



Technical Service Bulletin

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ELIMINATION OF PRESSURE / FLOW SURGES IN MEMBRANE SYSTEMS

DESIGN RECOMMENDATIONS

INTRODUCTION TO WATER HAMMER:

Quick closing valves, positive displacement pumps, and vertical pipe runs can create damaging pressure spikes, leading to membrane damage, pipe-work, diaphragms, seals and gaskets meters and gauges.

Liquid for all practical purposes is not compressible, any energy that is applied to it is instantly transmitted. This energy becomes dynamic in nature when a force such as quick closing valve or a pump applies velocity to the fluid.

Surge or water hammer, as it is commonly known is the result of a sudden change in liquid velocity. Water hammer usually occurs when a transfer system is quickly started, stopped or is forced to make a rapid change in direction. Any of these events can lead to catastrophic system component failure. Without question, the primary cause of water hammer in process applications is the quick closing valve, whether manual or automatic. A valve closing in 1.5 sec. or less (depending upon valve size and system conditions), can cause an abrupt stoppage of flow. The pressure spike (acoustic wave) created at rapid valve closure can easily be as high as five (5) times the system working pressure.

Unrestricted, this pressure spike or wave will rapidly accelerate to the speed of sound in liquid, which can exceed 4000 ft/sec. It is possible to estimate the pressure increase by the following formula

Simplified Water Hammer Formula: $P = (0.070) (V) (L) / t + P1$

Where

- P = Increase in pressure
- P1 = Inlet Pressure
- V = Flow velocity in ft/sec
- t = Time in sec.(Valve closing time)
- L = Upstream Pipe Length in feet

An example of pressure hammer when closing a solenoid valve, with a 50 ft long upstream pipe connection:

$$\begin{aligned} L &= 50 \text{ ft} \\ V &= 5.0 \text{ ft / sec (recommended velocity for PVC piping design)} \\ t &= 40 \text{ ms (solenoid valve closing time is approx. 40-50 ms)} \\ P_1 &= 50 \text{ psi inlet pressure} \end{aligned}$$

$$\begin{aligned} \text{therefore, } P &= 0.07 \times 5 \times 50 / 0.040 + P_1 \\ \text{or } P &= 437.5 \text{ psi} + P_1 \end{aligned}$$

$$\text{Total Pressure (Spike)} = 437.5 + 50 = 487.5 \text{ psi}$$

As can be seen from the above, the pressure spike is approaching 10× the original system pressure which demonstrates the potentially catastrophic effect of water Hammer in an extreme case.

DESIGN GUIDELINES TO ELIMINATE PRESSURE / FLOW SURGE

1. GENERAL

Hydranautics recommends the use of computer modeling software wherever possible to fully evaluate the pressure / flow characteristics of the system, and, in the case of large, multi-train and complex systems, this should be viewed as essential. This analysis should be carried out for the worst case scenario plus normal service conditions and for each and every pumped sub-circuit.

2. PUMP SELECTION AND CONTROL

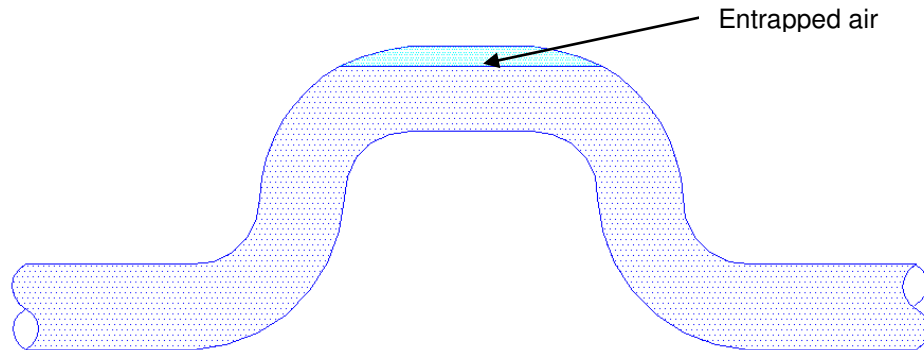
It is recommended that centrifugal type pumps be used at all times to provide pulsation free motive force. Should positive displacement pumps be used, these pumps must be fitted with the manufacturer's approved pulsation dampening equipment and further additional measures such as surge tanks may also be required dependent on the pipe-work configuration (i.e. very short and very long pipe runs require special consideration).

It is recommended that the system pressurization and de-pressurization rate does not exceed 0.25 bar per second or full system pressurization within 30 seconds whichever yields the higher period of time. To achieve this, it is recommended that all pumps have a controlled slow starting and stopping mechanism to eliminate sudden pressure surges during start-up and shut down. As a minimum this should consist of a slow start pump motor controller with at least 30 seconds of ramp up and ramp down time. Better still is a variable frequency drive (VFD) which gives even greater flexibility in ramp-up and ramp down times and also has the advantage of being able to match the duty point of the pump precisely to the process requirement.

3. AIR VENTING

It is essential that all pockets of air are effectively removed from the system prior to pressurization occurring. This entails the adoption of a flushing cycle where water is passed through the open vented system at lower flow and pressure until all air is expelled through a dedicated air vent valve. Flush cycle timing is normally determined during the commissioning phase of the system and the required flushing time for air removal programmed into the plant control system.

Pipe-work runs should wherever possible avoid air entrapment points as shown below:-



Should pipe-work layout constraints make it impossible to avoid such instances, provision for the automatic venting of entrapped air should be made at the uppermost section of the pipe-work.

4. AUTOMATIC VALVE SELECTION AND OPERATION

Valves and actuators should be selected with due consideration to type of valve and the time of actuation necessary to avoid water hammer occurring. Owing to their extremely short actuation time and lack of controllability, we do not recommend the use of solenoid valves in pressurized water membrane systems. It is always recommended that the sequencing of automatic valves should be as follows:-

- a. Flow valves should be in an open state or be confirmed as opening before commencing pump operation.
- b. Where a valve change-over e.g. to divert flow is to be effected, the initially closed valve should complete its opening cycle before closing the initially open valve.
- c. Wherever possible, flow valves should be failsafe open to eliminate the possibility of a valve unexpectedly closing against a pumped head in case of failure.
- d. It is not possible to apply firm rules to the time period for actuation of a valve since this is dependent on pressure and flow conditions specific to the installation and these times should wherever possible be determined by computer modeling software. However, for nominal flow and pressure

conditions the following may be considered as general guidelines for ball and butterfly valves in the absence of such analysis.

Pipe Dia.	Minimum Valve Actuation Time
Up to DN50	Not less than 2 seconds
DN65 – DN100	Not less than 3 seconds
DN125 – DN200	Not less than 4 seconds
DN250 – DN 300	Not less than 5 seconds
DN400 – DN500	Not less than 8 seconds
DN600 – DN900	Not less than 15 seconds

5. OTHER ANTI-SURGE / PRESSURE CONTROL EQUIPMENT

Below is a summary of recommended anti-surge / pressure control equipment to be considered for use in pressurised water membrane systems:-

a. Anti-Surge Vessels

These may be of the bladder type or compressed air over water type dependent on required performance and economic factors. Generally, bladder tanks are considered suitable for small – medium flow rate systems and air over water types considered for large flow rate systems with long and large diameter pipe runs.

b. Pulsation Dampeners

These devices are considered applicable to the pump outlet of reciprocating piston or plunger pump systems and are an essential fitment to such systems.

c. Snubbers / Pressure Restrictors

These items are an essential fitment to system instrumentation tapplings where it is felt necessary to eliminate potential pressure spikes which can irreversibly damage instrumentation sensors.

d. Pressure Relief Valves

A pressure relief valve is of particular benefit where a pump either cannot be stopped in service or it is of benefit to keep the pump operating. Usually the pressure relief valve is set to at least 10% lower than the maximum permissible system operating pressure and the surplus flow which is “bled off” to reduce system pressure is returned to the feed supplying the pump. Pressure relief valves are intended only for short periods of operation to eliminate excess system pressure when the pump continues to operate.

e. Burst or Rupture Discs

A rupture disk may be specified for primary relief in applications where pressure build-up can occur so rapidly that the response time of other devices is inadequate. A rupture disc consists of a thin disc of elastomer or metal installed into a flow branch which bursts to allow venting of excess pressure back to the pumped source and requires replacement after each event. Rupture disks are designed for reliable emergency relief of excess pressure since they instantaneously rupture at a specific predetermined pressure range.

f. Vacuum Break Valves

When a column of water falls vertically and unrestricted under gravity within a pipe section, it can create significant negative pressure or even a vacuum which can result in unstable flow surges within the pipe. A vacuum break valve will allow air to be drawn into the pipe section to eliminate the effects of this vacuum. Caution must however be taken to later remove this entrained air should the pipe system be connected downstream to a membrane system (see air vent valves above).

g. Pressure Sensing Equipment

A pressure switch or pressure transducer / controller combination if of a quick reaction type can be used to control pump operation, closing down the pump before any dangerously high pressure spikes are transmitted to the membrane system. It is recommended that such pressure control equipment is separate and in addition to other process control pressure control.

The above mentioned equipment is not exhaustive but covers many of the most commonly used items for control of surge and related pressure waves. A thorough system analysis will reveal which if any of the above are necessary within a given system and Hydraulics recommends that the manufacturer of any equipment be consulted to determine it's effectiveness in any given application.