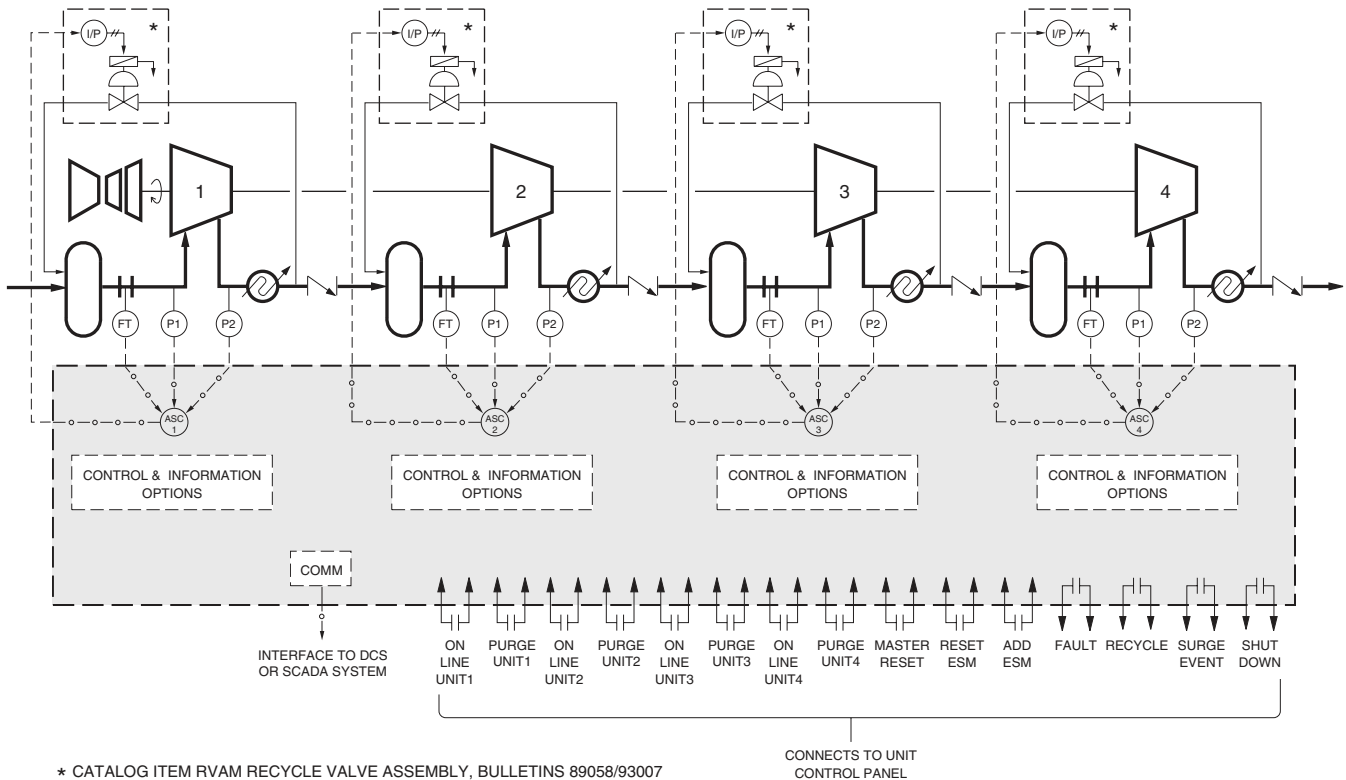


MULTIPLE-BODY INTEGRATED COMPRESSOR CONTROLLER APPLICATION CONTROL PRODUCT



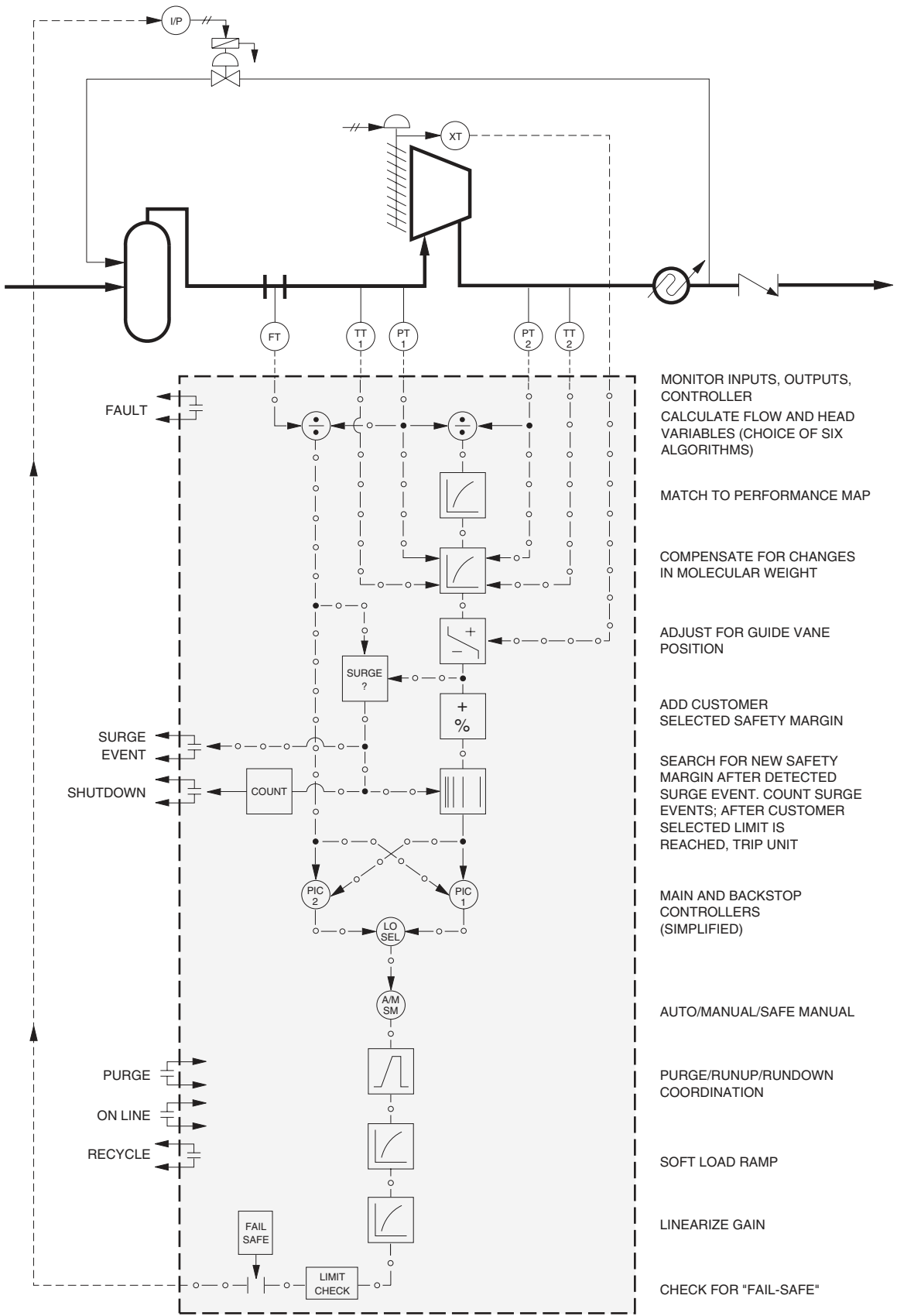
JANUARY 2012



Simplified instrument diagram showing one compressor controller in a four-body tandem compressor application with a recycle valve for each stage. Controls for each body are independently calibrated and configured per the requirements for each body. A single system can handle compressor control applications ranging from a single-stage compressor up to four independent stages, including various integrated control options and enhancements. This flexibility eliminates a multiple-box approach and reduces overall system complexity and cost. Each compressor body can have a different control algorithm, and can have flow measurement in the suction or discharge.

Runup, rundown, purge, loading, and upset control are coordinated between stages. Built-in high-select and low-select functions can combine two, three, or four "controller" outputs to a single recycle valve if required.

Each complete-train compressor controller is individually factory configured with exactly the inputs, outputs, and control functions appropriate for the particular compressor. Each controller requires an Application Engineering Service Package, Product Bulletin 03010, to provide preliminary calibration and configuration, as well as bench test. As shipped, a configured compressor controller typically requires only verification of the field wiring and minor field tuning to be placed in service.



Simplified function block diagram showing an application control package in control of a single-body centrifugal compressor with variable inlet guide vanes.



APPLICATION

The ASC controller provides fully-integrated, multi-loop, anti-surge control and real-time performance monitoring for multiple-body (tandem) turbocompressors on a hardware independent platform. Additionally, the system can incorporate a variety of compressor control options, making it a completely integrated compressor control system.

ADVANTAGES

- **Multiple-body compressor control capability:**

Provides integrated compressor control for up to four (4) compressor bodies in a single hardware platform.

Eliminates multiple-box control approach and simplifies controller to controller communication while also reducing overall system complexity and cost.

- **Built-in, proven algorithms for every application:**

Seven (7) built-in algorithms for each independent stage and ability to add customer-defined algorithms for each compressor body.

- **Advanced control strategies enhance process stability:**

Each compressor body controller is independently optimized.

Coordinated control action between body controllers for runup, rundown, loading, and upsets is much smoother and faster than multiple-box systems.

Anticipation-based control and asymmetrically-damped control provide superior response to upsets, and improved compression process stability.

Digital curve fit surge control lines for each stage produce constant safety margins for safe operation and reduced recycle.

Adaptive control strategies continuously adjust control safety margins to actual compressor body operating conditions.

Loop-gain linearization allows equal percentage valve trim for much improved stability at lower recycle, without requiring detuning for high recycle.

Valve actuator preload control eliminates delay in surge valve response. Typically, Petrotech compressor control systems have the valve full open on upsets in 3/4 second or less.

PURGE/RUNUP/RUNDOWN coordination feature provides optimum sequence functions without field solenoids, timers, or additional field cables.

- **More efficient compressor operation:**

Energy consumption of driver is reduced by eliminating unnecessary recycle.

- **Integrated compressor control options:**

Capability exists for integrated options such as capacity control, loadsharing, and pressure override control. Advanced control strategies are easily accomplished at a much lower cost than typical multi-box systems.

- **Improved operator information with optional MMI:**

Optional Man-Machine Interface MS Windows-based graphic operator interface displays system status, trending, and data logging which can be used to evaluate operating strategies and help identify and track problems.

- **Command initiatives on a per body basis:**

Individual PURGE and ON-LINE contacts for each compressor body allow for more complex, efficient loading sequences of multiple-body compressors.

- **Failed transmitter fallback algorithms:**

Fallback algorithm allows continued, safe operation in the event of a critical transmitter failure. Critical transmitters include compressor flow, suction pressure, and discharge pressure.

- **Molecular weight correction:**

Automatic surge line compensation for shifts attributable to changes in molecular weight protect against surge during changing inlet gas conditions.

- **Incipient surge detector:**

Detects mild surge and takes corrective action before a violent surge occurs. The incipient surge detection algorithm is independent of the compressor performance map and therefore is immune to inaccuracies in the compressor's respective map.

- **Increased analog input capability:**

Separate transmitter inputs for control and performance monitoring allow flexibility for optimization of control while also maximizing accuracy of performance calculations.

- **Assignable AUTO/MANUAL control block with flexible operator interface:**

AUTO/MANUAL station allows the manual adjustment of up to eight (8) controllers from a single location.

- **Hardware independent:**

Application control package's portability allows customer choice of hardware platform, reducing the need for additional spare parts and training expenses. Available PLCs include GE Fanuc, Siemens/PI, Modicon, Allen-Bradley, and ICS.

- **Fault tolerant:**

Control package is available on ICS Regent+Plus fault tolerant controllers for critical control applications. Software functionality is extended to 2 out of 3 (2oo3) voting at the CPU and I/O level.

- **Simplified, accurate calibration:**

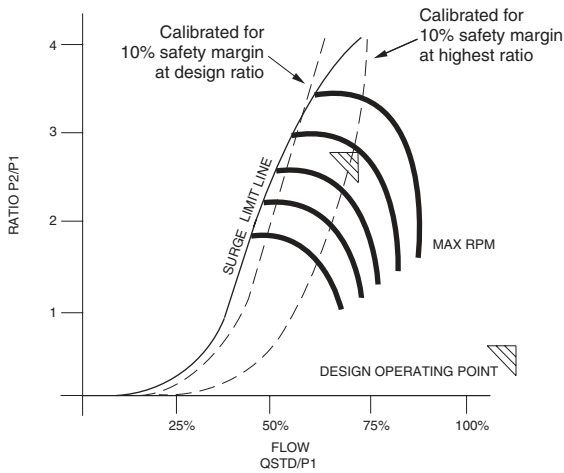
All-digital calibration is retained in permanent memory, which can be changed at any time via simple keypad entry.

- **Fail-safe features:**

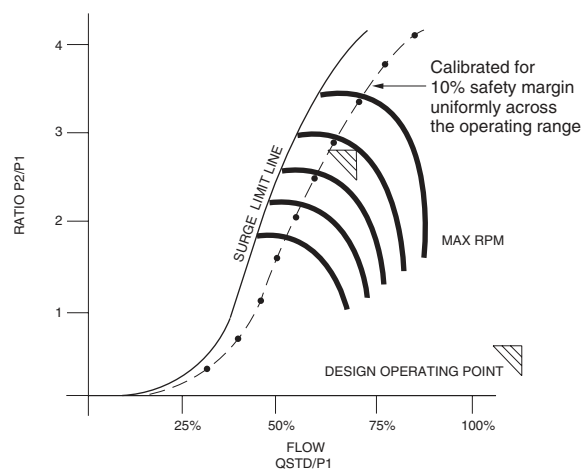
Open/short monitoring of mA inputs, readback monitoring of outputs, and special self-check features improve safety.

- **Simplified interface to DCS or SCADA:**

Communication tasks are handled with a separate, dedicated module in the PLC, increasing data throughput and simplifying network integration.

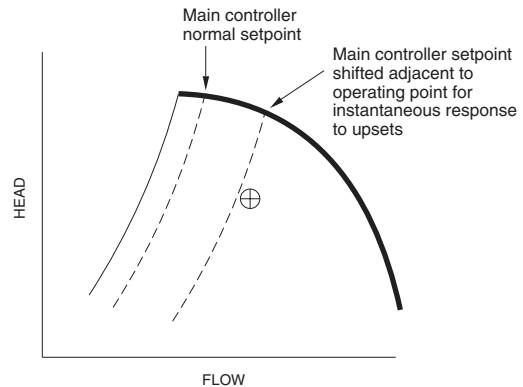
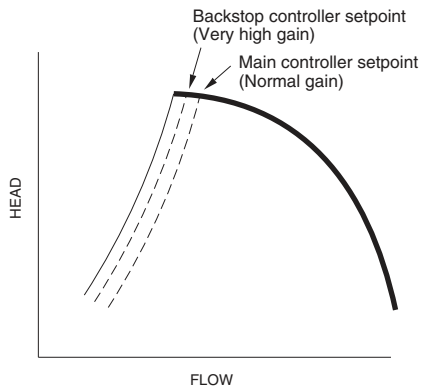


TRADITIONAL SURGE CONTROL STRATEGY

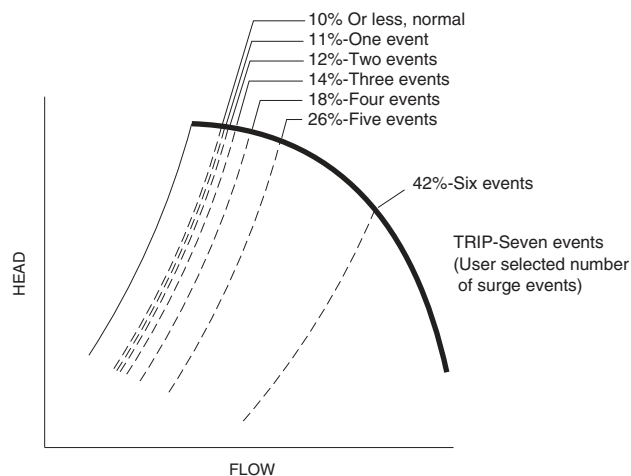


DIGITAL CURVE FITTING STRATEGY OF 9500-ASC(M) USING ADVANCED ALGORITHM TO AVOID SHIFT

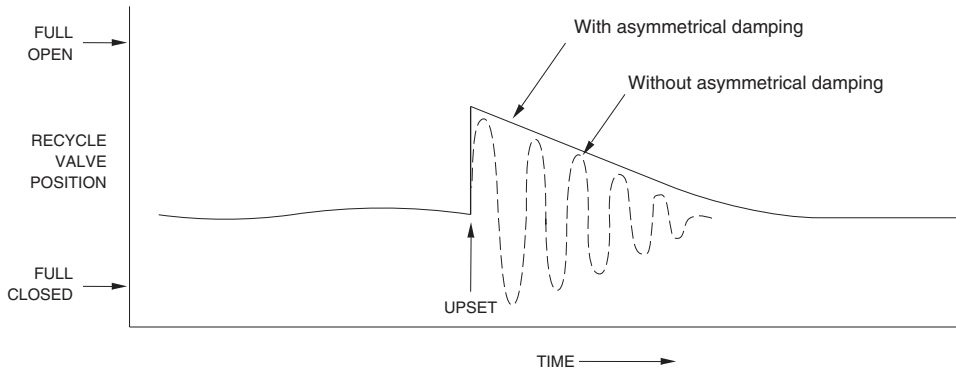
Compressor performance curves showing a 10% safety margin established at design ratio, and 10% safety margin at the highest ratio (left). Calibration of 10% at design ratio results in a loss of safety as ratio increases. Calibration of 10% at the highest ratio results in excess recycle and loss of efficiency. The Petrotech method (right) of digital curve fit results in a uniform safety margin across the entire operating range with no loss of efficiency due to excess recycle.



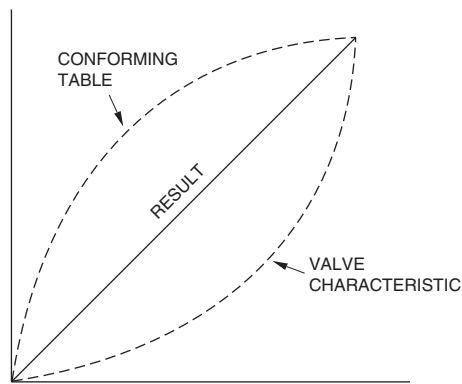
Compressor performance maps showing setpoints of the main controller and backstop controller. As the compressor ratio approaches the surge safety margin, the low-gain main controller begins to open the recycle valve. Low-gain action maintains stability during periods of normal recycle. During upsets, or when recycle has reached a predetermined level, the high-gain backstop controller opens the recycle valve rapidly.



After detection of surge, the Compressor Controller finds the minimum additional safety margin that will provide protection b safety margin with increasing aggressiveness



Asymmetrical damping critically damps valve response on upset recovery, restoring stability without oscillation, and eliminating unwanted interaction with other loops, without cross-coupling of controller.



This table conforms the controller GAIN vs. OUTPUT characteristic to be the mirror image of the valve FLOW vs. STROKE characteristic. Principally, it is used to produce linear overall loop gain while using equal percentage trim valves. Some of the advantages of equal percentage trim valves are:

- Much better (more stable) control at low recycle rates.
- Less tendency to oscillate, and bang the valve plug against the seat at very low recycle rates.
- Very high maximum capacity for upset control.

Unfortunately, the rising gain characteristic of equal percentage trim valves usually requires that the controller be detuned (more overshoot) at low recycle rates to avoid instability at higher recycle rates. The valve gain conforming table eliminates this disadvantage.



SCOPE OF SUPPLY

An application control package for multiple-stage centrifugal compressors, includes, per stage:

Analog inputs, 4-20 mA:

- Compressor flow element differential.
- Compressor differential.
- Suction pressure.
- Suction temperature.
- Discharge pressure.
- Discharge temperature.
- Shaft input power.
- Fuel flow element differential.
- Specific gravity.
- Guide vane position.
- Capacity control input.
- Compressor speed.

Analog outputs, 4-20 mA:

- Recycle valve position setpoint.

Operating states:

- On-line.
- Purge.

Status, alarms, and shutdowns:

- Fault.
- Surge event.
- Surge shutdown.
- Unstable flow.
- Transmitter failure alarms.
- Transmitter failure shutdowns.
- Output failure shutdowns.

Controllers/special features:

- Main anti-surge controller.
- Back-up anti-surge controller.
- Seven (7) anti-surge control algorithms:
 - HC vs. DP
 - HC/P1 vs. P2/P1
 - HC/P1 vs. DP/P1
 - HC/P2 vs. DP/P2
 - HC/P2 vs. Constant
 - HC/P2 vs. P1/P2
 - Q/N
- Safe auto/manual.
- Asymmetrical damping.
- Ten-point digital curve fit for surge line.
- Ten-point digital table for guide vane position compensation.
- Molecular weight compensation function.
- Ten-point digital loop-gain linearization table.
- Surge event detection system.
- Purge/runup/rundown sequence coordination.

Does not include:

- PLC or MMI hardware.
- Driver equipment application control package.
- Driver equipment sequencing and protection discrete logic.
- Compressor sequencing and protection discrete logic.

AVAILABLE OPTIONS

Application control packages for control options:

- Performance Display.
- Communication interface to DCS or SCADA.
- WonderWare InTouch® licensed software package for operator graphic display.
- High/Low Surge Margin Contact Outputs.
- Recycle Transfer Controller.
- Loadshare Controller.
- Quench Temperature Controller.
- Power Limit Controller.
- Header Pressure Controller.
- Minimum Differential Pressure Controller.
- Discharge and Suction Pressure Override Controllers.
- Recycle Temperature Controller.

Service Options:

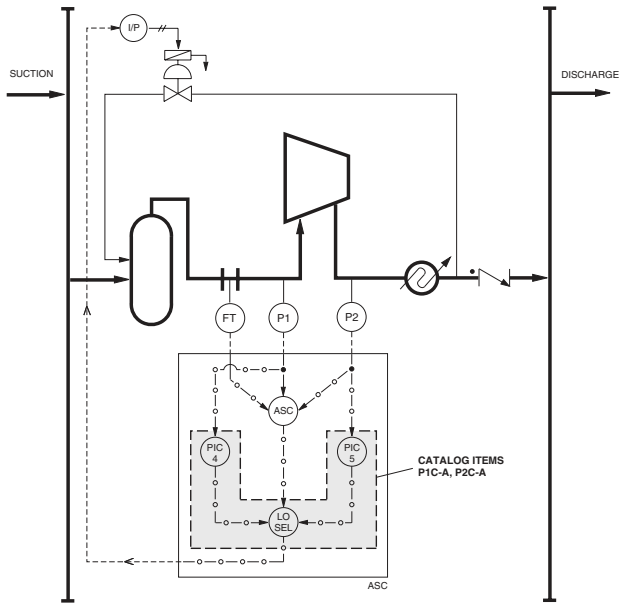
- Application Engineering Services Package.
- Basic and advanced training seminars.
- Installation and commissioning services.

Options for complete control system upgrade:

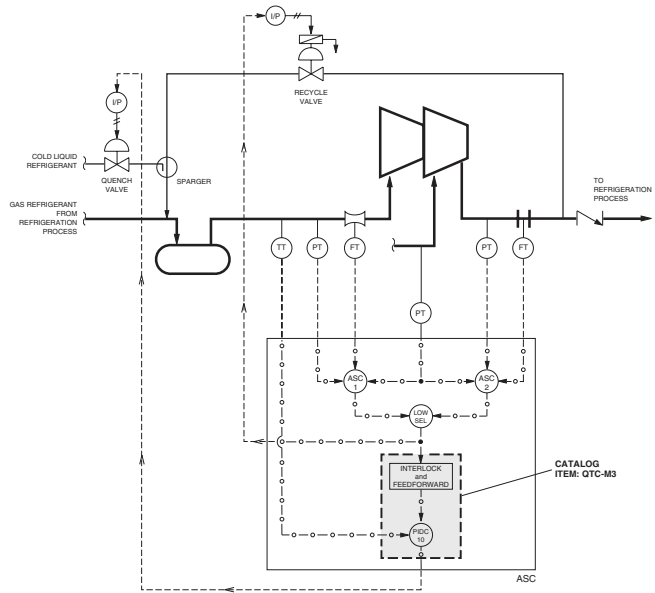
- Driver equipment application control package.
- Driver equipment sequencing and protection discrete logic.
- Compressor sequencing and protection discrete logic.
- PLC hardware.
- Man-Machine Interface hardware.
- Complete custom engineered control panel, factory tested and ready to install.
- Anti-surge valve system.



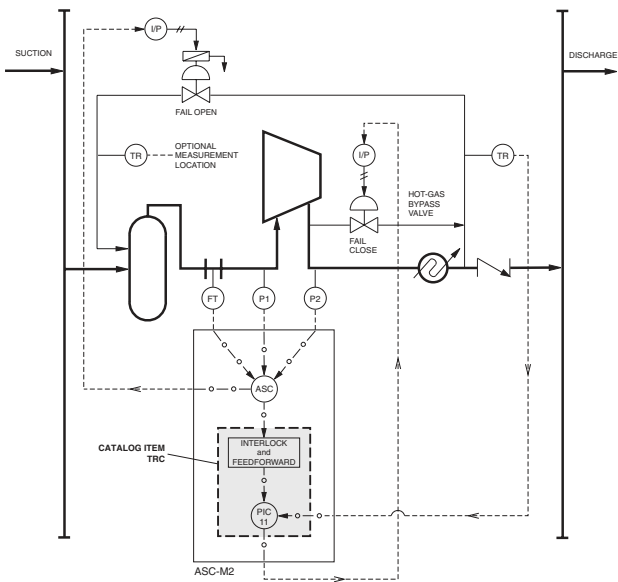
SIMPLIFIED INSTRUMENT DIAGRAMS FOR SELECTED COMPRESSOR CONTROL OPTIONS



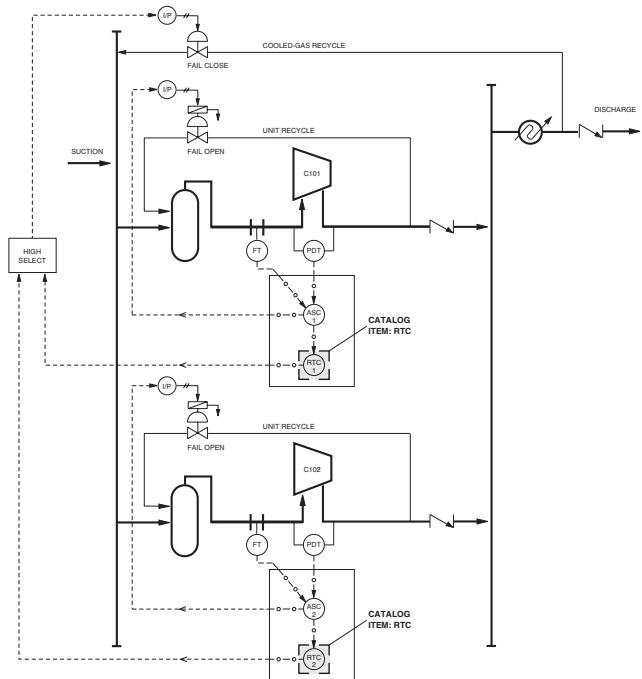
SUCTION AND DISCHARGE PRESSURE OVERRIDE CONTROLLERS



QUENCH TEMPERATURE CONTROLLER

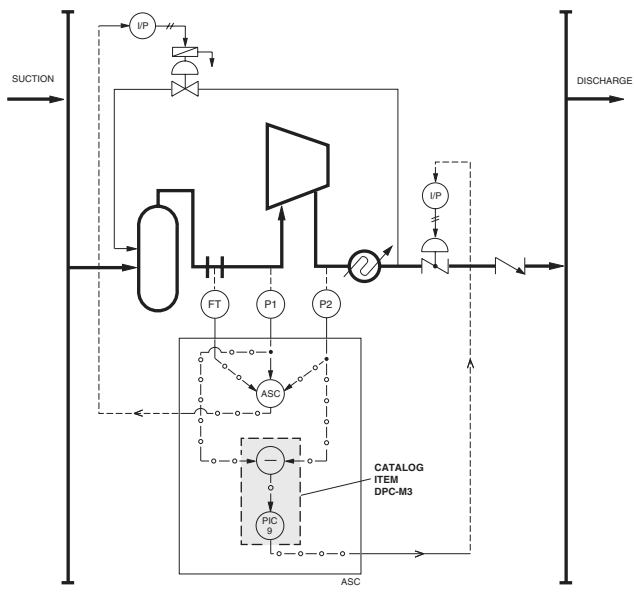
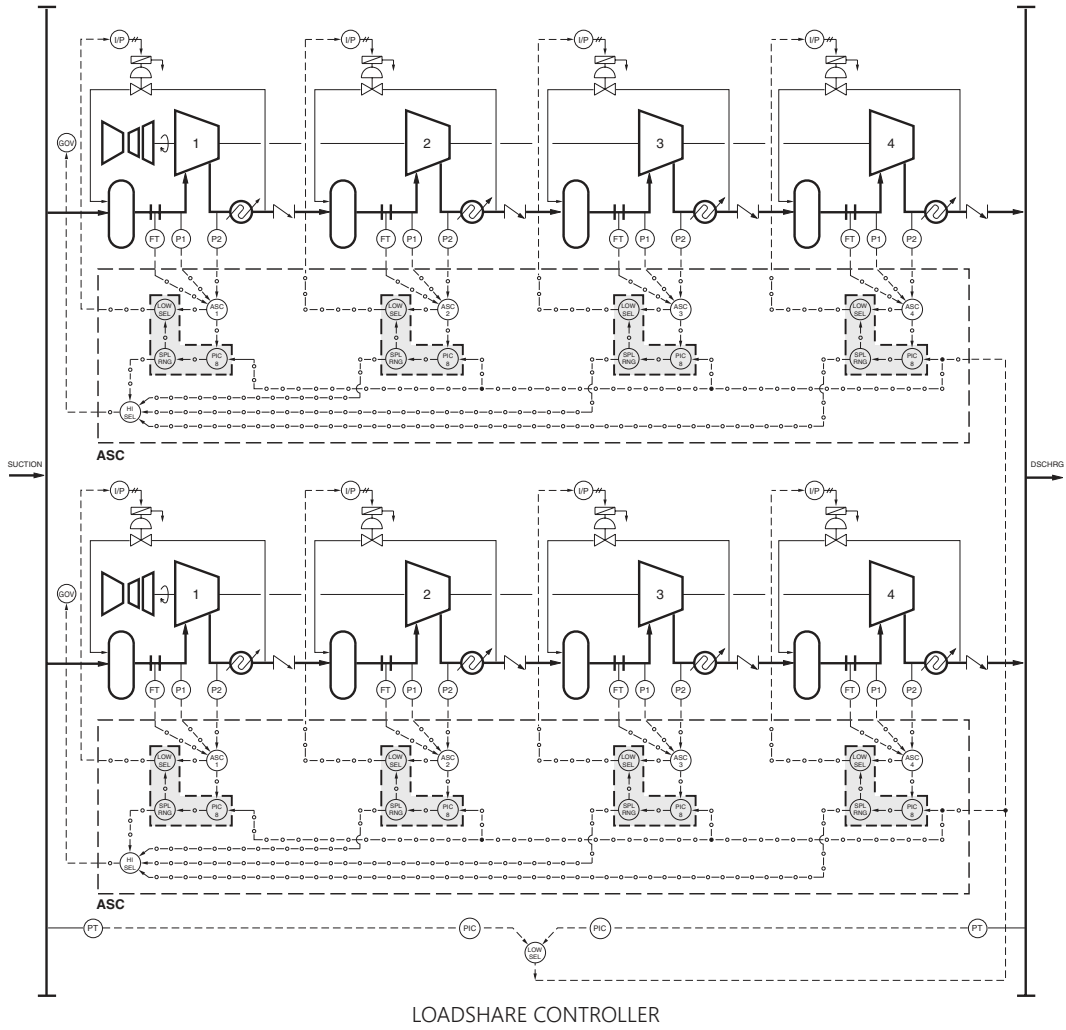


RECYCLE TEMPERATURE CONTROLLER

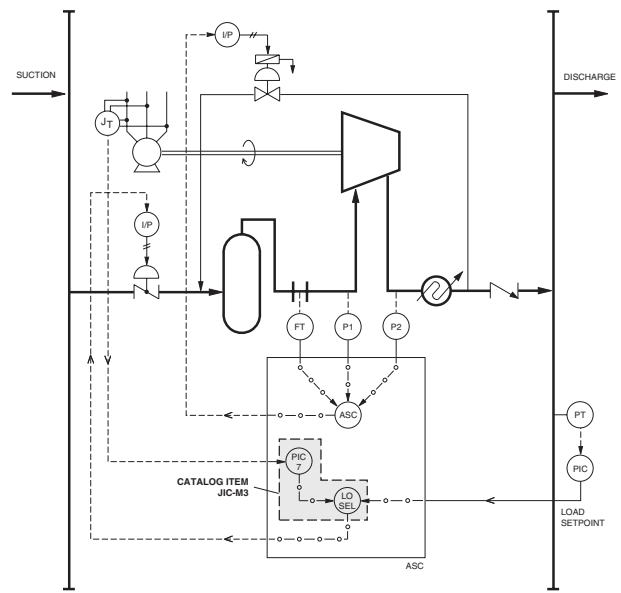


APPLICATION 1: AVOIDING THERMAL RUNAWAY

RECYCLE TRANSFER CONTROLLER



MINIMUM DIFFERENTIAL PRESSURE CONTROLLER



POWER LIMITING CONTROLLER

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