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ADVANTAGES OF BLADDER SURGE TANKS IN PIPELINES

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ABSTRACT

The paper advocates the use of bladder surge tanks to control pressure surges in pipelines created by transient operations. Transient pressures are created as a result of pumps starting and stopping as well as the opening and closing of valves. This paper describes why the utilization of bladder surge tanks is the best solution to transient operations. A bladder surge tank allows piping systems to meet pressure piping codes such as ASME B31.3 and B31.4. Controlling pressure transients reduces pressure stresses, thereby extending the pipeline's operating life. This paper compares the use of a bladder surge tank to other methods to attenuate pressure transient in pipelines.

Generally, water and hydrocarbon pipelines operate safely throughout the world, but failure can occur as a result of pressure transients created by certain operating conditions. In addition, pipe materials are weakened as a result of years of operation and exposure to corrosion, pressure cycling fatigue and over-pressurization.

The usable life of piping materials can be significantly reduced by cyclic loading and surge pressure overstressing the material. Therefore, controlling pressure surges will increase pipeline life and reliability. This can be achieved by installing surge control equipment at the location of the transient event.

NOMENCLATURE

ASME - American Society of Mechanical Engineers
BST - Bladder Surge Tank
HST - Hydropneumatic Surge Tank (non-separator)
HTA - Hydraulic Transient Analysis (computer simulations)
MOP- Maximum Operating Pressure
PRV- Pressure Relief Valve or Safety Relief Valve
Precharge- The initial gas charge (nitrogen or air) within the bladder
Transient- Unsteady flow conditions

INTRODUCTION

When designing a pipeline, early consideration of pressure surge must be investigated to assure reliable operation without failure. This is especially critical for pipelines transporting hazardous materials, such as hydrocarbons and waste materials. Advances in computer programs which can simulate transient events enable designers to anticipate potential problems in the operations of the pipelines [1]. Utilizing surge control equipment reduces pressure transient and thereby pipe material stresses are reduced to meet proven piping standards such as ASME B31.3, 2010 Edition [2] and B31.4, 2009 Edition [3]. In addition, by reducing pressure transients, pipeline life can be extended.

Water and hydrocarbon pipelines generally operate safely, but through years of operation, they can fail as a result of loss of material strength from corrosion, cyclic fatigue and pressure transients that can over-pressurize the pipe beyond the MOP.

When pipelines are designed, transient pressures must be considered and surge control equipment recommended. Digital computer modeling of the hydraulic piping system allows designers to account for pressure transients created during pump startup, shutdown and valve closure operations [1].

One of the main causes of pipe material strain is cyclic pressure or rapid pressure changes. Reducing the amplitude of these pressure changes will decrease the strain on the pipe material, thereby increasing operating life. Stress corrosion can also depreciate pipe material strength, reducing operating life and leading to premature failure. This can occur even if the pipeline has been hydraulically pressure tested [4]. Figure 1 illustrates the relationship between the percent of life to the crack initiation and fatigue life [5].

There are several different types of equipment being used today to control pressure surges in pipelines. Each has its advantages and disadvantages in mitigating pressure surges created by unsteady flow conditions. There are two major categories of products: Pressure Vessel type and Valve type surge control products.

In the Pressure Vessel category, it can be divided into Hydropneumatic Surge Tanks (HST) with non-separation between the gas to the operating fluid and Bladder Surge Tanks (BST) with positive separation of the gas and operating fluid. Both operate utilizing a gas charge to provide the pressure energy to supply and accept fluid from the operating pipeline. The main difference is an elastomeric bladder which physically separates the liquid from the gas within the pressure vessel in Bladder Surge Tanks (BST).

Hydropneumatic Surge Tanks (HST) are pressure vessels which are partially filled with the operating fluid and have a gas blanket to discharge the fluid when the pressure in the pipeline decreases. When the pipeline pressure increases, the tank accepts fluid by compressing the gas trapped within the tank. These tanks have a constant supply of gas or air to keep the proper levels and some have a level control system to automatically maintain the correct gas to liquid ratio. Because of gas absorption into the liquid, gas must constantly be replenished on this type of system and commonly an air compressor is required to keep the tank operational.

The Bladder Surge Tank incorporates an elastomeric bladder which keeps a positive separation between the gas and operating liquid. The loss of the gas in the bladder is minimal and is limited to the gas that permeates through the bladder material. Normally this type of product does not require a continuous source of gas or a level control system to maintain the proper gas-to-liquid volume ratios to operate effectively.

Bladder type (BST) and Hydropneumatic (HST) surge tanks both operate in the same manner to control pressure surges from valve operation and pump startup or shutdown conditions. In the case of valve closure or suction line pump shutoff, the product is typically installed as shown in Figure 4B.

When the valve closes or the pump shuts off, the fluid column begins to decelerate and the pressure begins to rise. The instant the pressure increases above the steady state pressure, fluid begins to enter the BST or HST through the connecting pipe in Figure 4B2F. As the fluid enters, it immediately compresses the trapped gas within the tank and the pipeline fluid energy is used to compress the gas volume until the pipeline stops. This smooth transitional event can be seen in Figure 3, pressure versus time curve. Note the lack of transient pressure during this compression cycle.

Upon the pipeline reversal, the surge tank discharges fluid and the gas expands. This prevents extremely low pressure which can result in column separation and can create pressure transients.

On the discharge side of the pump, the shutdown condition requires a surge tank to be installed as shown in Figure 4A. When the pump shuts down, the pressure at the discharge suddenly decreases. The fluid in the BST or HST begins discharging into the pipeline through the connecting pipeline (Figure 4A1G). The fluid slowly closes the check valve (Figure 4A1B) and prevents the fluid pressure from dropping below the fluid vapor pressure, thereby eliminating column separation.

When the pipeline reverses in flow direction, the BST or HST accepts the fluid and “cushions” the impact of the returning fluid column.

This is all done within the containment of the surge tank and piping system. No fluid is discharged from the pipeline or outside of the pressure vessel’s pressure boundaries.

This product can be sized utilizing a digital hydraulic transient analysis program (HTA) which simulates the flow condition as a function of time. Typically the longer piping system will require a surge tank of larger volume.

The second category is the Valve type surge control devices. These are known by such names as pressure relief valves (PRV), safety relief valves, surge anticipation valves and air release and vacuum valves. All of these devices incorporate a mechanical valve mechanism that allows the operating fluid to discharge outside of the pressure containment of the pipeline thus relieving pressure.

Pressure Relief Valves (PRV) are spring loaded valve devices which are designed to relieve the pipeline pressure when it reaches a predetermined set pressure. The pipeline fluid contents are discharged into a containment vessel or back to the pumps wet well. As a result of being a mechanical device, there is a delay in the response time of the valve's ability to relieve the pressure. This can result in transient pressures being generated (Figure 2).

Pressure Relief Valves (PRV) primarily operate to relieve the pressure only at the location they are installed. Pressure surges occurring at other locations cannot be relieved and as a result will travel within the piping at a high rate of speed (pressure wave speed). In addition, the high frequency pressure cycles not relieved by a PRV can cause fatigue cycling [6]. A pressure transient is short in duration, lasting just microseconds, but can lead to stress crack initiation and result in reduced material strength.

The containment vessel will eventually fill with this valve discharge fluid. The rate is dependent on the relief discharge flow and its duration. When this vessel becomes full, it will need to be emptied before the pressure relief valve (PRV) can continue to operate without spilling the fluid contents.

Air release and vacuum valves are fairly simple mechanical devices. These valves introduce air into the pipeline and discharge it out during an unsteady flow event. The introduction of air can sometimes prevent column separation by keeping the pressure from dropping below the liquid vapor pressure. The air that is introduced can be discharged through air release valves to prevent air pockets in the pipeline. These types of devices are often damaged from exposure to excessive pressures [7].

A surge anticipation valve is a product which senses an initial pressure drop and then opens when the pipeline reverses its flow direction to allow the fluid contents to be discharged from the pipeline. These valves require a bypass line for proper installation and are extremely complex in the initial settings [8]. This must be done after installation and through several test trials to achieve the proper settings.

CONCLUSION

Hydraulic pipelines are essential in the transportation of fluid across large distances. The consideration of transient flow conditions is critical for the optimum design of pipelines to prevent pipe leaks and potential failures and ensure safe operation. When surge control devices are used properly, piping pressure transients can be avoided and pipeline life expectancy is increased.

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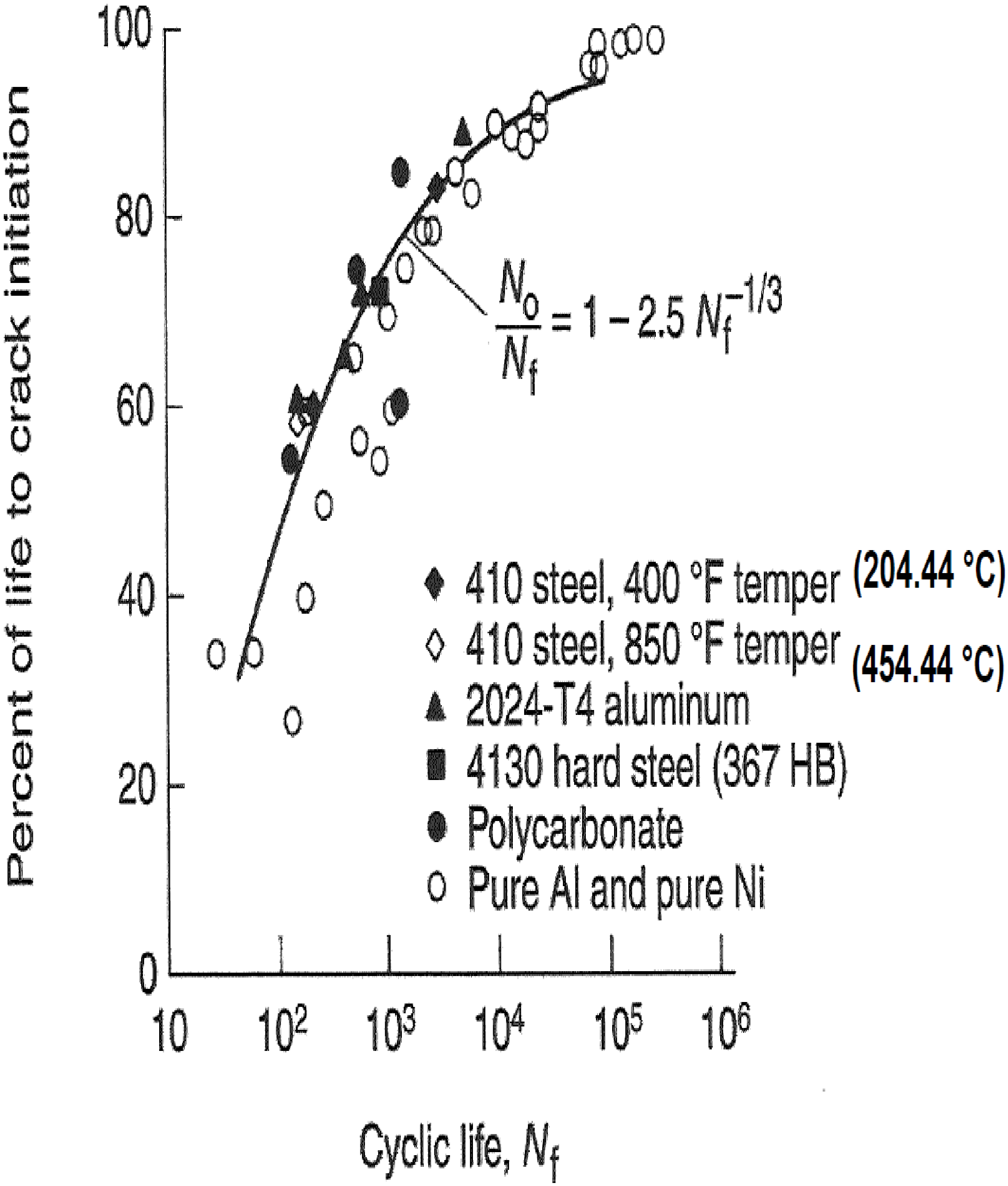

FIGURE 1
RELATION BETWEEN PERCENT OF LIFE TO CRACK INITIATION AND FATIGUE LIFE FOR VARIOUS MATERIALS

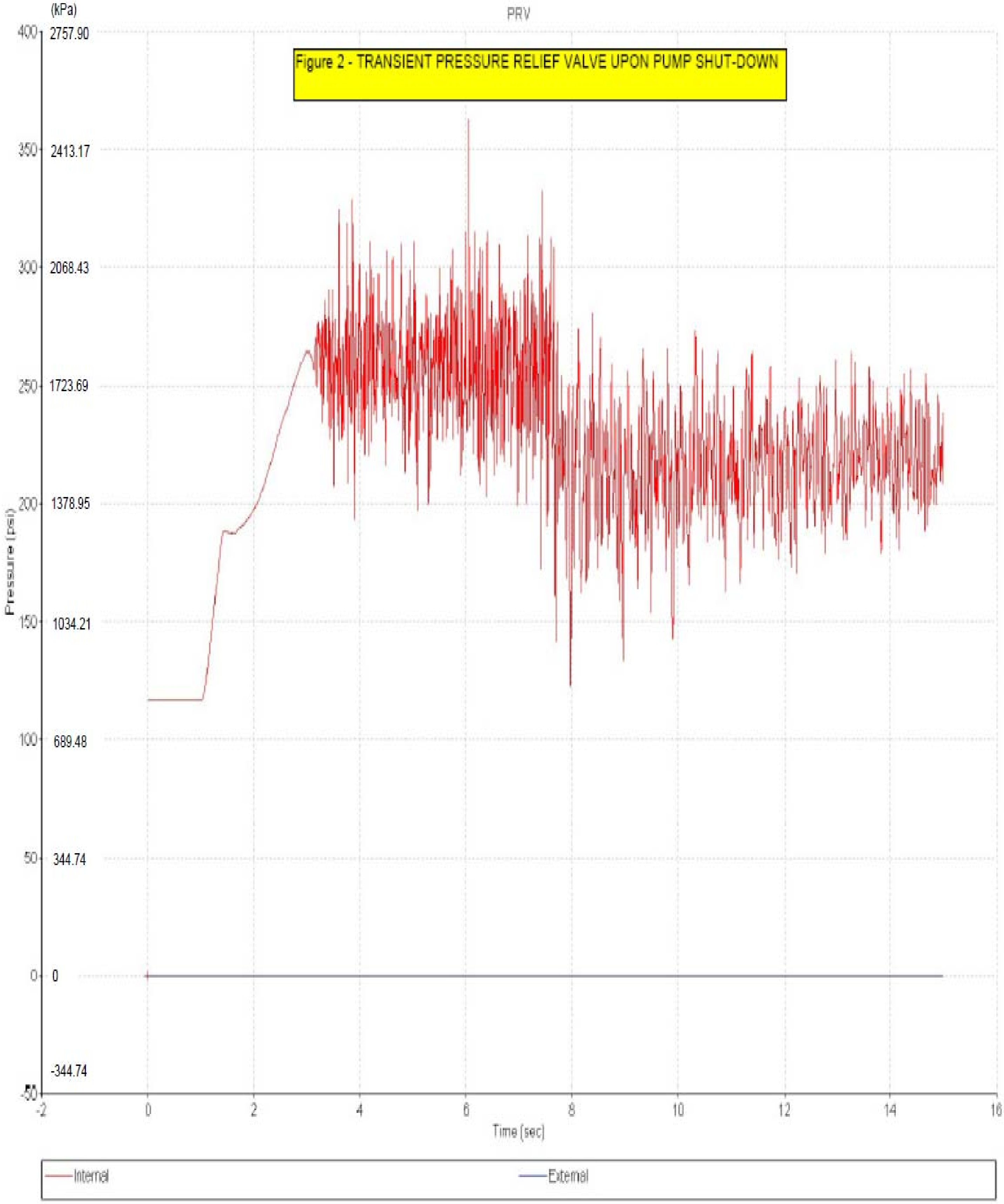

FIGURE 2
CHANGE IN PRESSURE OVER TIME FOR TRANSIENT PRESSURE RELIEF VALVE UPON PUMP SHUT-DOWN

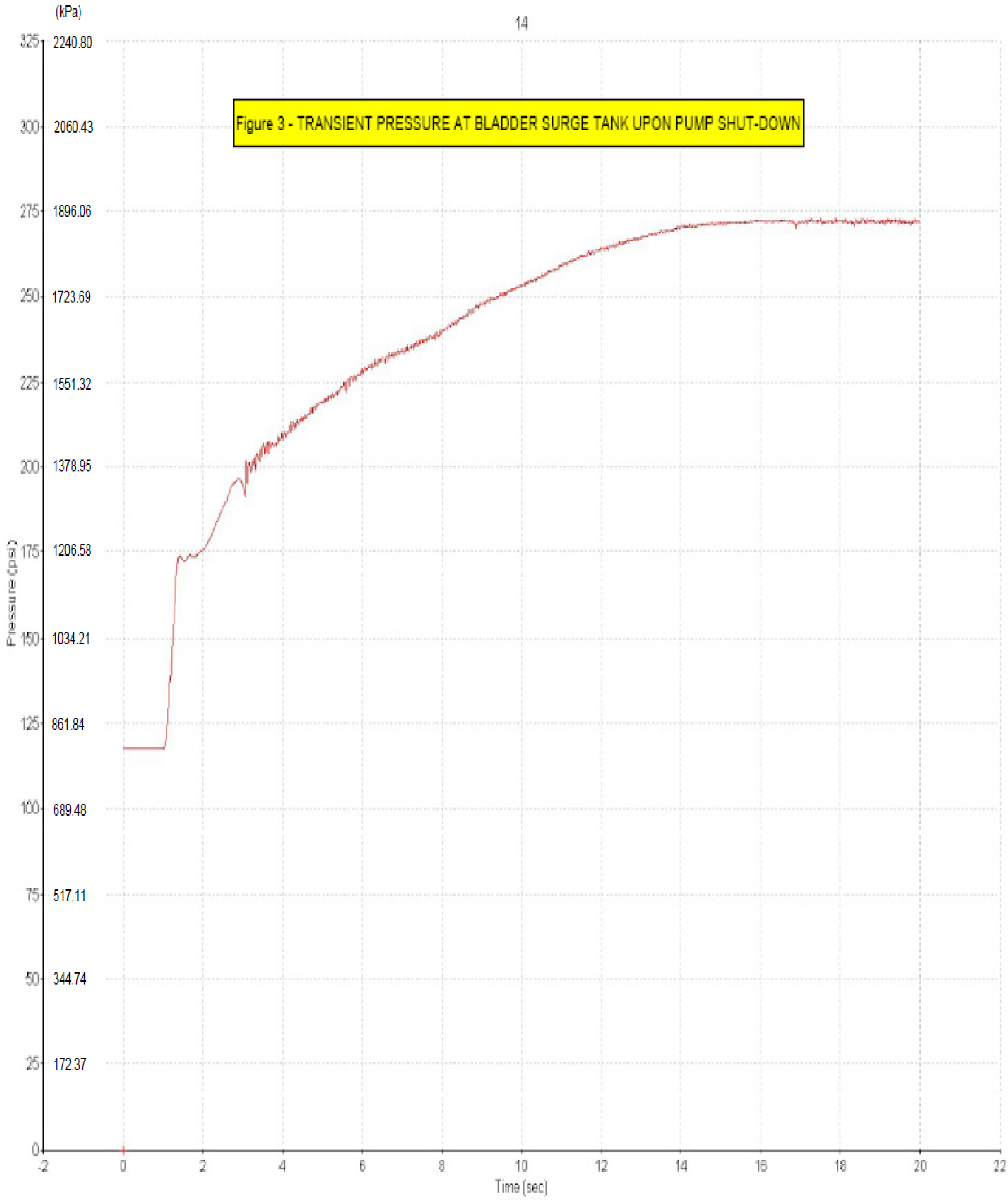

FIGURE 3
CHANGE IN PRESSURE OVER TIME FOR TRANSIENT PRESSURE BLADDER SURGE TANK UPON PUMP SHUT-DOWN

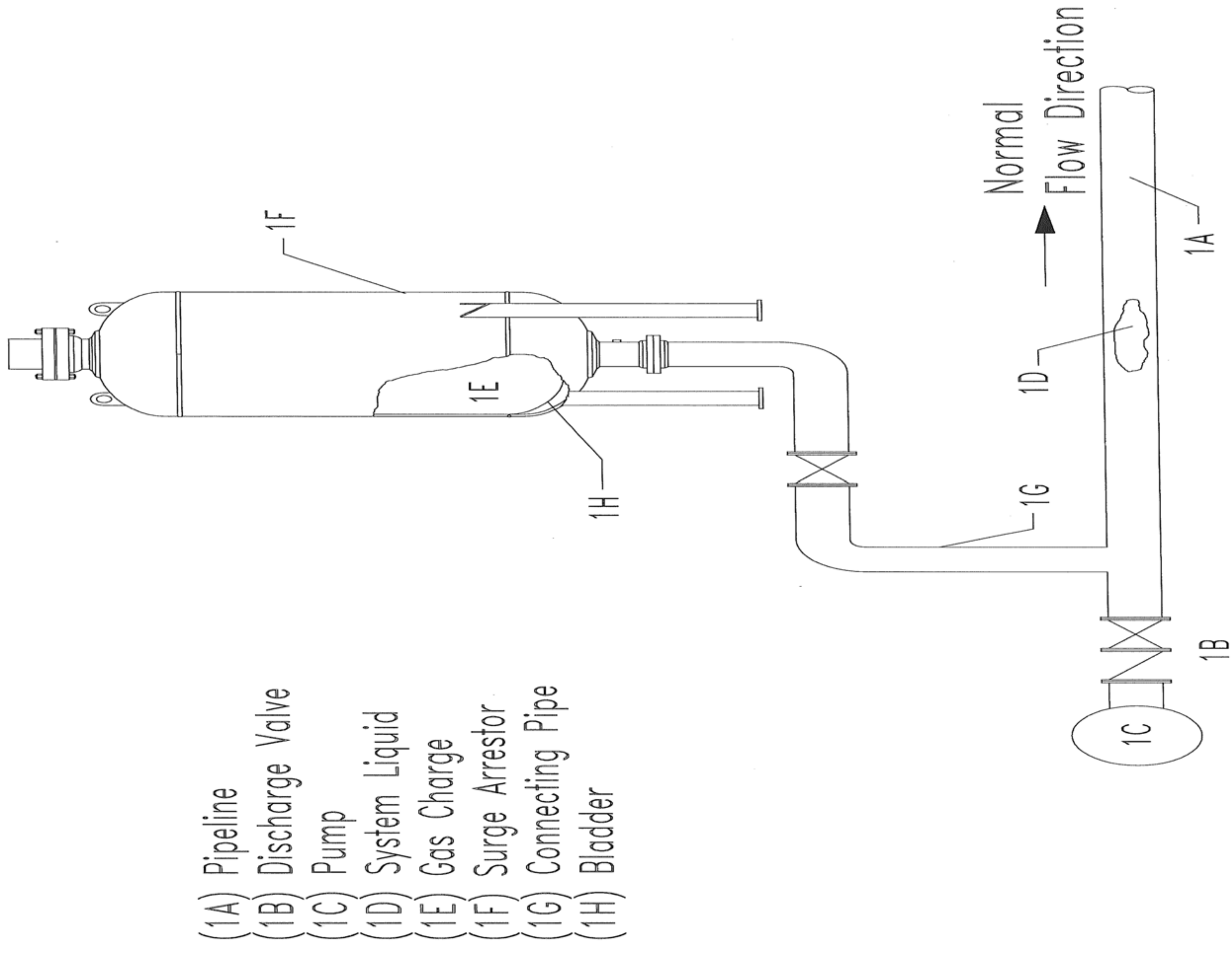

FIGURE 4A
TYPICAL INSTALLATION OF A SURGE TANK AT PUMP DISCHARGE

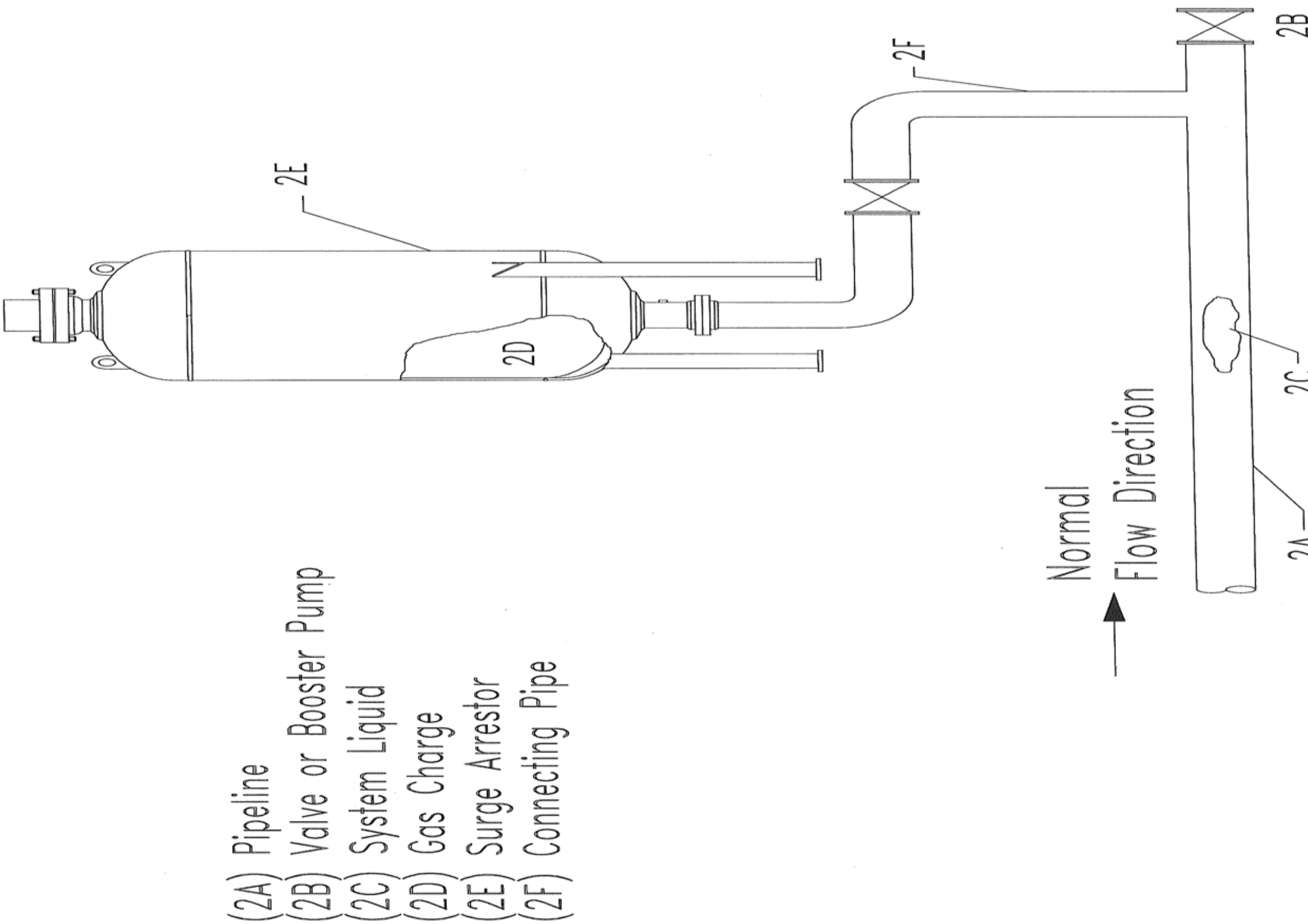

FIGURE 4B
TYPICAL INSTALLATION OF A SURGE TANK UPSTREAM OF A VALVE OR BOOSTER PUMP