# Waterhammer Analysis
# Jackfish 2 Boiler Feedwater System

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## Table of Contents

## Executive Summary


The boiler feedwater system at Jackfish 1 has experienced problems, specifically when the high pressure (HP) pumps trip during both start-up and normal operation. The purpose of this study is to evaluate the Jackfish 2 BFW system to determine whether anticipated surge pressures cause PSVs to relieve during potential similar events.

A waterhammer analysis was completed using three different methods to build confidence in the predicted surge results. The Joukowski formula and empirical methods were first employed to estimate the maximum possible surge pressures. A transient waterhammer computer program called WHAMO 3.0 was then used to validate the results while allowing refinement of system details which was not available in the simplified analysis.
The results demonstrate that the maximum possible surge pressure in the line without relief can be as high as 6375 kPa in comparison to the PSV relief set-point of 3800 kPa. The pressure margin previously calculated by Devon for Jackfish 2 from storage tank head and LP pump shutoff head amounts to 3503 kPa as compared to the 3800 kPa set-point. The calculated surge pressures will most definitely overcome this available pressure margin within the system.

Due to this surge magnitude expected during an HP pump trip, a minimum recommendation is put forth to direct the discharges of all PSVs, which are installed between the LP and HP pumps, to pop tanks to ensure a safe working environment. These modifications would involve rerouting of common discharge headers on relief valves PSV-2210A/B & PSV-2160A/B/C and construction of discharge dropdowns to pop tanks for the current vertical relief piping configuration on PSV-1460A/B. This would enable relief of the surge by the PSVs to safe locations.

Additional surge mitigation options have been evaluated at a high-level to provide Devon with further ways to provide protection within the JF2 BFW system. Rough cost estimates have been provided for each option within the body of the report. A recommended option is to install a bypass line around the HP pump suction to the BFW Recycle line using available flange tie-in points currently off the headers. This small bypass line would include an off-the-shelf fast-acting surge relief valve, check valve and regulator or orifice which would relieve the surge at the point of formation. Further analysis is needed to develop exact details but capital/construction costs of this solution are expected to be on the order of ~$130k.

Next steps would be for Jackfish 2 facility to modify the PSV discharge lines prior to operation and for Devon Engineering to consider the recommendation for additional modifications to mitigate surge within the BFW system. Additional details should be further defined for engineering this HP Pump surge relief line.

## Problem Description

The currently operating boiler feedwater system at Jackfish 1 has experienced waterhammer problems, specifically when high pressure (HP) pump trips during start-up and normal operation. Immediately following the trip, surge pressures within the line cause the various PSVs to relieve hot water/steam into uncontained areas causing unsafe conditions for possible nearby personnel. Based on this operating experience at JF1, Engineering & Operations wish to avoid similar surge conditions at JF2 in the new design.

## Process Summary

The Jackfish 2 boiler feedwater system contains a water storage tank (T-1100) which supplies BFW to the Low Pressure (LP) Pumps P-1100A-C. The LP pumps flow the BFW through Produced Water Coolers E-2210A-D and Field Gas Condensers E-2160A-C, stripping excess heat off these returning streams. The feedwater is then fed to Steam Generators SG-1320A-C, passes through the MP Steam Condensers E-1460A-B and is pressurized again with the HP Pumps P-1170A-C. The stream continues through the HP Steam Generators SG-1320D-F, HP Steam Seperator Vessels V-1400A-C, and is then directed to the well pads for injection.

Pressure relief valves, PSVs, are installed in the BFW system on each exchanger vessel and appear to be sized for protection during vessel fire cases or thermal relief. These PSVs pop open immediately following the HP pumps trip and relieving the surge volume caused by the surge pressure wave traveling from the stopped HP pumps to the LP pumps.

This piping system between the two sets of pumps was analyzed to determine maximum surge pressure magnitude and whether pressures are expected to exceed the pressure margin within the system (maximum expected steady state operating pressure to PSV settings).

## Method of Analysis

### *Waterhammer Analysis with Joukowsky*

Waterhammer calculations can be performed on a system to determine the maximum possible pressure rise due to an instantaneous change in flow velocity within a pipe. The Joukowsky Equation assumes an instantaneous valve closure and determines the maximum possible pressure rise on the upstream side of the closed valve. This surge pressure wave then travels down the piping system at the speed of sound within the fluid. This method was used in this analysis to determine maximum possible surge pressures at the worst case PSV location, PSV-1460A/B, nearest to the tripped HP pumps. Refer to Table 1 for these results.

### *Empirical Waterhammer Formulae*

An empirical analysis has also been performed to determine magnitude of the pressure wave in a pipe for slower valve closure times. This formula can be used on systems when valve close time is slow in comparison to the pressure wave transit time within the piping section. This formula was applied to the JF2 BFW system due to the fact that the HP pumps will take a small portion of time to spin down from full rpm following a trip signal and is analogous to a slow valve closure case.

The stop duration of the HP pumps can be estimated using the pump & motor mass moment of inertias, the rotational inertia equation for the pump/fluid and some rough assumptions on speed reduction profile. Surge pressures determined with this formula are reduced in comparison with the Joukowsky equation due to the fact that it is practically impossible to close a valve faster than the short reflection time of the surge wave (except on longer pipeline systems). Final results can be found in Table 2 for this analysis.

### *System Modeling & Analysis with Waterhammer Software*

A third analysis was performed using a program developed by the US Army Corp of Engineers called WHAMO 3.0 (Water Hammer And Mass Oscillation). The program calculates the time-varying flow and head in networks containing tanks, pipes, valves, and pumps. A finite difference method is used to solve the time-varying differential equations for momentum conservation and continuity. This program allows more detail to be inputted for a system including piping branches/splits and losses due to friction which provides slightly more accurate results than the simple methods.

Various system configurations were tested with the software and it was determined that a simple system without the LP & HP pumps included provided the most reliable results. The system modeled included the storage tank, all piping between the pumps and used a valve at the HP pump location to simulate line blockage on pump trip. A node at the MP Steam Condensers E-1460A/B, where the relief valves PSV-1460A/B are located, was monitored for pressure to determine potential over-pressuring without relief. The results from the simulation runs can be found in Table 3 & Figure 1.

## Conditions

During a meeting with Devon Operations & Engineering on August 4, 2010 various system & operational information was gathered on anticipated conditions at JF2.

***BFW Flow***

| | |
|---|---|
| Maximum: | 974 m3/h, rated LP pump flow (487 m3/h per pump, two units) |
| Start-up: | 850 m3/h, anticipated maximum during start-up conditions |
| Normal Op: | 700 m3/h, anticipated nominal flows |

Assumed two out of three LP pumps will operate in BFW system normally at JF2.

***Tank***

Tank Level: 20.2 m, HLL high tank level

***PSV Set Pressures***

Relief press: 3800 kPa,

Various PSVs are set at 3800 kPa in the analyzed portion of the BFW system: PSV-2210A/C, PSV-2160A/B/C, and PSV-1460A/B.

## Results

The following sections summarize the surge pressures estimated with the three methods used. All the methods determined surge pressures within relatively close precision in comparison and provides confidence in the study.

The maximum potential surge pressure in the BFW system was determined to be 6375 kPa, far above the system margins. See the detailed results for all three methods below.

### *Waterhammer Results Using Joukowsky*

The following table shows the maximum possible surge pressure at PSV-1460A/B off the MP Steam Condensers.

TABLE 1: SURGE RESULTS USING JOUKOWSKY METHOD

| Location | Description | Pump Design | Operating Max | Operating Normal | Units |
|---|---|---|---|---|---|
| At Tank | Maximum Head in tank | 20.2 | 20.2 | 20.2 | m |
| | Density | 965.3 | 965.3 | 965.3 | kg/m3 |
| At LP Pumps | Suction Pressure | 191.2 | 191.2 | 191.2 | kPa |
| | Pumps Running | 2 | 2 | 2 | # |
| | Pump Flow | 487 | 425 | 350 | m3/h |
| | Total BFW Flow | 974 | 850 | 700 | m3/h |
| | Pump Head | 300 | 313 | 326 | m |
| | Disch Pressure | 3031 | 3154 | 3277 | kPa |
| | Surge pressure rise | 3067 | 2677 | 2205 | kPa |
| | **Resultant max pressure** | **6098** | **5831** | **5482** | kPa |
| At PSVs | Elevation of PSVs | -4.72 | -4.72 | -4.72 | m |
| | Resultant PSV pressure | 6053 | 5786 | 5437 | kPa |
| | PSV setting | 3800 | 3800 | 3800 | kPa |
| | **% pressure increase** | **199.7%** | **183.5%** | **165.9%** | |
| | % overpressure to PSV | 159.3% | 152.3% | 143.1% | |

The maximum potential pressure calculated at the PSVs, <u>if no relief occurred</u>, would be 6098 kPa, twice the normal operating pressure.

### ***Empirical Waterhammer Results***

The following table shows the estimated surge pressures at PSV-1460A/B off the MP Steam Condensers using empirical formulas.

TABLE 2: SURGE RESULTS USING EMPIRICAL METHOD

| Location | Description | Pump Design | Operating Max | Operating Normal | |
|---|---|---|---|---|---|
| At Tank | Maximum Head in tank | 20.2 | 20.2 | 20.2 | m |
| | Density | 965.3 | 965.3 | 965.3 | kg/m3 |
| At LP Pumps | Suction Pressure | 191.2 | 191.2 | 191.2 | kPa |
| | Pumps Running | 2 | 2 | 2 | # |
| | Pump Flow | 487 | 425 | 350 | m3/h |
| | Total BFW Flow | 974 | 850 | 700 | m3/h |
| | Pump Head | 300 | 313 | 326 | m |
| | Disch Pressure | 3031 | 3154 | 3277 | kPa |
| | Surge pressure rise | 3324 | 2901 | 2389 | kPa |
| | **Resultant max pressure** | **6355** | **6055** | **5666** | **kPa** |
| At PSVs | Elevation of PSVs | -4.72 | -4.72 | -4.72 | m |
| | Resultant PSV pressure | 6310 | 6010 | 5621 | kPa |
| | PSV setting | 3800 | 3800 | 3800 | kPa |
| | **% pressure increase** | **208.2%** | **190.6%** | **171.5%** | |
| | % overpressure to PSV | 166.1% | 158.2% | 147.9% | |

The surge pressure calculated at the PSVs, if no relief occurred, would be 6355 kPa, over twice the normal operating pressure of the line.

### *Transient Analysis Results Using WHAMO*

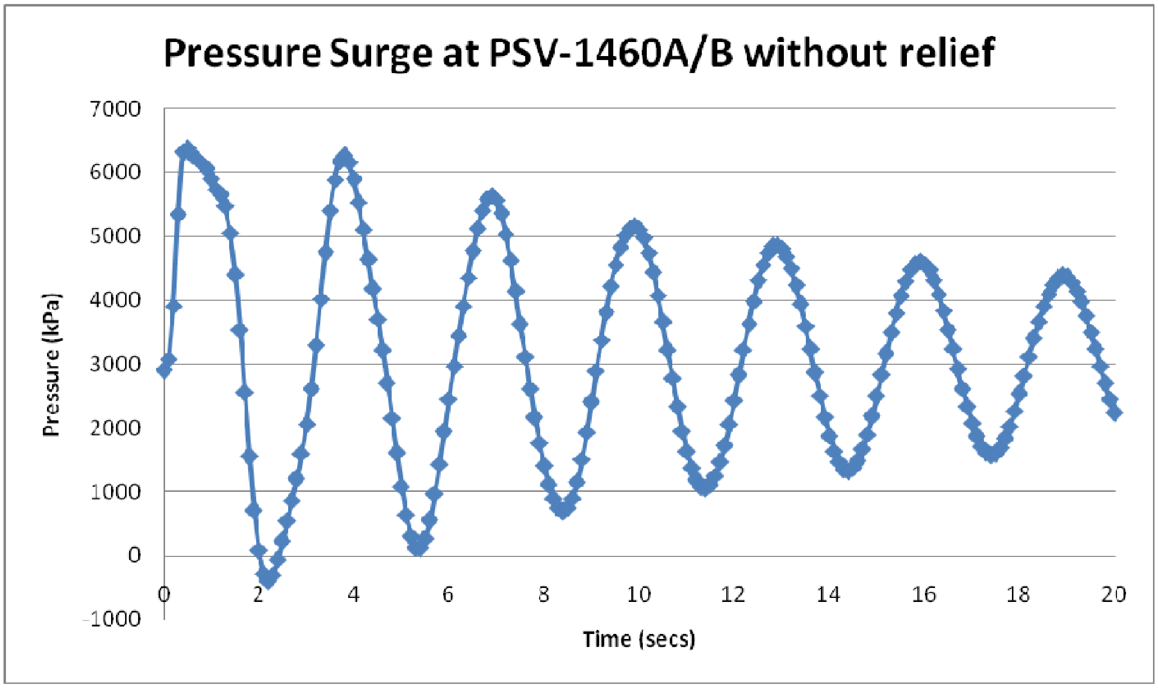
The following table shows the surge pressures at PSV-1460A/B off the MP Steam Condensers calculated with transient waterhammer software.

TABLE 3: SURGE RESULTS USING TRANSIENT SOFTWARE

| Location | Description | Pump Design | Operating Max | Operating Normal | Units |
|---|---|---|---|---|---|
| At Tank | Maximum Head in tank | 20.2 | 20.2 | 20.2 | m |
| | Density | 965.3 | 965.3 | 965.3 | kg/m3 |
| At LP Pumps | Suction Pressure | 191.2 | 191.2 | 191.2 | kPa |
| | Pumps Running | 2 | 2 | 2 | # |
| | Pump Flow | 487 | 425 | 350 | m3/h |
| | Total BFW Flow | 974 | 850 | 700 | m3/h |
| | Pump Head | 300 | 313 | 326 | m |
| | Disch Pressure | 3029 | 3151 | 3278 | kPa |
| | Surge pressure rise | 3346 | 2743 | 2428 | kPa |
| | **Resultant max pressure** | **6375** | **5894** | **5706** | kPa |
| At PSVs | Elevation of PSVs | -4.72 | -4.72 | -4.72 | m |
| | Resultant pressure @ PSV | 6331 | 5850 | 5661 | kPa |
| | PSV setting | 3800 | 3800 | 3800 | kPa |
| | **% pressure increase** | **209.0%** | **185.6%** | **172.7%** | |
| | % overpressure to PSV | 166.6% | 153.9% | 149.0% | |

The surge pressure calculated at the PSVs, <u>if no relief occurred</u>, would be 6375 kPa, over twice the normal operating pressure of the line. The program also provides additional transient pressures of the PSV location as shown below:

FIGURE 1: TRANSIENT SURGE PRESSURES AT PSV-1460A/B LOCATION




## Option Evaluation

Surge pressures estimated in the BFW system are above the PSV set-points at various locations in the piping section analyzed. Once these rising pressures within the actual system reach the relief set-points the PSVs are relieving pressure and surge volumes to protect the system.

As a minimum it is recommended that the all PSV discharges are directed to pop tanks, ensuring the system safety during this potential event.

Other mitigating solutions have been considered to further provide added protection to the system and properly alleviate the surge conditions. These solutions have been estimated at a high level and should be assessed further to determine sizing, relief capacity and effectiveness. A high level estimate has been provided to allow review of the economics by the client.

### *Minimum Case*

To ensure the safety of workers in the immediate vicinity, all PSV discharges should be directed to a safe location where nearby personnel will not be affected.

- **PSV-2210A/B off Produced Water Coolers**
  - Both PSV discharges are currently tied together, direct discharge header to a pop tank
- **PSV-2160A/B/C off Field Gas Condensers**
  - All three discharges are currently tied together, direct discharge header to a pop tank
- **PSV-1460A/B/C off MP Steam Condensers**
  - Both discharges are currently directed vertically at a high elevation. It is recommended these are directed down into a pop tank.

Further evaluation is required to determining costs associated with this work.

### *Option 1: Check valve/Control Valve Relief Bypass on HP Pumps*

During a HP pump trip event, the fluid starts packing on the upstream side of the pumps causing the surge wave. To immediately relieve this building surge pressure, a small 6” bypass line could be constructed around the pumps containing a check valve, control valve and pressure regulator/orifice. This configuration would allow discharge of the surge volume into the BFW recycle line downstream of the HP pumps. The air-actuated spring open control valve would open on a HP pump trip signal. The control valve would return to the closed position after a length of time.

Cost Estimate: $150k (Includes piping, fittings, valves, supervision, scaffolding, & camp costs), this is a +-50% figure.

Advantages:
- After reviewing the P&IDs, it was noticed that easy tie-points exist off the pump common suction and recycle header flanges for future pump connections.
- Relieves surge at worst point

Disadvantages
- Higher costs are incurred due to additional automation required for the control valve and the control valve higher capital cost.
- An unknown with this solution is the ability for certain types of control & check valves to open rapidly and this should be evaluated further.

### *Option 2: Relief bypass on HP Pump Suction*

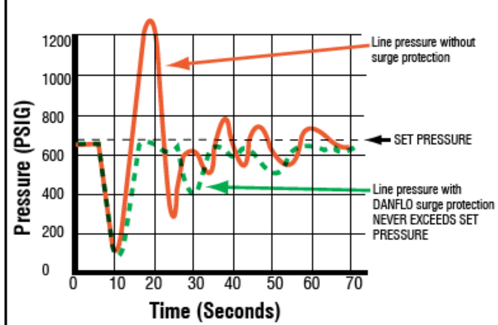
Similar to Option 1, the Option 2 concept is to discharge the excess surge volume into the BFW recycle line. It uses a relatively simple, effective, industry-available surge relief valve. A small 6" bypass line can be constructed around the pumps containing a check valve, a M&J DANFLO liquid relief valve and orifice/regulator valve. The DANFLO valve is fast-acting (ie. ~ 100 milliseconds) and is fit-for-service. It provides the ability to shave the peaks of the surge as seen below.

An advantage of this and the previous option is to relieve the surge at the location where it first is created. See the excerpt from DANFLO relief valve brochure:

Surge pressures are created from:

(a) closure of an automatic emergency shutdown device (ESD valve)
(b) rapid closure or opening of a manual or power operated valve
(c) slamming shut of a non-return valve
(d) starting or stopping of a pump

Surge pressure may vary in magnitude from virtually undetectable to sufficient severity to cause a major disaster. Prevalent problems from insufficient surge protection include axial separation of flanges, pipe fatigue at welds or longitudinal splits of the pipe, pumps knocked out of alignment, severe damage to piping and piping supports as well as damage to specialized components such as loading arms, hoses, filters, bellows, etc.




TYPICAL PRESSURE/TIME RESPONSE WITH AND WITHOUT SURGE RELIEF PROTECTIONS

Cost Estimate: $130k (Includes piping, fittings, valves, supervision, scaffolding, & camp costs), this is a +-50% figure.

Advantages:
- Industry-available, fit-for-service valve which is simple and effective
- Simple solution & lower cost than Option 1.

Disadvantages:
- Requires supply of Nitrogen

### *Option 3: Surge Accumulator Tank*

Addition of a one-way surge accumulator tank is an option to collect excess surge volume. The tank needs to be combined with surge relief valve connected off the HP Pump suction header.

This type of solution is usually expensive due to the required size of tank, additional maintenance, and cost for additional piping & equipment for tank level control/monitoring. No cost estimate has been provided due to the fact that this option has all the same equipment & piping is required to Options 1 & 2 including the surge tank over and above. The option is not recommended due to the large costs, large engineering effort and design involved with such a system.

## Recommendation & Next Steps

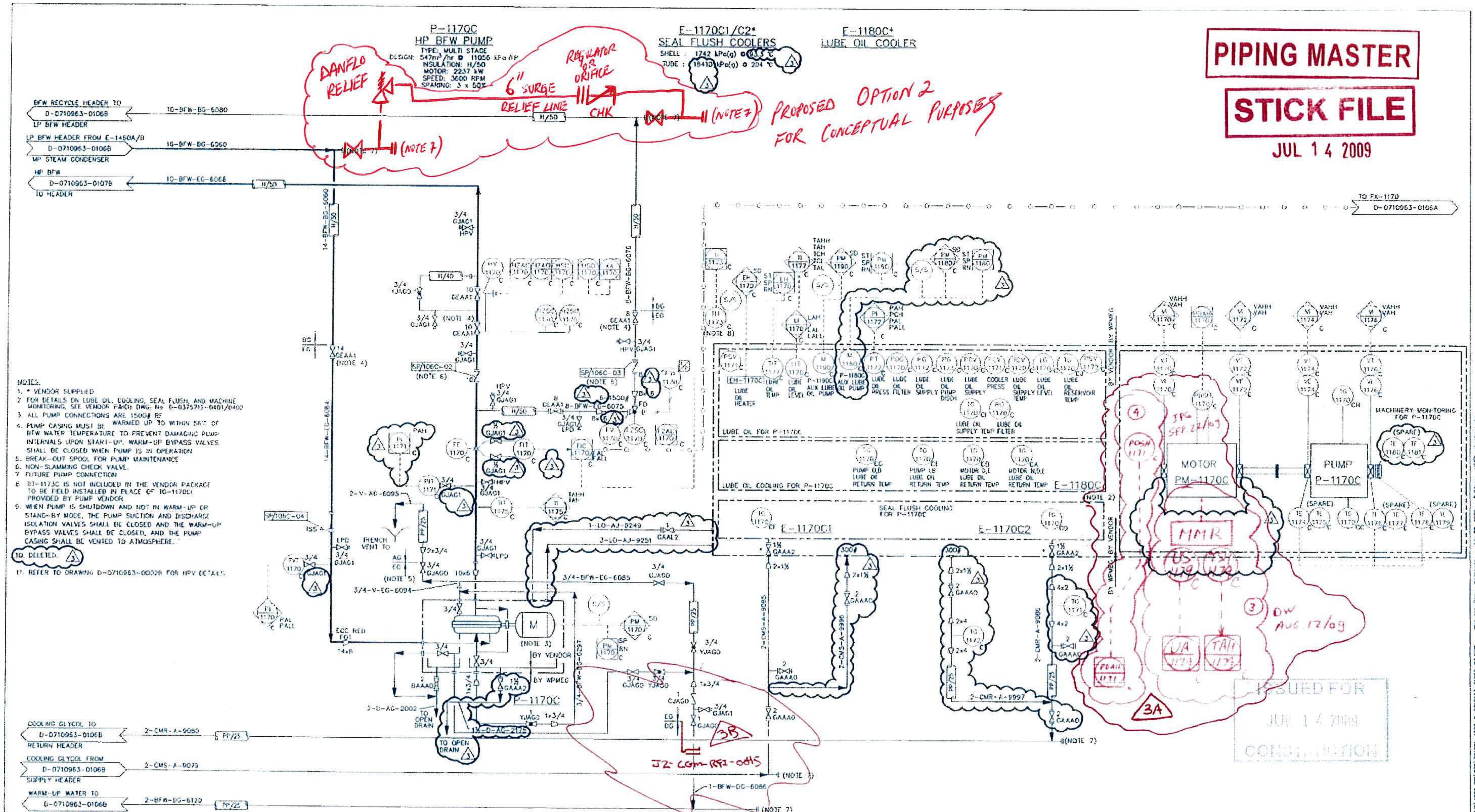
It is recommended at a minimum that Devon JF2 modify the BFW PSV discharge lines to provide safe conditions during relief.

To further protect the system and reduce the popping of PSVs, it is recommended that Devon introduce additional surge mitigation to eliminate future problems within the system. The study recommends installation of Option 2 which consists of a separate relief line off the HP Pump Suction header to the BFW Recycle line. An off-the-shelf, fast-acting, surge relief valve was selected for this purpose. It is recommended that further sizing, specs and costs are developed on this option to allow ease of integration into the construction effort currently underway.

Additional comments:

- Jackfish 1 facility has had surge events of this sort. It is recommended that the BFW system supports/flanges/piping are checked to ensure no damage has been induced to date. Caltech can assist in identifying specific supports/piping to check.
- At the earliest opportunity, JF1 should also consider additional surge mitigation as recommended in the study to enhance safety and protect equipment.

## APPENDIX A – OPTION 2 Preliminary P&ID Mark-up




NOTES:

1. * VENDOR SUPPLIED
2. FOR DETAILS ON LUBE OIL, COOLING, SEAL FLUSH, AND MACHINE MONITORING, SEE VENDOR P&ID DWG. No D-0375712-0401/0402
3. ALL PUMP CONNECTIONS ARE 1500# RF
4. PUMP CASING MUST BE WARMED UP TO WITHIN 56°C OF BFW WATER TEMPERATURE TO PREVENT DAMAGING PUMP INTERNALS UPON START-UP. WARM-UP BYPASS VALVES SHALL BE CLOSED WHEN PUMP IS IN OPERATION
5. BREAK-OUT SPOOL FOR PUMP MAINTENANCE
6. NON-SLAMMING CHECK VALVE.
7. FUTURE PUMP CONNECTION
8. TIT-1173C IS NOT INCLUDED IN THE VENDOR PACKAGE TO BE FIELD INSTALLED IN PLACE OF TG-1170CI, PROVIDED BY PUMP VENDOR.
9. WHEN PUMP IS SHUTDOWN AND NOT IN WARM-UP OR STAND-BY MODE, THE PUMP SUCTION AND DISCHARGE ISOLATION VALVES SHALL BE CLOSED AND THE WARM-UP BYPASS VALVES SHALL BE CLOSED, AND THE PUMP CASING SHALL BE VENTED TO ATMOSPHERE.
10. DELETED. 3
11. REFER TO DRAWING D-0710963-00028 FOR HPV DETAILS.

| DWG. NO. | REFERENCE DRAWINGS |
|---|---|
| | |
| | |
| | |

WorleyParsons MEG
resources & energy

| DEVON PROJECT | REV | REVISIONS | DATE | BY | CHK'D | APP'D | OWNR APP'D |
|---|---|---|---|---|---|---|---|
| 0710963 | 3 | RE-ISSUED FOR CONSTRUCTION | 2009-07-07 | CH | YS | WF | DS |
| 0710963 | 2 | ISSUED FOR CONSTRUCTION | 2008-12-09 | CH | YS | WF | DS |
| 0710963 | 1 | IFC (1ST HAZOP & 23 MODULES) | 2008-08-31 | RC | HK | AL | DS |
| 0710963 | 0 | ISSUED FOR DESIGN | 2008-03-05 | CH | HK | AL | DS |

CADD FILE

ENGINEER AND PERMIT STAMPS

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PROFESSIONAL ENGINEER
W. GREGG MAXWELL
ALBERTA
July 10/2009

| | | |
|---|---|---|
| DESIGNED | HC | - |
| DRAWN | PH | - |
| CHECKED | HK | - |
| PROCESS CK. | HQ | - |
| MECH. CK. | VS | - |
| STRUCT. CK. | HY | - |
| ELECT. CK. | DA | - |
| I/C CK. | GS | - |
| OWNER APP. | DS | - |

devon
JACKFISH 2
CENTRAL PROCESSING FACILITY
P&ID – HP BFW PUMP, P-1170C
LSD. 7-27-75-07 W4M

| CONTR JOB NO | SCALE | DWG. NO. | DEVON PROJ |
|---|---|---|---|
| 021001 | NTS | D-0710963-0106C.DWG | 0710963 |

REV 3A
Rev 3B

# APPENDIX B – OPTION 2 DANFLO Surge Relief Valve Brochure

M&J VALVE

AN SPX BRAND

# DANFLO
# Liquid Surge Relief Valve

SPX®

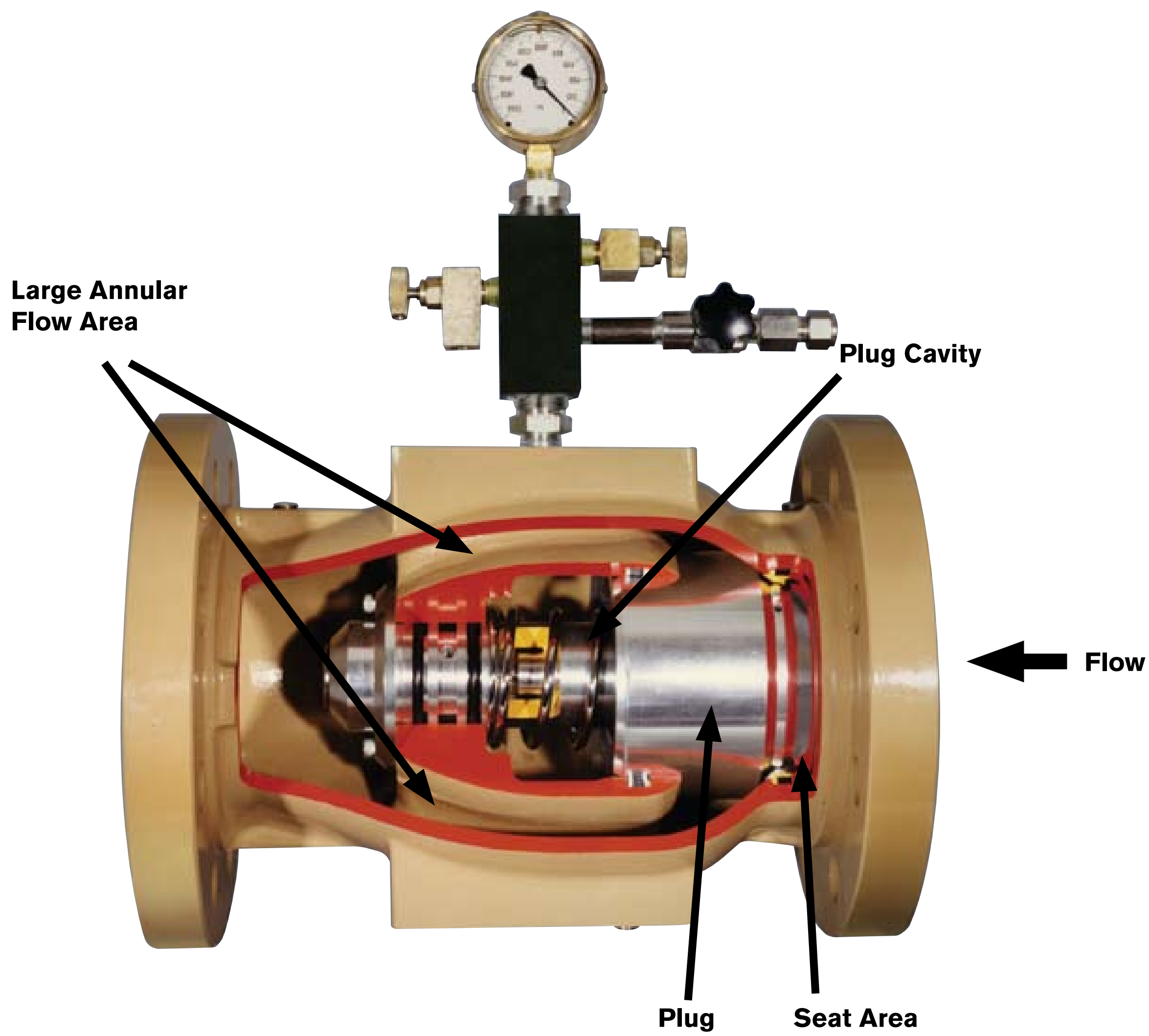
# DANFLO Surge Relief Valves

DANFLO Surge Relief Valves are engineered to track unabated surge-wave pressure transients-open quickly, then closes without slamming shut. The “speed of response” in surge valves is defined as the ability of the valve/valves to relieve peak wave surge flow in the time stated in a hydraulic transient surge analysis. Although this time varies with each application, timed responses of 100 milliseconds or less are not unusual. DANFLO surge relief valves meet these criteria.

DANFLO surge valve operation is simple. The cavity behind the valve plug is filled with nitrogen gas to affect proper relief set pressure of the valve. This cavity loading force seats the valve and opposes the force generated by line pressure in front of the valve. The valve remains closed until surge wave pressure exceeds the force behind the plug (set pressure). The DANFLO surge valve then opens quickly to track the unabated surge wave. The closing cycle responds directly to pressure decay in the upstream piping in front of the DANFLO surge valve.

A M&J Valve DANFLO surge relief system consists of the appropriate quantity of specific sizes of gas-loaded valves to handle requested flow conditions. High flow coefficients (Cv) of DANFLO surge valves usually mean fewer and/or smaller size valves to meet user requirements.

Operation at recommended settings provides flow reserve for protection against surges larger than expected. Problems such as nitrogen loss through permeable elements, valve failure due to tube splits caused by contaminant flow, or tubes taking a permanent set which prevents valve operation-are all eliminated with the DANFLO design.

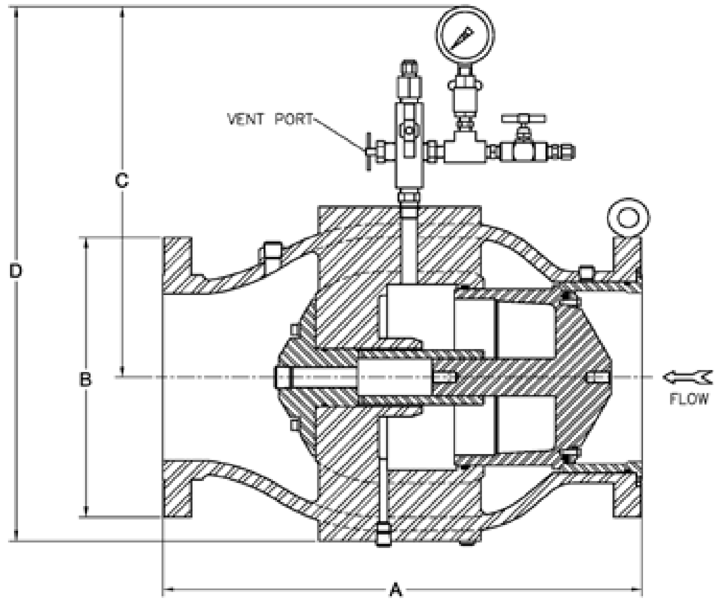


## Dimensions for Surge Relief Valves

| Valve Size (in) | DIN (mm) | ANSI | A In (mm) | B In (mm) | C In (mm) | D In (mm) |
|---|---|---|---|---|---|---|
| 2 | 50 | 150 | 11 1/2 (292) | 6 (152) | 13 1/5 (335) | 16 (406) |
| | | 300 | 11 1/2 (292) | 6 1/2 (165) | 13 1/5 (335) | 16 1/4 (413) |
| | | 600 | 11 1/2 (292) | 6 1/2 (165) | 13 1/5 (335) | 16 1/4 (413) |
| | | 900 | 12 1/2 (318) | 8 1/2 (216) | 13 1/5 (335) | 17 1/4 (438) |
| 3 | 75 | 150 | 12 1/2 (318) | 7 1/2 (191) | 13 1/2 (343) | 16 3/4 (425) |
| | | 300 | 12 1/2 (318) | 8 1/4 (210) | 13 1/2 (343) | 17 1/8 (435) |
| | | 600 | 13 1/4 (292) | 8 1/4 (210) | 13 1/2 (343) | 17 1/8 (435) |
| | | 900 | - | - | 13 1/2 (343) | - |
| 4 | 100 | 150 | 13 15/16 (354) | 9 (229) | 14 1/2 (368) | 17 1/2 (445) |
| | | 300 | 13 15/16 (354) | 10 (254) | 14 1/2 (368) | 18 (457) |
| | | 600 | 15 (381) | 10 3/4 (273) | 14 1/2 (368) | 18 3/8 (467) |
| | | 900 | 17 1/4 (438) | 11 1/2 (292) | 14 1/2 (368) | 18 3/4 (476) |
| 6 | 150 | 150 | 17 3/4 (451) | 11 (279) | 16 1/2 (419) | 18 1/2 (470) |
| | | 300 | 17 3/4 (451) | 12 1/2 (318) | 16 1/2 (419) | 19 1/4 (489) |
| | | 600 | 19 1/8 (486) | 14 (356) | 16 1/2 (419) | 20 (508) |
| | | 900 | 20 3/4 (527) | 15 (381) | 16 1/2 (419) | 20 1/2 (467) |
| 8 | 200 | 150 | 22 1/4 (565) | 13 1/8 (333) | 18 1/8 (460) | 19 9/16 (497) |
| | | 300 | 22 1/4 (565) | 15 (381) | 18 1/8 (460) | 20 1/2 (521) |
| | | 600 | 22 3/4 (603) | 16 1/2 (419) | 18 1/8 (460) | 21 1/4 (540) |
| | | 900 | 26 (660) | 18 1/2 (470) | 18 1/8 (460) | 22 1/4 (565) |
| 10 | 250 | 150 | 30 1/8 (765) | 16 (406) | 20 (508) | 21 (533) |
| | | 300 | 30 1/8 (765) | 17 1/2 (445) | 20 (508) | 21 3/4 (552) |
| | | 600 | 30 5/16 (770) | 20 (508) | 20 (508) | 23 (584) |
| | | 900 | 32 (813) | 21 1/2 (546) | 20 (508) | 23 3/4 (603) |
| 12 | 300 | 150 | 35 (889) | 19 (483) | 22 (559) | 22 1/2 (572) |
| | | 300 | 35 (889) | 20 1/2 (521) | 22 (559) | 23 1/4 (591) |
| | | 600 | 36 3/4 (933) | 22 (559) | 22 (559) | 24 (610) |
| | | 900 | 36 3/4 (933) | 24 (610) | 22 (559) | 36 1/4 (921) |
| 16 | 400 | 150 | 44 1/2 (1130) | 23 1/2 (597) | 27 1/2 (660) | 43 1/4 (1099) |
| | | 300 | 44 1/2 (1130) | 23 1/2 (597) | 27 1/2 (660) | 43 1/4 (1099) |
| | | 600 | 44 1/2 (1130) | 27 (686) | 31 11/16 (805) | 47 7/16 (1205) |
| | | 900 | 45 (1143) | 27 3/4 (705) | 32 1/8 (816) | 48 5/16 (1227) |

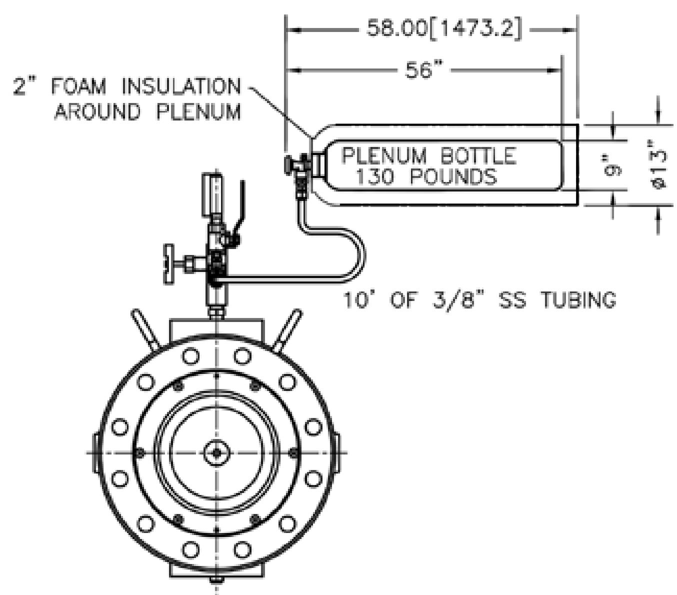
## Approximate Shipping Weight & Dimensions

| Size | | Shipping Cube | Weight |
|---|---|---|---|
| 2" | 300# | 0.92 Cu. Ft. (0.026 M³) | 80 Lbs. (36 Kg.) |
| | 600# | 1.01 Cu. Ft. (0.029 M³) | 86 Lbs. (39 Kg.) |
| | 900# | 1.02 Cu. Ft. (0.029 M³) | 125 Lbs. (57 Kg.) |
| 3" | 300# | 1.27 Cu. Ft. (0.036 M³) | 123 Lbs. (55 Kg.) |
| | 600# | 1.35 Cu. Ft. (0.038 M³) | 129 Lbs. (58 Kg.) |
| 4" | 300# | 1.57 Cu. Ft. (0.045 M³) | 154 Lbs. (70 Kg.) |
| | 600# | 1.88 Cu. Ft. (0.053 M³) | 180 Lbs. (81 Kg.) |
| | 900# | 2.24 Cu. Ft. (0.063 M³) | 420 Lbs. (190 Kg.) |
| 6" | 300# | 3.01 Cu. Ft. (0.085 M³) | 368 Lbs. (167 Kg.) |
| | 600# | 3.32 Cu. Ft. (0.094 M³) | 412 Lbs. (187 Kg.) |
| | 900# | 3.78 Cu. Ft. (0.107 M³) | 650 Lbs. (295 Kg.) |
| 8" | 300# | 5.42 Cu. Ft. (0.153 M³) | 560 Lbs. (254 Kg.) |
| | 600# | 5.74 Cu. Ft. (0.163 M³) | 630 Lbs. (286 Kg.) |
| 10" | 300# | 9.43 Cu. Ft. (0.267 M³) | 970 Lbs. (440 Kg.) |
| | 600# | 9.49 Cu. Ft. (0.269 M³) | 1100 Lbs. (500 Kg.) |
| 12" | 300# | 14.45 Cu. Ft. (0.409 M³) | 1625 Lbs. (737 Kg.) |
| | 600# | 17.36 Cu. Ft. (0.492 M³) | 1820 Lbs. (825 Kg.) |
| 16" | 150# | 25.61 Cu. Ft. (0.725 M³) | 4500 Lbs. (2041 Kg.) |
| | 300# | 25.61 Cu. Ft. (0.725 M³) | 4500 Lbs. (2041 Kg.) |
| | 600# | 26.0 Cu. Ft. (0.736 M³) | 4500 Lbs. (2041 Kg.) |
| | 900# | 27.54 Cu. Ft. (0.780 M³) | 5000 Lbs. (2268 Kg.) |



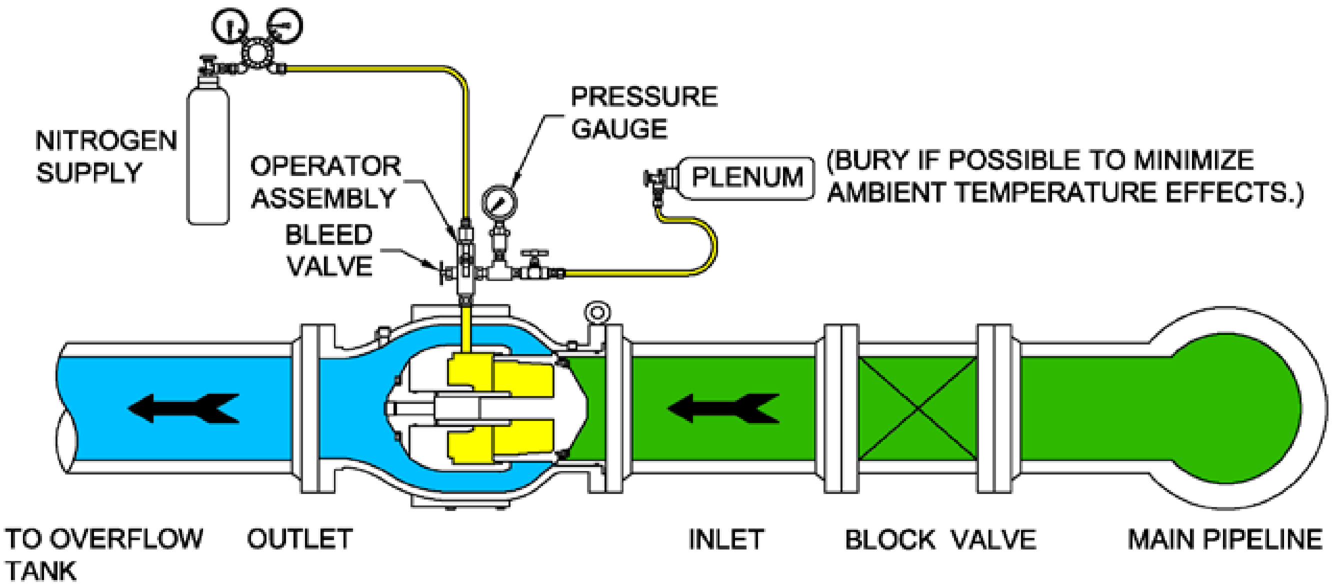

## Maximum Valve Cv for delta P 25≥psi

| Valve Size (in) | DIN (mm) | Maximum Valve Cv For delta P 25≥psi |
|---|---|---|
| 2 | 50 | 120 |
| 3 | 75 | 330 |
| 4 | 100 | 480 |
| 6 | 150 | 1200 |
| 8 | 200 | 1900 |
| 10 | 250 | 3100 |
| 12 | 300 | 4200 |
| 16 | 400 | 7630 |



# M&J Can Supply the Whole Package

We can-and usually do-supply complete fabricated skids and nitrogen-control packages which can be temperature compensated for wide ambient temperature changes.




TYPICAL INSTALLATION

M&J can supply everything from surge relief valves to complete systems. DANFLO Surge Relief Systems provide the most effective way to protect your pipeline and equipment from unabated transient pressure surge waves (“water hammer”).

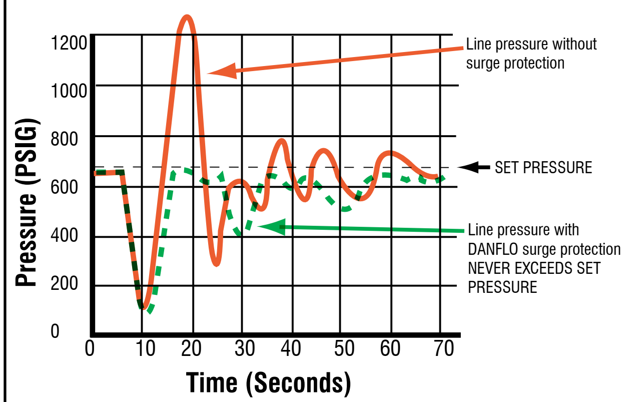
# Track Transient Pressure Surges Precisely for Maximum Protection (1)

A pressure surge is generated in a pipeline system when there is any change in the rate of flow of liquid in the line. The surge pressure can be dangerously high if the change is too rapid.

Surge pressures are created from:

(a) closure of an automatic emergency shutdown device (ESD valve)
(b) rapid closure or opening of a manual or power operated valve
(c) slamming shut of a non-return valve
(d) starting or stopping of a pump

Surge pressure may vary in magnitude from virtually undetectable to sufficient severity to cause a major disaster. Prevalent problems from insufficient surge protection include axial separation of flanges, pipe fatigue at welds or longitudinal splits of the pipe, pumps knocked out of alignment, severe damage to piping and piping supports as well as damage to specialized components such as loading arms, hoses, filters, bellows, etc.




**TYPICAL PRESSURE/TIME RESPONSE WITH AND WITHOUT SURGE RELIEF PROTECTIONS**

One of the first phases of a hydraulic-surge package should be a complete surge analysis. Part of the results of such analysis is the determination of how much flow will need to be relieved and at what set pressure. These two design criteria will help select a properly sized surge-relief package which will reduce surge pressure to an acceptable level during unsteady-state flow conditions.

Surge relief valves must respond rapidly yet operate very smoothly. They should open quickly to "track" the large initial pressure rise, then close in direct response to pressure decay at the valve inlet. The relieved flow is usually dumped into a large storage vessel and later returned to the product line.

(1) From Hydraulic Analysis, Ltd., Mill House, Hawksworth Rd., Horsforth, Leeds, LS18 4JP, England. Telephone (44) 0532 581622.

M&J Valve surge relief system protects pipelines from transient pressure surges

# Ordering Information

M&J has established a standard numbering system for DANFLO Surge Relief Valves.

## Materials of Construction

| Service(3) | Trim Type | Body Material(1) | Metal Trim Components | | | | | | Seats & Seals | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plug | Retainer | Seat Ring | Guide Sleeve | Optional Spring(4) | Internal Bolting | Seat Material | O-Ring Material |
| Non-Corrosive -20 to 240°F | ANR | ASTM A216 WCC | ASTM-A216 WCC(ENP)(2) | ASTM-A216 WCC(ENP)(2) | 316 SS | ASTM-A216 WCC Impreglon | Chromium Vanadium (Alloy Steel) | 18-8 SS | Nylon | Viton-A Viton-GFLT |
| Non-Corrosive -50 to 240°F | BNR | ASTM A352 LCC | ASTM-A352 LCC(ENP) | ASTM-A352 LCC(ENP) | 316 SS | ASTM-A352 LCC Impreglon | 17-4PH SS | 18-8 SS | Nylon | LT-Buna N |

(1) Where internal body corrosion is unacceptable with WCC material, consult factory for body recommendation.
(2) ENP=Electroless Nickel Plated
(3) On application, all trims can be altered as needed to comply with NACE MR-01-75 latest edition
(4) Spring is not required for nitrogen loaded Danflo valves

Trim Type from Table

## Example: 4”, Model 423 - ANR -40

DANFLO Valve Series
42 Nitrogen Loaded

Pressure Ratings
1 150# ANSI
3 300# ANSI
4 400# ANSI
5 600# ANSI
6 900# ANSI
7 1500# ANSI

Control Mode
40 Surge Relief

## Nitrogen Usage Formula

### For Surge Relief Systems with DANFLO Valves and Self-Relieving Regulators

1. Daily surge relief valve usage, SCFD

$$V=35.92\,(P_R \times 0.75)\,V_T\left(\frac{1}{T_1}-\frac{1}{T_2}\right)n$$

2. Usable nitrogen supply per “K” bottle, ft³

$$N=235-\left[\frac{(P_1+100)}{14.7}\times V_P\right]$$

3. Days supply available per “K” bottle

$$D=\frac{N}{V}\ \text{(See Notes)}$$

Where: V=daily surge relief valve usage, SCFD
n=number relief valves per location
$P_R$=relief valve set pressure, psia
$P_1$= relief valve cavity set pressure, psia=$P_R$ x 0.75
$V_T$=relief valve changer volume=($I+V_P$) ft$^3$ (see table)
I=relief valve plug cavity volume, ft$^3$ (see table)
$V_P$=plenum volume empty, ft$^3$=1.55 ft$^3$
$T_1$=average low temperature, °R=°F+460
$T_2$=average high temperature, °R=°F+460
$V_N$=initial volume of “K” bottle at 2200 psi, ft$^3$=253ft$^3$

NOTES: Because of valve internal construction, nitrogen set pressure should be approximately 75% of desired valve relief pressure; the formula shown above takes this into account.
Also, care should be taken in calculating the term involving the difference of the reciprocals of temperatures (Formula 1 above). Since the term expresses the differences of two similar numbers, it should be calculated to 4 significant figures.

## Example:

Nitrogen usage for Four 12” 150# DANFLO Valves in a Surge Relief System
Set Pressure (PR)=190 psig or 204.7 psia
T1=50°F or 510°R
T2=86°F or 546°R

1. Daily Surge Relief Valve Usage, SCFD

$$V=35.92\,(204.7 \times 0.75)\,1.95\left(\frac{1}{510}-\frac{1}{546}\right)4$$

$$V=35.92\,(153.5)\,(1.95)\,(0.00196-0.00183)\,(4)$$

V=5.59 SCFD

2. Usable Nitrogen Supply per “K” Bottle, ft3

$$N=235-\left[\frac{(153.5+100)}{14.7}\times 1.55\right]$$

N=235 - (17.24) x (1.55)
N=208.3 ft3

3. Days Supply Available per “K” Bottle*

$$D=\frac{208.3}{5.59}$$

D=37.3 days/bottle

### Table 1

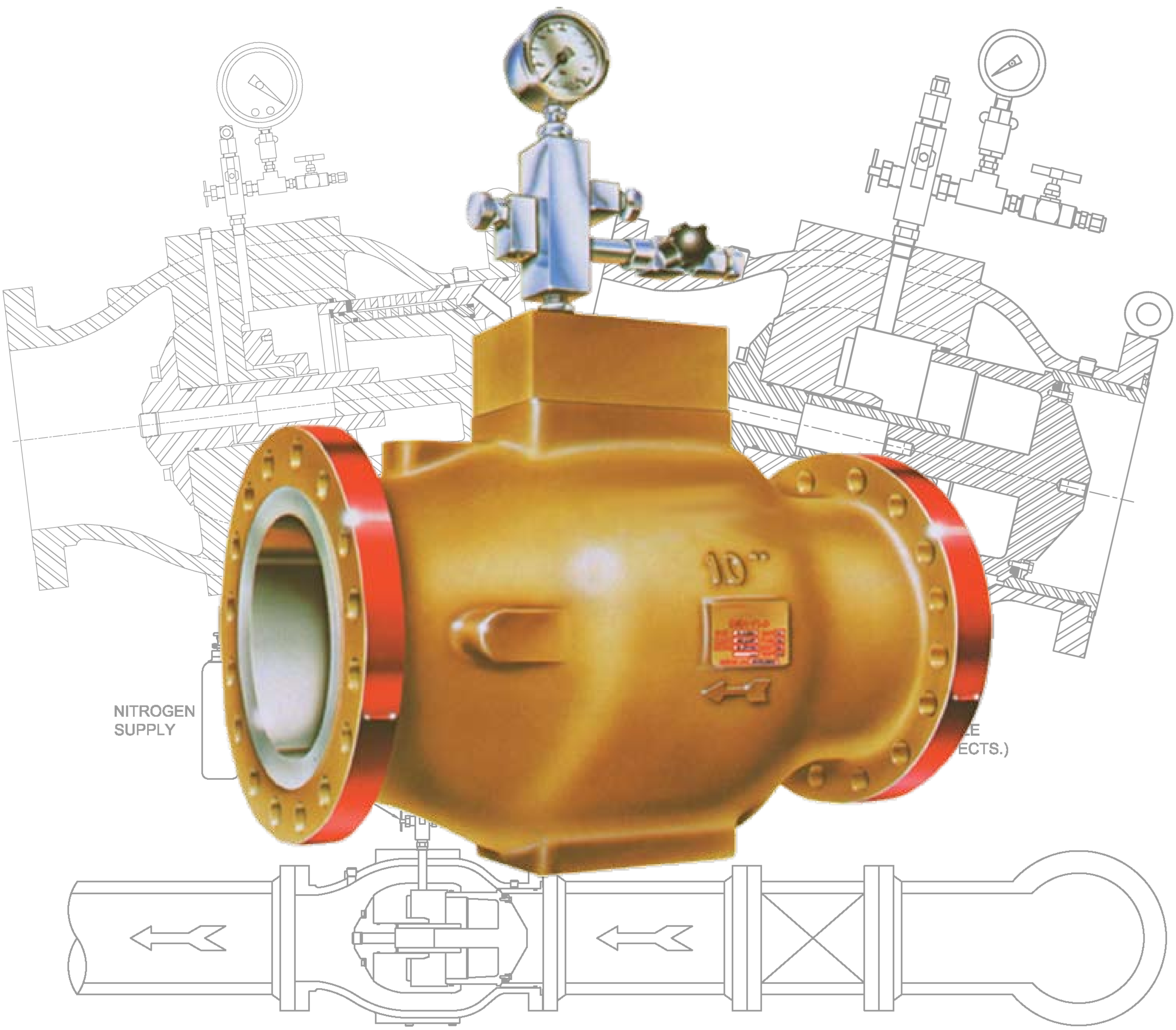
**DANFLO Plug Cavity (Volumes in Ft₃)**

| Size | I | Vp* | VT=I+Vp |
|---|---|---|---|
| 2” | 0.004 | 1.55 | 1.55 |
| 3” | 0.013 | 1.55 | 1.56 |
| 4” | 0.017 | 1.55 | 1.57 |
| 6” | 0.056 | 1.55 | 1.61 |
| 8” | 0.118 | 1.55 | 1.67 |
| 10” | 0.239 | 1.55 | 1.79 |
| 12” | 0.401 | 1.55 | 1.95 |
| 16” | 0.800 | 1.55 | 2.35 |

NOTE: This data for “K” sized bottle.
(Size 200, meets DOT Spec. 2265)

# Major Benefits and Advantages of DANFLO Liquid Surge Relief Valves

- **High flow capacities (Cv) mean you can use smaller and/or fewer valves to provide the surge protection you need. Save on installation cost and save weight.**
- **Fast response-rapid open/closing without slamming shut-allows the valve to "track the surge."**
- **Additional reserve flow capacity allows for unforeseen transient surge flow.**
- **Set pressure test port to meet Department of Transportation periodic-testing requirements. Reference U.S. Department of Transportation, Pipeline Safety Regulations, Hazardous Liquids Part 195, paragraph 195.428, Overpressure Safety Devices.**



Your local contact:

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For more information about our worldwide locations, approvals, certifications, and local representatives, please visit www.mandjvalve.com.

SPX Corporation reserves the right to incorporate our latest design and material changes without notice or obligation.
Design features, materials of construction and dimensional data, as described in this bulletin, are provided for your information only and should not be relied upon unless confirmed in writing.

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