antifreeze has been added, the pump can be run until the return flow to the tank shows that antifreeze is circulating. The dump and any bypass circuits should also be activated to ensure that the water in those lines is similarly treated with antifreeze.

WARNING:

IF THE WATER IN A PUMP OR HOSE APPEARS FROZEN, THEN **NEITHER** THE PUMP NOR THE DRIVE MOTOR TO THE PUMP SHALL BE STARTED UNTIL THE SYSTEM HAS BEEN SHOWN TO BE CLEAR OF ICE BY HAVING LOW PRESSURE WATER PASSED THROUGH THE SYSTEM TO THE NOZZLE END, WITH THE NOZZLE FIRST HAVING BEEN REMOVED.

12.0 PERMANENT CLEANING AREAS

12.1 **Use of a Permanent Site** - A special area may be set aside for waterjet operations. This area **shall** be managed with the same degree of precaution, and with similar barriers and warning signs, as any temporary waterjet area.

The correct operating procedures for the use of jetting equipment should be prominently and clearly displayed in permanent cleaning areas. The area should be designed and maintained with proper lighting, ventilation and with facilities for the proper collection and disposal of both solid and liquid wastes.

12.2 **Recommendations** - All other parts of these *Recommended Practices* **shall** apply to the use of permanent cleaning areas.

13.0 GLOSSARY: DEFINITIONS OF AND GUIDELINES FOR OPERATING COMPONENTS OF WATERJET SYSTEMS

Note: Similar equipment is now used for waterjet operations in many countries. It is considered important that the same words be used for similar parts of a system, where this is possible. For this reason many of the following terms have been based on an original definition in the "Code of Practice for the Use of High Pressure Waterjetting Equipment," published by the Association of High Pressure Waterjetting Contractors in the United Kingdom. This source is gratefully acknowledged.

13.1 **Abrasive** - Any solid particles, either soluble or insoluble in carrier fluid, that are introduced into a waterjet before it hits the target surface. Such particles are often used to increase the effectiveness of pure waterjets for some applications. Abrasives can be used to prepare a surface for painting as well as for cutting materials.

13.2 **Abrasive Feed System** - System that includes a storage vessel or hopper for the abrasive, a hose or tube to carry the abrasive to the point where it is inserted into the waterjet, and a device for inserting the abrasive into the waterjet stream (Figure 24).

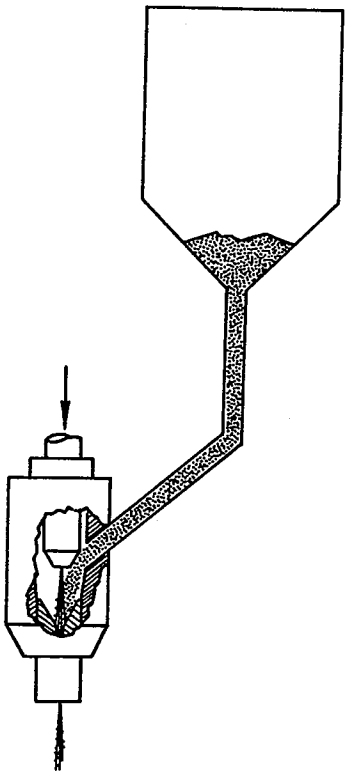


Figure 24.

13.3 **Abrasive Jet** - A waterjet where solid particles are introduced into the jet stream before the jet hits the target. Such abrasive particles can be introduced in three ways: Entrained Abrasive, External Abrasive, and Slurry Abrasive.

13.3.1 **Entrained Abrasive** - The particles are added to the jet stream after the jet has accelerated through an orifice but before the resulting stream has been reshaped through a collimating nozzle.

13.3.2 **External Abrasive** - The particles are added to the jet steam after it has left the final orifice.

13.3.3 **Slurry Abrasive** - The particles are added to the water before it is accelerated through an orifice.

13.4 **Automatic Pressure Relief Devices** - Devices included in a high pressure waterjet system to provide a way of automatically limiting the system pressure. Automatic Pressure Relief Devices can be of several types:

(a) Automatic Pressure Regulating Valves;
(b) Bursting and rupture discs, when set in a proper holder;
(c) Bypass Valves; or
(d) Pressure Relief Valves.

An Automatic Pressure Relief Device should be mounted close to the discharge outlet of the pressurizing pump, since the pressure at this point is the highest in the system. This location will also allow a more immediate reduction in pressure, without retaining higher pressures in downstream components of the system.

13.4.1 **Automatic Pressure Regulating Valve** - Valve used to automatically control the working pressure in the high pressure waterjet system by controlling the bypassing water flow. When the pressure in the system exceeds a set level, the valve will partially open. As the valve opens more, more water is bypassed and less flows to the nozzle. The water passing through the valve can be directed either back to the supply reservoir to the pump or to other disposal.

An Automatic Pressure Regulating Valve may be used to control the operating pressure at which a system operates, and if so, the valve should be checked to ensure that it is set at the correct value before it is used in each waterjet operation.

When there is no demand for high pressure water, this valve may be used to ensure that the system pressure is brought down to a low level. This valve is sometimes referred to as an unloading valve.

13.4.2 **Bursting or Rupture Disc** - This is normally a metal disc, held in a specially designed holder, that will fail when the pressure applied to it exceeds a set level. Discs can be made of different materials and are of different sizes. A proper-sized disc **shall** be used for a given operating pressure.

The holder **shall** be designed and located so that any water passing through it is not directed at an operator or other component of the high pressure waterjet system.

13.4.3 **Bypass Valve** - Valve that can be adjusted by the operator, either manually or automatically, to control the flow, and thus the pressure, of the jet stream issuing from the nozzle.

13.4.4 **Pressure Relief Valve** - Valve that is normally held in the closed position by a mechanical device, such as a spring. It is designed to open when the pressure in the system exceeds a set value.

13.5 **Burst Pressure** - The internal pressure within a component of a high pressure waterjet system at which it will fail.

Note: High pressure equipment undergoes a cyclic loading because of the reciprocating movement of pistons. This will fatigue the parts of the system so that, with time, the strength of the components will decline.

13.6 **Catcher** - When a plain or abrasive laden waterjet is used in a cutting operation, a device can be placed on the opposite side of the workpiece to catch the spent jet, abrasive, and particles of the material. This Catcher is fitted with a waste tube that carries this spent material away from the area.

13.7 **Changeover Valve** - A valve that the operator can adjust to send the water from the pressurizing pump to either one or several pieces of waterjet equipment that are supplied by the pump. This valve can be operated either manually or by a secondary power circuit attached to the high pressure waterjet system.

13.8 **Collimating Nozzle** - The secondary nozzle used below the mixing chamber to refocus the stream of high pressure water and abrasive in conventionally mixed abrasive waterjet systems (Figure 25).

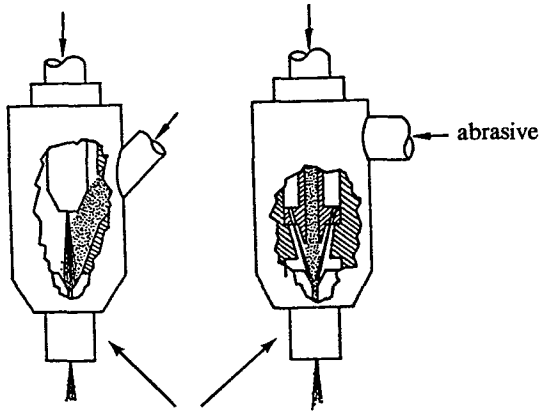


Figure 25. Abrasive Mixing Nozzle Assembly

13.9 **Dry Shutoff Control Valve** - Valve that is normally manually controlled by the Lance or Nozzle Operator to start and stop the flow of water to the nozzle. Although closing this valve stops the water flow to the nozzle, it keeps the pressure in the supply line at the system's working pressure. When this valve is used the system **shall** also be fitted with an Automatic Pressure Regulating Valve to ensure that the system's working pressure is not exceeded.

When this valve is used the operator **shall** take care to release the pressure in the water supply lines after the pump has been shut down. This is to ensure that the system is not left under pressure. This valve can also be operated by a secondary power circuit attached to the high pressure waterjet system.

13.10 **Double Trigger Gun** - A gun which requires that two triggers be activated by the operator, one with each hand, in order to generate a high pressure waterjet.

13.11 **Dump System** - The system should be equipped with a device that will either shut down the pump, idle it to a low revolutions per minute (rpm), bypass the flow, or reduce the discharge pressure to a low level. The dump system **shall** be manually controlled only by the Nozzle Operator. The dump system actuator device should be shielded to prevent accidental operation. This device **shall** be controlled by the operator's hand or foot and **shall** dump the high pressure water stream if the operator releases it. Where the water dumped through a dump system is not immediately released to the open air, but passed into a dump line, the dump line must be secured so that it does not whip when active.

13.11.1 **Dump Control Valve** - The valve controlling the dump system is normally manually controlled by the operator of the lance or jetting equipment. This valve is normally closed by the operator to send the water to the nozzle. When the valve is released, it will automatically stop water flow to the lance and/or nozzle assembly, since it opens a much larger flow passage through which the water is diverted at low pressure. For this to be effective both the passage through the valve and the diameter of the relief line should be large enough that no significant resistance to the water flow develops, even at maximum pump output. A valve size should be selected that will not cause generation of significant back pressure at the maximum possible pumping rate of the pump.

This valve can also be used with an electrical or pilot pressure system that includes additional circuits that must be engaged for the valve to actuate. These systems should be designed such that if the valve fails, it opens.

13.11.2 **Solenoid and Electrically Operated Control Dump Systems** - All electrically controlled dump systems should be of fail-safe design. Voltage of an alternating current (AC) or direct current (DC) dump system, handled by personnel, should not exceed 24 volts and should be fuse protected.

13.12 **End Fittings and Couplings** - High pressure hose end fittings and couplings **shall** be manufactured to be compatible with the hose and **shall** be tested as a unit.

13.13 **Filter or Strainer** - The water system should be equipped with a filter or strainer to prevent particles from restricting the flow through orifices in the nozzle or damaging seals of the pump, etc. The strainer or filter should be capable of removing particles smaller in size than half the diameter of the smallest opening. Smaller filter sizes are strongly recommended, since the pump and other system components will last much longer.

13.14 **Flexible Lance** - A flexible tube or hose section carrying water to the nozzle; normally located between the trigger or control valve and the nozzle.

13.15 **Foot-controlled Valves** - Control valve designed so that the operator can activate it using a foot (Figure 26). This allows the operator to use both hands to hold and move the lance and/or nozzle assembly.

When a foot valve is used, it must be placed within a frame that will guard the valve from being accidentally operated and that is sturdy enough so that it will not be accidentally moved or knocked over when it is used.

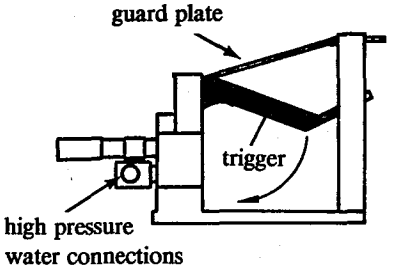


Figure 26. Foot Valve

13.16 **High Pressure Hose** - A flexible hose that can be used to carry water and/or other fluids from one part of the high pressure waterjet system to another. The hose should have a

burst rating of a minimum of 2.5 times the intended working pressure it is certified for use at by the manufacturer. The high pressure hose **should** be tested at 1.5 times working pressure.

Note: The hose shall not be used at a pressure above the manufacturer's recommended working pressure.

13.16.1 **Fiber Reinforced Hoses** – The failure of a fiber reinforced hose may cause a "pin prick" hole, with the possible formation of a hazardous jet. Adequate safety precautions must be taken.

13.17 **High Pressure Waterjet Systems** – High Pressure Waterjet Systems are water delivery systems that have nozzles whose function is to increase the speed of liquids. Solid particles or additional chemicals may also be introduced, but the exit in all cases will be a free stream.

In terms of these *Recommended Practices*, the system **shall** include the pumps (pressure-producing devices), hoses, lances, nozzles, valves, safety devices, and attached heating elements or injection systems.

High pressure waterjets are used in several ranges of pressure. The following divisions are made to clarify these ranges:

13.17.1 **High Pressure Water Cleaning** - The use of high pressure water, with or without the addition of other liquids or solid particles, to remove unwanted matter from various surfaces, and where the pump pressure is between 5,000 psi (340 bar) and 30,000 psi (2,041 bar).

Where the term "high pressure" is used without further qualification it is considered to describe jets being used at pressures below 30,000 psi (2,041 bar).

13.17.2 **High Pressure Water Cutting** - The use of high pressure water, with or without the addition of other liquids or solid particles, to penetrate into the surface of a material for the purpose of cutting that material, and where the pump pressure is between 5,000 psi (340 bar) and 30,000 psi (2,041 bar). Where the term "high pressure" is used without further qualification it is considered to describe jets being used at pressures below 30,000 psi (2,041 bar).

13.17.3 **Pressure Cleaning** - The use of pressurized water, with or without the addition of other liquids or solid particles, to remove unwanted matter from various surfaces, and where the pump pressure is below 5,000 psi (340 bar).

13.17.4 **Pressure Cutting** - The use of pressurized water, with or without the addition of other liquids or solid particles, to penetrate into the surface of a material for the purpose of cutting that material, and where the pump pressure is below 5,000 psi (340 bar).

13.17.5 **Ultra High Pressure Water Cleaning** - The use of high pressure water, with or without the addition of other liquids or solid particles, to remove unwanted matter from various surfaces, and where the pump pressure exceeds 30,000 psi (2,041 bar).

13.17.6 **Ultra High Pressure Water Cutting** - The use of high pressure water, with or without the addition of other liquids or solid particles, to penetrate into the surface of a material for the purpose of cutting that material, and where the pump pressure exceeds 30,000 psi (2,041 bar).

13.18 **Hose Assembly** - The hose with a suitable end coupling attached, at each end of the hose, in accordance with the manufacturer's specifications.

13.19 **Hose Shroud** - A length of flexible material, usually formed into a tube around a hose end coupling or across the connection to the jetting gun. The shroud provides some instantaneous protection should a hose burst. It will not form a permanent barrier to the flow of water from a damaged hose.

13.20 **Jetting Gun** - The hand-operated device that is often used in manual waterjet (Figure 27). It is normally connected to the high pressure system by a high pressure hose assembly. The gun is made up of a control valve, mounted within a guard, a lance section, and then a nozzle assembly, which may include one or more nozzles. The gun may also include a support bracket and shoulder pad and/or one or more support handles.

The gun can be further defined by the type of control valve that is used to release the pressure. If the pressure is dumped to atmosphere when the valve is released, then the gun is a dump gun; if the pressure is retained in the system, by using a Dry Shutoff Control Valve, then the gun is a dry shutoff gun.

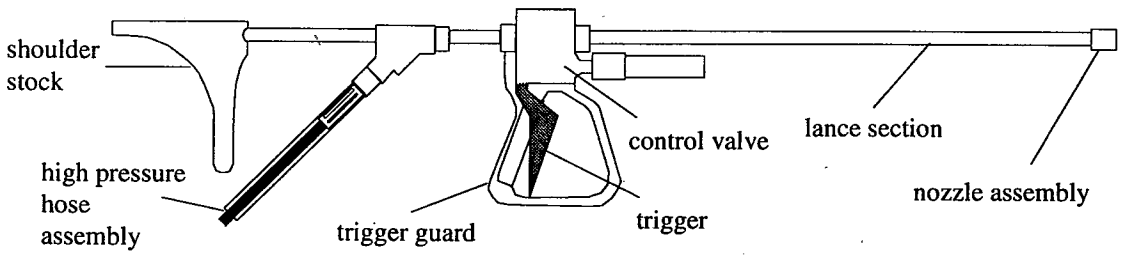


Figure 27. Jetting Lance

13.21 **Jetting Gun Extension** - The jetting gun extension is a length of tubing, either piping or lance, that is used to extend the reach of the gun. Extension pieces **shall** be manufactured from suitable material and with proper end connections for the application. Each extension

shall have a minimum burst strength of at least 2.5 times the highest actual working pressure used. Reference should also be made to paragraphs 10.9.6 and 10.9.7.

13.22 **Jetting Gun Trigger** - The control valve has a trigger that makes it easier for the operator to control the device. This lever, or trigger, **shall** be designed for easy operation by an operator wearing gloves. The trigger **shall** include a catch or other method of lock-out so that it cannot be operated until this catch is released.

13.23 **Jetting Manifold** - The manifold provides an attachment at the end of the lance into which individual nozzles or nozzle holders may be threaded to distribute the waterjets over a given pattern. Alternating nozzles may be directed forward and backward from the manifold to reduce or even balance the thrust exerted by the jets on the manifold (see section 10.1.9). The lance and operator **shall** be so arranged to shut the system down without damage if a nozzle is plugged, causing unbalanced thrust.

13.24 **Lancing** - An application whereby a rigid or flexible lance and nozzle combination is inserted into, and retracted from, the interior of a pipe or tubular product.

13.24.1 **Flexible Lance** - A flexible tube or hose section carrying water to the nozzle or nozzle manifold.

13.24.2 **Rigid Lance** - A rigid tube carrying water to the nozzle or nozzle manifold.

13.25 **Moleing** - An application whereby a hose fitted with a nozzle is inserted into, and retracted from, the interior of a tube. It is a system commonly used with a self-propelling nozzle for cleaning the internal surfaces of pipes or drains (Figure 28).

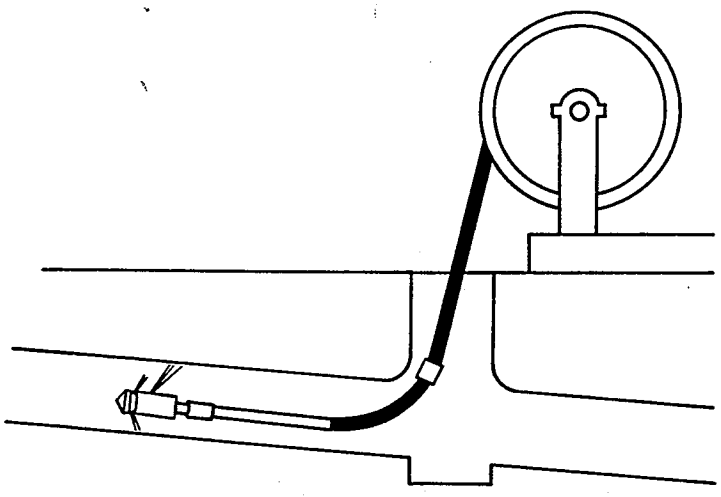


Figure 28. Moleing

Moles can be self-propelled by their backward-directed jets or can be manufactured to be fitted with various shapes, sizes, and combinations of forward-directed and backward-directed jets. A mole should include, directly behind the nozzle assembly, a section of rigid pipe or tubing sufficiently long that it will prevent the mole from turning around within the pipe.

13.26 **Nozzle** - A device with one or more orifices through which the water discharges from the system. The nozzle restricts the area of flow of the fluid, accelerating the water to the required velocity and shaping it to the required flow pattern. Nozzles are also commonly referred to as bits, tips, or orifices.

The nozzle may be further defined by the type of jet that it produces.

13.27 **Nozzle Holder** - The threaded fitting that holds a nozzle insert and attaches it to the jetting manifold or shot gun lance extension.

13.28 **Nozzle Insert** - A replaceable nozzle, usually fitted with one orifice and designed to fit into a nozzle holder.

13.29 **Operator** - A person who has been trained and has demonstrated the knowledge, skill and experience to assemble, operate, and maintain a waterjet system.

13.30 **Operator Trainee** - A person not qualified, because of lack of knowledge, skill and/or experience, to perform as an operator without supervision.

13.31 **Orifice** - The opening at the end of a nozzle through which the water or fluid jet exits from the system.

13.32 **Pressure Gauge** - The high pressure waterjet system should be equipped with a gauge indicating the pressure being developed. Gauges **shall** have a scale range of at least fifty percent (50%) above the maximum working pressure of the system and should be fitted with a pressure snubber for more accurate pressure reading.

13.33 **Pressure Intensifier** - A pump that increases the pressure of water supplied to it, using the reduction in area of a common piston to multiply the pressure from the driving fluid, which is usually oil.

13.34 **Pressure Pump** - A pump that will increase the pressure of water delivered to it and deliver it into a common manifold to which either flexible hoses or rigid tubing connecting to lances and nozzles is attached. These pumps can be either mobile or permanently mounted and are most often of a positive displacement plunger style that will provide a constant flow of water at a given speed of rotation.

The pump should have a permanently mounted tag designed to provide the following information:

(a) Name of manufacturer;

(b) Model, serial number, and year of manufacture;

(c) Maximum performance in terms of gallons or liters per minute and pressure in bar or psi; and

(d) An outline of recommended safety procedures.

13.35 **Pressure Relief** - The high pressure waterjet system **shall** be equipped with an automatic relief device on the discharge side of the pump.

13.36 **Pulsating Waterjet** - A jet that consists of individual slugs of water or liquid.

13.37 **Rigid Lance** - A rigid metal tube used to extend the nozzle from the end of the hose or jetting gun.

13.38 **Rigid Lancing** - An application whereby a lance or jetting gun extension is fitted with a nozzle, nozzle assembly, or nozzle manifold. This lance is inserted into, and retracted from, the interior of a tube, tank, or vessel.

13.39 **Bursting or Rupture Disc** - This is normally a metal disc, held in a specially designed holder, that will fail when the pressure applied to it exceeds a set level. Discs can be made of different materials and are of different sizes. A proper-sized disc **shall** be used for a given operating pressure.

The holder **shall** be designed and located so that any water passing through it is not directed at an operator or other component of the high pressure waterjet system.

13.40 **Self-Rotating Nozzle Assembly** - A device, including a bearing or swivel assembly, that fits onto a hose or lance section. The device contains at least two jets offset so that the reaction force from the jets causes the nozzle assembly to rotate without any additional external force being applied.

13.41 **Shotgunning** - A hand-held application whereby an assembly of a lance and a nozzle can be manually manipulated in virtually all planes of operation.

13.42 **Spray Bar** - A special manifold designed to distribute nozzles along a linear tube or pipe. A spray bar is most often used to provide an array of fan jets that overlap, and is frequently used to clean large areas.

13.43 **Starter Rod** - A length of rigid tubing or pipe mounted behind the nozzle assembly for use with a flexible lance.

13.44 **Support Handle** - An additional handle that can be attached to a jetting gun to provide additional support for the operator in directing the gun. A support handle can be fitted with a switch for additional control functions.

13.45 **Waterjet** - A rapidly moving stream of water of different shapes and types exiting from a nozzle orifice. The speed of the jet depends on the pressure drop across the nozzle orifice.

13.45.1 **Fan Jet** - A jet designed to spread out as it leaves the orifice. The divergence is usually, but not necessarily, restricted to one plane. The degree at which the jet tapers out from the central axis is often used to designate the jet produced. A typical application is for cleaning larger areas requiring less energy to remove unwanted matter.

13.45.2 **Retro Jet** - A jet that is directed in the reverse direction of motion of the nozzle. A retrojet is typically used to provide a thrust force to move the nozzle into the workpiece and to provide jets to clean in otherwise inaccessible locations. It may also be used to balance the forward jet thus providing zero thrust for underwater applications or those on scaffolding.

13.45.3 **Straight Jet** - The straight jet exits from a circular orifice and is used to carry the maximum force to the target with a minimum of energy dispersion. A typical application is for cutting or for general cleaning of matter with higher shear and/or bond strength. A straight jet is also known as a zero-degree jet, since it is not designed to spread.

13.46 **Whip Lock** - A short length of wire or cable looped over each end of two hoses that are connected by a coupling. A whip lock or whip check is designed to stop the ends of the hose from whipping around if the coupling breaks.

13.47 **Working Area** - The area, within the barriers set up to provide warning and restricted access, in which waterjetting will take place.

13.48 **Working Pressure** - The maximum pressure, recommended by the manufacturer, at which a component is to be used. The working pressure **shall** not exceed forty percent (40%) of the burst pressure of the component. This pressure is sometimes referred to as the operating pressure. A system is not to be operated above the lowest working pressure of any of its components.

14.0 REFERENCES

The following references are from the biennial WaterJet Technology Association meetings, which until the 4th U.S. Waterjet Conference were published as the Proceedings of the U.S. Waterjet Conference, and which are now published as the Proceedings of the American Waterjet Conference.

These references provide additional information on different aspects of waterjet use and should be used to supplement the information attached.

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