TRAC

Turbine Redundant Actuator Control

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Life Is On

Schneider Electric

Unique Features

- Boosts reliability via redundant hydraulic servo assembly
- Provides immediate and bumpless fault tolerance via redundancy and parallel operation for electrical and mechanical malfunctions
- Pinpoints failures with enhanced diagnostics
- Enables online replacement and calibration of affected components via isolation valves
- Interfaces with existing machinery or can be supplemented with a new actuator assembly

Benefits

TRAC helps a plant:

- Turbocharge efficiency: TRAC's configurable, fault-tolerant design enables online testing and maintenance
- Achieve reliable, precise, and direct (pilot-less) control of the hydraulic actuator that handles steam admission to the turbine
- Create a direct hydraulic path to the main cylinder via a simple pilot spool modification where integral pilots exist

Product Overview

TRAC is a configurable redundant servo assembly comprised of standard, off-the-shelf components assembled onto a custom manifold.
Coupled with any of the Schneider Electric TMC systems, TRAC provides superior availability and reliability.

Design

TRAC design allows for fault tolerance of all possible failure modes, mechanical and electrical. Continuous detailed diagnostics can pinpoint existing and potential issues.

Integrated isolation valves enable all active components to be removed, repaired or replaced, reinstalled, calibrated, and brought back into service without interrupting or diminishing the turbine control. Trip valves can be operated hydraulically or electrically from an independent system and can override the servo output, forcing the valve to a fail-safe position (see Figure 2). These features make TRAC ideal for critical applications.

Features

- TRAC is configurable:
  - For two or three servos
  - For single or double-acting applications
  - With trip valve for independent electric or hydraulic trip capabilities
- TRAC uses standard, off-the-shelf components to:
  - Shorten lead times
  - Reduce costs for spares
  - Utilize modern design, including diverter jet technology, which is resilient to oil contamination

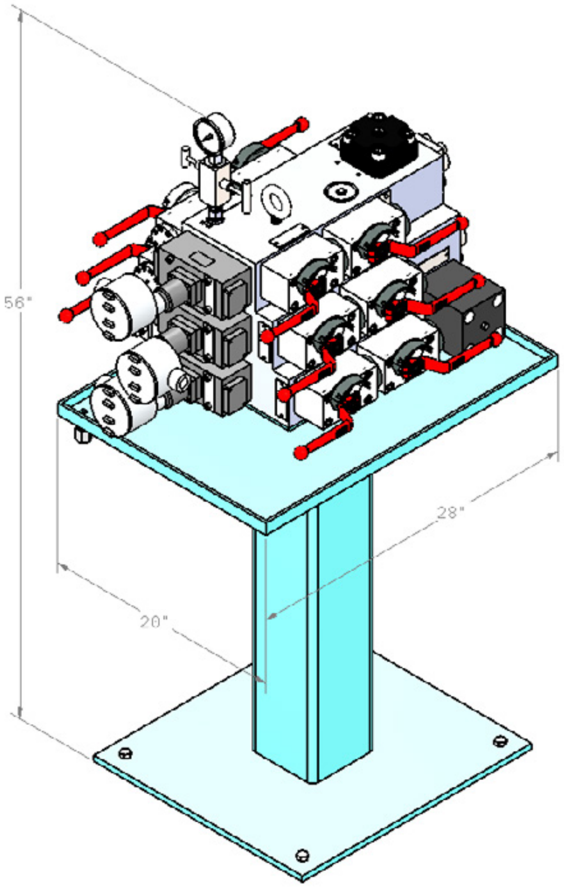

Figure 1: TRAC Dimensions

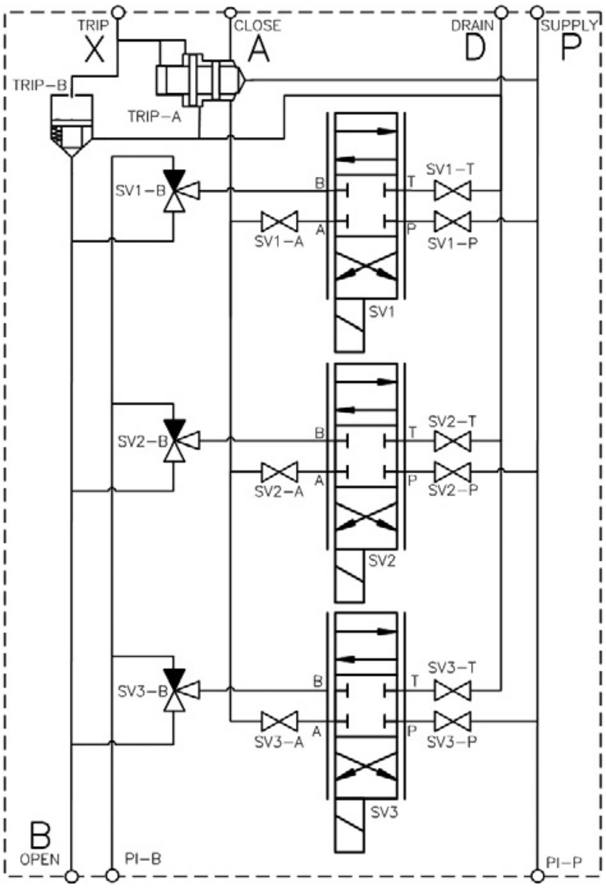

Figure 2: TRAC Schematic

- TRAC delivers several benefits:
  - Enables online calibration via local gauges and isolation valves for each servo
  - Enables online servicing
  - Interfaces to new or existing high-or low-pressure actuators
  - Servos operating in parallel compensates for electrical and mechanical malfunctions
  - Boosts fault tolerance
  - Provides continuous diagnostics and generates alarms for malfunctions
  - Test program to detect latent malfunctions and to exercise servos

Typical Architecture

The turbine control system servo control loop receives a position demand generated by either pressure control or speed control.

Linear variable differential transformers (LVDT) provide position feedback of the main actuator, governor, or extraction. Typically, three LVDTs are installed providing our standard selection logic and allowing for a mid-select value. See Figure 3.

The servo loop responds to the error between the position demand and the position feedback by adjusting the bipolar servo current above or below its null current to force oil in or out of the actuator and reach its demand.

Hardware Overview

The TRAC utilizes the standard, off-the-shelf components that can be purchased directly from the manufacturer. This allows for shorter lead times and reduce costs for spares. They also utilize a modern diverter jet technology which is more resilient to oil contamination verses a common flapper nozzle design.

The typical assembly includes a stand with a junction box where servo valves and any optional equipment can be pre-terminated. It also includes:

- Custom Manifold
- Parker BD Series Servo Valves
- DMIC Manifold Mounted Ball Valves
- Gauge with Block and Bleed
- Parker Cartridge Trip Valve
- Pedestal
- Junction Box

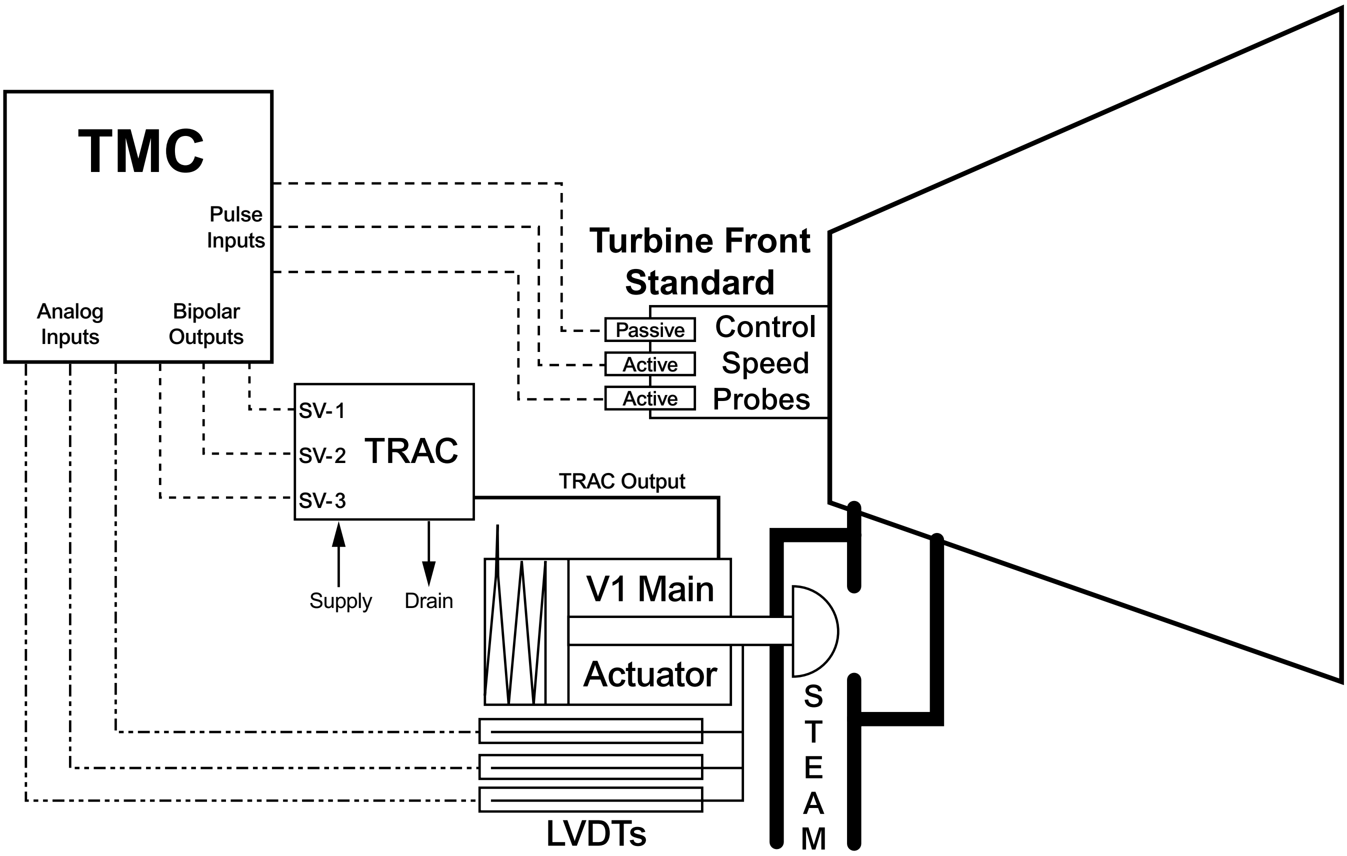

Figure 3: TRAC Architecture

I/O Requirements

TRAC is configurable for two or three servos. The total I/O requirements for each TRAC are based on application-specific configuration. Single coil servos are used for all zones and area classifications requiring +/-60mA each.

Controls

Servos operate in parallel continuously via a Bipolar +/-60mA control signal. No need for additional power. All diagnostics are available through the same control signal. This provides instantaneous fault tolerance, and no deviation over time required to generate a switch. The control system will immediately compensate for any failure mode as it is attempting to maintain the position demand with every scan.

Diagnostics

Voltage is monitored to detect opens or shorts in the servo coil circuit. If these are detected, they are voted out of the control and the system then adjusts the tuning parameters to provide simultaneous control characteristics while operating with fewer servos. Alarms are produced and diagnostics can pinpoint the malfunction.

Mechanical malfunctions are compensated for instantaneously, and produce a steady state current offset, which triggers an alarm. An automated test sequence can be initiated to reveal the specific issue. The affected servo output can then be disabled through the HMI (Human Machine Interface) or EWS (Engineering Work Station).

Service

Each servo is equipped with four isolation valves. If an issue presents itself, a specific isolation sequence can be performed to allow the affected servo to be removed from service, repaired or replaced, calibrated, and brought back into service while the turbine control is still in operation and functioning normally.

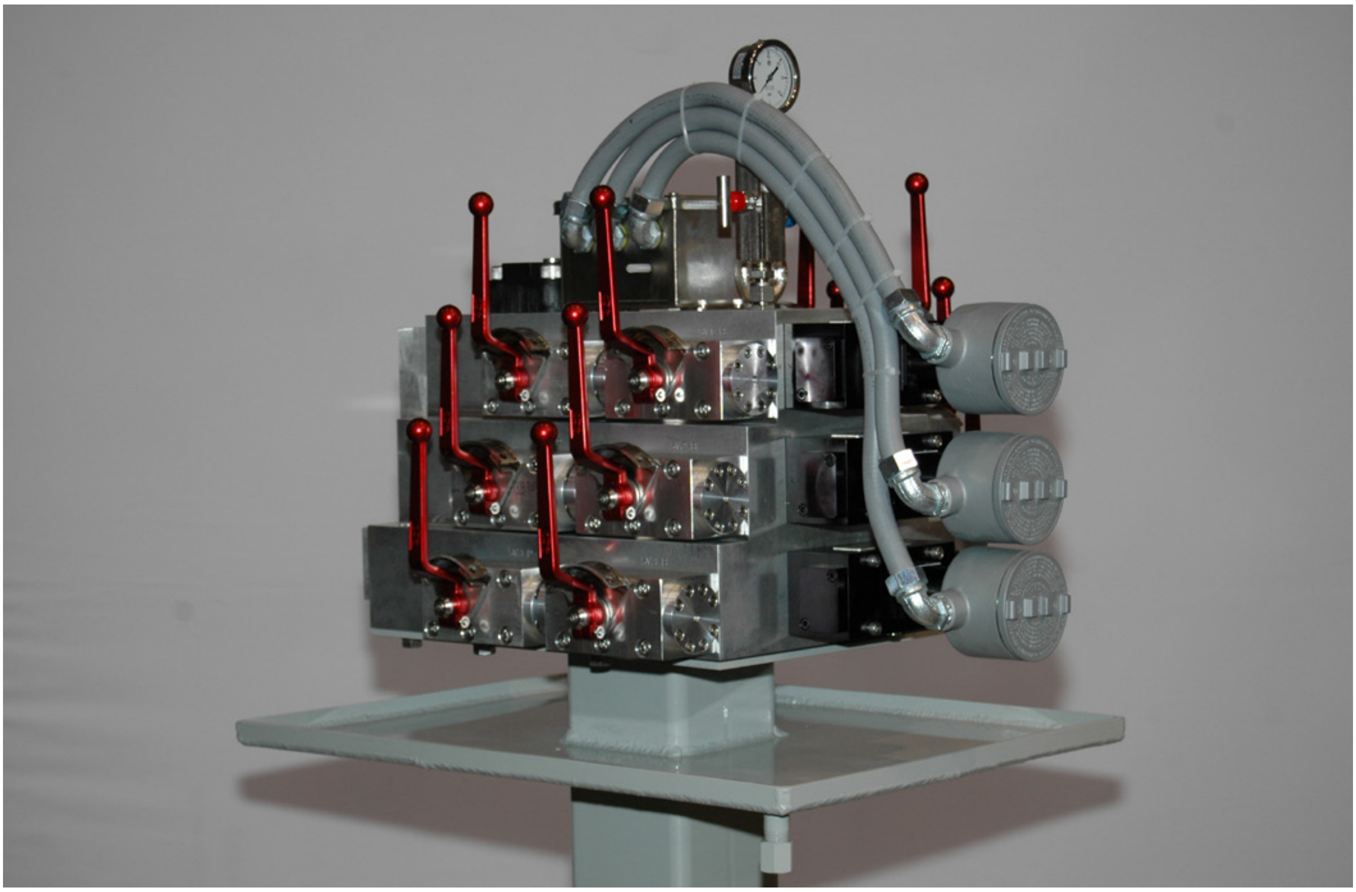

Figure 4: TRAC Hardware

Specifications

Servo Valve Operation

The BD series servo valves used in the TRAC assembly operates on a force feedback principle between the second stage spool metering valve and the first stage pilot valve torque motor. The pilot valve is a single jet pressure recovery unit that directs a continuing stream of control fluid into a receiver.

The receiver has two outlets that are ported to the ends of the valve main spool, PC1, and PC2. Pressure in these ports is equal when the fluid jet is centered in the receiver opening. The feedback spring attached to the armature measures the spool position as a force. This force and the force of the torque motor armature provide the error displacement of the armature and its diverter blade window. Then, window edges divert the jet stream to the proper receiver outlet to position the spool to the electrically-commanded position. See Figure 5.

An electrical signal applied to the pilot valve coil generates a magnetic force on the armature/diverter blade assembly, which pivots the assembly and allows fluid to flow into PC1. This positions the main power spool to the left until the force from the feedback spring matches the magnetic force. Then, the diverter blade is re-centered over the receiving orifices and the spool motion stops at this position. The flow proportional to the input electrical current is metered out in the C2 port. Removal of the electrical signal to the coil unbalances the forces, which reverses the armature deflection and drives the spool to the zero current or null position. Changing the polarity of the current in the coil causes a magnetic force in the opposite direction, which initiates flow from the C1 port. See Figure 6.

The TRAC "Operation and Maintenance Manual" provides details regarding the null adjustment for each servo installed.

System resolution can sometimes be improved through the use of "dither," which is a small amplitude signal at a low (5-10Hz) frequency superimposed on the valve command signal. Dither is expressed by the dither frequency (Hz) and the peak-to-peak dither current amplitude (mA). This signal will cycle the valve spool sufficiently to prevent valve silting and "stiction." Note that if the amplitude is high enough, or the frequency is low enough, the actuator could follow the signal in such a way that would wear the seals rapidly. Therefore, care should be exercised in setting the frequency and amplitude of the dither. If dither does not enhance precision, then the feedback device may be the limiting factor, or the servo valve may be too large.

See Figure 7 for a view of TRAC installed.

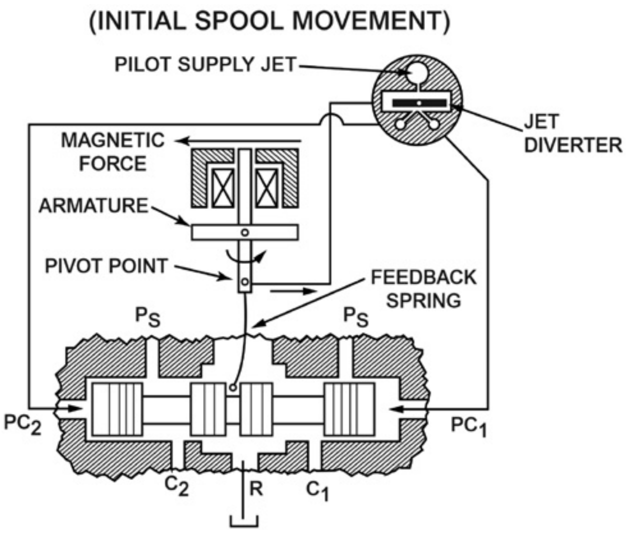

Figure 5: Servo Valve Operation: Command for Flow from Control Port C2

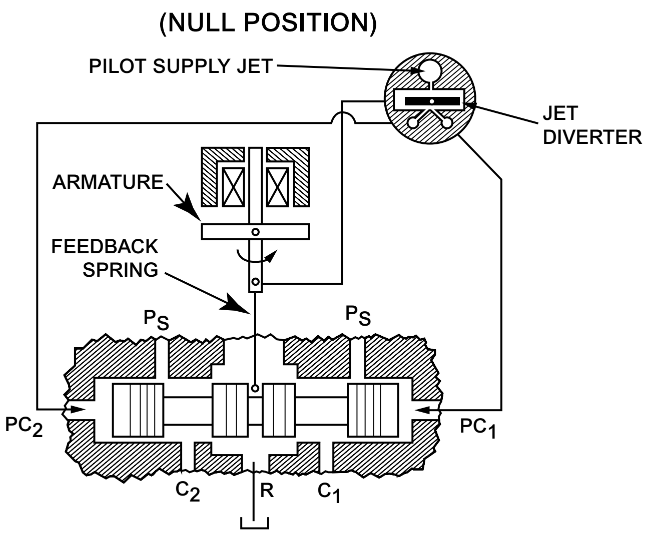

Figure 6: Null Position, Valve in Balance

TRAC Electrical Characteristics

Rated Current and Coil Resistance

The current required to obtain rated flows for the standard Parker BD 30 Servo Valve is 60mA. The torque motor coil resistance is 60 +/-6 Ohms.

Coil Connections

The coil leads are sealed for zone rated applications and terminated in a conduit junction mounted on each servo. For general purpose applications, the coil leads are attached to the A and B pins of an industry standard electrical connector that mates with a MS3106-14S-2S.

Flow-Load Characteristics

Polarity is preconfigured to provide pressure to the opening side of the actuator when a positive current is applied.

TRAC Hydraulic Characteristics

Fluid Supply

Parker BD30 Servo Valves used on the TRAC assembly are intended to operate with a constant supply pressure. Orifices in the valve housing provide the pilot with a constant low pressure.

Supply Pressure	
Minimum	80 psi
Maximum Standard	3000 psi
Factory Proof Pressure	
At Pressure Port	4500 psi
At Return Port	200 psi
Fluid Hydraulic Fluids	
60-225 SUS at 100 ºF	
Consult Factory for other fluids	
Supply Filtration	25μm absolute
Operating Temperature	
Minimum	-30 ºF
Maximum Sustained	225 ºF

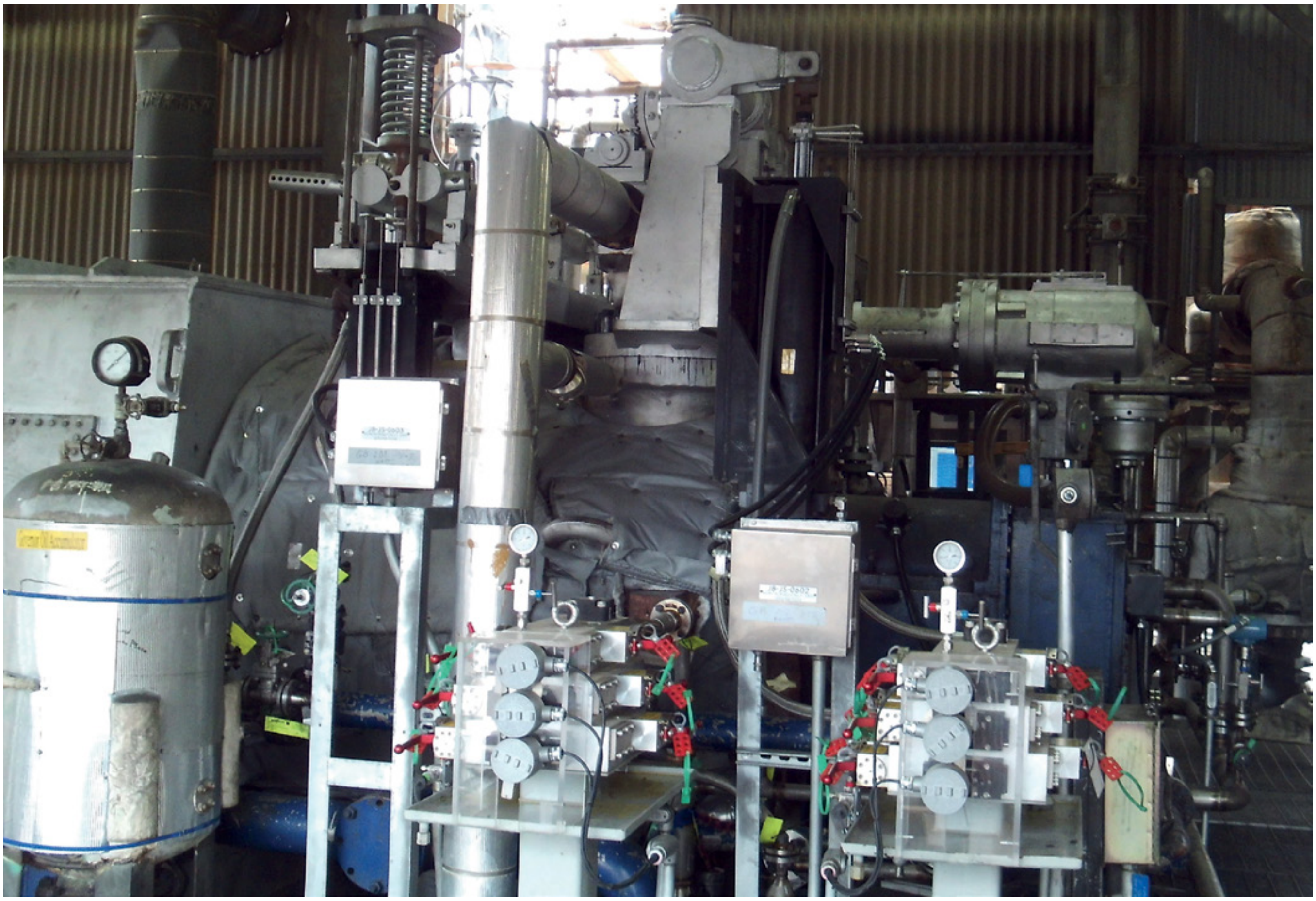

Figure 7: TRAC Installed

Rated Flow

Flow is directly proportional to the differential pressure across the actuator and varies for each application with spring constants, spring preloads, and stroke length. Figure 8 indicates the expected no-load flow in gallons per minute for a standard TRAC configured with three servos.

The no-load flow is determined by noting the intersection of the supply pressure and the valve of the no-load flow lines. The intersection point is followed to the left margin where the no-load flow is determined. If the valve pressure drops, the valve pressure drop (PV) is substituted for supply pressure and can also be used to determine the valve flow in a loaded system (as evident in Figure 8).

EQUATION 1 $PV = PS - PR - PL$
PV = valve pressure drop
PS = supply pressure
PR = return pressure
PL = load pressure (pressure required to support the load)

The resulting PV is used in place of the System Supply Pressure and the flow noted on the left margin of Figure 8 becomes the loaded flow capability. Once the loaded flow capability is determined, the actuator volume can be divided by that flow to determine the expected maximum travel rate. Two inches per second or greater is desirable for most turbine control applications.

Flow-Load Characteristics

The control flow to the load will change with load pressure drop and the electric input as shown in Figure 9.

These characteristics closely follow the theoretical square root relationship for sharp-edged orifices as illustrated in this equation.

EQUATION 2 $Q = K\sqrt{(\Delta P)}$
Q = control flow
K = valve constant
ΔP = valve pressure drop

Contamination Resistance

The Parker BD series servo valves are ruggedly designed for use in the industrial market place. From its inception, the first stage amplifier (pilot valve) has established a solid history of a trouble-free operation in very harsh environments. Minimum orifice diameters up to 20 times larger than other servo valve models substantially increase reliability by reducing problems due to contamination. The second stage is a closed center, four-way spool, and sleeve assembly which features rectangular slots in the sleeve. The spool metering edges exactly match the flow slot edges in the sleeve to provide a linear flow with respect to the electrical input.

Internal Leakage

Maximum internal leakage for each servo is 0.7 GPM for a total maximum leakage of 2.1 GPM if configured with three servo valves.

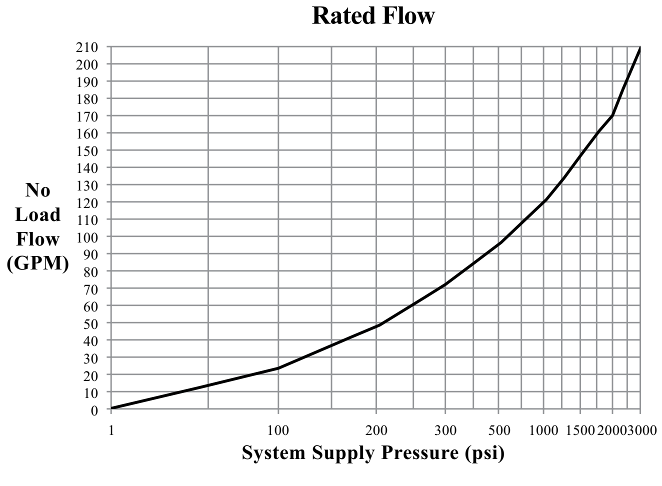

Figure 8: Rated Flow

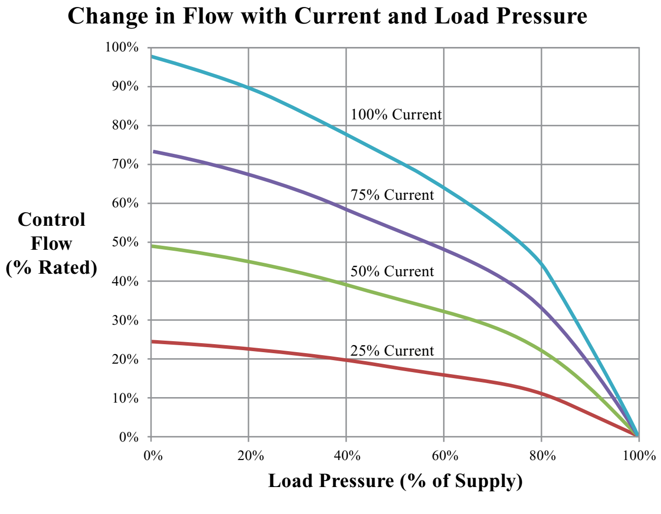

Figure 9: Change in Flow with Current and Load Pressure

TRAC Performance Characteristics

Fluid Gain

The no-load flow characteristics of each BD30 Servo Valve are plotted at the factory to show flow gain, symmetry, and linearity. Typical limits (excluding hysteresis effects) are shown in Figure 10.

Linearity

Linearity is within 5% for all servo valves. Non-linearity of control flow to the input current is most severe in the null region due to variations in the spool null cut. Using standard production tolerances, the valve flow gain about null (within ±3% of rated current input) may range from 25 to 100% of the normal flow gain.

Flow Performance

The following data are also determined from the flow plot:

Rated Flow Symmetry	±10%
Symmetry	<10%
Hysteresis	< 3%
Threshold	< ½%

The blocked cylinder port pressure changes rapidly from one limit to the other as input current causes the valve spool to pass through the null region. The pressure gain at null for the servo valves exceeds 30% of supply pressure for commands of 1% of rated current, and normally is between 60% and 80%.

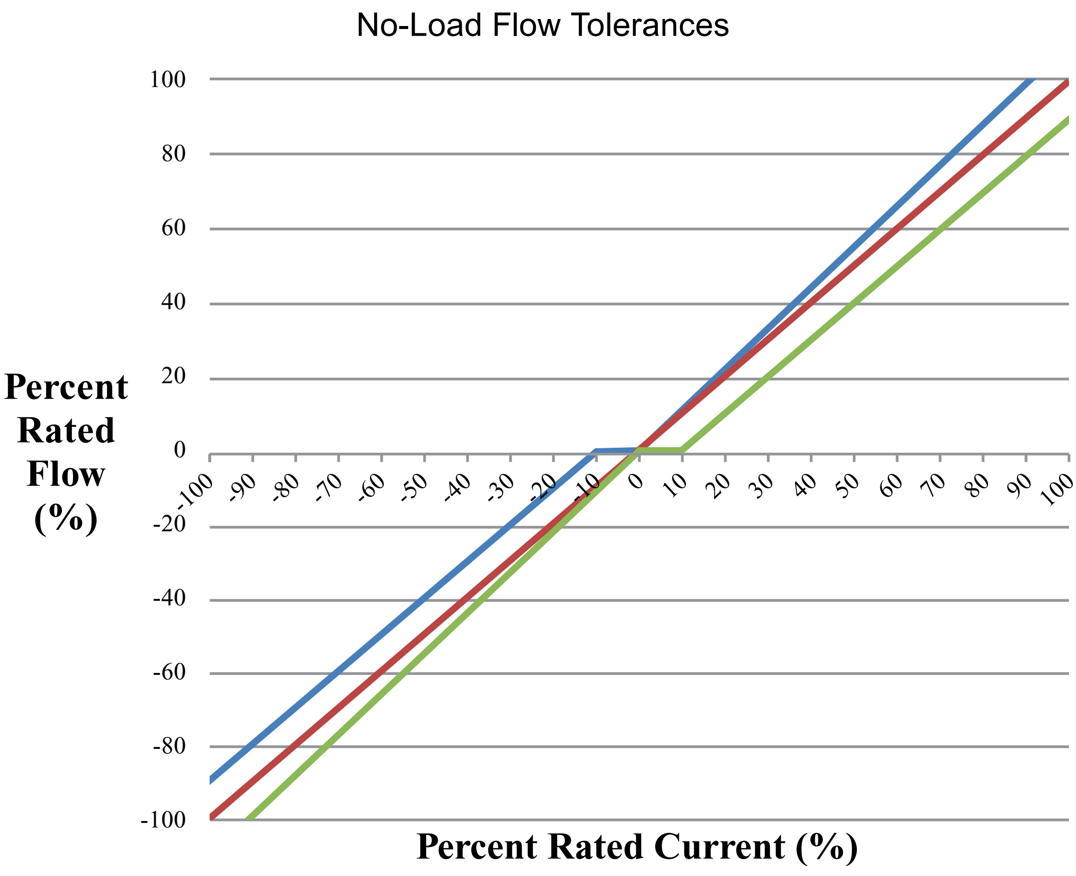

Figure 10: No-Load Flow Tolerances

Null and Null Shift

The valve is externally adjustable to ±10 to 15% of rated current. See Figure 11 for the typical frequency response. Null shift is as follows:

With Temperature variation 100 ºF	<2%
With Supply Pressure 1000 psi change	<2%
With Return Pressure 0 to 500 psi	<2%

Step Response

Typical response of the BD30 Servo Valve to a stepped electrical command is given in Figure 12. The valve time constant is 12ms.

Frequency Response

The frequency response shown in Figure 11 is typical for any supply pressure between 500 and 3000 psi. The response changes only slightly with lower supply pressure because the pilot valve pressure is maintained very near to constant regardless of the supply pressure.

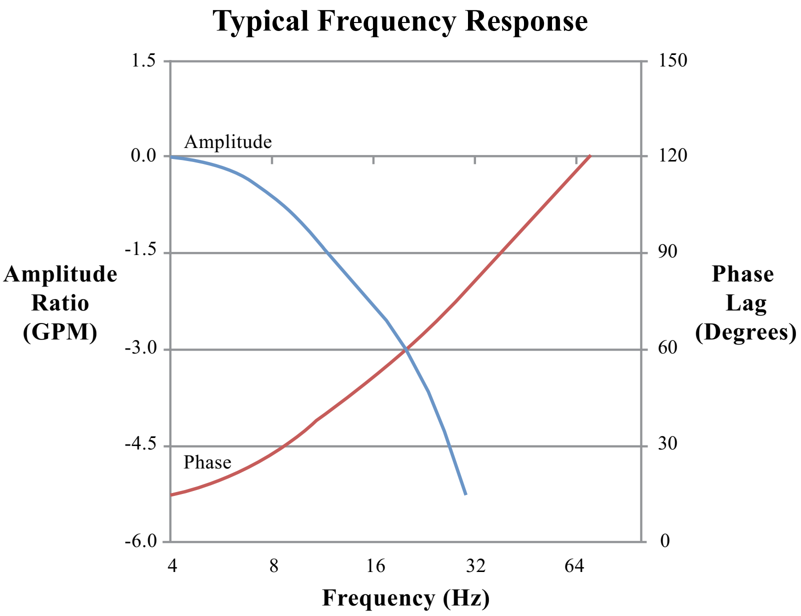

Figure 11: Typical Frequency Response

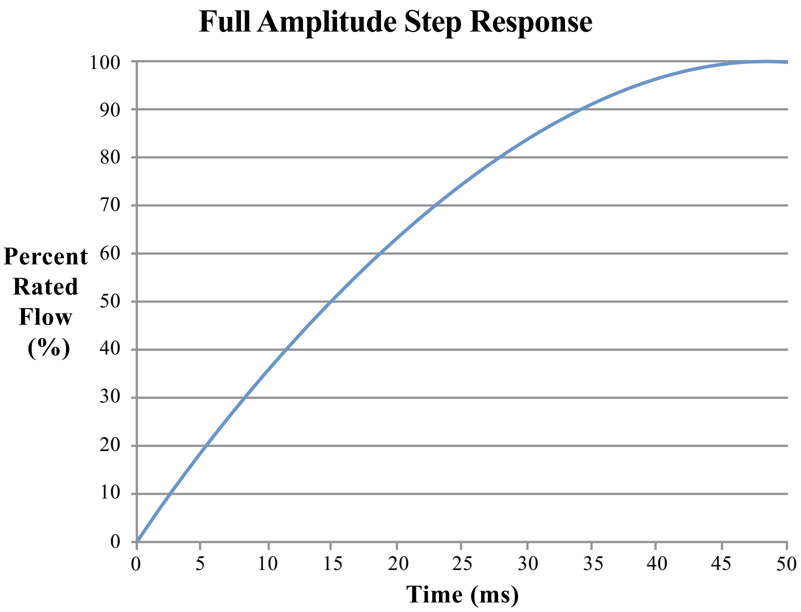

Figure 12: Full Amplitude Step Response

Key Terminology

Control Flow
The flow through the valve control ports to the load expressed in gallons per minute (gpm).

Dither
Low amplitude, low frequency signal, is superimposed on the servo valve input to improve the system resolution. Dither is expressed by the dither frequency (Hz) and the peak-to-peak dither current amplitude (mA).

Frequency Response
The relationship of no-load control flow to the input current as the current is varied sinusoidally over a range of frequencies. Frequency response is normally measured with constant input current amplitude and zero-load pressure drop, expressed as amplitude ratio (in decibels, or db) and phase angle (in degrees). Servo valve frequency response may vary with the input current amplitude, temperature, supply pressure, and other operating conditions.

Flow Gain
This is the ratio of control flow to input current (gpm/mA).

Hysteresis
The difference between the response of a servo valve to an increasing signal and the response of the valve to a decreasing signal; i.e., the difference in servo valve is slowly cycled between plus and minus rated current. This is expressed as a percentage of rated current.

Input Current
The electrical current (Command Signal) to the valve which commands control flow; expressed in milliamperes (mA).

Internal Leakage
This is the total internal servo valve flow from the pressure to return with a zero control flow. This is usually measured with control ports blocked. Leakage flow will vary with input current, generally being at maximum at the servo valve null (null leakage).

Linearity
This is the degree of straightness of the hysteresis plot. This is expressed as percent of rated current.

Load Pressure Drop
This is the differential pressure between the control ports (that is across the load actuator), expressed in pounds per square in (psi).

Null
This is a condition where the valve supplies zero control flow at a zero load pressure drop.

Null Shift
A change in null position in a servo valve expressed as a percent of rated current. Null shift may occur with changes in supply pressure, temperature, and other operating conditions.

Valve Pressure Drop
The sum of the differential pressures across the control orifices of the Output Stage I of a servo valve. Pressure drop will equal the supply pressure minus the return pressure minus the load pressure drop.

Pressure Gain
The change of load pressure drop with input current and zero control flow (control ports blocked). This is expressed as the nominal psi/mA throughout the range of load pressure between plus or minus 40% supply pressure.

Rated Current
The specified servo valve input current of either polarity to produce rated flow. This is expressed in milliamperes (mA).

Rated Flow
The specified control flow corresponding to the rated current and the given supply and the load pressure conditions. Rated flow is normally specified as the no-load flow and is expressed in gpm.

Symmetry
The degree of quality between the flow gain of one polarity and that of the reverse polarity. It is measured as the difference in flow gain for each polarity and is expressed as the percentage of the greater.

Threshold
The increment of input current required to produce a change in the servo valve output. Servo valve threshold is usually measured as the current increment required to change from an increasing output to a decreasing output. This is expressed as the percentage of related current.

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