



# TURBINE BYPASS SYSTEMS



## Turbine Bypass Systems

Copes-Vulcan has been supplying steam conditioning equipment for turbine bypass applications since the 1950s.

Modernization in the 1960s brought about revised start-up practices due to the change from wet to dry superheaters of once through boilers together with the requirement for reheater cooling. The current HP and LP bypass philosophy was adopted providing far greater flexibility to power generation plant operators.

The requirements of a modern bypass system include:

- Reduced commissioning time of the boiler and turbine plant. The boiler and associated equipment (e.g. the fuel systems), can be fully tested and commissioned totally independent of the turbine (100% capacity bypass system).
- Efficient matching of steam and turbine metal temperatures during cold, warm and hot start-up cycles.
- Prevention of excessive boiler pressure fluctuations in the event of turbine trip or load rejection.
- Avoidance of the spring loaded HP safety valves lifting with the associated seat maintenance and condensate loss in the event of a turbine trip.
- Maintained reheater tube cooling and controlled pressure build-up during turbine start-up or following a turbine trip.
- Cooling of the final superheater in the case of sliding pressure operation.
- Partial bypass to maintain steady upstream pressure when the turbine runs back to house load.
- Protection of the condenser against excessive pressure and temperature.

Copes-Vulcan is at the forefront of developing today's turbine bypass systems, with over 90 years experience in the global power generation business.



Copes-Vulcan HP and LP Bypass Valves prior to shipment to India.

Our experience is complemented by an extensive range of power oriented products including inter-stage attemperation desuperheaters, boiler feed control valves, boiler feed pump recirculation valves with "soft seat" Class VI shutoff, blow down valves and vent valves. The evolution of standard systems and complex custom engineered solutions is a continuous process, facilitated through over 50 international agents and manufacturing service centers.

Copes-Vulcan bypass system designs have continuously developed to satisfy the ever increasing demands of the power industry for this highly critical and integral process within a power generation station.

The introduction of combined cycle plants and the associated higher pressures and temperatures, in the search for greater efficiency, resulted in the need for HP bypass systems to operate at pressures up to 220 bar (3200 psig) and temperatures approaching 590°C (1100°F).

All bypass systems are custom designed and engineered for each installation to suit the various turbine designs and operating regimes. This ensures that the bypass system is ideally matched to fully satisfy the required performance envelope.

The method of actuation also has to be carefully selected to meet the demands of the operating scenarios and failure modes. Normal actuation will be either hydraulic or pneumatic depending on the speed and accuracy that the plant operating characteristics demand.

# Turbine Bypass Valves

## Direct Steam Conditioning Valve (DSCV)

The Copes-Vulcan DSCV is a custom engineered steam conditioning valve which is contract specific, designed to fully satisfy individual application performance criteria. A forged pressure boundary design facilitates compatibility of the DSCV with steam and cooling water pipework.

Pressure/temperature ratings up to Class 4500 are available as standard and intermediate/split ratings are provided as required. The DSCV is often utilized by piping engineers as the transition point for piping class and material.

Trim options range from a balance plug through to multi-stage pressure profiling, HUSH®, for active noise attenuation. Shutoff ratings up to ANSI/FCI 70-2 Class V. Depending on valve orientation and shutoff class, integral adjustable drain/warming valves can be incorporated into the design.

End connections can be welded or flanged. Maintenance can be carried out with the valve body in line since the trim is removable via the bolted or pressure seal bonnet.



DSCV Valve



TE-PRDS Valve

## Top Entry — Pressure Reducing and Desuperheating Valve (TE-PRDS)

The TE-PRDS allows for the valve internals to be removed via the bonnet connection, thus facilitating maintenance to be carried out while the valve body remains in line.

The unit is of cast design per ASME B16.34 and is available in most materials with ratings from Class 150 to 2500.

The standard trim is a fully guided ported cage. Where noise attenuation is required, then our multi-stage pressure profiling trim, HUSH® is fitted. All trims are of the quick change variety being held in position under controlled compressive loading between the valve web and bonnet.

Standard units have welded connections on the inlet, cooling water and outlet with flanges being available as an additional option. The range of sizes available are (inlet x outlet connection size) 1x2" (25x50mm), 2x4" (25x100mm), 3x6" (80x150mm), 4x8" (100x200mm), 6x12" (150x300mm) and 8x16" (200x400mm).

## Pressure Reducing and Desuperheating Valve (PRDS)

One of the original combined pressure reducing and desuperheating valves, the Copes-Vulcan PRDS, has been reliably serving industry for over forty years. This model is a cast design available in a variety of materials with pressure ratings from Class 600 to 2500 and split rated designs.

The valve body is in accordance with ASME B16.34 and the bonnet closure to Section VIII of the ASME Unfired Pressure Vessel code.

A comprehensive range of trim options can be fitted from a cage-guided balanced plug throttle to multi-stage pressure profiling design, HUSH®, for active noise attenuation. The inlet steam and cooling water connections are either flanged or butt-weld and the outlet steam connection is flanged.

Standard sizes are (inlet x outlet connection size) 1x2" (25x50mm), 2x4" (25x100mm), 3x6" (80x150mm), 4x8" (100x200mm) and 6x12" (150x300mm).



PRDS Valve

## HP Bypass Valve

The performance requirements of the HP Bypass valve present one of the most arduous and critical of all valve applications, demanding specific design to withstand the high pressures and temperature cycling to which it is subjected.

The HP Bypass valve has to rapidly condition up to 100% MCR boiler outlet steam by reducing both pressure and temperature to cold reheat conditions. On some applications where there is no reheater, the steam has to be conditioned down to a level acceptable to the condenser.

Every component of the unit must be designed to remain dynamically stable while dissipating this vast amount of thermal energy.

All HP Bypass valves have cage-guided trims ensuring stability and in most cases a multi-stage, pressure profiling HUSH® Trim will be fitted for active noise attenuation.

The final stage of pressure reduction is performed by a specifically designed diffuser arrangement mounted in the valve outlet.

There are several methods of introducing the cooling water depending on factors such as inlet steam to cooling water mass ratio and the cooling water pressure.



Copes-Vulcan 6x14" (150x350mm) Class 2500-S DSCV  
produced from ASTM A182 F22.

Drawing on the many decades of experience in all forms of desuperheating, Copes-Vulcan will offer the most appropriate method of cooling water introduction for the specific application. The method employed will be one of aspiration, mechanical spray atomization or steam atomizing.

Rapid actuation is required to prevent the boiler safety valves from lifting and the turbine block valves from fast closing in the event of a turbine trip. Actuation is either hydraulic or pneumatic.

Hydraulic actuators are generally adopted where rapid and accurate positioning is required, or where end user preference dictates.

For HP bypass, the actuators are normally set in a fail-open mode either by mechanical springs, hydraulic accumulators or pneumatic volume tanks.

### Key Features

- Contract specific designs fully accommodate performance requirements.
- Multi-stage pressure profiling HUSH® Trims for active noise attenuation.
- Forged body designs up to Class 4500 with intermediate and split ratings being available.
- End connections to match pipework sizes and materials.
- Bolted or pressure seal bonnets.
- Trim removable in line through the bonnet connection.
- Integral, adjustable condensate drain and warming valve options.
- Installation in any orientation without actuator support.
- Shutoff up to ANSI/FCI 70-2 Class V.
- All methods of actuation are available.

## LP Bypass Valve

The LP Bypass valve is primarily a protection device for the condenser. The valve simultaneously reduces reheat steam to a condition acceptable to the condenser and is normally of a large size due to the radical increase in specific volume of the steam as it is let down to condenser pressures which are often sub-atmospheric.

For this reason it is often necessary to supply the bypass valve with either an integral or separate dump tube, depending upon the installation configuration and pipework layout. Separate dump tubes are normally installed directly into the condenser inlet duct some distance downstream of the LP Bypass valve.

The LP Bypass valve has to rapidly condition up to 100% MCR boiler outlet steam by reducing pressure and temperature to condenser conditions.

All LP Bypass valves have cage-guided trims which ensure stability and in most cases a multi-stage, pressure profiling HUSH® Trim will be fitted for active noise attenuation. The final stage of pressure reduction is performed by a specifically designed diffuser or dump tube arrangement either integral to the valve or supplied separately.



LP Bypass Valve Type DSCV

Drawing on many decades of experience in all forms of desuperheating, Copes-Vulcan will offer the most appropriate method of cooling water introduction for the specific application. The method employed will be one of aspiration, mechanical spray atomization or steam atomizing.

Rapid actuation is required in the event of turbine trip achieved with either hydraulic or pneumatic actuators. Hydraulic actuators are generally adopted where both rapid and accurate positioning is required, or where end user preference dictates. For LP bypass, the actuators are normally set in a fail-closed mode either by mechanical springs, hydraulic accumulators or pneumatic volume tanks.



Multi-stage HUSH® prior to Micro-brazing.

### Key Features

- Contract specific designs fully accommodate performance requirements.
- Multi-stage pressure profiling HUSH® Trim for active noise attenuation.
- Forged body design up to Class 900 with split ratings available.
- End connections to match pipework sizes and materials.
- Bolted bonnets with quick change trims.
- Trim removable in line through the bonnet connection.
- Installation in any orientation without actuator support.
- Shutoff up to ANSI/FCI 70-2 Class V.
- All methods of actuation are available.
- Optional dump tubes with small hole technology for noise attenuation.

## Pneumatic Actuation Systems

With Copes-Vulcan Turbine Bypass valves, it is often possible to utilize a more commercially attractive pneumatic actuation option due to the balanced design of the trim, resulting in relatively low actuation forces.

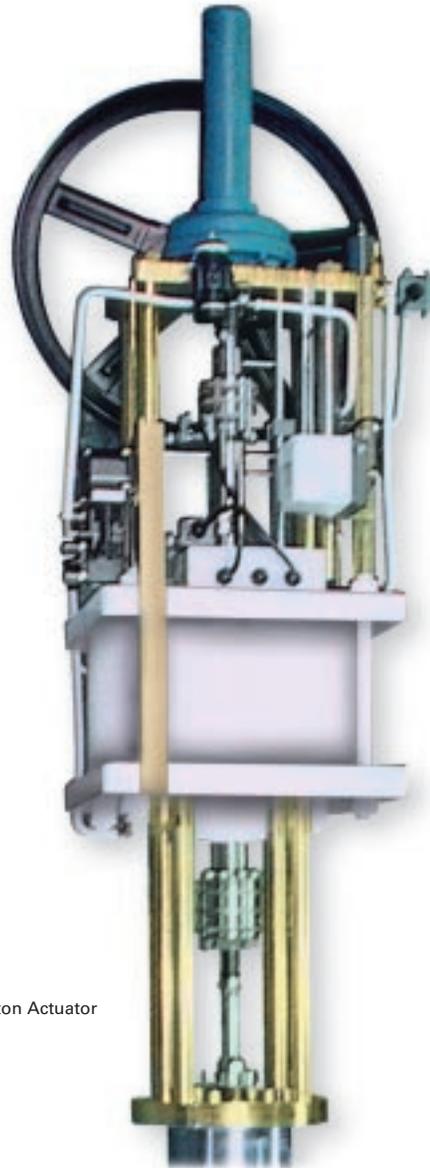
Piston actuators are commonly used for the bypass valve due to the stroke lengths often required. However, on smaller installations and cooling water control valves, pneumatic diaphragm actuators can be successfully employed.

A critical function of any bypass system is its speed of response in the event of a turbine trip. Fast, full stroking speeds, which approach those gained with hydraulic actuation, are achieved with the addition of boosters and quick exhaust valves.

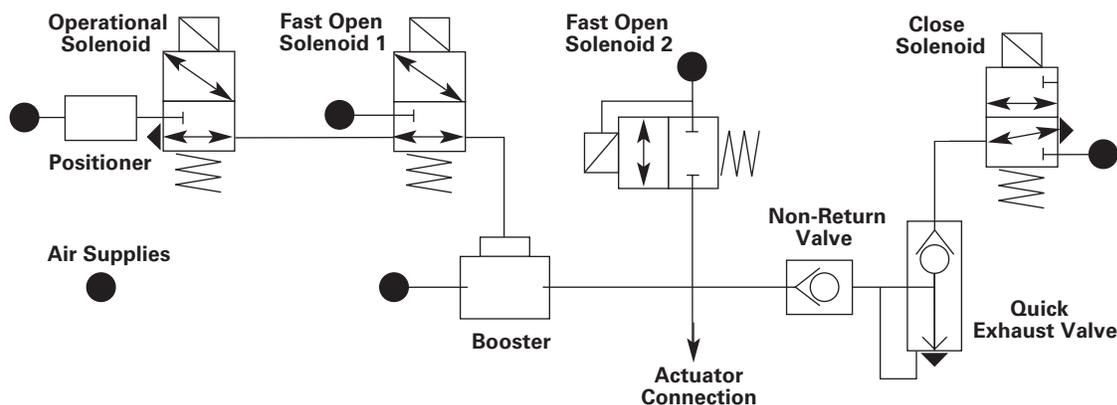
Pneumatic piston actuators are either double-acting or spring-returned, according to the plant specifications.

Both options are available with local accumulator tanks sized to perform the specified number of full stroke operations in the event of plant air failure.

The diagram below illustrates a typical pneumatic hookup for fast stroking in both directions, together with moderate modulating speed.



Double-Acting Piston Actuator



Typical hookup for emergency fast and normal moderate stroking speeds.

# Electro-Hydraulic Systems

Electro-hydraulic actuation is often the preferred modulation method due to its speed and accuracy. Two types of electro-hydraulic actuation are available; HPU systems, where a centralized skid mounted hydraulic power unit, complete with control panel, provides the fluid power to all the actuated valves from a single source, or self-contained actuators mounted directly on the valve.

## Hydraulic Power Unit (HPU)

All HPUs are contract specific, tailored to suit the power plants operating logic.

- Skid mounted design.
- Dual motorized fixed or variable displacement hydraulic pumps for 100% redundancy.
- Optional dual D.O.L. starter gear complete with automatic change over and local control. Pumps are sized to recharge the accumulators from minimum to maximum in approximately one minute.
- Nitrogen filled bladder or piston type accumulators sized to match the system requirements.
- High-grade stainless steel high and low pressure filtration systems with visual condition indicator. Optional pressure switches and automatic changeover.
- Stainless steel reservoir pipework and fittings. Control components are of a manifold design to ensure minimum pipework and are mounted within IP65 enclosures.
- Emergency hand pump.
- Control panel containing positional and modulating PLC instrumentation with DCS interface.
- Optional operating fluids – mineral oil or fire resistant fluids such as Phosphate Ester.
- Hydraulic fluid temperature control by means of Oil/ Water or Oil/Air heat exchangers for cooling. For low ambient temperature installations, heaters can be installed to maintain correct operating temperature.

On smaller bypass installations, where there may be only two hydraulic actuated valves, it is commercially beneficial to fit self-contained electro-hydraulic actuators directly to the valves.



Typical skid mounted HPU.

## Self-Contained Electro-Hydraulic Actuators

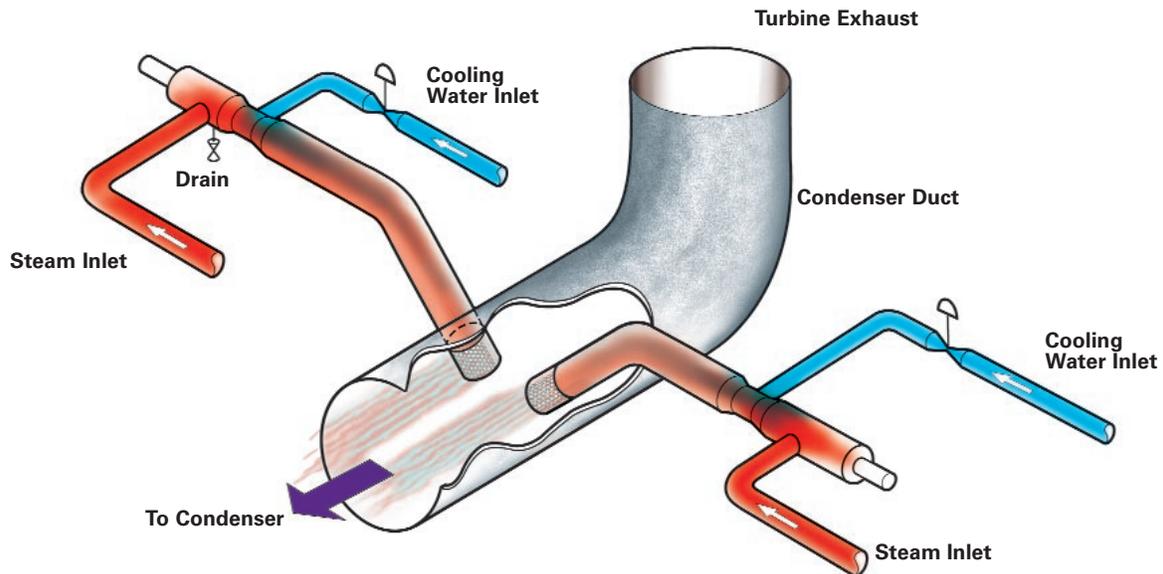
- Motorized hydraulic pump operates continuously, ensuring positional control with continuous modulation is available in addition to accumulator storage. When the system is fully charged, the pump will automatically unload with a signal from the integral pressure switch ensuring no excessive heat generation.
- Centrally mounted directly on the valve bonnet.
- Complete assembly suitable for outside conditions.
- Accumulator storage provides valve stroking in the event of power loss.
- Hydraulic reservoir capacity is sufficient to ensure that overflowing is not possible, complete with oil level indication.
- Fire resistant hydraulic fluids available.
- 10 micron stainless steel pressure filters.
- Hand pump for manual operation.
- Wire-armour braided, fire resistant, halogen-free cable with Exd certified cable glands.



Self-contained electro-hydraulic actuator.

## Dump Tubes and Diffuser Cartridges

Copes-Vulcan specializes in tailoring their bypass systems to fully complement specific plant requirements. An important part of any system discharging to a condenser is the dump tube or expanding diffuser cartridge. These industry proven devices are primarily employed to minimize the size of the bypass valve where the specific volume of steam dramatically increases at low or subatmospheric pressures.



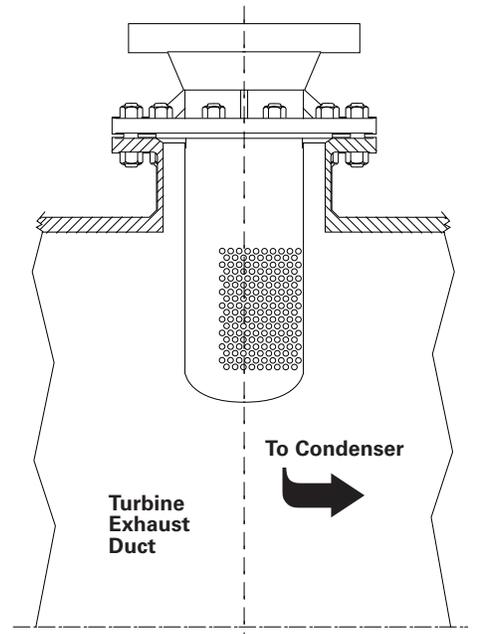
Typical layout showing dump tube diffusers fitted into the condenser inlet duct.

### Dump Tubes

Normally fitted into the condenser inlet duct, the dump tubes are carefully designed to fulfill the final pressure reduction stage and allow the steam to expand and cool prior to entering the condenser. Careful consideration is given to the size, shape and profile of the dump tube to avoid interference with the turbine exhaust steam path under normal turbine operation. The array and size of holes in the dump tube are arranged to minimize noise generation and direct the steam away from the duct walls and towards the condenser inlet. The isometric sketch above shows a typical utility plant installation.

### Diffuser Cartridges

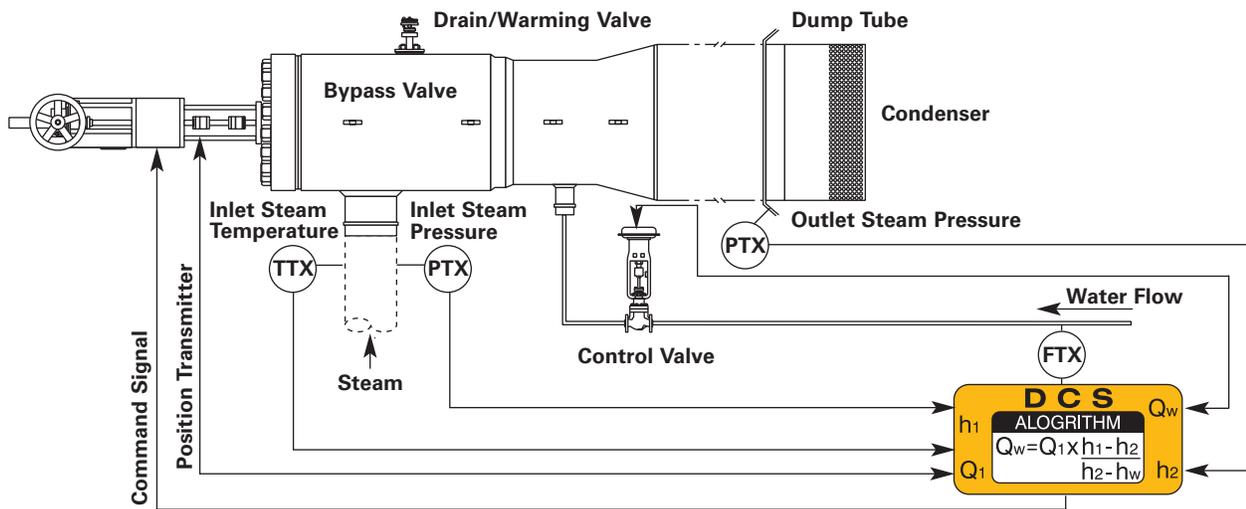
The expanding diffuser cartridge is fitted with several application specific diffuser plates to achieve the final stages of pressure reduction. Normally fitted directly to the outlet of the bypass valve, they minimize the size of the valve and assist in maintaining low noise generation at full flow rates. Generally employed on smaller installations where a single IP bypass is fitted, the IP Bypass valve is sized for 100% of the turbine steam load discharging directly to the condenser.



Dump tube shown fitted into the condenser duct (optionally welded).

# Algorithmic Temperature Control

Algorithmic temperature control is utilized for accurate temperature control at or close to steam saturation temperatures. Conventional temperature sensing via insertion, thermowells cannot accurately measure steam temperatures within 10°F (5°C) of saturation. This is due to unevaporated water droplets collecting on the thermowell leading to erroneous temperature readings and loss of control of the cooling water control valve. Taking advantage of the rapid advance in electronic technology, Copes-Vulcan can offer a preprogrammed logic module to interface with the DCS or panel mounted with local controllers.



Algorithmic temperature control logic diagram.

## Operating Philosophy

The amount of cooling water supplied to the combined turbine bypass valve or separate desuperheating element is determined by a heat balance calculation performed within the algorithm module. The module receives several inputs.

### Input:

- Inlet steam temperature —  $T_1$   
(required to calculate inlet steam enthalpy —  $h_1$ ).
- Inlet steam pressure —  $P_1$   
(required to calculate inlet steam enthalpy —  $h_1$ ).
- Inlet steam flow —  $Q_1$   
(the steam flow into the bypass valve is measured either by an orifice plate or valve position feed back).
- Outlet or condenser pressure —  $P_2$   
(required to determine saturation enthalpy —  $h_2$ ).
- (The cooling water temperature and hence cooling water enthalpy —  $h_w$  is an adjustable constant within the algorithm. Even relatively large changes in water temperature have only very small effects in overall enthalpy.)

$$\text{Cooling water quantity } Q_w = Q_1 \times \frac{h_1 - h_2}{h_2 - h_w}$$

### Output:

- Cooling water flow rate —  $Q_w$ .

The algorithm has preprogrammed steam tables and instantly calculates the required cooling water quantity. This analog output is directed to the temperature controller which constantly monitors required water flow against actual water flow.

The actual water flow is measured either from an orifice plate or valve position feed back.

This extremely rapid and accurate method of temperature control negates the temperature sensor problems encountered when bypassing to condensers, especially when utilizing dump tubes or where there are only short distances from the bypass valve to the condenser inlet.

## Bypass Systems for Back Pressure Turbines

Back pressure turbines are most frequently employed on Combined Heat and Power (CHP) plants or turbine driven machinery applications such as Syngas/CO<sub>2</sub> compressors for fertilizer production or shredders on sugar mills. The turbine exhaust steam is discharged at either IP or LP conditions to be utilized by the process downstream.

The turbine bypass application is highly critical and one of the most demanding. Frequently, the bypass can be required to perform continuously at low load conditions providing IP or LP makeup steam to satisfy process plant requirements. Should the turbine be taken off load, the whole steam demand is handled by the bypass system.

To fully satisfy such applications, the bypass system must be extremely flexible within a wide ranging performance envelope. The Copes-Vulcan Turbine Bypass valves have, for many years, satisfied such industry demands and more than justified the investment and confidence placed by system designers. Copes-Vulcan supplies the valves and control instrumentation to satisfy the various operational modes, including fast-acting, in the event of a turbine trip, and slower modulating functions when providing makeup steam.

Copes-Vulcan has also developed specific algorithmic temperature control instrumentation for applications where conventional thermowells and temperature sensing elements are difficult or impossible to use due to installation constraints. A typical case study follows, demonstrating the critical nature and highly specific criteria demanded from one of our bypass systems.

### Case Study 96TW20706

These bypass systems were installed around HP steam turbine driven Syngas and CO<sub>2</sub> compressors. The turbine exhaust steam was fed to the downstream catalyst unit where constant steam pressure and temperature requirements were extremely critical.

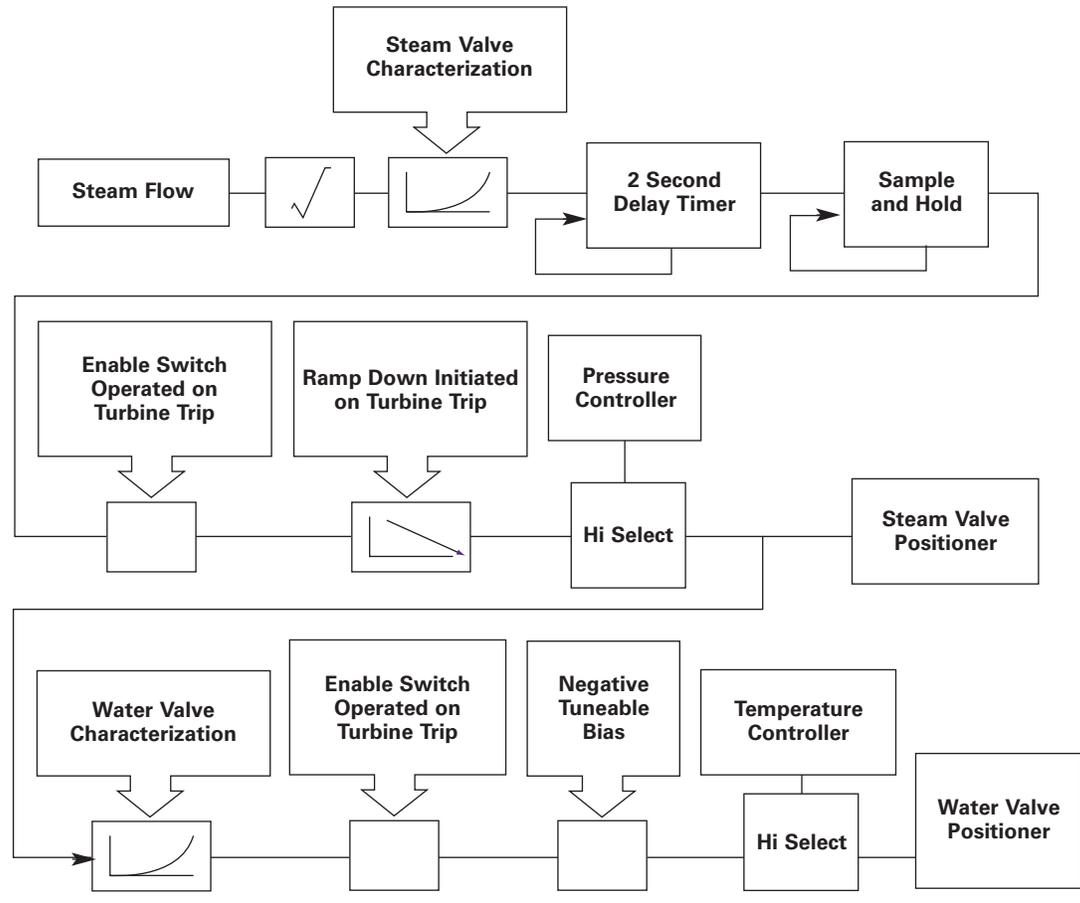
The scope of supply, per turbine compressor, included a single 6x12" (150x300mm) Class 2500 ASTM A182 F22 HP DSCV bypass valve, and a 2" (50mm) Class 2500 ASTM A217 WC9 cooling water control valve, both actuated by a centralized hydraulic power unit (HPU) and PLC control and instrumentation. Under normal process conditions, the bypass valve and cooling water control valve remain closed. In the event of turbine trip, the turbine isolator valves closed in less than one second and the process steam demand passed to the bypass system.

The downstream process required a virtually "bumpless" transfer when the turbine tripped. Therefore, Copes-Vulcan designed the control philosophy shown on page II to satisfy this critical requirement. The control system continuously monitored the steam conditions entering and exiting the turbine; flow, pressure and temperature. The PLC controllers were preprogrammed with the bypass and cooling water valve characteristics; valve lift versus Cv.

The PLC controllers constantly calculated the position that the valves had to travel to simulate the turbine in the event of turbine trip. The output from the PLC controllers was held at neutral by a switch which was only activated via a digital signal from the plant's DSC system. The bypass control system was fitted with a 2 second "look back" feature and built in sample and hold loop, thus ensuring a "clean" thermodynamic status for the system prior to the turbine tripping.

On receiving a digital signal, the valves, in rapid actuation mode, almost instantly travelled to the predetermined position. This position was then held for an adjustable time period, approximately 10 seconds, by a ramp down timer. Once this "hold" time had elapsed, the system would then revert to a more conventional PIC and TIC loop control with the hydraulic actuators automatically changing over to a slower modulation mode for fine control.

Site chart recorders demonstrated that during turbine trip, pressure excursions of less than 1 bar were experienced by the downstream process, thus ensuring safe and continuous production.



Control philosophy logic diagram.

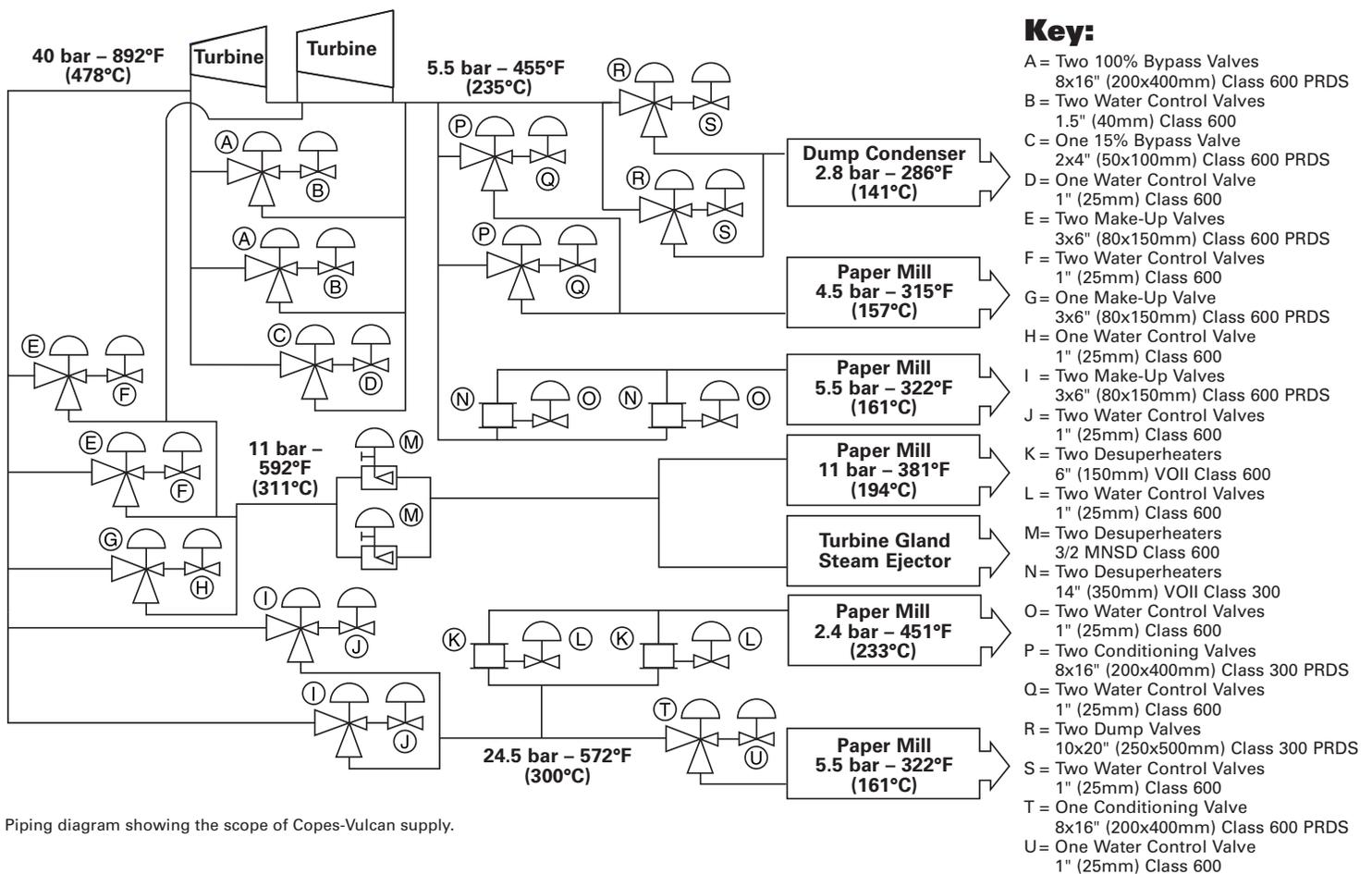
# Combined Heat and Power

Copes-Vulcan, with many decades of experience and product development, has a comprehensive portfolio of steam conditioning equipment to completely satisfy the total requirements of a modern CHP plant — from the main turbine bypass valve to the less critical but equally important IP and LP makeup lines.

A typical package of equipment for the total steam conditioning requirement of a CHP plant draws from almost the entire range of Copes-Vulcan's products. Our capability of single sourcing a major package of equipment offers the contractor significant commercial advantages.

The diagram below illustrates a package of steam conditioning equipment supplied to a paper mill's new CHP plant clearly demonstrating Copes-Vulcan's unique position in this market sector.

The scope of equipment supplied ranges from combined DSCV units for the main turbine bypass valve, conventional combined PRDS valves, makeup steam control valves with downstream independent desuperheaters (both multi-nozzle mechanically atomizing type, MNSD, and the high turndown aspirating VOII type) together with the Copes-Vulcan Cascade trim cooling water control valves with 200:1 turndown capabilities.



Piping diagram showing the scope of Copes-Vulcan supply.

## Sales and Service

