EMAE 355 Group 7 Project 1 Report: CO_2 Supply System for Turbine Fluid Bearing

Will MacCormack Owen Braun Julian Town Natalia Parla Rodriguez

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1 Executive summary

The design for the turbine bearing CO_2 supply system consists of 2 1/2in Badger Meter Type 807 Low Flow Control Valves, each with a size E linear trim. Each valve is also fit with a Type 759 Pneumatic actuator. One valve is attached at location 2, and the other at location 4. The fluid from these valves are combined in the piping system, where they feed the bearing. There are two 4576 A G-20 D H-VR filters, located in front of each valve. These filters fit 1in diameter pipes. The fluid exits the turbine and is reintroduced to the main system at location 5. Analysis shows that the necessary bearing fluid conditions can be achieved with two valves across operational and startup conditions. The valves were sized to fit the full range of necessary control. Additionally, pressure analysis was conducted to ensure that there would be no backflow in the bearing supply system. The system is incredibly simplistic, resulting in lower installation costs, energy costs, space consumption, and risk exposure than any other plausible system.

2 Problem statement

The final goal of this design is to modify the heat engine by selecting a combination of valves, heat exchangers, pumps, and filters to supply CO_2 for the turbine fluid bearing in the CO_2 Heat Engine. The turbine fluid bearing requires a constant mass flow rate of 0.26kg/s at a temperature of 150°C. This results in a pressure differential across the bearing of 2.1MPa. The CO_2 must be pulled from and returned to the heat engine cycle.

The design must consider control mechanisms necessary to adapt dynamically to changes in ambient and cycle state conditions, as well as components from the design need sizing and specification. Furthermore, potential failures from minimum bearing supply conditions and projected turbine power loss need to be taken into account.

3 Background

Bearings are used to reduce friction between a rotating shaft and its fixed supports. They can be used to prevent both radial and linear movement. Radial bearings keep the shaft rotating along the same axis. Linear movement is mitigated by a thrust bearing, which also has a radial component.

Bearings are mainly mechanical, with rotating, oil-lubricated balls that promote low resistance rotation. In situations with very rapid rotation, the oil dries up quickly. The bearings also wear down quickly due to the rapid load cycles. An alternative is to employ fluid bearings, which do not have such issues [5].

A fluid bearing replaces sliding mechanical element with a thin layer of highly pressurized fluid. The fluid can either be externally pressurized or pressurized by the rotation of the shaft. Externally pressurized bearings are called hydrostatic fluid bearings; whereas, internally pressurized bearings are called hydrodynamic [5].

This system will use a hydrostatic bearing supplied with the CO_2 used in the heat engine. The CO_2 must be consistently provided at the required temperature and pressure for the turbine to function properly.

4 Design – Lead: Julian Town

The turbine fluid bearing requires a constant mass flow rate of 0.26kg/s at a temperature of 150°C. Imposed requirements include that the system should use the minimum number of components to prepare the fluid for the turbine. Additionally, the fluid should be returned to the system in a location that minimally impacts heat engine operation.

The Diagram of the overall system and locations to siphon fluid from are shown below in Figure 1.

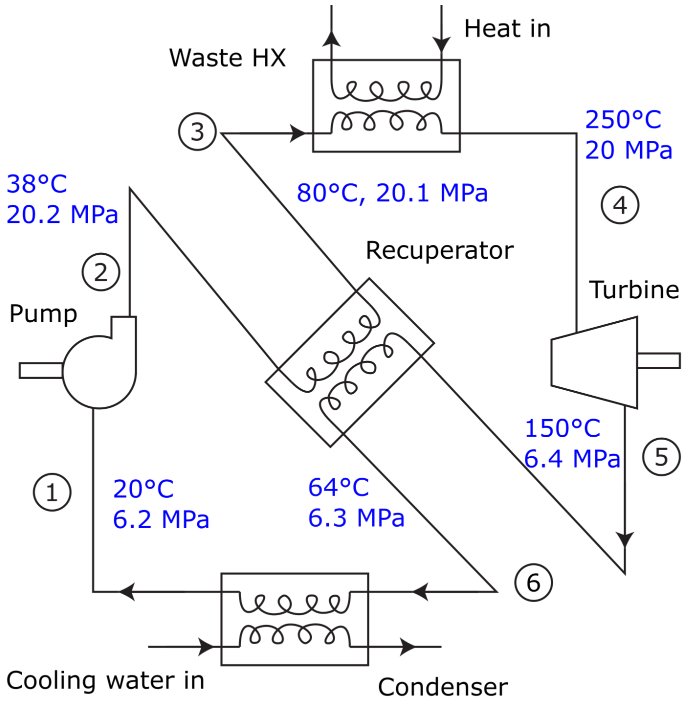


Figure 1: Overall System Diagram

To provide the Turbine bearing with 0.26kg/s of CO_2 at 250 °C, only two valves are needed. Each valve is a 1/2in Badger Meter Type 807 Low Flow Control Valves, each with a size E linear trim with a type 759 pneumatic actuator. The first valve draws fluid from location 2 and the second draws fluid from location 4. These valves have a Cv range of 0.025 to 0.500, as can be seen in Chart 4 [1]. The valves fail in an open position to keep feeding the bearing in case of a loss of power. In front of each valve is a 4576 A G-20 D H-VR filter. These filters are sized to block particles greater than 20 microns in size. Once used in the fluid bearing, it is returned to location 5. A 1in to 1/2in diameter pipe transition is required between the filter and the valve, but that is outside the scope of the report. The process is shown in the Process Flow Diagram below.

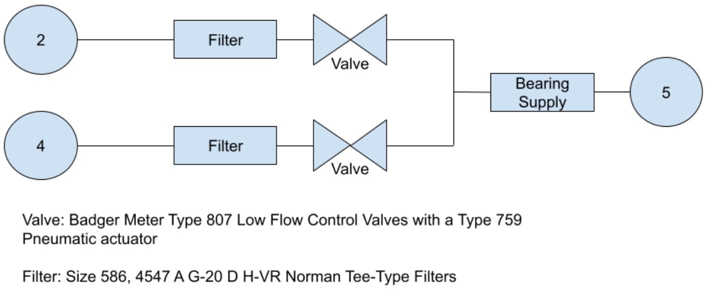


Figure 2: Process Flow Diagram

5 Analysis – Lead: Will MacCormack

The system has two filters, two valves, and a tee joint. These were modeled to verify that the configuration could provide CO_2 at the proper conditions for the turbine across all system conditions.

5.1 Tee Modeling

Tee joints are assumed to maintain equal pressures on all branches, conserve mass flow rate, and conserve the mass weighted flow of enthalpy.

Assuming a tee in which pipes A and B flow into pipe C, we can express the continuity with the following:

$$P_A = P_B = P_C \tag{1}$$

$$\dot{m}_A + \dot{m}_B = \dot{m}_C \tag{2}$$

$$\dot{m}_A h_A + \dot{m}_B h_B = \dot{m}_C h_C \tag{3}$$

5.2 Valve Modeling

Valve flows are assumed to be adiabatic from entrance to exit point and isentropic from entrance to throttle. Additionally, throttle pressure must not drop below exit pressure, and throttle flow rate must not exceed the speed of sound.

Given an input thermodynamic state and an output pressure, the valve can be modeled as follows:

$$h_{ent} = h_{exit} \tag{4}$$

$$s_{ent} = s_{thr} \tag{5}$$

$$P_{thr} \geq P_{exit} \tag{6}$$

$$v_{thr} \leq c_{thr} \tag{7}$$

where c_{thr} is the speed of sound in the medium at the throttle thermodynamic state.

The velocity at the throttle for a given throttle pressure can be solved by energy conservation:

$$v_{thr} = \sqrt{2(h_{ent} - h_{thr}) + v_{ent}^2} \tag{8}$$

The minimum required valve impingement upon the flow can be found by starting the throttle pressure at the entrance pressure and decreasing throttle pressure until one of the two inequalities no longer holds.

Once minimum impingement is found, the corresponding valve coefficient can be found by,

$$A_{thr} = \frac{\dot{m}}{v_{thr} * \rho_{thr}} \tag{9}$$

$$C_d = \frac{P_{exit}}{P_{thr}} \tag{10}$$

$$C_v = 58888.5 * C_d * A_{thr} \tag{11}$$

5.3 Filter Modeling

One approach is modeling a filter is to treat it as a valve. The flow is assumed to be adiabatic causing enthalpy to be constant across the filter. Furthermore, the flow drop in pressure can be calculated due to a reduction in area at the throat of the valve/filter. However, manufacturers such as Norman Filter give the pressure differential across the filter with respect to flow rate shown in Figures 5 and 6. The filters were modeled using the same equations found in section above along with some additional equations to obtain the pressure drop from the manufacturer's specifications. First, the volumetric flow rate was calculated across the filter in GPM, allowing the pressure drop to be calculated:

$$\dot{V} = \frac{\dot{m}}{\rho} \tag{12}$$

However, the pressure drop from the manufacturer is given with respect to oil in SSU. Thus a series of conversions must be performed. The specific gravity, and kinematic viscosity of the fluid must be calculated:

$$\text{Specific Gravity} = \frac{\rho}{1000} \tag{13}$$

$$\nu_{centistokes} = \nu_{SI} * 1E6 \tag{14}$$

Additionally, Norman Filter's testing was performed in Seconds Saybolt Universal (SSU). Thus, the following equation can be solved to obtain the density of the working fluid in SSU from [6]:

$$0 = 0.226SSU - \frac{195}{SSU} - \nu_{centistokes} \tag{15}$$

Next, the pressure drop must be calculated across both the housing and filter elements. Note that the pressure drop is in Psi. The following equations, represent the lines in graphs 5 and 6 for 1inch piping and a 20 micron stainless steel filter element:
Pressure Drop: Housing

$$pDrop_{housing} = 0.0672 * \dot{V}_{GPM} + 8.21E - 4 * (\dot{V}_{GPM})^2 \tag{16}$$

Pressure Drop: Filter Element

$$pDrop_{filter} = 0.0618 * \dot{V}_{GPM} + .0108 * (\dot{V}_{GPM})^2 \tag{17}$$

Lastly, the pressure drops across the elements are added, and the pressure drop is modified based on the viscosity of the fluid.

$$dP_{tot} = (pDrop_{housing} + pDrop_{filter}) * \frac{SSU}{100} * \frac{Specificgravity}{0.9} \tag{18}$$

After finding the pressure drop after the filter, both pressure and enthalpy can be used to specify the state point after the filter.

5.4 Conditions and Assumptions

It is assumed that there is no significant pressure loss due to piping elements in the system. Mathematically, the pressures at each location follow the equations below.

$$P1 = P5 = P6 \tag{19}$$

$$P2 = P3 = P4 \tag{20}$$

Additionally, it is assumed that the thermodynamic state of the heat engine is unaffected by the relatively small draw of mass flow rate for the bearing.

As seen from Tables 4 and 5 in Appendix A, the maximum pressure in the entire system is 20.7 MPa, or 3002.3 psi. A factor of safety of 1.66 w.r.t. pressure failures was achieved by selecting valves nominally rated for 5,000 psi. Also from Tables 4 and 5 in Appendix A, the maximum temperature the valves experience is 250 °C. The valves are rated for 25.1 MPa (3680 psi) at 260 °C [2], both are which are greater than the expected maximum conditions.

When designing and analyzing the filter elements in the system, a couple of parameters needed to be considered. First, the specific filter used must be rated for the specific pressure and temperature that it will be subjected too. Similar to the valve selection, the filters will be subjected to a pressure of 20.7 MPa (3003 psi), and a maximum temperature of 250 °C as shown in Tables 4 and 5 in Appendix A. The filters satfisfy these conditions as they are rated for 5000 psi and an operating range of -40 °C to 315 °C. In addition, the specific filter element must be sized to ensure all harmful particles are stopped. Typical bearings have a clearance of about 0.001" or about 25 microns. As a result, looking at Figure 6 there are three sizes for a stainless steel filter element. Since the bearing gap is about 25 microns, a 20 micron filter element was selected. Additionally, the filter must be rated for flow rate, which most manufacturers use gallons per minute (GPM). The size 586 filter is rated for 24 GPM, which is well above the maximum volumetric flowrate achieved in the filters. Lastly, the selected filter has an indicator and valve. The pressure indicator will indicate when the filter is clogging, and must be cleaned.

5.5 Solving Methodology

All analysis was done using a Jupyter notebook. Fluid properties were sourced from PyFluids and CoolProp.

All possible combinations of sources and equivalent sinks were attempted to find any viable dual valve configurations. For this automated analysis, the pressure was the only factor of the sink location that impacted the calculation; therefore, only the pressure values of cycle locations 1 and 2 were analyzed.

First, each configuration was checked to ensure sufficient pressure neglecting filter or valve losses to drive flow into the bearing.

Then, as both the valves and filters are assumed to be adiabatic, the enthalpy of both source flows at the tee inlet are known prior to any mass flow rate calculation. If the required enthalpy of the bearing supply is between the two source enthalpies, the mass flow rate contributions from each source that would provide the needed enthalpy can be computed with,

$$\dot{m}_A = \dot{m}_{ent} * \frac{h_{ent} - h_B}{h_A - h_B} \tag{21}$$

and

$$\dot{m}_B = \dot{m}_{ent} - \dot{m}_A \tag{22}$$

After finding the required mass flow rates from each source, the pressure drop across the filter can be computed from the input temperature, pressure, and mass flow rate. Finally, the post filter pressure, enthalpy, and mass flow rate can be used to find the appropriate valve coefficient to supply flow at the bearing inlet pressure. The possible sources and their success/failure reasoning can be seen below in Figure 3. The valve coefficients are summarized in Table 1 below.

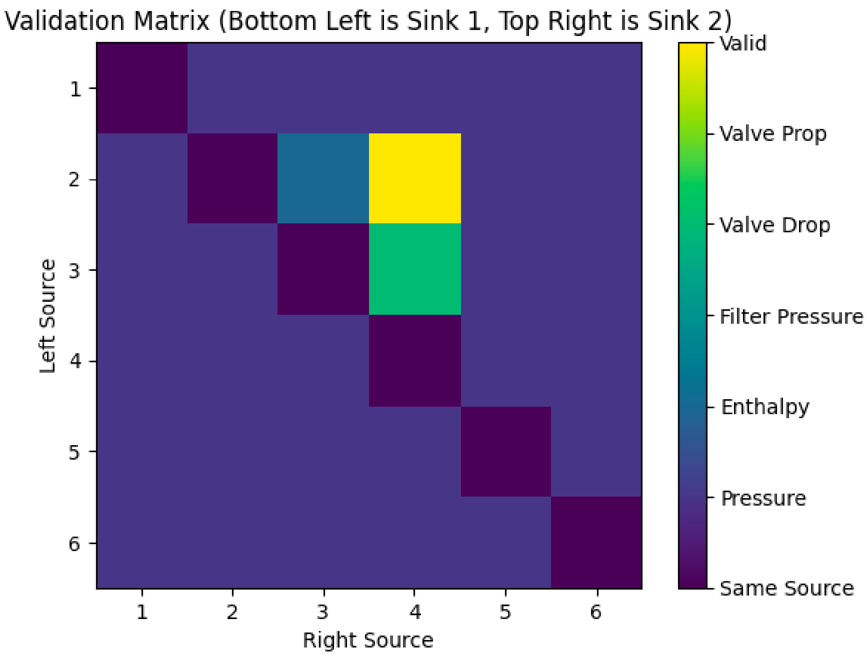


Figure 3: Configuration Validation Matrix: Configurations Colored by Validity/Invalidity Reason

Ambient Temperature (°C)	Valve 1 Cv ($m^{7/2}/kg^{1/2}$)—	Valve 2 Cv ($m^{7/2}/kg^{1/2}$)
-20	0.0438	0.1812
-10	0.0472	0.1750
0	0.0500	0.1654
10	0.0522	0.1474
20	0.0567	0.1304
30	0.0718	0.1234
40	0.1061	0.1267
50	0.1737	0.0996
Startup	0.1205	0.3501

Table 1: Cv of Each Valve for Each Condition

5.6 Power Output

The power loss due to the bearing supply system can found by analyzing the mass flow rate impacts upon the heat engine turbine and pump. As this setup draws from cycle points 2 and 4, the impact can be analyzed as an additional mass flow rate load on the pump of the draw from 2, and a reduction in turbine mass flow rate of the draw from 4.

$$\dot{Q}_{loss} = \dot{m}_{4,draw}(h_4 - h_5) + \dot{m}_{2,draw}(h_2 - h_1) \tag{23}$$

$$\dot{Q}_{prod} = \dot{m}((h_4 - h_5) - (h_2 - h_1)) \tag{24}$$

$$\dot{Q}_{draw\%} = \frac{\dot{Q}_{loss}}{\dot{Q}_{prod}} * 100 \tag{25}$$

The power loss at each condition is summarized below in Table 2

Ambient Temperature (°C)	Power Lost (%)—
-20	3.56
-10	3.53
0	3.30
10	2.95
20	2.68
30	2.57
40	3.03
50	4.06
Startup	11.38

Table 2: Power Lost For for Each Condition

5.7 Filter Blockage

Throughout, the life cycle of the system the filter can be expected to accumulate debris and clog. This was modeled through a similar method to the valve analysis. The filter is treated as a valve, with an entrance, throttle and exit. The thermodynamic states are defined the same as the valve per equations 4, and 5. When the flow does not choke the pressure at the throttle can be set equal to the pressure at the exit. Thus the thermodynamic state, at the throttle can be specified using pressure and entropy. The velocity and effective area can then be solved using equations 8 and 9 when the throttle state is specificed. The effective area was calculated for normal operation of the filter.

In order to find the maximum blockage that would still allow the filter to operate, a double iterative method was employed. In the outer loop, the valve input pressure was incremented, starting at the tee inlet pressure. In the inner loop, the valve throttle pressure was iterated until the rated minimum C_V of the valve was produced. By solving for the throttle state at the C_V limit of the valve, the pressure drop across the valve was computed through the discharge coefficient seen across valve operation. The outer loop was continued until the input pressure to the valve minus the computed pressure drop agreed with the tee inlet pressure. At this point, the required filter area to produce the pressure drop from source to valve inlet was computed, and the area ratio between normal operation and maximum clog was used to compute a maximal filter clog percentage for the less tolerant of the two source pathways. The maximum allowable filter blockage allowed is summarized below in Table 3.

Ambient Temperature (°C)	**Max Filter Blockage (%)—**
-20	97.75
-10	97.81
0	97.98
10	98.22
20	98.44
30	98.60
40	98.57
50	97.48
Startup	83.00

Table 3: Maximum Allowed Filter Blockage for Each Condition

6 Evaluation

This arrangement was chosen because it minimizes the components and power input needed. The total system has only two valves and two filters. From the analysis, it was determined that this is the minimum viable option. One valve with a filter would not be sufficient. Since there are two sources, dual filters are needed to protect the valves.

Heat exchangers and pumps were removed from consideration after preliminary calculations proved that valves alone would be sufficient while reducing packaging and power costs. A heat exchanger is not needed in this application as the supply fluid is available in enthalpies both above and below the target at pressures exceeding the required supply value. As such, the target heat energy of the supply fluid can be achieved purely through mixing instead of heat exchange.

Unlike systems that employ a single filter before the bearing, this filter placement was chosen to protect both the bearing system and the small components of the control valves. The filter size of 20 microns ensures that the bearing film surface, an average of 25 microns across, is undisturbed by particles.

The system is also smaller than any alternative. The filters chosen are Tee filters, which are installed in-line with the piping system. Likewise, the valves require a small footprint in addition to the necessary piping between the draw and drain points, when compared to systems that employ heat exchangers or pumps.

7 References

[1] "RCV-DS-02507-EN_Research Control Valves CV vs Lift Chart." Badger Meter, Nov. 2023

[2] "RCV-DS-00576-EN_Small Control Valve - Type 807 Product Data Sheet." Badger Meter, Feb. 2021

[3] "RCV-DS-00268-EN_Positioner Actuator - Type 759, .25 & .5in Air-to-Close Product Data Sheet." Badger Meter

[4] "NormanFilters586." Norman Filter Company

[5] N. Way, "Fluid bearings: Types, applications, and the porous difference," Fluid Film Bearings Types, Applications, and the Porous Media Difference, https://www.newwayairbearings.com/news/blog/13235/fluid-film-bearing/ (accessed Feb. 13, 2024).

[6] "Viscosity," www.contractorsunlimited.co.uk. https://www.contractorsunlimited.co.uk/toolbox/viscosity.shtml

8 Appendix A: Provided Conditions

Ambient T (°C)	**T1 (°C)**	**T2 (°C)**	**T3 (°C)**	**T4 (°C)**	**T5 (°C)**	**T6 (°C)**	**P1 (MPa)**	**P2 (MPa)**	**m´ (kg/s)**
-20	-20	-14	46	250	129	6.6	3.3	15	4.9
-10	-10	-2	50	250	129	15.4	3.3	15	4.9
0	0	10	58	250	135	28.8	3.9	16	5.2
10	10	23	68	250	143	46.0	5	18	5.8
20	20	38	80	250	150	63.9	6.2	20	6.4
30	30	57	96	250	160	82.1	7.4	20.7	6.5
40	40	71	117	250	181	94.6	9.2	19.9	5.5
50	50	85	145	250	198	102.8	10	17.8	4

Table 4: Steady State Conditions of Heat Engines

Ambient T (°C)	**T1 (°C)**	**T2 (°C)**	**T3 (°C)**	**T4 (°C)**	**T5 (°C)**	**T6 (°C)**	**P1 (MPa)**	**P2 (MPa)**	**m´ (kg/s)**
20	20	27	207	250	238	73	6.2	11	3

Table 5: Start-Up Conditions of Heat Engine

9 Appendix B: Manufacturer Provided Valve Cv Table [1]

RCV
Research Control® | ReCo Valves

Research Control Valves

CV vs Lift Chart

RCV Valves		Trim Sizes Equal %															
% Lift	**% Cv**	**6.0**	**5**	**4.5**	**4**	**3.5**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**% Lift**
0%	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
5 %	**1.0%**	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.01	0.008	0.005	0.003	0.002	0.001	0.001	0.000	5%
10 %	**1.9%**	0.11	0.10	0.09	0.08	0.07	0.05	0.04	0.02	0.015	0.010	0.006	0.004	0.002	0.002	0.001	10%
20 %	**3.8%**	0.23	0.19	0.17	0.15	0.13	0.10	0.08	0.05	0.031	0.019	0.012	0.008	0.005	0.003	0.002	20%
25 %	**4.8%**	0.29	0.24	0.22	0.19	0.17	0.12	0.10	0.06	0.038	0.024	0.015	0.010	0.006	0.004	0.002	25%
30 %	**5.9%**	0.35	0.29	0.26	0.23	0.20	0.15	0.12	0.07	0.047	0.029	0.019	0.012	0.008	0.005	0.003	30%
40 %	**8.8%**	0.53	0.44	0.40	0.35	0.31	0.22	0.18	0.11	0.070	0.044	0.028	0.018	0.011	0.007	0.004	40%
50 %	**13.2%**	0.79	0.66	0.59	0.53	0.46	0.33	0.26	0.16	0.105	0.066	0.042	0.026	0.017	0.011	0.007	50%
60 %	**19.8%**	1.19	0.99	0.89	0.79	0.69	0.49	0.40	0.25	0.158	0.099	0.063	0.040	0.026	0.016	0.010	60%
70 %	**29.6%**	1.78	1.48	1.33	1.19	1.04	0.74	0.59	0.37	0.237	0.148	0.095	0.059	0.039	0.024	0.015	70%
75 %	**36.3%**	2.18	1.81	1.63	1.45	1.27	0.91	0.73	0.45	0.290	0.181	0.116	0.073	0.047	0.029	0.018	75%
80 %	**44.4%**	2.67	2.22	2.00	1.78	1.56	1.11	0.89	0.56	0.356	0.222	0.142	0.089	0.058	0.036	0.022	80%
90 %	**66.7%**	4.00	3.33	3.00	2.67	2.33	1.67	1.33	0.83	0.533	0.333	0.213	0.133	0.087	0.053	0.033	90%
100%	**100%**	6.00	5.00	4.50	4.00	3.50	2.50	2.00	1.25	0.800	0.500	0.320	0.200	0.130	0.080	0.050	100%
Valve Sizes		1"	1"	1"	1", 3/4"	1", 3/4"	1-1/2"	1-1/2"	1-1/2"	1-1/2"	1-1/2"	1-1/4"	1-1/4"	1-1/4"	1-1/4"	1-1/4"	

Trim Sizes O through P-18 are available only in linear characteristic. See Product Data Sheets for maximum Cvs.

RCV Valves		Trim Sizes Linear															
% Lift	**% Cv**	**6.0**	**5**	**4.5**	**4**	**3.5**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**% Lift**
0%	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
5 %	**5 %**	0.30	0.25	0.23	0.20	0.18	0.13	0.10	0.06	0.040	0.025	0.016	0.010	0.007	0.004	0.003	5%
10 %	**10 %**	0.60	0.50	0.45	0.40	0.35	0.25	0.20	0.13	0.080	0.050	0.032	0.020	0.013	0.008	0.005	10%
20 %	**20 %**	1.20	1.00	0.90	0.80	0.70	0.50	0.40	0.25	0.160	0.100	0.064	0.040	0.026	0.016	0.010	20%
25 %	**25 %**	1.50	1.25	1.13	1.00	0.88	0.63	0.50	0.31	0.200	0.125	0.080	0.050	0.033	0.020	0.013	25%
30 %	**30 %**	1.80	1.50	1.35	1.20	1.05	0.75	0.60	0.38	0.240	0.150	0.096	0.060	0.039	0.024	0.015	30%
40 %	**40 %**	2.40	2.00	1.80	1.60	1.40	1.00	0.80	0.50	0.320	0.200	0.128	0.080	0.052	0.032	0.020	40%
50 %	**50 %**	3.00	2.50	2.25	2.00	1.75	1.25	1.00	0.63	0.400	0.250	0.160	0.100	0.065	0.040	0.025	50%
60 %	**60 %**	3.60	3.00	2.70	2.40	2.10	1.50	1.20	0.75	0.480	0.300	0.192	0.120	0.078	0.048	0.030	60%
70 %	**70 %**	4.20	3.50	3.15	2.80	2.45	1.75	1.40	0.88	0.560	0.350	0.224	0.140	0.091	0.056	0.035	70%
75 %	**75 %**	4.50	3.75	3.38	3.00	2.63	1.88	1.50	0.94	0.600	0.375	0.240	0.150	0.098	0.060	0.038	75%
80 %	**80 %**	4.80	4.00	3.60	3.20	2.80	2.00	1.60	1.00	0.640	0.400	0.256	0.160	0.104	0.064	0.040	80%
90 %	**90 %**	5.40	4.50	4.05	3.60	3.15	2.25	1.80	1.13	0.720	0.450	0.288	0.180	0.117	0.072	0.045	90%
100 %	**100 %**	6.00	5.00	4.50	4.00	3.50	2.50	2.00	1.25	0.800	0.500	0.320	0.200	0.130	0.080	0.050	100%
Valve Sizes		1"	1"	1"	1", 3/4"	1", 3/4"	1-1/2"	1-1/2"	1-1/2"	1-1/2"	1-1/2"	1-1/4"	1-1/4"	1-1/4"	1-1/4"	1-1/4"	

Numbers are for reference or comparison only.

Badger Meter®

RCV-DS-02507-EN-03 (November 2023)

Product Data Sheet

Figure 4: Manufacture Provided 807 Valve Cv Charts

10 Appendix C: Manufacturer Provided Valve Product Data Sheet [2]

RCV
Research Control® | ReCo® Valves

Small Control Valve

U.S. Type 807 and Type 752 (Includes RC200, RC220, RC250)

DESCRIPTION

For more than 60 years, Type 807 and Type 752 valves have performed in some of the world's most demanding applications. If your application requires critical control of liquid, gas or steam, your choice of control valves is one of the most important decisions you will make.

When it comes to specifying a control valve, the variables are complicated and exacting. That is why Research Control® Valves are available in a broad range of options—so we can design a truly engineered solution that matches your requirements.

APPLICATION

Processing plants, research facilities and government agencies worldwide rely on Research Control Valves for repeatable performance and durability. Built for applications 1 in. (25.4 mm) and under, our Types 807 and 752 control valve are integral components in systems ranging from petrochemical to pharmaceutical manufacturing. It is an ideal choice for additive injection or flow and pressure control.

CONSTRUCTION

Body – Bonnet	
Standard	316/316L stainless steel, carbon steel (WCB)
Optional	Monel®, alloy 20, Hastelloy® C or ASTM equivalent, DIN 1.4581/1.4571. Other materials available upon request.
Innervalve	
Standard	316 stainless steel
Optional	Stellite®, Monel, alloy 20, Hastelloy C or B or ASTM equivalent
Packing	
Standard	TFE chevron rings
Optional	Graphite, Reduced Emissions Kalrez® (REK)
Actuator	
Standard	Die cast aluminum
Optional	316L stainless steel on 1/2", 3/4" and 1" models

ACTUATOR CHOICES

Standard	Air to open, fail close Air to close, fail open
Optional	With integral top-mounted positioner
Standard Signals	3-15#, 3-27#, 6-30#
Optional Signals	3-9#, 9-15#, with positioner
Accessories	Filter regulator, gauges, I/P converter, limit switches, handwheel, solenoids

Shown with Type 754 Actuator

STANDARD FEATURES

- 1/4 in. (6.4 mm), 1/2 in. (12.7 mm), 3/4 (19.1 mm) and 1 in. (25.4 mm) models
- Interchangeable trim sets
- Threaded bonnet for quick disassembly
- Trim characteristics: Linear, equal percent, quick open or double taper
- TFE chevron packing
- ANSI Class IV shutoff (size O and larger)

OPTIONAL FEATURES FOR 1/2 IN. (12.7 MM), 3/4 IN. (19.1 MM) AND 1 IN. (25.4 MM) MODELS

- Butt and socket weld ends, BSPP, tube connection and others
- Bonnet extensions for temperature extremes
- Bellows packing solutions
- Angle pattern bodies
- Reduced Emissions Kalrez® (REK), graphite, spring loaded chevron and others
- Exotic alloys for complete valves or trims
- Stellited trims & soft seats (PTFE & Kel-F)
- TiN coating of innervalve stem and seat
- Purge or leak ports

Badger Meter

RCV-DS-00576-EN-05 (February 2021)

Product Data Sheet

PRESSURE VS TEMPERATURE RATINGS FOR VALVE SUPERSTRUCTURE

The pressure/temperature ratings listed here are based on material cross sections at the joint between the body and bonnet where a gasketed screw type bonnet is used. When the proper torque levels are used, the valve should not experience rupture of the joint or the material. The listed torque levels were used in hydrostatic tests at the factory at 70° F (21.1° C) at maximum body rating and were found to provide acceptable seating. Other factors, such as high or cyclic temperatures, light process gases, or poor gasket surfaces can dictate the ability of a seal to be made. Under such conditions, the only way to be sure of tight sealing is to perform a test under the actual process conditions.

These charts are not intended as an indication of functionality or suitability for control service. Other charts are available to assist in the choosing of valve type, bonnet type, trim type and actuator.

When flanges, fittings or other pressure containing elements are added to the valve, the pressure rating of the total valve assumes the rating of the weakest component.

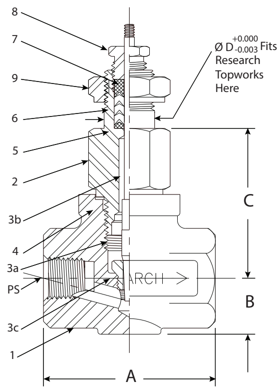
The following charts exclude packing or end fittings:

1/4 in. Research Control Valve						
Temp	**316 S/S psi (bar)**	**Carbon Steel psi (bar)**	**Hastelloy B or = psi (bar)**	**Hastelloy C or = psi (bar)**	**Monel psi (bar)**	**Alloy 20 psi (bar)**
100° F (37.8° C)	5000 (345)	4000 (276)	5000 (345)	5000 (345)	4000 (276)	5000 (345)
200° F (93.3° C)	5000 (345)	3700 (255)	5000 (345)	5000 (345)	4000 (276)	5000 (345)
300° F (148.9° C)	4750 (328)	3500 (241)	5000 (345)	5000 (345)	3880 (268)	4850 (334)
400° F (204.4° C)	4190 (289)	3200 (221)	5000 (345)	5000 (345)	3770 (260)	4700 (324)
500° F (260.0° C)	4000 (276)	2900 (200)	4900 (338)	4900 (338)	3740 (258)	4500 (310)
600° F (315.6° C)	3820 (263)	2600 (179)	4850 (334)	4850 (334)	3740 (258)	4200 (290)
700° F (371.1° C)	3640 (351)	2300 (159)	4800 (331)	4800 (331)	3640 (251)	3900 (269)
800° F (426.7° C)	3580 (247)	—	4750 (328)	4750 (328)	3580 (247)	3700 (255)
900° F (482.2° C)	2840 (196)	—	—	4500 (310)	2280 (157)	3000 (207)
1000° F (537.8° C)	1160 (80)	—	—	4000 (276)	940 (65)	1500 (103)
1100° F (593.3° C)	Consult factory for higher temperatures.			3500 (241)	—	—
1200° F (648.9° C)				3000 (207)	—	—
	Recommended torque in ft-lb (Nm), +/- 2 ft-lb (2.71 Nm)					
	37 (50)	37 (50)	39 (53)	37 (50)	31 (42)	35 (47)

1/2 in. Research Control Valve						
Temp	**316 S/S psi (bar)**	**Carbon Steel psi (bar)**	**Hastelloy B or = psi (bar)**	**Hastelloy C or = psi (bar)**	**Monel psi (bar)**	**Alloy 20 psi (bar)**
100° F (37.8° C)	5000 (345)	4000 (276)	5000 (345)	5000 (345)	4000 (276)	5000 (345)
200° F (93.3° C)	4750 (328)	3800 (262)	5000 (345)	5000 (345)	3780 (261)	5000 (345)
300° F (148.9° C)	4310 (297)	3600 (248)	5000 (345)	5000 (345)	3520 (243)	4950 (341)
400° F (204.4° C)	3860 (266)	3300 (228)	5000 (345)	5000 (345)	3420 (236)	4850 (334)
500° F (260.0° C)	3640 (251)	3100 (214)	4900 (338)	4900 (338)	3390 (234)	4600 (317)
600° F (315.6° C)	3470 (239)	2900 (200)	4850 (334)	4870 (336)	3390 (234)	4300 (296)
700° F (371.1° C)	3310 (228)	2700 (186)	4800 (331)	4610 (318)	3310 (228)	4200 (290)
800° F (426.7° C)	3255 (224)	—	4750 (328)	4430 (305)	2090 (114)	4000 (276)
900° F (482.2° C)	3190 (220)	—	—	4200 (290)	2070 (143)	3000 (207)
1000° F (537.8° C)	1860 (128)	—	—	4000 (276)	850 (59)	1500 (103)
1100° F (593.3° C)	Consult factory for higher temperatures.			3400 (234)	—	—
1200° F (648.9° C)				3000 (207)	—	—
	Recommended torque in ft-lb (Nm), +/- 2 ft-lb (2.71 Nm)					
	122 (165)	122 (165)	131 (178)	124 (168)	102 (138)	117 (159)

3/4 in. and 1 in. Research Control Valve				
Temp	**316 S/S psi (bar)**		**Carbon Steel psi (bar)**	
	3/4 in. (19.1 mm)	**1 in. (25.4 mm)**	**3/4 in. (19.1 mm)**	**1 in. (25.4 mm)**
100° F (37.8° C)	1500 (103)	1500 (103)	1500 (103)	1500 (103)
200° F (93.3° C)	1450 (100)	1450 (100)	1350 (93)	1350 (93)
300° F (148.9° C)	1325 (91)	1325 (91)	1325 (91)	1325 (91)
400° F (204.4° C)	1175 (81)	1175 (81)	1275 (88)	1275 (88)
500° F (260.0° C)	1100 (76)	1100 (76)	1200 (83)	1200 (83)
600° F (315.6° C)	1050 (72)	675 (46)	1100 (76)	1100 (76)
700° F (371.1° C)	840 (58)	250 (17)	1075 (74)	1075 (74)
800° F (426.7° C)	575 (40)	—	—	—
3/4 in. and 1 in. Torque = 290 ft-lb (393 Nm)				

DIMENSIONS



1. Valve Body
2. Valve Bonnet
3. Trim Set (innervalve)
4. Body Bonnet Gasket
5. Packing Adaptor
6. Packing (CV ring)
7. Packing Follower
8. Packing Gland
9. Yoke Lock Nut

PS	A	B	C	D	Stroke
0.25 in. (6.4 mm)	2.12 in. (53.8 mm)	0.68 in. (17.3 mm)	1.87 in. (47.5 mm)	0.625 in. (115.9 mm)	0.437 in. (11.1 mm)
0.50 in. (12.7 mm)	2.75 in. (69.9 mm)	1.00 in. (25.4 mm)	2.85 in. (72.4 mm)	0.875 in. (22.2 mm)	0.562 in. (14.3 mm)
0.75 in. (19.1 mm)	3.37 in. (85.6 mm)	1.18 in. (30.0 mm)	3.84 in. (97.5 mm)		
1 in. (25.4 mm)	4.00 in. (101.6 mm)	1.50 in. (38.1 mm)	3.95 in. (100.3 mm)		

INNERVALVE CHART

Valve Size	Trim Designation	Nominal Cv	Theoretical Turbulent Cv	Orifice Dia.	Orifice Area	Nominal Rangeability Linear	Equal %
1 in. (25.4 mm)	6.0	6.0	6.0	0.6250 (15.9 mm)	0.3068 in.^{2} (197.9 mm^2)	50:1	60:1
	5.0	5.0	5.0	0.6250 (15.9 mm)	0.3068 in.^{2} (197.9 mm^2)	50:1	60:1
	4.5	4.5	4.5	0.5000 (12.7 mm)	0.1963 in.^{2} (126.6 mm^2)	50:1	60:1
3/4 in. (19.1 mm) and 1 in. (25.4 mm)	4.0	4.0	4.0	0.5000 (12.7 mm)	0.1963 in.^{2} (126.6 mm^2)	50:1	60:1
	3.5	3.5	3.5	0.5000 (12.7 mm)	0.1963 in.^{2} (126.6 mm^2)	50:1	60:1
1/2 in. (12.7 mm), 3/4 in. (19.1 mm) and 1 in. (25.4 mm)	A	2.5	2.5	0.3750 (9.5 mm)	0.1104 in.^{2} (71.2 mm^2)	40:1	50:1
	B	2.0	2.0	0.3750 (9.5 mm)	0.1104 in.^{2} (71.2 mm^2)	40:1	50:1
	C	1.25	1.25	0.2810 (7.1 mm)	0.0620 in.^{2} (40.0 mm^2)	40:1	50:1
	D	0.8	0.8	0.2500 (6.4 mm)	0.0491 in.^{2} (31.7 mm^2)	40:1	50:1
	E	0.5	0.5	0.2500 (6.4 mm)	0.0491 in.^{2} (31.7 mm^2)	40:1	50:1
1/4 in. (6.4 mm), 1/2 in. (12.7 mm), 3/4 in. (19.1 mm) and 1 in. (25.4 mm)	F	0.32	0.32	0.1560 (3.9 mm)	0.0191 in.^{2} (12.3 mm^2)	30:1	40:1
	G	0.2	0.2	0.1560 (3.9 mm)	0.0191 in.^{2} (12.3 mm^2)	30:1	40:1
	H	0.13	0.13	0.1560 (3.9 mm)	0.0191 in.^{2} (12.3 mm^2)	30:1	40:1
	I	0.08	0.08	0.1560 (3.9 mm)	0.0191 in.^{2} (12.3 mm^2)	30:1	40:1
	J	0.05	0.05	0.1560 (3.9 mm)	0.0191 in.^{2} (12.3 mm^2)	30:1	40:1
	K	0.03	4.8E-02	0.0860 (2.2 mm)	0.0058 in.^{2} (3.7 mm^2)	25:1	—
	L	0.02	3.4E-02	0.0860 (2.2 mm)	0.0058 in.^{2} (3.7 mm^2)	25:1	—
	M	0.01	1.6E-02	0.0860 (2.2 mm)	0.0058 in.^{2} (3.7 mm^2)	25:1	—
	N	0.006	1.0E-02	0.0860 (2.2 mm)	0.0058 in.^{2} (3.7 mm^2)	25:1	—
	O	0.003	5.3E-03	0.0860 (2.2 mm)	0.0058 in.^{2} (3.7 mm^2)	25:1	—
1/4 in. (6.4 mm) and 1/2 in. (12.7 mm)	P1	0.002	3.6E-03	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P2	0.0013	2.5E-03	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P3	0.001	2.0E-03	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P4	0.0006	1.4E-03	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P5	0.0004	1.0E-03	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P6	0.00027	8.3E-04	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P7	0.00018	6.8E-04	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P8	0.00012	5.6E-04	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
	P9	0.00008	4.6E-04	0.0625 (1.6 mm)	0.0031 in.^{2} (2.0 mm^2)	15:1	—
1/4 in. (6.4 mm)	P10	0.00005	1.9E-04	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P11	0.000036	1.6E-04	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P12	0.000024	1.3E-04	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P13	0.000016	1.1E-04	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P14	0.00001	8.4E-05	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P15	0.000006	6.6E-05	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P16	0.000004	5.3E-05	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P17	0.0000027	4.4E-05	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—
	P18	0.0000018	3.6E-05	0.0420 (1.1 mm)	0.0014 in.^{2} (0.9 mm^2)	15:1	—

11 Appendix D: Manufacturer Provided Actuator Product Data Sheet [3]

RCV
Research Control® | ReCo® Valves

Actuator

Type 759

DESCRIPTION

The Type 759 actuator with integral, top-mounted positioner is a pneumatically operated, spring opposed diaphragm actuator designed specifically to fit the Research Control Valve body-bonnet assembly. The unit is available in two sizes: one for the 1/4 in. (6 mm) valve and another larger version for the 1/2…1 in. (12…25 mm) valves. The unit, when equipped with the model TLDA positioner, functions as an air-to-close actuator extending the stem and closing the valve on an increasing instrument signal. The unit is designed to retract the stem, opening the valve, on a decreasing or loss of instrument signal. A force-balance system is incorporated using the full force of the supply air to position the stem precisely and with a high degree of repeatability. This type actuator should be used when the application calls for high positioning accuracy or when greater force is required over the standard actuator such as in the case of high shutoff pressures or excess packing friction.

FUNCTION

The Type 759 actuator normally operates in response to a 3…15 psi (0.2…1.0 bar) change in instrument signal, or a 12 psi (0.8 bar) range. The span, or range, of instrument signal is determined by the feedback range spring mounted directly under the positioner. The feedback range spring is responsible for sensing the position of the main diaphragm as the instrument signal changes. The position is then transmitted through the spring, directly to the positioner diaphragm assembly. The valve spring, housed inside the casting just above the yoke area, provides the upward thrust necessary to open the valve on a decreasing signal. Although few applications require additional spring forces over the standard spring and loading, additional supply pressure can occasionally be required to offset high forces or excess packing friction within the valve.

OPERATION

The actual operation of the unit is simple. Two air lines are required: one to provide the instrument signal and one to provide supply air. The amount of supply air required is determined by the amount of thrust necessary to overcome forces generated within the valve. The standard minimum supply pressure is 22 psig (1 bar) of clean, filtered, dry air.

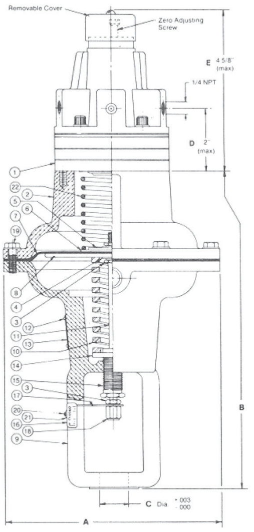
The two air lines should be connected to the ports marked *Supply* and *Inst* on the positioner. The unmarked port between the supply and instrument port is provided with a blind pipe plug. Since this port is an integral part of the piping of air from the positioner to the main diaphragm, it can also be plugged with a gauge, which will indicate the actual output of the positioner to the main diaphragm. Upon an increase in instrument signal, the position of the pilot within the positioner is shifted up, causing the supply air to be directed through the positioner to the top of the main valve diaphragm cavity. As the main diaphragm travels downward, the compression on the feedback range spring decreases. The decreased force of the range spring is transmitted to the diaphragm assembly in the positioner. The downward shift in the positioner diaphragm assembly causes the pilot to re-position and assume a balanced state. The entire function creates a complete feedback loop within the unit, causing the valve to position accurately and with a high degree of repeatability.

NOTE: The positioner, when in operation, will constantly bleed unused supply air.

Badger Meter

RCV-DS-00268-EN-05 (November 2020)

Product Data Sheet



DESCRIPTION OF ITEMS

Item	Description	Material	Material Size 1/4 in. (6.4 mm)	Material Size 1/2 in. (12.7 mm)
1	Positioner	Aluminum	—	—
2	Positioner case	Aluminum	—	—
3	Stem nut	300 stainless steel	1/4 in. (6.4 mm) hx	3/8 in. (9.5 mm) hx
4	Washer	Steel-Zn/Pl	—	—
5	Spring loc. plate	Aluminum	—	—
6	Spring loc. plate	Aluminum	—	—
7	Diaphragm	Buna or Nylon	—	—
8	Diaphragm plate	Steel-Zn/Pl	—	—
9	Spring case & yoke	Aluminum	—	—
10	Spring	Steel	—	—
11	Stem	316 stainless steel	1/8 in. (3.2 mm) dia	3/16 in. (4.8 mm) dia
12	Drive screw (2 ea.)	300 stainless steel	—	—
13	Nameplate	Stainless steel*	—	—
14	Spring seat	Aluminum	—	—
15	Spring adjuster	300 stainless steel	—	—
16	Travel scale	Stainless steel*	—	—
17	Travel pointer	Stainless steel	—	—
18	Stem connector	Stainless steel	—	—
19	Rim screws (6 ea)	300 stainless steel*	5/16 in. (7.9 mm) hx	3/8 in. (9.5 mm) hx
20	Screw	Stainless steel*	—	—
21	Washer	Stainless steel	—	—
22	Range spring	Steel	—	—

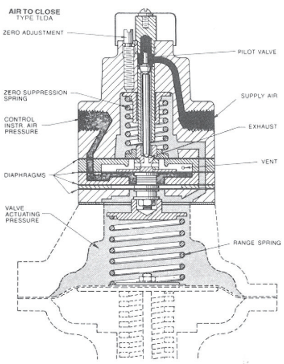
DIMENSIONS

Dimensions	Actuator Size 1/4 in. (6.4 mm)	Actuator Size 1/2 in. (12.7 mm)
A	5.12 in. (103.0 mm)	6.43 in. (163.3 mm)
B	7.93 in. (201.4 mm)	9.40 in. (238.8 mm)
C	0.625 in. (15.9 mm)	0.875 in. (22.2 mm)
D	2 in. (50.8 mm)	2 in. (50.8 mm)
E	4.63 in. (117.6 mm)	4.63 in. (117.6 mm)
Stroke	0.437 in. (11.1 mm)	0.562 in. (14.3 mm)

SPECIFICATIONS

Weight w/ Positioner	1/4 in. (6.4 mm)	Approx. 6 lbs (2.7 kg)
	1/2 in. (12.7 mm)	Approx. 7 lbs (3.2 kg)
Pressure Rating	Max. operating	60 psig (4.1 bar)
	Max. overload	100 psig (6.9 bar)
Temp. Range*	–20…160° F (–28.9…71.1° C)	
Effective Diaphragm Area	1/4 in. (6.4 mm)	7.3 in.^{2} (4709.7 mm^2)
	1/2 in. (12.7 mm)	11.25 in.^{2} (7258.1 mm^2)
Positioner Data	Air consumption*	0.60 scfm balanced
		0.22 scfm unbalanced
	Response level	The output sensitive to changes in control-air pressure as small as 0.1% of full range.

* At 25 psig (1.7 bar)



Zero Adjustment

The point at which the valve closes can be adjusted with the zero adjusting screw located under the protective cap on top of the positioner. The closing point can be adjusted to begin at any point between 12…16 psi (0.8…1.1 bar) and will still allow full stroke of the valve with a 12 psi (0.8 bar) change in signal when using a 12 pound range spring.

Force Spring Adjustment

The valve spring under the diaphragm plate is normally preadjusted at the factory to allow the valve to attain full travel when the instrument signal is at 15 psi (1.0 bar). Only when high packing hysteresis is encountered or when using a bellows sealed bonnet will additional forces need to be adjusted into the spring. If it becomes necessary, turning the spring adjuster (item 15) clockwise will increase the tension on the spring. If the adjuster is turned more than one complete turn, additional supply air may be required.

Supply Air Requirements

The standard supply pressure of 22 psig (1.5 bar) is sufficient to handle most applications. This amount of supply pressure required can be calculated prior to installation using the following procedure:

1. Multiply the maximum shutoff pressure by the seat orifice area.
2. Multiply the trim stem or bellows, if used, by the maximum downstream pressure.
3. Divide whichever is greater by the effective area of the actuator. This number is the amount of supply air in psi that is required over and above the *Inst.* signal.

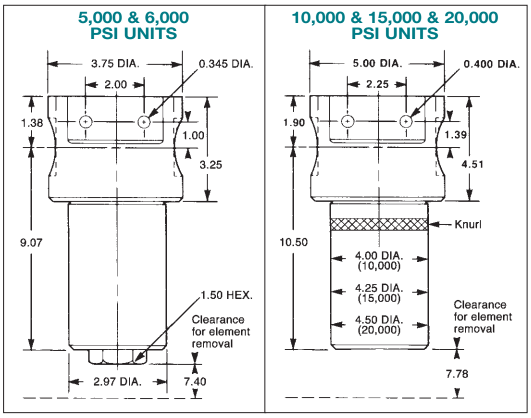
Example: *Inst.* signal is 3…15 pounds
Calculated additional supply is 8 psi (0.5 bar)
8 + 15 = 23 psi

NOTE: Do not exceed 25 psi (1.7 bar) without consulting the factory.

NOTE: Do not mount upside down for outdoor use, as water can enter the spring cavity via the stem and may freeze in colder climates.

12 Appendix E: Manufacturer Provided Tee-Type Filter Specification Sheet [4]

586 SIZE 24 GPM / 1200 SCFM



SPECIFICATIONS

Rated Flow @ 10 PSID, clean (max.):
- 24 GPM (w/100 SSU oil)
- 1200 SCFM (@ 3,000 PSI, GN_2)

Housing Material:
- 5,000 PSI Units:
  - 7075T6 Aluminum
- 6,000 PSI Units:
  - 303 & 316 Stainless Steel
- 10,000 PSI Units: 17-4 PH, 316LSS
- 15,000 PSI Units: 17-4 PH, 316LSS
- 20,000 PSI Units: 17-4 PH

Pressure Ratings:
- 5,000 PSI Units:
  - 5,000 PSI Operating
  - 7,500 PSI Proof
  - 20,000 PSI Burst
- 6,000 PSI Units:
  - 6,000 PSI Operating
  - 9,000 PSI Proof
  - 24,000 PSI Burst
- 10,000 PSI Units:
  - 10,000 PSI Operating
  - 15,000 PSI Proof
  - 40,000 PSI Burst
- 15,000 PSI Units:
  - 15,000 PSI Operating
  - 22,500 PSI Proof
  - 60,000 PSI Burst

Pressure Ratings (continued):
- 20,000 PSI Units:
  - 20,000 PSI Operating
  - 30,000 PSI Proof
  - 80,000 PSI Burst

O-Ring Temperature Range:
- Buna-N: -40°F to +250°F
- Viton: -20°F to +350°F
- Ethylene Propylene: -65°F to +300°F
- Teflon*: -320°F to +400°F
- Kalrez*: -40°F to +600°F

Element Temperature Range:
- Cellulose: -65°F to +275°F
- Glass Fiber: -70°F to 350°F
- 304 Stainless: -425°F to 1,000°F

Options:
- Relief Valve Setting: 50 PSID
- Visual Indicator Setting: 40 PSID
- Electrical Indicator Setting: 40 PSID
- Electrical Indicator Current Rating:
  - 0.5 Amps Resistive

Total Assembly Weight:
- Aluminum 6.0 Lbs.
- Stainless Steel: 15 Lbs.
- 10K, 15K, & 20K Stainless: 45 Lbs.

*T.M. DuPont Corp.

HOW-TO-ORDER

Pressure	
45	5000 psi
45	6000 psi
147	10000 psi
347	15000 psi
547	20000 psi

Port Size, Type	
37	1" NPT
47	1/2" SAE (–8)
76	1" SAE (-16)
86	3/4" FPT
90	1/2" FPT
92	1/4" FPT
96	3/4" SAE (–12)
250	1/4" Medium Pressure*
375	3/8" Medium Pressure*
562	9/16" Medium Pressure*
750	3/4" Medium Pressure*
43S	1/4" SAE (–4)
63S	3/8" SAE (–6)

*10K, 15 & 20K Only

Note: SAE port not recommended over 6000 psi.

Socket weld ports available on special order.

Housng Material	
A	Aluminum**
G	303 Stainless
T	316 Stainless*

** 5K Only

* 6K, 10K, 15K

Element Code	
A	Celulose
D	Dual*
F	Glass Fiber
G	Stainless Mesh
P	316 Sintered

Micron Rating						
Code	Nom.	Abs.	G	A	F	P
.5	.2	.5				
1	.5	1				
2X	2	10	•			
B1	—	1			•	C
B3	—	3			•	A
3	.1	3				L
03	3	10		•		L
05	5	18	•			
B5	—	5			•	F
7		7				A
10	10	25	•	•		C
B10	—	10			•	T
20	20	40	•			O
25	25	40		•		R
B25	—	25			•	Y
40	40	75	•			
100	100	200	•			
200	200	300	•			

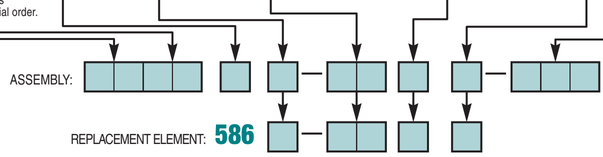
Collapse Rating	
P	150# Cellulose
R	300# Cellulose
A	300# Glass Fiber
F	2000# PSS
C	3250# Glass Fiber
D	4500# Stainless Mesh

O-Ring Material	
L	Buna-N
N	Viton
E	Ethylene Propylene
M	Teflon™
K	90 Durometer Nitrile
H	Kalrez™

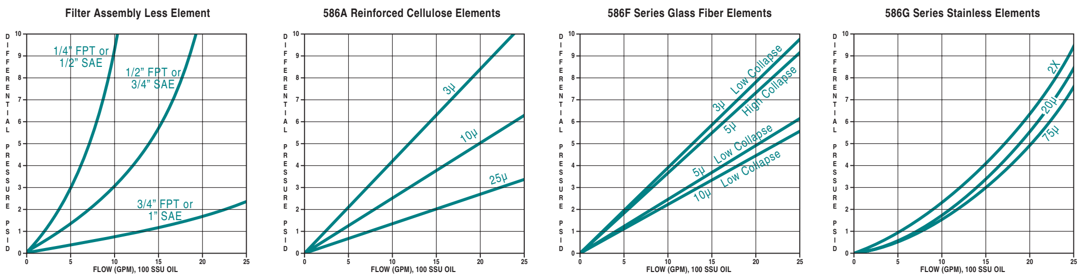
Teflon and Kalrez are registered trademarks of DuPont.

Optional Accessories	
DR-1	1/8" NPT Bowl Drain*
DR-2	1/4" NPT Bowl Drain*
DR-3	1/8" SAE Bowl Drain*
DR-4	1/8" SAE Bowl Drain*
DRCT4	1/4" MP Bowl Drain
DRCT6	3/8" MP Bowl Drain
EE	40 psid Elec. Switch*
EER	Switch + Valve*
R	50 psid Valve
S1	1/8" NPT DP Ports*
S2	1/4" NPT DP Ports*
S3	1/8" SAE DP Ports*
S4	1/4" SAE DP Ports*
SCT4	1/4" MP DP Ports
SCT6	3/8" MP DP Ports
V	40 psid Indicator*
VR	Indicator + Valve*

* Not available on 20K



FLOW DATA (PRESSURE DROP vs. FLOW)



NOTE: Add pressure drop of the housing to that of the element to obtain total initial clean pressure drop of the assembly. To determine pressure drop for a different viscosity and density fluid, use the following conversion factor:

$$\text{New } \Delta P = \Delta P \text{ @ 100 SSU} \times \frac{\text{new viscosity, SSU}}{\text{100 SSU}} \times \frac{\text{new spec. gravity}}{0.9}$$

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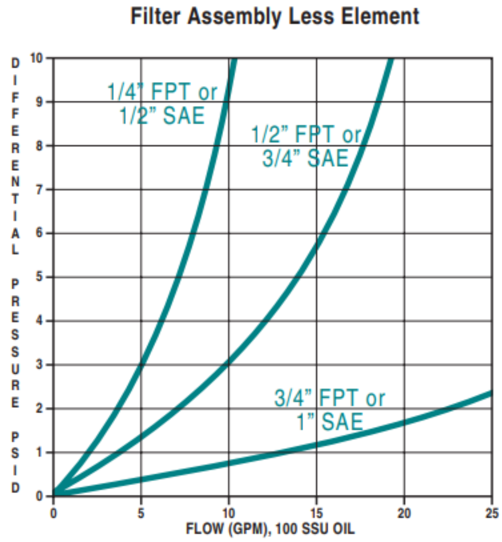

Figure 5: Pressure Drop Across Filter Housing. From [4]

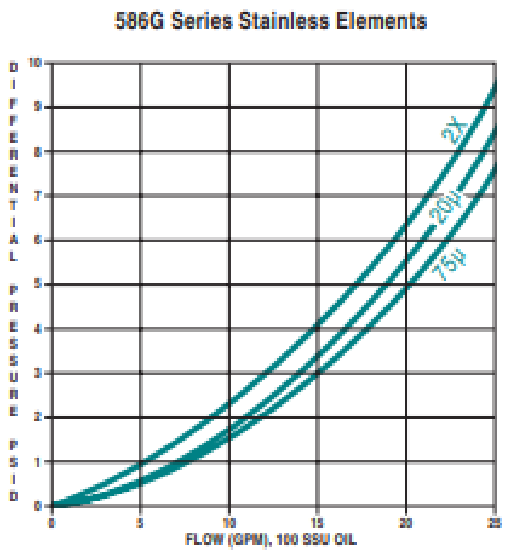

Figure 6: Pressure Drop Across Filter Element. From [4]