2017 WJTA American Waterjet Conference
October 25-27, 2017● New Orleans, Louisiana

Paper

DESIGN AND OPERATION OF HIGH FLOW WATERBLAST TOOLS AND SYSTEMS

D. Wright
StoneAge, Inc.
Durango, Colorado, U.S.A.

ABSTRACT

High flow waterblast cleaning may be performed with flow rates of 100 to 300 gallons per minute and pressures from 10,000 to 20,000 psi. The design and operation of a high flow waterblast system includes the management of pumps, pressure loss, proper tool support and balance, and deployment means. This paper addresses the considerations and possible methods to manage the issues that are inherently present in high flow systems and tools.

Organized and Sponsored by WJTA-IMCA

1. PUMP POWER

The pump power to achieve high flow rates may be provided by multiple high pressure pumps connected together in parallel at a manifold, or by a single larger high pressure pump capable of supplying the entire flow. The single high pressure pump requires a bit less space and can be simpler to operate, but when multiple pumps are used, and one has a problem, it can be disconnected and another added to allow continued operation. Operation of multiple pumps together requires coordination in bringing the system up to pressure, to avoid stalling of engines. If a pump is not to be used, it can be disconnected at the manifold and this manifold branch plugged. Hoses from each pump may be routed up the structure to a manifold before the tooling, as multiple hose runs can be a method for managing pressure loss. Figure 1 illustrates a manifold fed by six 1" waterblast hoses on structure; outgoing from manifold is single 1-1/2" hose.

2. PRESSURE LOSS

2.1 Hose

Managing pressure loss is one of the more significant demands of designing and operating a high flow system, particularly on large structures where the high pressure pumps may be up to 400 feet (120 m) away from the tooling, and this mostly cannot be changed. Pressure loss in a hose is most strongly dependent on the inside diameter of the hose, nearly to the fifth power, meaning that where possible, using the largest hose available for the pressure rating would first be used to minimize pressure loss. The next alternative is running multiple hoses in parallel, where the flow rate through each hose is the total flow rate divided by the number of hoses, and the pressure loss is then based on the lower flow through each hose. Table 1 illustrates various combinations of hose size, number of hoses in parallel, and pressure losses at various flows. The pressure loss is not dependent on the operating pressure; it is subtracted from the operating pressure to determine pressure reaching the tool. The equation below is the calculation for pressure loss through a hose.

$$\text{(1) Pressure loss (MPa)} = (\text{Flow (lpm)} / (.387 \times (\text{I.D. of hose (mm)})^{2.5} / \text{Length of hose (m)}^{.5})))^2$$

$$\text{(1) Pressure loss (psi)} = (\text{Flow (gpm)} / (53 \times (\text{I.D. of hose (in.)})^{2.5} / \text{Length of hose (ft)}^{.5})))^2$$

Generally, it is simpler to operate the tooling on a single high pressure hose inside the vessel, although two hoses in parallel may sometimes be manageable. This final section of hose should be kept as short as possible, to minimize the pressure loss, and the largest possible hose size used where practical. Figure 2 illustrates two parallel hoses feeding a 3-D tool, and Figure 3 illustrates a single 1-1/2" hose feeding a 3-D tool. Table 2 lists some currently available large hose sizes and their maximum working pressures. Tooling may be positioned, raised or lowered, on a hose end from above by use of a hose reel or hose tractor, or lifted by a cable winch with the hose feeding from below. The large hose sizes generally require means of deploying by hose reel or hose tractor due to their size and weight for manual handling.

2.2 Tooling

Another selection that involves pressure loss considerations is the tooling to be used at the end of the hose in support and operation of the nozzles themselves. The inside diameter of the seals and other internal passages determine how much flow the tooling is capable of passing with acceptable pressure loss. Fortunately, these passages are relatively short, compared to even a single section of high pressure hose run. Generally, a coefficient of flow value, or C_v value, is given for tooling to allow calculation of the expected pressure loss through the tool at a given flow rate, this equation is shown below.

$$(2)\ \text{Pressure loss (psi)} = (\text{Flow (gpm)} / C_v)^2$$

The allowable pressure loss depends on several parameters. If a specific pressure is known to remove the material being cleaned, the pressure loss subtracted from the pressure at the pump must be equal to or greater than this pressure, as in equation 3.

(3) Pressure at nozzle orifice = Pressure at pump – Pressure loss

The other major consideration is additional jet impact loss due to the distance the jets must travel before reaching the surface to be cleaned. As a jet travels through the air, it loses power at a rate proportional to the orifice diameter. This loss can be estimated to determine expected impact and performance.

3. ENERGY AND REACTION FORCE

The systems supplying high flow rates may have considerably more potential for stored energy, in the larger hoses and more volume capacity of multiple hoses and manifolds and pumps. The jet reaction forces may be balanced, or nearly balanced, or tooling must be well supported to be capable of handling large reaction forces.

3.1 Large Hose Whip Checks

The calculation for whip check strength required for 25 mm hose at 10,000 psi (700 bar) shows a necessary strength of 7800 pounds. The common whip check seen on 13 mm hose is rated to a working strength of 1300 to 2500 pounds. Higher strength whip checks are available to match the larger hose sizes, even to the 18,000 pound requirement for the 1-1/2” (38 mm) hose size. Whip checks should be properly applied to prevent excessive whipping of the hose end which can otherwise result in breaking off the hose end or fitting.

3.2 Pressure Dump

With the high flow rates, the management of pressure in the system is commonly done by the operation of the pumps, without a dump system. When operating by this fashion, it is important that complete containment of the tooling and separation from personnel is performed as part of the start-up procedure. Dump valves with a capacity up to 250 gpm at 10,000 psi are available; these can be routed as a side branch of a Tee to avoid additional pressure losses.

3.3 Jet Reaction Force

When operating with a 2-D or 3-D tool, the jets can be equal and balanced to cancel the high reaction forces generated by the high flow rates at pressure. When operating at 300 gpm at 10,000 psi and two nozzles, each one at 150 gpm, the thrust produced by each nozzle is 880 pounds. When nozzle orifices were measured and selected to be within .0002" (.0051 mm) their measured thrust varied by a maximum of 3 percent, but 3 percent of 880 pounds is still 26 pounds difference. The average was 1.5% difference, or 13 pounds, over 60 tested. To avoid the potential tool swing due to this unbalance, thrust can be measured and nozzles paired to be within a desired tolerance of balance, recommended to be within 5 pounds of each other. Counterweights may also be added to the tools to dampen out the potential swing caused by jet unbalance, as shown in Figure 4.

4. SUMMARY

With the increased power of operating at higher flow rates, additional considerations and details will greatly increase the chance for successful operation, and minimize total time to complete work. Considerations should be made for pump selection and operation, hose selection and minimizing pressure loss getting from pumps to structure, and the additional energy present in high flow systems.

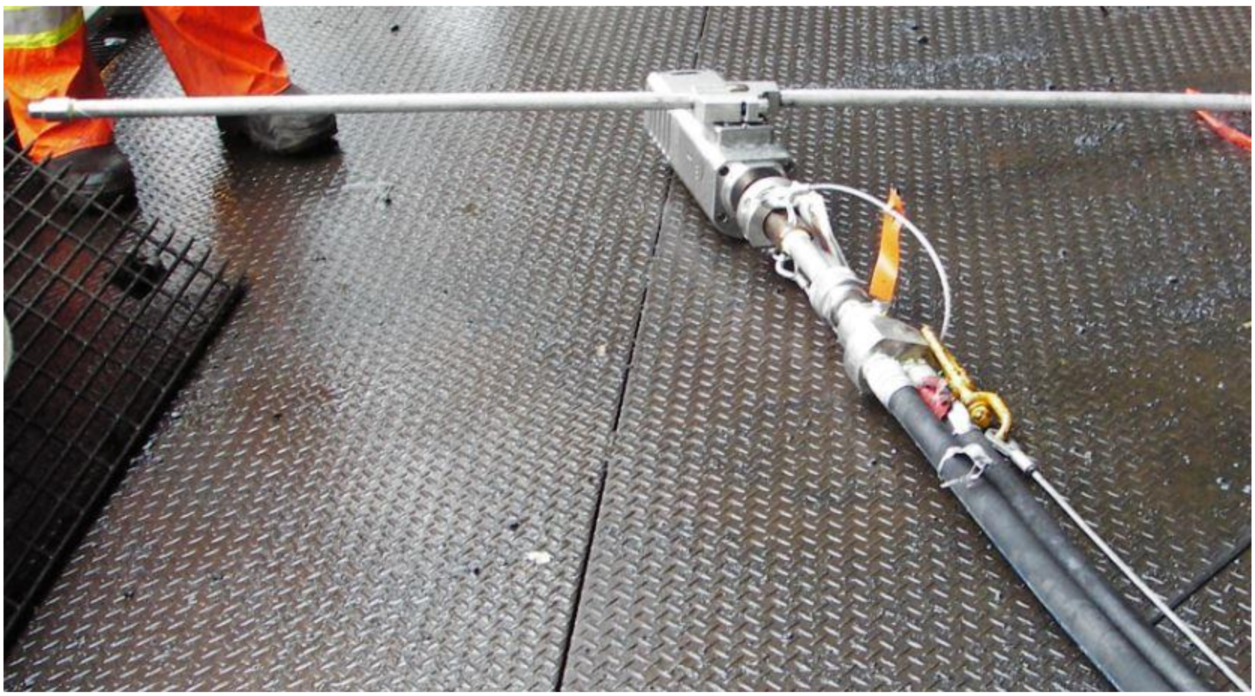
Length of Run, feet	Flow, gpm	Hose ID, inches	Number of Hoses in Parallel	Pressure Loss, psi
250	120	1	1	1050
250	120	1	2	260
250	120	1.25	1	345
100	200	1	1	1170
100	200	1.25	1	380
100	300	1.25	1	860
100	300	1.50	1	350
400	300	1	2	2630
400	300	1	4	660
400	300	1	6	290
400	300	1.25	2	860
400	300	1.25	3	380

Table Illustrating Effect of Hose Size and Number of Hoses in Parallel at High Flow Rates
Table 1.

Hose ID, Inches	Hose ID, mm	Working Pressure, psi
1	25	10,000 and 20,000
1.25	32	10,000
1.5	38	10,000

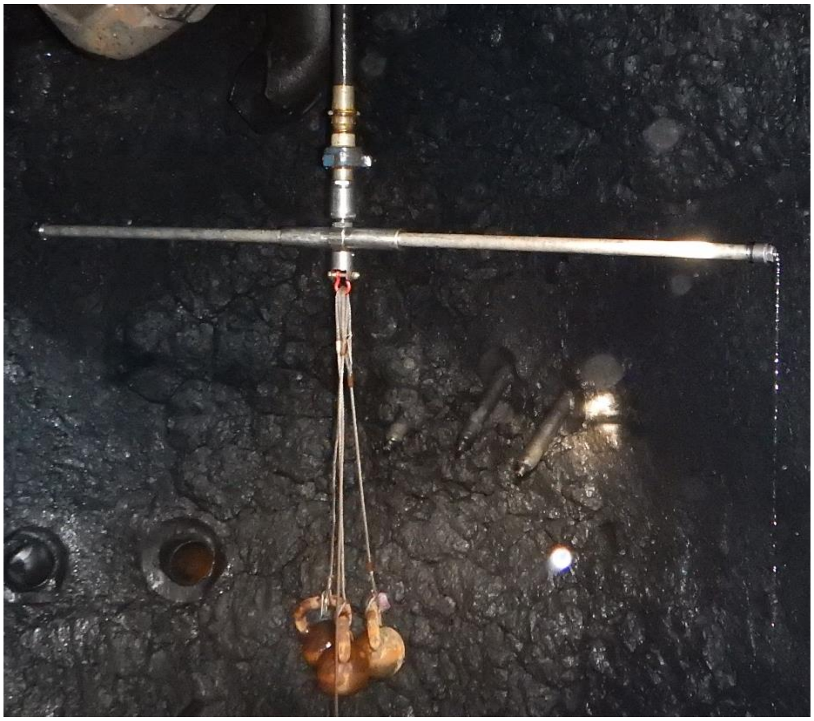
Table of Large Hose Sizes Currently Available for Waterblast Industry
Table 2.

Manifold on Structure Fed by Six 1" Waterblast Hose, into Single 1-1/2" Hose
Figure 1.



Two 1" Waterblast Hoses in Parallel Feeding a 3-D Tool to be Operated at 200 gpm
Figure 2.

Single 1-1/2” Waterblast Hose Feeding a 3-D Tool
Figure 3.



Counterweights to Dampen Swing on 2-D Tool Hanging on 1-1/2” Waterblast Hose
Figure 4.