LIQUID PIPELINE APPLICATIONS

OVERVIEW

REXA Electraulic™ actuators are widely used throughout the liquid pipeline industry. Actuation needs within the liquid pipeline industry are diverse due to the wide range of product properties, flow rates, pipeline sizes and pipeline lengths encountered. Both linear and rotary actuators, from the smallest to the largest, are applicable.

REXA Electraulic actuators have been used on many applications to improve control performance on a number of different pipelines including:

Crude Oil
- Trunk Lines – 8 to 24 inches in diameter and larger
- Gathering Lines – 2 to 6 inches in diameter

Refined Products – 6 to 12 inches in diameter and larger
- Gasoline
- Jet Fuel
- Diesel
- Chemicals

Carbon Dioxide

Other Liquids

REQUIREMENTS

Flexibility in pipeline operation requires frequent changes in flow rates and delivery sites. Responsive line pressure control is essential to prevent line shutdowns due to pressure excursions. High resolution and fast response are necessary for successful applications.

OPTIONS

Electro-hydraulic actuators are widely used in the liquid pipeline industry because:

- Thrust or torque requirements for many applications require excessively large pneumatic actuators.
- The repeatability, frequency response, dead time, and resolution requirements to intercept and control pressure fluctuations may exceed pneumatic actuator capabilities.
- Instrument air compressor systems needed to operate pneumatic actuators are expensive to install and require continuous, high cost maintenance.
- 100% modulating duty cycle requirements exceed the capabilities of electro-mechanical actuators, resulting in premature failure of the mechanical gear train and electric induction motors.
- Fail-safe options are limited with electro-mechanical actuators.

LIQUID PIPELINE APPLICATIONS

Conventional electro-hydraulic technology has several drawbacks:

- Reservoir based systems require interconnecting hydraulic piping systems.
- Piping systems frequently leak.
- High volumes of special hydraulic fluid are required.
- Fluid filtering systems and associated maintenance are costly.
- Reservoir communicates with atmosphere, requiring air filters and possibly introducing condensation and contamination into the hydraulic fluid.
- Motors and hydraulic pumps run continuously.
- High capital costs.
- High maintenance costs.
- High operation costs.

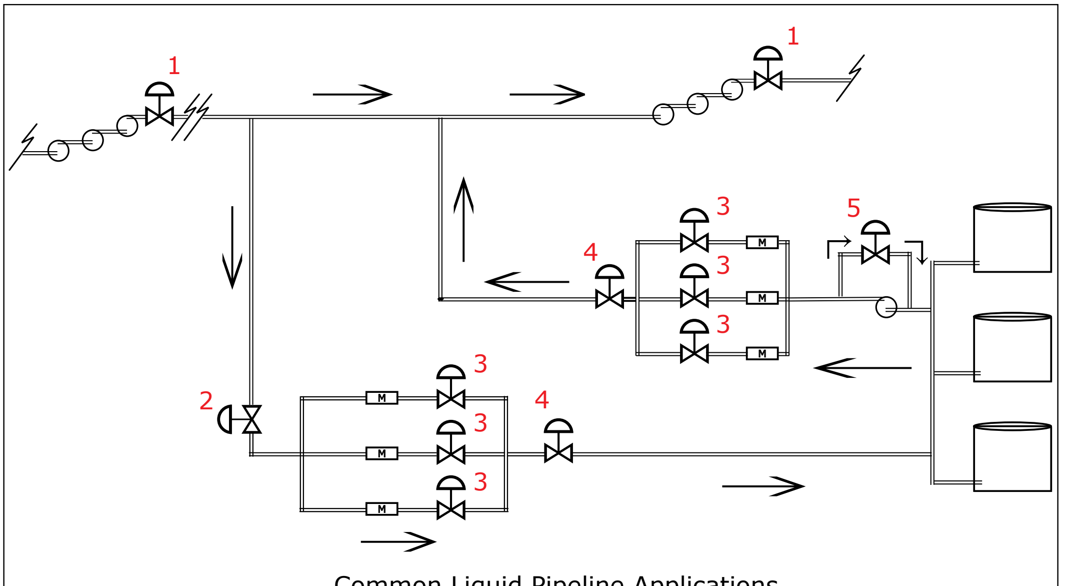
REXA Electraulic™ actuators are used for many critical applications in this industry due to:

- Positioning Accuracy – Very precise positioning with high position resolution.
- Repeatability.
- Dead Time.
- Speed of Response – Very fast acting.
- Frequency Response – Very high frequency response.
- Reliability.
- 100% Duty Cycle – continuous modulating service.
- No Scheduled Maintenance.
- Ease of Repair – modular design.
- Self Contained Hydraulics – hermetically sealed.
- Fail-Safe Capable.

APPLICATIONS

Five applications most commonly found in the liquid pipeline industry are:

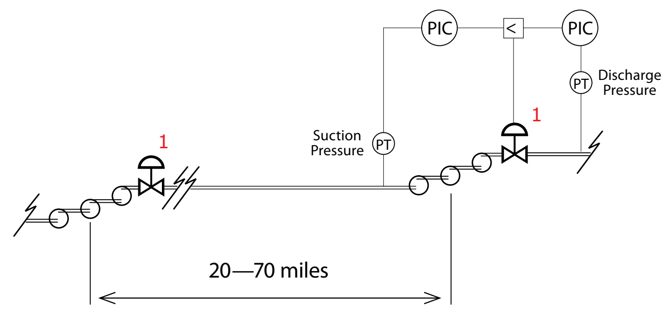
1. Pump Station Pressure Control
2. Terminal Inlet Pressure Control
3. Metering Balance Control
4. Meter Back Pressure Control
5. Pump Recycle Control



Common Liquid Pipeline Applications

(1) Pump Station Pressure Control

Effective pump station pressure control is essential to the safe and reliable operation of liquid pipelines. The pressure control serves two purposes in the operation of the pipeline.



Pump Station Pressure Control

The first purpose is to control the discharge pressure of the pump station. This controls the flow rate and attenuates pressure fluctuations to downstream pump stations. The pressure control function ensures that the pipeline is operating below the system design pressures.

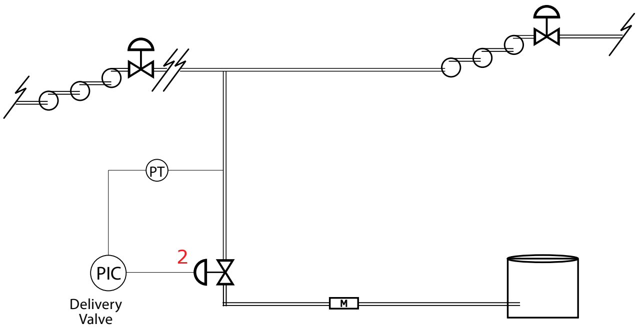
The second purpose is to control the incoming pressure to the pump station. The incoming pressure must be kept above the NPSH (Net Positive Suction Head) required by the pumps in order to prevent cavitation within the pumps and the ensuing damage that would result.

Pressure control is very interactive from one pump station to another. Pressure fluctuations at one station will affect all of the other pump stations on the pipeline. Stable pressure control allows the operator to run the pipeline closer to hydraulic capacity, resulting in increased throughput. The control system must be able to provide fast response to pressure disturbances including starts, stops and flow rate changes. It must also provide fast response to setpoint adjustments at one station in order to achieve the desired flow rate and pressure at another.

Pump station pressure control valves are generally ball valve designs due to the high capacity and efficiency requirements. These valves are selected to minimize the pressure drop through the valve during steady state operating conditions, thereby reducing pump energy costs. During those steady state conditions the pressure control valve will be 100% open producing a minimum energy loss. However, during transient conditions the valves must operate with large pressure drops. These valves are required to control through a very wide flow range. Product variability, varying flow rates and the number of pumps running, all contribute to the flow range that is required. During transient conditions the differential pressure can be high for short durations. Differential pressures of 500 psid are common. Speed of response should be fast to match the time constants that are associated with these pressure control loops. Response times of five to ten seconds for 100% travel are appropriate for most pump station pressure control applications. Studies have shown that in many applications the valve will be required to move from 100% open in the steady state operating conditions to 50-60% open before it will have any effect upon the actual pressure control during a transient. The normal throttling range during transients will often be between 20-50% open.

(2) Terminal Inlet Pressure Control

The terminal inlet pressure control system —also known as Delivery or Holding Pressure Control—reduces the pressure from the main pipeline to the terminal. This pressure is changed to alter the flow rate into the terminal or to another pipeline. The control system must provide fast response to flow and pressure disturbances.

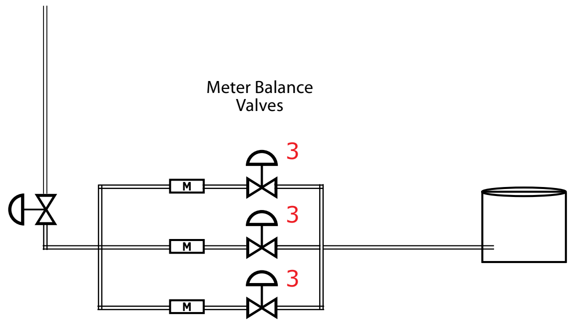


Terminal Inlet Pressure Control

Globe valve designs are generally preferred for terminal inlet pressure control due to their higher cavitation coefficient. However, many ball valve designs are used in this application due to their lower costs for a given flow capacity. High differential pressures from 50 to 250 psid are normal during continuous duty. Cavitation is an important consideration in the selection of control valves for this application. Response times of ten to fifteen seconds for 100% travel are appropriate for most terminal inlet pressure control applications.

(3) Metering Balance Control

Metering balance control valves control the flow rate through each individual meter run. Flow range requirements into and out of the terminal may be high. Multiple meter runs are used in many applications to keep flow rates within the optimum accuracy range of the individual flowmeters.

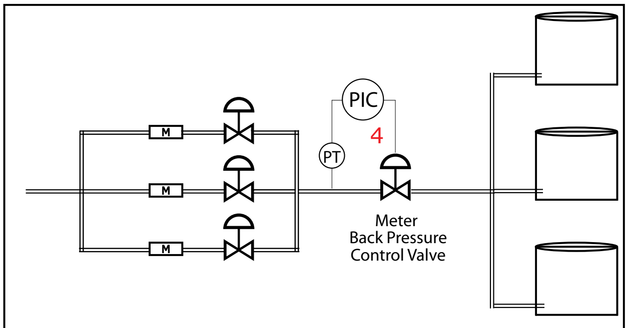


Metering Balance Control

Ball valve designs are generally preferred for metering balance control. Butterfly valves may be used due to their lower costs but control performance will be reduced. Differential pressures are small. Speed of response should be moderately fast to prevent meter over–ranging during transients.

(4) Meter Back Pressure Control

Back pressure must be maintained on the flowmeters to ensure that there is no phase change of the product as it flows through the meter. Any amount of phase change affects the accuracy of the meter. The back pressure setpoint is usually around 35 psig. The control system must provide fast response to main line pressure changes as well as flow and pressure changes in the delivery line.

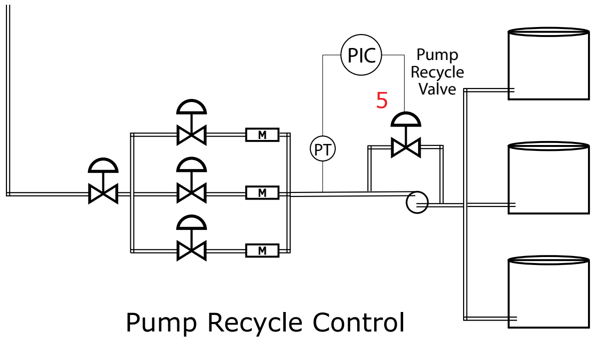


Meter Back Pressure Control

Ball valve designs are generally preferred for meter back pressure control. Butterfly valves may be used due to their lower costs but control performance will be reduced. Differential pressures are small, usually less than 50 psid. The meter back pressure control valves are throttling during normal operation. Cavitation is an important consideration in valve selection. Speed of response should be moderately fast.

(5) Pump Recycle Control

Pump recycle control—also known as pump recirculation flow control—is implemented to keep the pumps operating at a point on their curve to prevent overpressure of downstream piping and components. The loop controls pressure directly and, by the nature of the system hydraulics, flow rate.



Pump Recycle Control

Globe valve designs are generally preferred for pump recycle control due to their higher cavitation coefficient. Cavitation is an important consideration in the selection of control valves for this application. Speed of response should be moderately fast.

There are many other applications where REXA actuation will provide improved control performance. REXA actuators should be considered for any application with demanding control requirements. Attributes of these applications may include:

- Precise Control
- Long Stroke
- Speed
- Fail Safe
- Low Power Requirement
- Extreme Environmental Conditions

Some examples of other applications within the liquid pipeline industry where REXA actuation is often specified are:

- ESD Applications
- Turbine Upgrades
- Carbon Dioxide Pipelines

PROCESS CONTROL OPTIMIZATION

Many pipeline control loops do not deliver maximum value and a significant percentage of control loops add to process variability which is contrary to their intended purpose. Liquid pipeline companies can dramatically improve availability and reliability through optimization of their process controls while achieving significant reductions in operating costs.

Process dynamics describe how a process responds to a change in the controller output. There are many different types of process responses so a good understanding of the process dynamics is critical to good control design and tuning. The process response will often vary significantly over the operating range of the control loop; this is known as non-linearity. The primary sources of non-linearity include valve tracking issues such as backlash, stiction and installed valve characteristic non-linearities.

The following parameters are used to describe the process dynamics of a control system:

Process Gain $\mathbf{K_P}$ is equal to the change in process variable divided by the change in controller output. A good range for the process gain is 0.5–2.0% Span /% Output. Good control valve resolution is critical for high process gains. Even small control valve problems will cause significant process variability with high process gains.

The process Time Constant $\mathbf{T}$ is defined as the time it takes for the process to reach 63.2% of the steady-state change following a step change into the system. Processes essentially reach steady-state after a period of time equal to four time constants. For hydraulic pressure and flow control loops the time constant should be 0.3–2.0 seconds. The primary factors that affect the time constant are the control valve response time, filtering, and the time constant associated with acceleration of the fluid to the new steady state.

Deadtime $\boldsymbol{\theta_D}$ is defined as the time between the controller output change and the initial process response. The process deadtime in the majority of pipeline processes is 0.4–0.9 seconds. Deadtime is very destabilizing and should be minimized. Excessive deadtime will compromise control loop performance and increase process variability. Deadtime results from controller execution rate, actuator electronics execution rate, and the time for the control valve to move under line forces.

Through the use of these measured process dynamics parameters, the optimum controller tuning values can be calculated. Several techniques are available and the Lambda tuning methodology has been adopted by several pipeline companies. Lambda λ tuning will provide a high speed of response with minimal overshoot and will be very robust, or stable, through large process disturbances.

The Lambda λ value is selected. The Lambda λ value should be at least two to three times the larger of the process Time Constant τ or Deadtime θ_D, whichever is bigger. This will ensure a minimum level of robustness to decrease the likelihood of oscillatory response or controller instability. Poor performance from the control valve will require larger multiples of the process dynamic parameters and will result in less responsive control system performance. Controller tuning parameters are calculated with these formulas:

$$\text{Controller Gain } K_C = \frac{\tau}{K_P(\lambda + \theta_D)}$$

$$\text{Controller Integral } T_I = \frac{\tau}{60}$$

Derivative control response is not used in most control loops that are tuned through the Lambda methodology.

NON-LINEARITIES

Many liquid pipeline control applications have highly non-linear process gains. The process dynamics vary as a result of changes in operating conditions, production rates, control valve performance and other factors. Output characterization can be used to compensate for these non-linearities.

WHY REXA

Liquid pipeline applications require extraordinary dynamic performance from the control system in order to ensure reliable operation and to maximize the throughput of the pipeline. The control system must be able to respond quickly with high precision and with minimal deadtime in order to meet the objectives. The performance of the control valve and actuator are key components that may determine the success or failure of the control system. Rexa Electraulic actuator technology provides the high performance that is required to meet the challenges. ■

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