Application Data Sheet

INDUSTRY: Pipeline *APPLICATION: Booster Station Control*

PIPELINE BOOSTER STATION CONTROL SYSTEMS

INTRODUCTION

Booster pumping stations are essential for maintaining sufficient pressures and flow rates to efficiently operate a pipeline.

Figure 1 shows a simplified layout of a typical booster pumping station. Booster stations increase pipeline pressure sufficiently to maintain the flow rate necessary to meet contract requirements. Flow rates are manipulated by starting or stopping pumps and stations rather than by throttling a control valve.

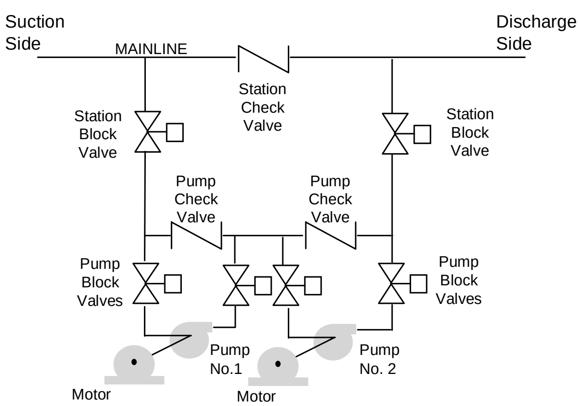

Figure 1 - Typical Booster Pump Station

Station controls vary according to the operations performed and the types of equipment employed. For instance, originating stations often have pumps with flat head curves and require flow control most of the time, but booster stations are usually designed to operate at design speed. If the station consists of constant speed electric motors driving centrifugal pumps, control is exercised by throttling a control valve in the station discharge line. If the station has diesel engines with positive displacement pumps, the final control element is a speed governor. (Variations on the control systems required by speed governors are discussed at the end of this article.)

Station control systems are designed to perform two separate functions: safety limiting and startup/shutdown control. If the basic control system cannot maintain the pipeline within the safety limits then automatic safety shutdown occurs. Care must be taken in design of station control systems to avoid spurious shutdowns. If the line is operating at capacity, one shutdown can cost a pipeline company more than the original cost of the station control package.

THE CONTROL SYSTEM - SAFETY LIMITS

The control system must maintain the pressure in a pipeline below its maximum design limit. If a downstream station loses power or if some malfunction in valving occurs, pressure surges can rise to dangerous levels. The control valve in the station discharge line can be throttled to maintain safe pressure. The suction pressure at a pipeline station must be maintained above a certain value to avoid cavitation in the pump. The safe suction pressure is determined by the material being moved. For instance, the safe suction pressure for propane may be 250 psi while that for the motor gasoline may be 50 psi. Since there can only be one control valve, the station control must be an override system.

The most common control system for a pipeline station is suction-discharge pressure override control as shown in Figure 2. For pipe protection, discharge pressure is controlled. The control set-point is within a few percent of the maximum limit, which emphasizes the need for no overshoot on the recovery after an upset. For pump and product protection, suction pressure is also controlled. The outputs from the Suction and Discharge pressure controllers, PIC-1 and PIC-2, are fed into a low signal selector PY-1. The lower of the two inputs is selected and fed to the discharge flow control valve, the flow being varied to maintain the suction and discharge pressure at their respective setpoints. The signal is also used as *external feedback* to the controllers to prevent reset wind-up and overshoot.

Other station parameters may require safety limit control. For example, to avoid excessive power rates based on peak demand, the power to each motor may be measured and controlled by throttling the station valve. As the flow through a centrifugal pump increases, the horsepower required (and therefore the motor current required) increases. When the interface between two different API gravity products passes through a station, the flow rate may increase drastically. If these high flow rates are maintained the motor can burn up. The flow rate may be measured and controlled by throttling the station control valve.

Usually a signal selector is combined with an automatic to-manual transfer station so that the override controls are removed from the circuit when the operator selects manual control. This system is shown in Figure 3.

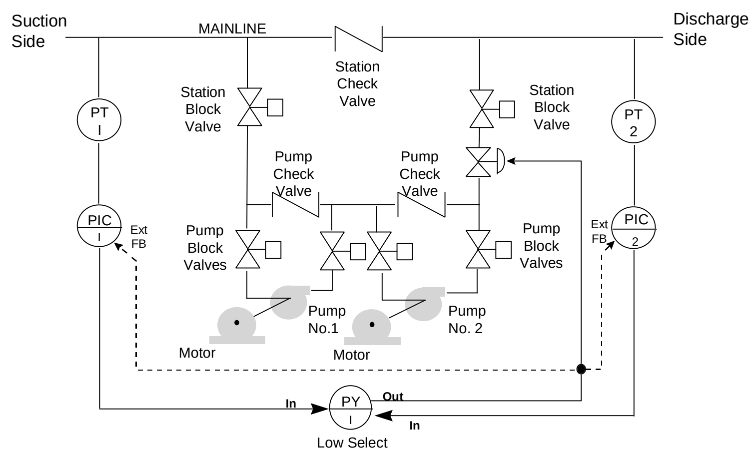

Figure 2 - Suction-Discharge Override Control System

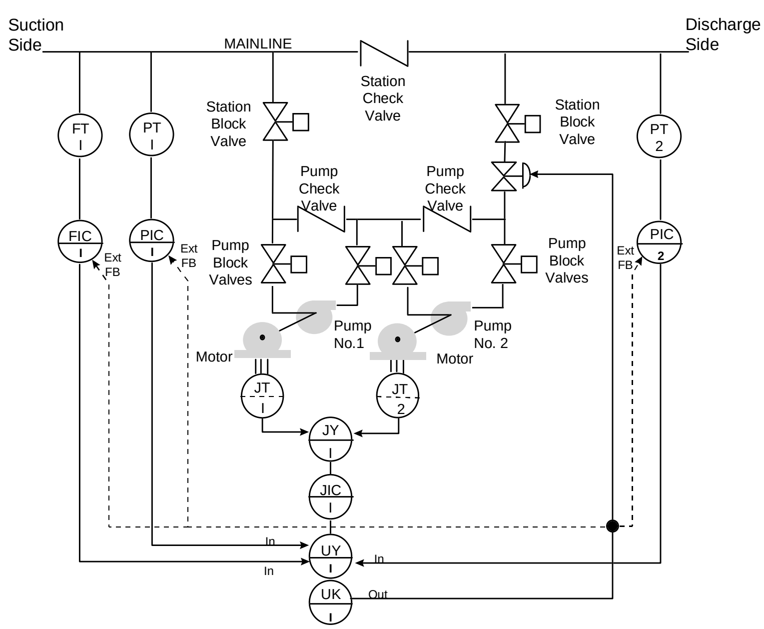

Figure 3 - Flow, Suction Pressure, K.W., and Discharge Pressure Override System

THE CONTROL SYSTEM - STARTUP

The problems in starting a pipeline station or in starting an additional pump at the station result from the inertia of the large mass of material being moved. The motor and pump can come up to full speed much more rapidly than the total pipeline can change to new pressure and flow conditions. Unless special care is exercised each of the safety limits previously discussed is in danger of being exceeded. Depending on how the rest of the pipeline is operating when this station is started up, there could be an overloaded motor or a cavitating pump or a shock wave of high pressure transmitted down the pipeline.

MANNED OPERATION

As an example of a booster station startup, assume the following conditions exist before starting the pump:

> A suction-discharge override control system as shown in Figure 2. With the set-point of the suction pressure controller at 40 psi, the actual suction pressure at 100 psi, the controller in direct action, its output would be 20 milliamps.
>
> Discharge pressure setpoint is at 500 psi, the actual discharge pressure is at 100 psi, the controller in reverse action, its output would also be 20 milliamps.
>
> The signal selector is a low current selector and its output will be 20 milliamps.

Before starting the first pump, the operator will switch the Auto/Manual station to manual and close the control valve. The pump is started and increases pressure in the line between the pump and the control valve (called the case pressure). When the pump is up to speed, the operator slowly opens the control valve while observing both discharge pressure and suction pressure. When the valve is fully open, the operator returns the controls to automatic.

REMOTE OPERATION

Remote Startup-Ramp Function Generator

With a device known as a ramp function generator the station can be started remotely. The ramp function generator responds to contact closures to increase or decrease its 4 to 20 milliamp output at preset rates.

The ramp function generator's output will be a third input to the low signal selector. Figure 4 shows a control system employing the ramp function generator.

The following sequence starts the station. A contact closure activates the ramp function generator to drive its output to 4 milliamps which closes the valve. The pump is then started, (it usually takes five to ten seconds to get an electric motor and centrifugal pump up to speed). Another contact actuates the ramp function generator to ramp its output up. The rate of ramp is determined and set such that the station will be brought on as rapidly as possible without exceeding any of the safety override limits. If an upset should occur during the sequence of startup, the override controllers would maintain the safety limits.

A slightly different sequence is required when one pump is operating and the second pump needs to be brought on the line. The ramp function generator is started by a contact closure but ramps down to a predetermined point. This lower limit of the down ramp is dependent upon a number of variables: flow rate, the product, the valve characteristics, and the size of the pumps. As a result of various products being pumped through a pipeline, the predetermined limit must be safe for *all* conditions.

Figure 5 is a graph of ramp signal and discharge pressure during a startup using a ramp function generator. Note that the ramp rate must be set at the low rate required at first opening the valve. Also a ramp limit is chosen to be on the safe side. Thus, optimum operating conditions must be sacrificed for safety.

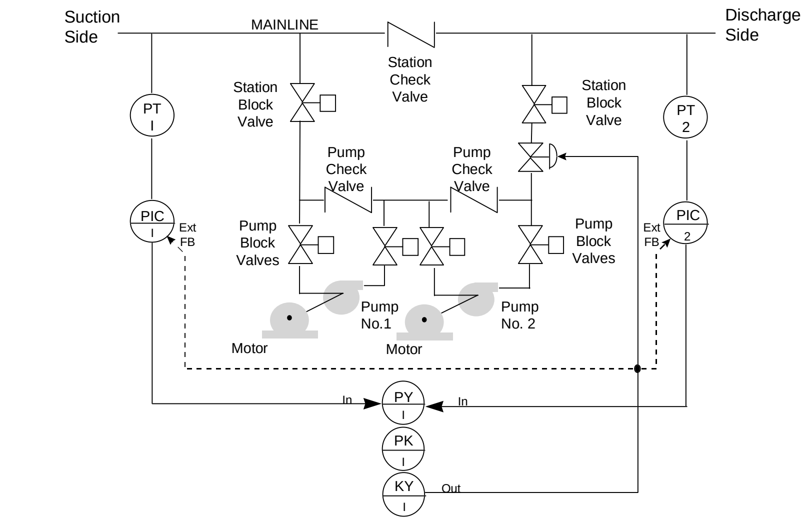

Figure 4 - Suction Discharge Override with Ramp Function Generator

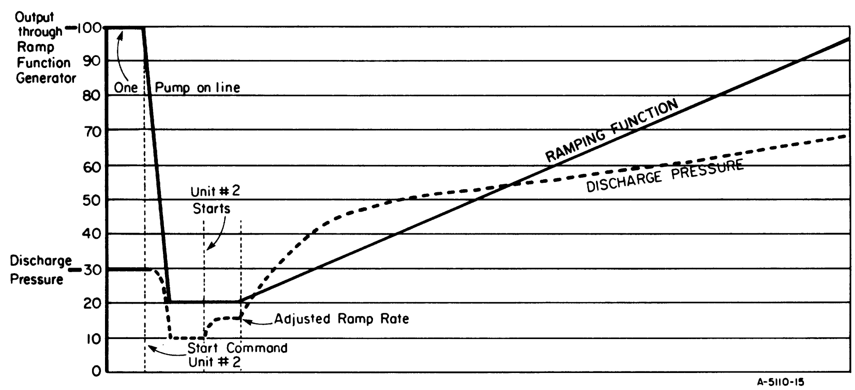

Figure 5 - Ramp Function Generator Startup

Remote Startup-Ramp Setpoint Control

By controlling setpoint ramp rate, a booster station or pump can be brought on the line in the shortest safe time with a minimum of valve throttling. The most critical of station parameters - flow, suction pressure or discharge pressure - is selected for control.

That controller brings the station on line at a controlled ramp rate. Figure 6 is a control system with a ramp setpoint controller.

Assuming the same initial conditions of suction pressure, discharge pressure and output to the valve as before and assuming that the critical parameter for the ramp setpoint controller is discharge pressure, the following startup sequence is performed.

The station receives the signal to initiate the startup sequence. As part of this sequence, a contact is provided to the *float* terminals of the ramp set-point controller.

In the *float* condition the discharge pressure controller's set-point is driven at a ten second ramp rate to the discharge pressure value.

After ten seconds a second contact closure is applied to the *lock* terminals of the set-point controller. As long as this.contact closure is maintained the set-point remains locked at this pre-startup value.

The pump startup sequence is initiated. This sequence includes opening the suction valve, opening the discharge valve and monitoring the pump parameters.

As the discharge pressure starts to increase, the controller will immediately start to drive the control valve closed to prevent the discharge pressure from increasing beyond the discharge pressure set-point.

When the pump is up to speed, all of the additional pressure developed by the pump is being dropped across the control valve. Therefore, the discharge pressure of the station and the flow past the station have not increased.

Now the contact closures (float and lock) are removed, and the set-point ramps at its preset rate to the remote set-point value. The controller will send whatever signal is necessary to the valve to control at the required discharge pressure set-point.

The sequence works equally well to bring a booster station on line or to bring a second pump on line with the first pump running. Figure 7 is a graphical representation of this advanced method of station or pump startup.

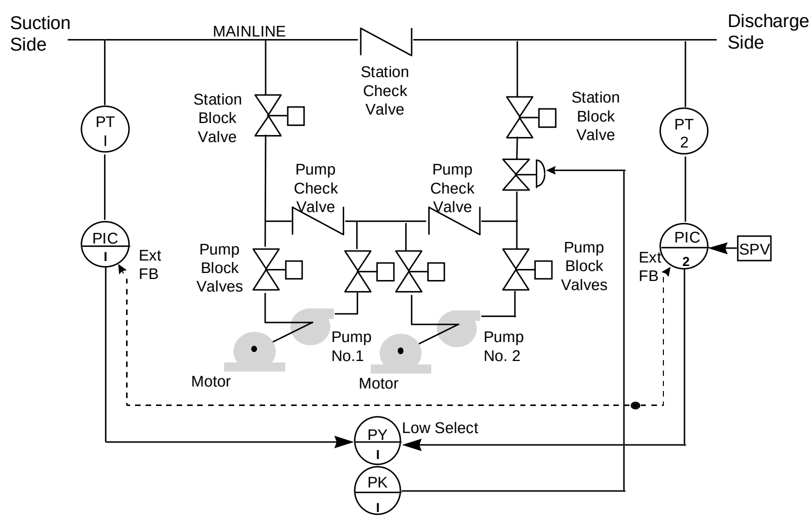

Figure 6 - Suction-Discharge Pressure Override with Ramp Set Point Controller

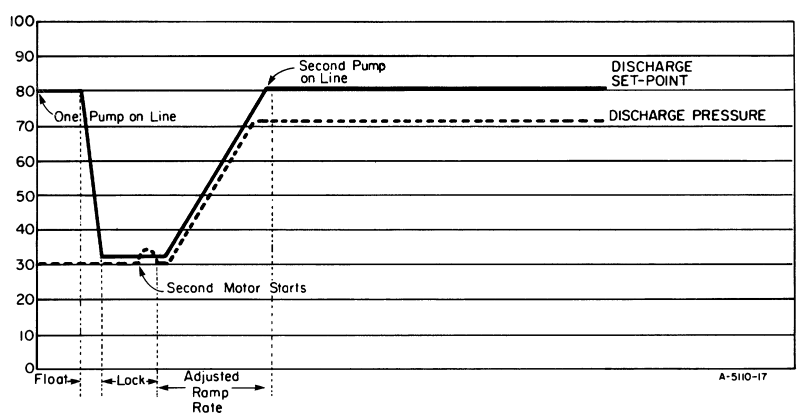

Figure 7 - Ramp Set Point Controller Startup

POSITIVE DISPLACEMENT PUMPS

Most positive discharge pumps are diesel driven and are variable speed, therefore, the final control element is a speed governor. The control system is similar to the previous systems, except that the selector output goes to the speed governors of each pump, instead of a control valve. A ramp function generator (R.F.G.) has to be added for each unit to bring them up to speed. An example of this control system is shown in Figure 8.

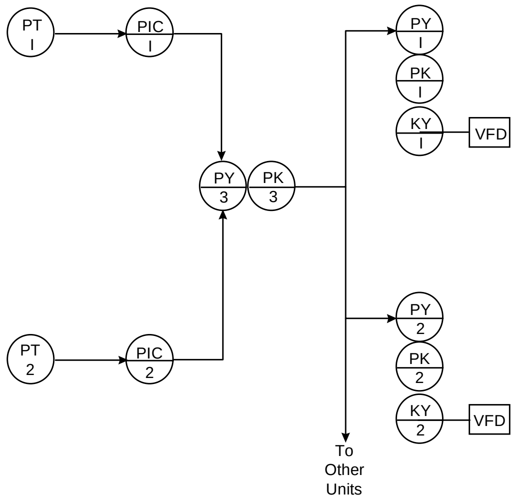

Figure 8 - Positive Displacement Pump Control System

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