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Paper

**CURRENT PRACTICES IN DESIGN STANDARDS AND CRITERIA
FOR HIGH PRESSURE WATERBLASTING TOOLS
AND SYSTEM COMPONENTS**

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ABSTRACT

When designing tooling and components for use in waterblast cleaning, the practicality, portability and safety of this equipment must be taken into consideration. The purpose of this paper is to survey existing design practices being used by manufacturers in the industry, compare to other design standards, and provide a basis for acceptance of design recommendations or a design standard for use in the waterblasting industry.

1. INTRODUCTION

The basis for the design of tooling and components for use in waterblast cleaning takes into consideration the practicality, portability and safety of the equipment. One of the greatest advantages of waterblasting is the portability of the tooling, through which a large amount of cleaning power can be applied in difficult access locations in the largest of boilers and vessels, through hundreds of feet of piping, and down to the smallest tubes in heat exchangers.

A factor of safety is used to allow for uncertainty in material properties, geometry and the load from the operating environment. The risk of failure as well as the type of failure must also be considered in the selection of the factor of safety. Safety factors can be as high as 20 for structures such as dams, to as low as 1.5 for commercial aircraft, which would not get off the ground if built like a dam, but must be inspected and maintained regularly.

While it has been accepted and published by the WJTA¹, SIR², and others that the factor of safety for hoses used in the waterblast industry shall be 2.5:1 for pressures up to 276 MPa (40,000 psi), there is no such published guideline for the fittings and components used in waterblast systems. The petro-chemical industry practice for their in-plant process piping is to follow the ANSI B31.3 piping code for pipes and fittings, which produces a minimum 4:1 factor of safety.

The following paper is a discussion of the considerations taken in the design of waterblast equipment in terms of the operating environment, materials, loading and wear, and the current practice among manufacturers in this industry regarding design factor of safety.

2. CURRENT PRACTICE IN THE WATERBLAST INDUSTRY

The results of a survey of pump, component and fitting manufacturers in the United States³ shows the current practice in the waterblast industry to be the use of a 2.5:1 factor of safety as the minimum in the design of components as is allowed for hoses. Factors such as material type, fatigue, location, type of failure, and protective containment play a role in the design considerations of all surveyed.

The table in Figure 1 lists the medium and high pressure tubing sizes currently used throughout the world, along with their accepted working pressures and calculated working pressures based on a 2.5:1 design factor of safety.

3. DISCUSSION OF DESIGN CRITERIA IN WATERBLAST APPLICATIONS

3.1 Waterblast Systems

An important consideration in the choice of design factor of safety is how well the load is known and controlled. Vessels and piping containing chemical or other reactions having the potential of uncontrolled reactions could lead to possible over-pressurization, and this potential must be

compensated for in the design factor. The maximum pressure of a waterblast system is a well controlled value, as over-pressurization is prevented through the use of rupture discs typically selected for a value of 15% over maximum allowable working pressure.

The most common waterblast systems are open flow from the pump to the nozzles; when the pump is de-energized, system pressure is immediately relieved through the nozzle orifices. In manually operated systems, an operator controlled pressure dump valve is also present and is typically open flow, but a type of these also exist that block the flow of water to the nozzles and can maintain system pressure in the hose or piping from the valve to the pump.

The volume of pressurized water contained in the entire system is dependent primarily on the hose size and length of hose run, while the volume contained in the waterblast tooling itself is less than 300 cc (20 cubic inches) in the largest assemblies, and the volume contained in a typical tooling component is less than 100 cc (6 cu in.)

3.2 Environment of the Pressurized Fluid

Standards used in industries such as petroleum, nuclear and chemical must account for corrosion and erosion, the risk of pressures exceeding design due to being a closed system containing materials and processes that are capable of reaction, and the extremely high risk involved if the materials should escape. If contained materials such as gases exist, failure can cause an explosive response due to the compressibility of gas. If a failure does occur, the potential for massive relief of volumes of potentially hazardous material exists.

Waterblasting equipment, however, is designed for the pressurized containment and transport of water, where the internal pressure is a controlled value due to the design of the system. Water is corrosive, but to a degree that can be easily overcome through proper selection of stainless steel materials. The temperature of the pressurized water used in most waterblasting applications is below 50°C. The water is filtered to 50 micron or less, eliminating the need for erosion compensation in design. The compressibility of water is negligible relative to a gas; the only considerable source of stored energy comes from the expansion of the hose while under pressure, typically up to 8% of the inner diameter.

3.2 External Environment

The greatest external influence that must be considered in the component design is the mechanical load that can be applied by an operator of the tooling, particularly in hand held manual applications. If possible, additional external mechanical means of support may be provided, but in applications such as small tube cleaning, there is not room to allow this.

Other considerations of the external environment are erosive wear of tools and heads. Where the material being removed is of an abrasive nature, and when combined with the velocity of the water exiting the jets, erosion will occur in any practical material. However, since it is external wear, inspection can be visual and the tool or head replaced as recommended.

In some applications, tools and lances are used in high temperature environments. Waterblasting tools and equipment lend themselves well to these applications, as long as a constant flow of water is maintained through the system, even at a low pressure.

The most common risk of damage to components and fittings occurs during the transporting of equipment from site to site, where threaded connections may be damaged to the point of preventing proper assembly.

3.3 Location of Use

The 2.5 factor of safety is a minimum design factor, and greater values are used depending on material types used, the location and service. The stainless steels most commonly in use have a fatigue limit of 50% of their ultimate tensile strengths, whereby operating with a factor of safety of at least 2.5 places them below their fatigue limit. A “leak before break” design and material selection is preferred. Testing of components is often used to determine the necessary design factor. Many waterblast systems are mobile in application, as contractors or operators move from site to site assembling the system, which allows for frequent inspection in terms of component, hose and fitting connections. Safety devices such as shrouds, backout preventers and whip checks are used in areas of personnel exposure.

4. CONCLUSIONS

Through more than 40 years of design and application experience, the waterblast industry has continued to improve and evolve into a successful method of applying the power of water to clean and remove material more effectively than other means. The minimum 2.5:1 design factor of safety has proven to be effective in the production of components and fittings, which in practice are more controlled in material and repeatability than hose construction. It is recommended that the waterblast industry, through the WJTA, adopt a minimum factor of safety of 2.5:1 for components and fittings as has been done for hoses. Additional considerations could be made for a committee to compile a more complete recommended design practice for waterblast components and fittings. If we as an industry do not take the initiative to enact a standard, we risk the possibility of having less practical standards imposed on us by others.

5.0 REFERENCES

1. “Recommended Practices For The Use Of Manually Operated High Pressure Waterjetting Equipment,” *WaterJet Technology Association*, pp. 33-34, St. Louis MO USA, 2005.
2. “High Pressure Water Jetting,” *Industrial Cleaning Foundation- SIR*, p. 30, Maassluis, Netherlands, 2008.
3. Those in the survey included the following manufacturers: NLB, Gardner Denver, A.P.S., Parker Hannifin, and StoneAge. In acknowledgement, Paul Webster of Parker Hannifin and Peter Goldsmith of A.P.S. provided additional valuable input.

Tubing Size	O.D. mm (in.)	I.D. mm (in.)	Calculated Factor of Safety	Working Pressure MPa (psi)
1/4 M. P.	6.35 (.250)	2.77 (.109)	3.56	152 (22,000)
1/4 H. P.	6.35 (.250)	2.11 (.083)	2.51	276 (40,000)
3/8 M. P.	9.53 (.375)	5.16 (.203)	2.76	152 (22,000)
3/8 H. P.	9.53 (.375)	3.18 (.125)	2.59	276 (40,000)
9/16 M. P.	14.27 (.562)	7.92 (.312)	2.72	152 (22,000)
9/16 H. P.	14.27 (.562)	4.78 (.188)	2.61	276 (40,000)
3/4 M. P.	19.05 (.750)	11.12 (.438)	2.57	152 (22,000)
1 M. P.	25.4 (1.000)	14.27 (.562)	2.77	152 (22,000)
1 H. P.	25.4 (1.000)	11.10 (.437)	2.87	207 (30,000)

**Medium and High Pressure Tubing Commonly Used Throughout the World in the
Waterblast Industry
Table 1.**