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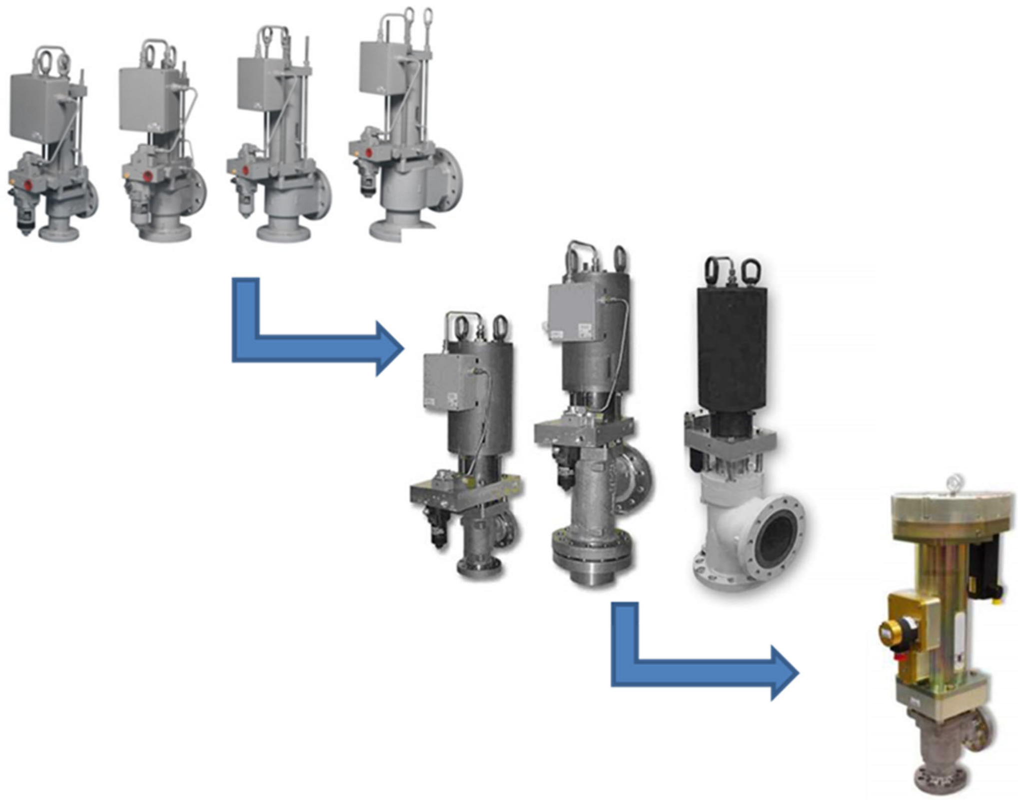

Woodward Application Manual
SonicFlo

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Illustrations and Tables

Chapter 1.
SonicFlo Valve Background

Objectives

This document provides a summary of Woodward's evolution in high recovery valve design with an overview of the product families. The fundamentals of sonic flow in nozzles and valves are detailed, with an emphasis on the physical, rather than the mathematical, point of view.

Background

Definitions

Critical Pressure Ratio (Choke Point) –
: The pressure ratio (Pb/P0 or P2/P1) at which the back pressure (Pb or P2) is equal to the critical pressure P* (the pressure required to increase the fluid velocity to the speed of sound at the throat or vena contracta). This pressure ratio produces the maximum pressure recovery while still maintaining sonic flow at the throat.
Note: Some OEMs define the choke point as a P1/P2 ratio (P1/P2 of 1.11 = P2/P1 of 0.9).

Throat –
: The vena contracta of the flow, where the cross sectional area of the flow is the smallest.

Standard Valve –
: A valve with un-choked flow, which is modeled as a standard nozzle orifice shown in Figure 1.

Standard Recovery Valve –
: A valve with choked flow and a recovery of 1.25 (P1/P2).

High Recovery Valve –
: A valve with choked flow and a recovery of 1.08 (P1/P2) for some stroke positions.

Ultra-High Recovery Valve–
: A valve with choked flow and a recovery of 1.06 (P1/P2) for some stroke positions.

Stagnation Pressure –
: The sum of the static and dynamic pressures; it represents the pressure at a point where the fluid is brought to a complete stop isentropically.

Normal Shock –
: A shock wave that occurs in a plane normal to the direction of flow. The flow process through the shock is highly irreversible and cannot be approximated as isentropic.

Sonic or Choked Valve –
: A valve that is choked, where Ma=1 at the vena contracta.

Woodward Compressible Flow Equation (WCFE) –
: An equation used to predict the mass flow through a valve assuming the following: The gas is ideal with constant compressibility, the gas has constant specific heats, the flow is isentropic, and the flow is adiabatic. The WCFE is a two-part equation that switches when the critical pressure ratio is reached.

Inlet Plenum –
: The concentric volume around the metering plug.

Inlet Pipe –
: The flow path that feeds the inlet plenum.

Metering Area –
: The area between the metering plug and the seat.

Expansion Angle –
: The angle at which the diverging sleeve expands the fluid.

Expansion Rate –
: The rate at which the cross sectional flow area increases (%) through the diverging sleeve of a valve.

Flow Separation –
A phenomenon where a boundary layer adjacent to a surface is forced to leave, or separate from, the surface due to adverse pressure forces in the flow direction. Flow separation occurs in regions of high surface curvature.

CFD-
Computational Fluid Dynamics.

Center to Face Distance –
For flanged angle type valves (those in which the ends are at an angle of 90 deg to each other), the center to face dimension is the distance from the centerline of the inlet port to the extreme end face of the discharge flange, which is the gasket contact surface.

Variable Definitions

Pb	The back pressure is the pressure applied at the nozzle or valve discharge region.
P0	The stagnation pressure, which is usually the pressure applied at the inlet of the nozzle or valve orifice.
P1	The pressure measured upstream of the nozzle or valve. Woodward recommends that the measurement be taken at 2 pipe diameters upstream of the inlet flange.
P2	The pressure measured downstream of the valve. Woodward recommends that the measurement be taken at 6 pipe diameters downstream of the discharge flange.
Pi	The pressure at the inlet of the nozzle or valve orifice.
Pe	The pressure at the exit of the nozzle or valve orifice. Note: It is assumed that: Pb=P2=Pe and P0=P1=Pi
$\dot{m}$/Wg	The mass flow rate.
P*	The back pressure required to increase the fluid velocity to the speed of sound at the throat or vena contracta.
Q	Volumetric flow rate (SCFH)
T	Valve inlet gas temperature
Z	Gas compressibility factor
Cg	Valve gas capacity coefficient, a dimensionless flow number which is a measure of flow
Ag or A	Geometric metering area
K	Ratio of specific heats (Cp/Cv)
Cd	Gas valve discharge coefficient
SG	Specific gravity relative to air
A*	The flow area at the throat or vena contracta (metering area)

Sonic Flow Fundamentals

Sonic flow (or choked flow) is the point at which the throat area of a nozzle has reached the maximum mass flow throughput. The boundary of a sonic condition is based on the velocity of the fluid reaching or exceeding the local speed of sound (Mach>=1). When a flow stream is in a choked condition, pressure information from the downstream flow path cannot propagate beyond the sonic barrier to the upstream flow path, thus not influencing the P1 pressure or the effectiveness of the metering area. In the figures below, the standard nozzle orifice is defined as a converging nozzle, and the sonic nozzle orifice is defined as a converging-diverging nozzle.

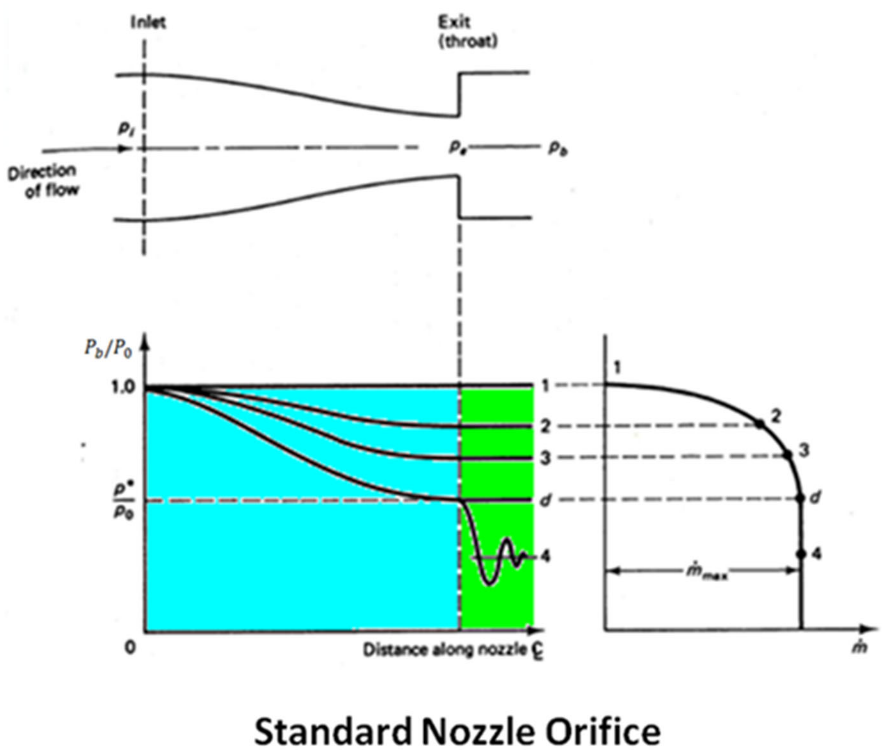


Figure 1-1. Standard Nozzle Orifice

Referring to the figure of the standard nozzle, we begin by reducing the back pressure Pb and observe the resulting effects on the pressure distribution along the length of the nozzle. When Pb=P0 (where P0=Pi=P1), there is no flow, and the pressure distribution is uniform. If Pb is equal to P2, this will cause an increase in mass flow and flow velocity, and a decrease in pressure along the nozzle. When Pb is reduced to a critical value of P* (the pressure required to increase the fluid velocity to the speed of sound at the throat) the mass flow reaches a maximum value, and the flow is said to be choked. This occurs around Pb/P0=0.528. The highest velocity to which a fluid can be accelerated in a converging nozzle is limited to the sonic velocity Ma=1, which occurs at the throat of the nozzle. Further reduction of the back pressure does not result in additional changes in the pressure distribution or anything else along the nozzle length. However, a shock may form downstream of the nozzle shown in the green shaded area of the picture above.

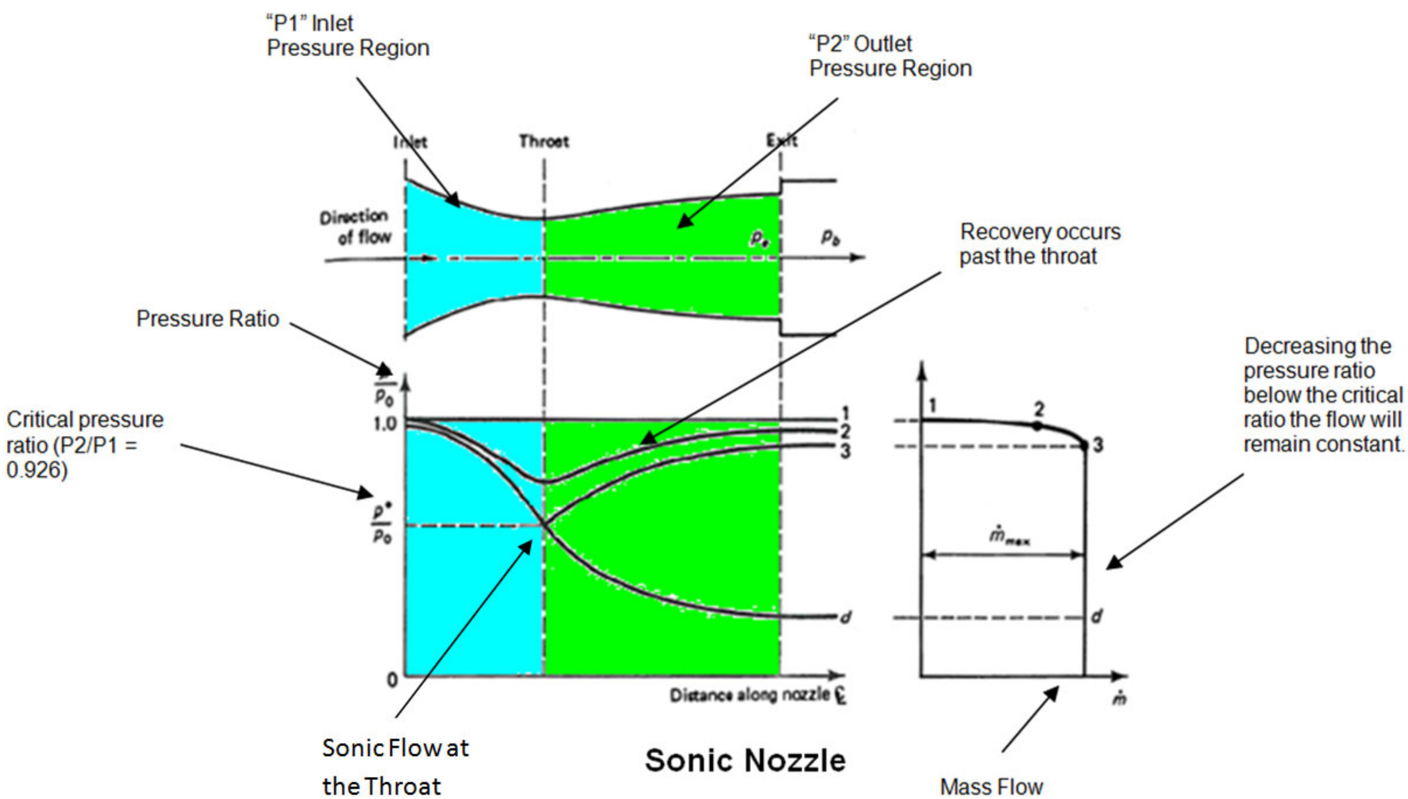


Figure 1-2. Sonic Nozzle

Consider the sonic nozzle shown above, the diverging section of the nozzle enables the fluid to accelerate to supersonic velocities. However, the state of the nozzle flow is determined by the overall pressure ratio Pb/P0, as will be explained.

As a fluid enters the nozzle with a low velocity at stagnation pressure P0, when Pb=P0 there is no flow through the nozzle. This is expected since flow is driven by the pressure difference between the nozzle inlet and exit. Now examine what happens as the back pressure is lowered:

When P0>Pb>P3 the flow remains subsonic throughout the nozzle, and the mass flow is less than that for choked flow. The fluid velocity increases in the first (converging) section and reaches a maximum at the throat (Ma<1). However, most of the gain in velocity is lost in the second (diverging) section of the nozzle, which acts as a diffuser. The pressure decreases in the converging section, reaches a minimum at the throat, and increases at the expense of velocity in the diverging section.

When Pb=P3 the throat pressure becomes P* and the fluid achieves sonic velocity at the throat. But the diverging section of the nozzle still acts as a diffuser, slowing the fluid to subsonic velocities. The mass flow rate that was increasing with decreasing Pb also reaches its maximum value. Recall that P* is the lowest pressure that can be obtained at the throat, and sonic velocity is the highest velocity that can be achieved at the throat. Thus, lowering Pb further has no influence on the fluid flow in the converging part of the nozzle or the mass flow rate through the nozzle. However, it does influence the character of the flow in the diverging section.

When Pb<P3, the fluid that achieved sonic velocity at the throat continues accelerating to supersonic velocities in the diverging section as the pressure decreases. This acceleration comes to a sudden stop, however, as a normal shock develops at a section between the throat and the exit plane, which causes a sudden increase in pressure. The fluid then continues to decelerate further in the remaining part of the diverging section of the nozzle and pressure increases. Flow through the shock is highly irreversible, and thus cannot be approximated as isentropic. The normal shock weakens and moves upstream towards the throat as Pb is increased/approaches P3.

The fundamental difference between the standard and sonic nozzles is the ability to achieve the maximum mass flow rate at higher pressure ratios (Pb/P0) for the sonic nozzle case, thus allowing for a lower, required supply pressure P0 for a given downstream pressure Pb (compare point #3 in the right-hand graph for both cases). This difference is due to the fact that the diverging section of the sonic nozzle causes the mass flow rate to sharply decrease with increasing pressure ratio (Pb/P0) forming a “cliff”, while in a standard nozzle orifice the flow rate gradually decreases.

Sonic Valves, the Isentropic Flow Equation, Cg, and Effective Metering Area

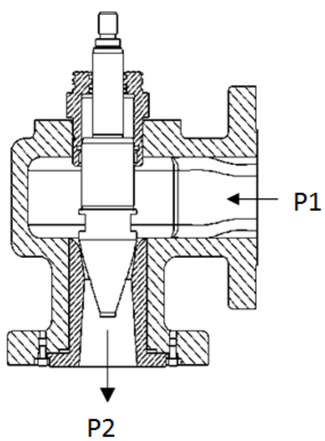


Figure 1-3. Representative Sonic Valve

Sonic Valve Orifice Characteristic	**CPR Impact** (Critical Pressure Ratio)
Right angle flow required for actuation access	Bend in flow causes asymmetric flow at the vena contracta, and flow separation
Variable throat area to provide metering function	Expansion rate cannot be optimized for a single throat area
Constrained Cg verses stroke characteristic	Cg curve is generally not negotiable to optimize recovery
Scalability of stroke length is limited by valve body and actuation package size limits (particularly for 8” and larger valves)	Length available to regulate expansion is limited
Valve body dimensions are somewhat limited by industry standards	Entry conditioning and expansion rate control is limited

The Isentropic Flow Equation

To predict the mass flow through a valve, the Woodward compressible flow equation (WCFE) is used. The WCFE is a two-part equation that switches when the calculated sonic or “critical” pressure ratio is reached denoted by R1. One can see that the downstream pressure (P2) is no longer a constituent of the equation when the actual pressure ratio is less than the R1 value.

The WCFE has four key assumptions about gas flow: the gas is ideal with constant compressibility, the gas has constant specific heats, the flow is isentropic, and the flow is adiabatic.

Isentropic Gas Valve Mass Flow Equation for Standard Valves:

$$Wg = K_1.P_1.(A_g.C_d).\sqrt{\left(\frac{k.SG}{(k-1).T*Z}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{k}} - \left(\frac{P_2}{P_1}\right)^{\frac{1+k}{k}}\right]}$$

$$Wg = K_1.P_1.(A_g.C_d).\sqrt{\left(\frac{k.SG}{(k-1).T*Z}\right)\left[(R1)^{\frac{2}{k}} - (R1)^{\frac{1+k}{k}}\right]}$$

$$R1 = \left(\frac{2}{k+1}\right)^{\left(\frac{k}{k-1}\right)}$$

Where:
Wg = Gas Flow (lbsm/h)
P1 = Inlet Gas Pressure (psia)
P2 = Discharge Gas Pressure (psia)
T = Inlet Gas Temperature (°R)
K = Ratio of Specific Heats
Cd = Gas Valve Discharge Coefficient
Z = Gas Compressibility Factor
Ag = Geometric Port Area
K1 = 3955.289 (Constant)

Sonic valves are designed to stay choked throughout its operating range; therefore, only the sonic ACd calculation applies for all pressure ratio conditions.

R1 (air) = .528
R1 (Natural Gas) = .546

$$Wg = K_1.P_1.(A_g.C_d).\sqrt{\left(\frac{k.SG}{(k-1).T*Z}\right)\left[(R1)^{\frac{2}{k}} - (R1)^{\frac{1+k}{k}}\right]}$$

$$R1 = \left(\frac{2}{k+1}\right)^{\left(\frac{k}{k-1}\right)}$$

Cg (Flow Number)

The flow rating of a Sonic Valve can be determined by flowing air through the valve at pressure ratios that ensure choked flow. At various valve positions, the flow is used to calculate a dimensionless flow number Cg. The equation for Cg is defined below:

Q	Volumetric Flow Rate (SCFH)
P1	Upstream Static Pressure (PSIA)
T	Valve Inlet Gas Temperature (Degrees R)
Z	Gas Compressibility Factor (Z = 1 assumed)
Cg	Valve Gas Capacity Coefficient

$$Cg = \sqrt{\frac{(T \cdot Z)}{520}}.\frac{Q}{P1}$$

Cg is another scale for flow measurement. The relationship to ACd can be approximated by the equation:

Cg = 1098 * ACd

Effective Metering Area

The Cd (discharge coefficient ranging from 0 to 1) is a measure of inefficiency in the flow due to friction and other flow effects. The Cd proportionally decreases the actual flow metering area known as geometric area and the result is the effective metering area (ACd).

Sonic Valves Compared to Standard (un-choked) Valves:

The below figure shows a larger metering area (ACd) is required for standard valves (un-choked) for the same maximum mass flow rate at higher pressure ratios (approximately 0.9 below). This is because the increase in back pressure (P2) negatively affects the ability to meet the maximum flow rate in the standard valve. For a given valve ACd size (0.67 in^2 below), the Sonic Valve (magenta trace) will flow more than the standard valve (dark blue trace) for pressure ratios greater than the critical pressure ratio for the standard valve (approximately 0.546 for natural gas).

A larger metering area is required for subsonic valves used at low pressure drops (high pressure ratios P2/P1). For Sonic Valves, a smaller metering area is required for use at low pressure drops.

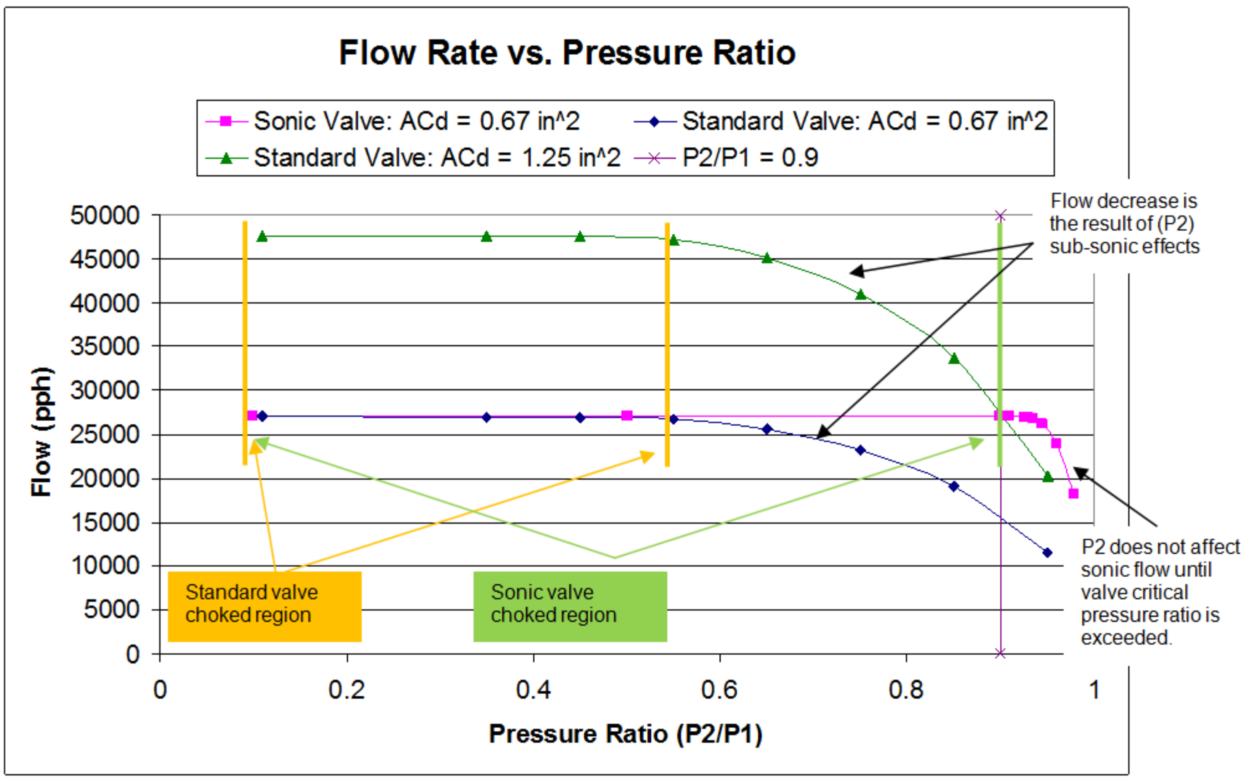


Figure 1-4. Benefits of Sonic Valves

Advantages of Sonic Valves

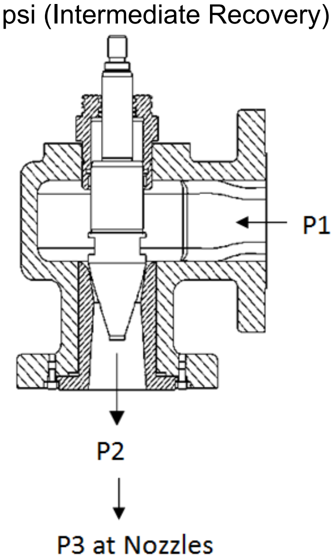
High recovery valves used in flow measurement fuel control systems have several advantages over valves that operate in sub sonic flow modes:

- Sonic flow enables exceptional flow rate measurement accuracy- Measurement of valve discharge pressure to determine flow is not necessary (refer to the subsonic version of the WCFE). This improves the system accuracy, as the accuracy of valve discharge pressure measurement is no longer an issue.
- Sonic flow simplifies computations
- Sonic flow reduces instrumentation requirements to determine flow rate
- Sonic flow decouples P1 and mass flow from P2 changes
- Sonic flow allows for a smaller valve (as described in section 2.5)
- High recovery (1.08) Sonic Valves allow for a lower pressure drop than historical Sonic Valves, eliminating or reducing the need for expensive compressors which provides significant savings to end users
- High recovery valves give a competitive advantage for GE new unit bids

Benefits of High Recovery Example

System Cost Example:
Given:
- P3 needed at nozzles = 300 psi
- (P2-P3) is fixed at 40 psi for a given flow condition

- If the valve choke point is P1/P2 = 1.25, then P1 = (1.25 * 340) = 425 psi (Standard Recovery)
- If the valve choke point is P1/P2 = 1.15, then P1 = (1.15 * 340) = 391 psi (Intermediate Recovery)
- If the valve choke point is P1/P2 = 1.08, then P1 = (1.08 * 340) = 367.2 psi (High Recovery)



Therefore:
For a high recovery valve, if the gas line pressure to the valves is sufficient to provide 370 psi, then no compression stage is needed to boost the inlet pressure (significant savings).

In other words, a higher recovery means that the gas fuel control valve will remain sonic at higher pressure ratios (P2/P1) thereby not requiring the need for a gas compressor. The lower pressure drop required by a valve with higher recovery is especially important in new turbines applications where higher P3 pressure requirements at the nozzles is raising the supply pressure requirements above what is commonly available from line pressure. This forces GE to add a compressor where other turbine OEM's may not require a compressor.

Measuring Recovery

To measure recovery, first the valve is flow tested with a pressure ratio of 0.5 P2/P1. Then the valve is tested at increasing P2 values to find the P2/P1 ratio at which the sonic ACd value decreases by 2% of the maximum value at a given valve position. This is called the recovery ratio (or choke point) and is the pressure ratio at which the valve is operated because it will give maximum recovery.

To measure recovery for multiple valve positions, the following procedure should be used:

At each of 10-15 stroke positions:

- Measure flow and calculate Cg at P2/P1 = 0.5
- Measure flow and calculate Cg at increasing P2/P1 points
- Plot P2/P1 versus normalized Cg
- Choke point is defined at the point where the curve crosses the 0.98 Cg line (2% drop in Cg from Cg at P2/P1 = 0.5)

The plot below shows this procedure, where the orange line in Figure 1-5 is the 0.98 normalized Cg line (2% drop in Cg). Notice that the plot is zoomed in on the upper end of the choke curves to highlight the choke point.

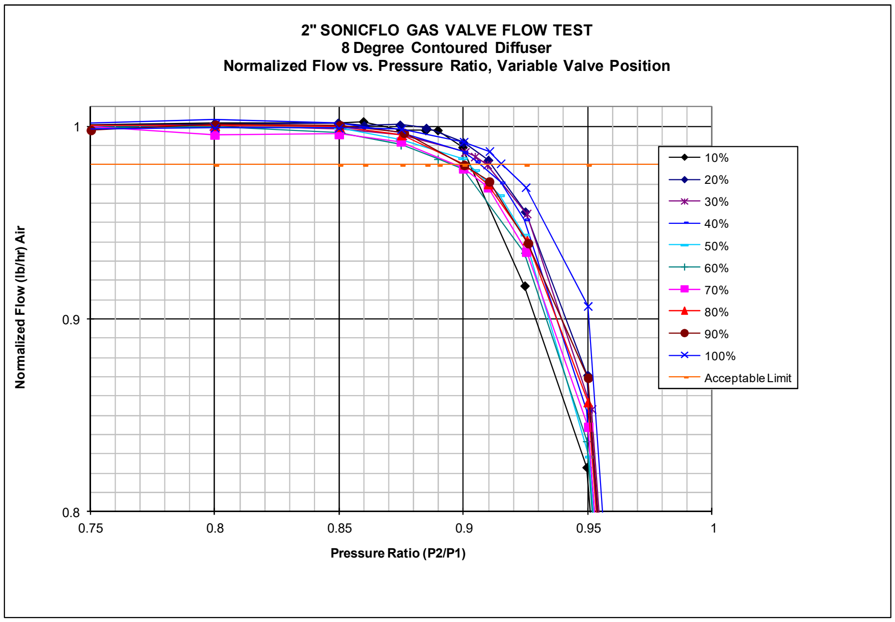


Figure 1-5. Pressure Recovery

Plotting P2/P1 vs. normalized Cg is the most direct method of determining the choke point. The 2% drop standard is an accurate and consistent method that ensures the valve is at the transition zone between choked and un choked flow.

When flowing a Sonic Valve beyond the choke point (> 0.926 P2/P1 for the high recovery versions), the above curve shows the "cliff" that can occur as Cg drops off quickly. Essentially, the valve starts to behave like a standard (un-choked) valve and very quickly loses its max effective area (ACd) and mass flow. At high pressure ratios (P2/P1) it would be very difficult to control the flow rate with any kind of reasonable accuracy.

Recovery Capability Example

Below is a sample graph showing the choke point characteristics of a 3", 2000 Cg Sonic Valve. The data is shown in a slightly different way than previous graphs by taking the choke point for each valve position and plotting only the one point per valve position. Previous graphs showed multiple test points for each valve position. This is an easier to read data set for showing the capability of the product over a set of several valves.

The legend on the graph provides the necessary details, however, it is important to highlight the green line. The green line indicates the calculated 3-sigma level for the data set. Woodward 100% tests each valve prior to shipment to verify the product meets or exceeds the stated performance. This data is continually collected and evaluated to maintain the Woodward quality and performance.

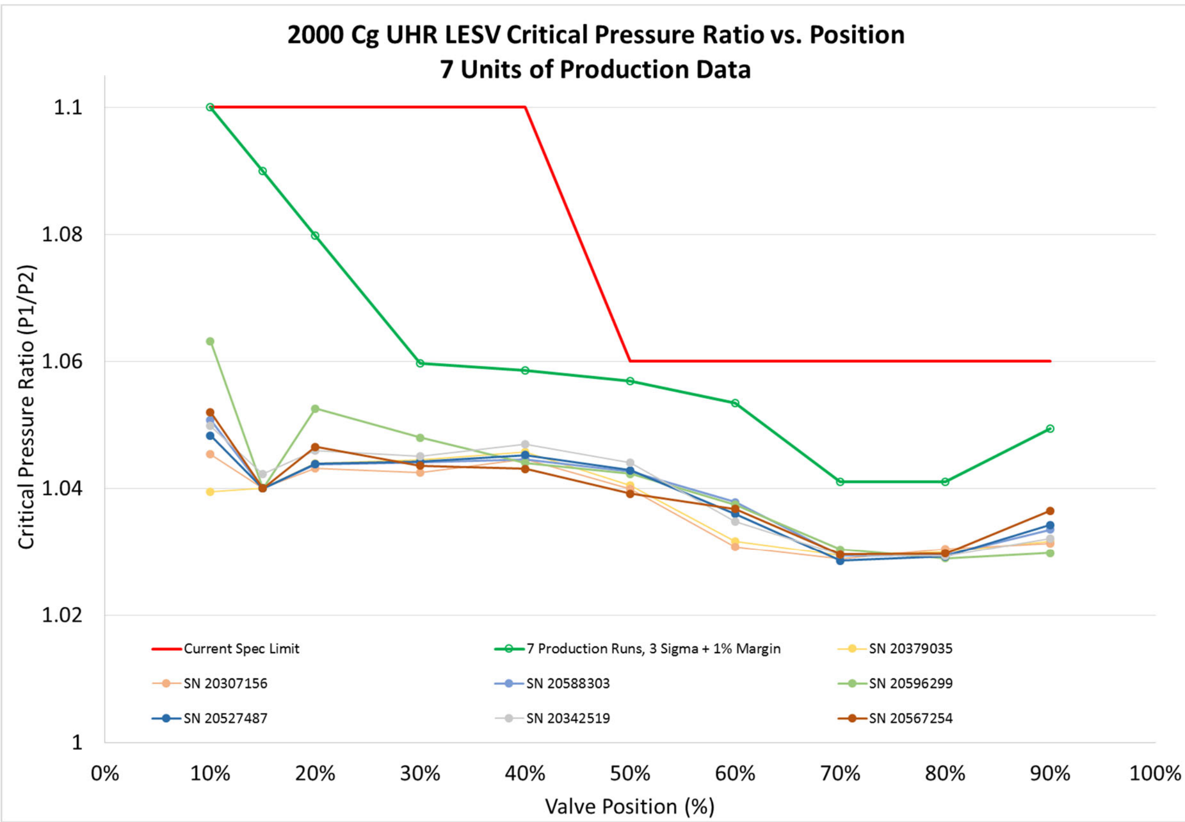
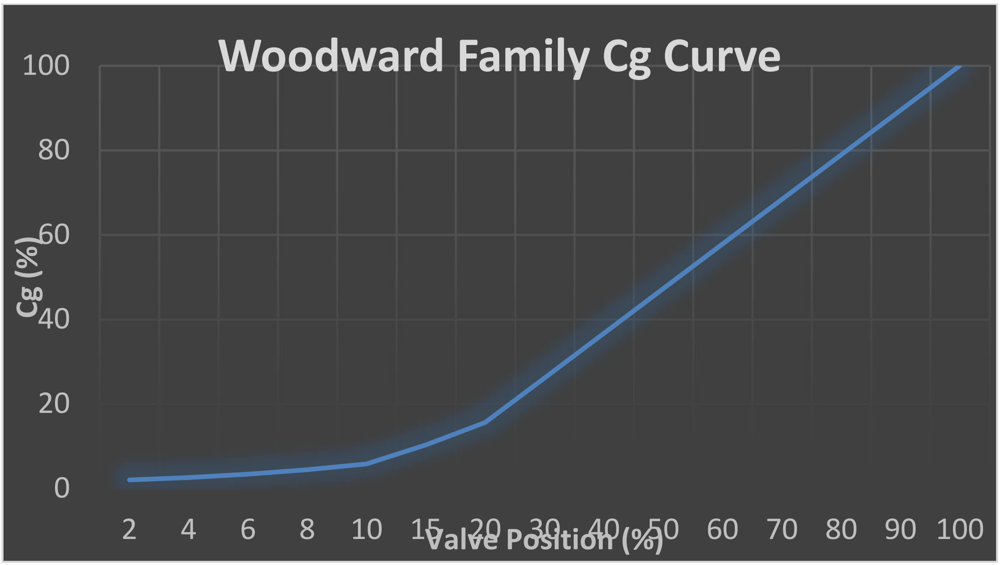


Figure 1-6. 3" Valve Performance

Chapter 2.
SonicFlo Valve Flow Characteristics

Flow Curve

The following Figure 2-1 provides the nominal Cg curve of the Woodward SonicFlo valves. The curve combines the low-end controllability of an equal percentage curve and the linear curve at larger valve openings to give optimal flow gain. Figure 2-2 is a tabular list of all the Cg curves available by valve size. Each column of values are based on the same valve positions shown in Figure 2-1.



Percent	Nominal
Open	Cg
2	2
4	2.54
6	3.34
8	4.41
10	5.75
15	10.28
20	15.56
30	26.11
40	36.67
50	47.22
60	57.78
70	68.33
80	78.89
90	89.44
100	100

Figure 2-1. Family Cg Curve

2 Inch	2 Inch	2 Inch	2 Inch	3 Inch	3 Inch	3 Inch	3 Inch	4 Inch	4 Inch	4 Inch	6 Inch	6 Inch	6 Inch	6 Inch	8 Inch	8 Inch	8 Inch	8 Inch
Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	Nominal
Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg
6.0	12.0	18.0	24.0	30.0	40.0	50.0	58.0	66.0	73.1	82.0	90.0	115.5	132.0	150.0	180.0	260.0	300.0	340.0
7.6	15.2	22.9	30.5	38.1	50.8	63.5	73.7	83.8	92.8	104.1	114.3	146.7	167.6	190.5	228.6	330.2	381.0	431.8
10.0	20.0	30.1	40.1	50.1	66.8	83.5	96.9	110.2	122.1	136.9	150.3	192.9	220.4	250.5	300.6	434.2	501.0	567.8
13.2	26.5	39.7	52.9	66.2	88.2	110.3	127.9	145.5	161.2	180.8	198.5	254.7	291.1	330.8	396.9	573.3	661.5	749.7
17.3	34.5	51.8	69.0	86.3	115.0	143.8	166.8	189.8	210.2	235.8	258.8	332.1	379.5	431.3	517.5	747.5	862.5	977.5
30.8	61.7	92.5	123.4	154.2	205.6	257.0	298.1	339.2	375.7	421.5	462.6	593.7	678.5	771.0	925.2	1336.4	1542.0	1747.6
46.7	93.4	140.0	186.7	233.4	311.2	389.0	451.2	513.5	568.7	638.0	700.2	898.6	1027.0	1167.0	1400.4	2022.8	2334.0	2645.2
78.3	156.7	235.0	313.3	391.7	522.2	652.8	757.2	861.6	954.3	1070.5	1175.0	1507.9	1723.3	1958.3	2349.9	3394.3	3916.5	4438.7
110.0	220.0	330.0	440.0	550.1	733.4	916.8	1063.4	1210.1	1340.3	1503.5	1650.2	2117.7	2420.2	2750.3	3300.3	4767.1	5500.5	6233.9
141.7	283.3	425.0	566.6	708.3	944.4	1180.5	1369.4	1558.3	1725.9	1936.0	2124.9	2727.0	3116.5	3541.5	4249.8	6138.6	7083.0	8027.4
173.3	346.7	520.0	693.4	866.7	1155.6	1444.5	1675.6	1906.7	2111.9	2369.0	2600.1	3336.8	3813.5	4333.5	5200.2	7511.4	8667.0	9822.6
205.0	410.0	615.0	820.0	1025.0	1366.6	1708.3	1981.6	2254.9	2497.5	2801.5	3074.9	3946.1	4509.8	5124.8	6149.7	8882.9	10249.5	11616.1
236.7	473.3	710.0	946.7	1183.4	1577.8	1972.3	2287.8	2603.4	2883.4	3234.5	3550.1	4555.9	5206.7	5916.8	7100.1	10255.7	11833.5	13411.3
268.3	536.6	805.0	1073.3	1341.6	1788.8	2236.0	2593.8	2951.5	3269.0	3667.0	4024.8	5165.2	5903.0	6708.0	8049.6	11627.2	13416.0	15204.8
300.0	600.0	900.0	1200.0	1500.0	2000.0	2500.0	2900.0	3300.0	3655.0	4100.0	4500.0	5775.0	6600.0	7500.0	9000.0	13000.0	15000.0	17000.0

Figure 2-2. Nominal Cg Curves based on Valve Sizes

Flow Error

Figure 2-3 provides the standard flow accuracy of the valves relative to valve position. Higher levels of accuracy are available for consideration should the application require.

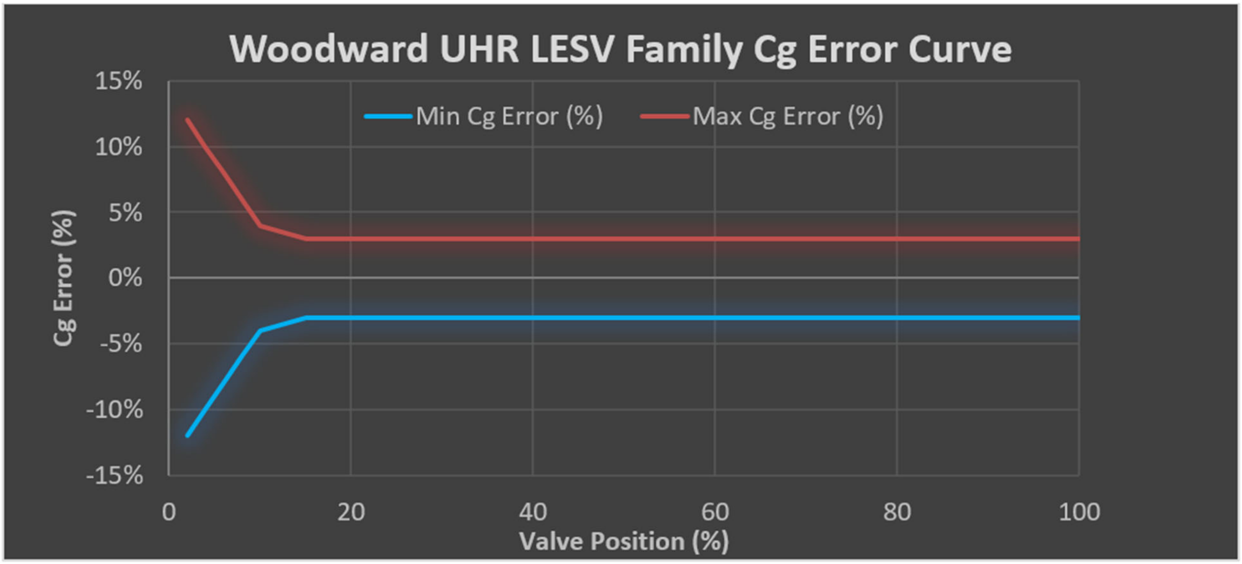


Figure 2-3. Standard Cg Accuracy

Chapter 3. Hydraulic SonicFlo Valves

Introduction

This section describes Woodward's Hydraulic SonicFlo Fuel Control Valves, which are used to control the flow of gas fuel to the combustion system of an industrial or utility gas turbine. The key attributes of the SonicFlo are safe turbine fuel shutoff (fail closed design), repeatable dynamic response, and reliable valve positioning.

Note: This manual is for reference only. Always follow all instructions provided in SonicFlo Installation and Operation manuals.

The SonicFlo valve controls the flow of gas fuel to the combustion system of an industrial or utility gas turbine.

Two unique designs are available depending on the requirements of the combustion system. The first is our standard recovery design, and the second is our high recovery design. Both designs yield a flow characteristic unaffected by discharge pressure at very low pressure ratios (P1/P2) [1.25 and 1.08]. Both designs integrate the valve and actuator into a compact assembly.

The integral actuator is a single-acting spring-loaded design for failsafe operation. The actuator includes an onboard hydraulic filter for last chance filtration of the fluid to ensure reliability of the servo valve and actuator. The servo valve is electrically redundant with triple coil design. Feedback for the actuator is provided by a dual coil, dual rod LVDT (linear variable differential transformer), or a triple coil, single rod LVDT, directly coupled to the hydraulic piston.

Figure 3-1 shows the two versions of hydraulic SonicFlo valves available with Standard Recovery on the left and High Recovery on the right. Detailed characteristics are shown in the following table.

Figure 3-1. Photos of SonicFlo Valves

Control Valve Functional Characteristics

Valve Type	Two way–right angle per ASME B16.34-1996
Type of Operation	Run—Valve Open Trip—Valve Closed
Fluid Ports	ASME B16.5-1996 Class 300 and Class 600 flanges Size 2, 3, 4, 6 inch (50, 75, 100, 150 mm)
Flowing Media	Natural gas
Valve Proof Pressure Level	per ANSI B16.34, ANSI B16.37/ISA S75.19
Minimum Valve Burst Pressure	2900 psig/19 996 kPa (based on 580 psig/4000 kPa max working pressure)
Gas Filtration	25 µm absolute at 75 beta requirement
Ambient Temperature	–20 to +180 °F (–29 to +82 °C)
Shut-off Classification	Class IV per ANSI B16.104/FCI 70-2 (0.01% of rated valve capacity at full travel measured with air at 50 psid/345 kPa)
External Leakage	None
Inter-seal Vent Leakage	50 cc/min maximum
Position Accuracy	±1% of full scale (Over ±25 °F/±14 °C deviation from calibration)
Position Repeatability	±0.5% of point over range of 10% to 100%
Hydraulic Fluid Type	Petroleum based hydraulic fluids
Hydraulic Supply Pressure	1200 to 1700 psig/8274 to 11 722 kPa
Hyd. Proof Test Fluid Pressure Level	2550 psig/17 582 kPa minimum per SAE J214
Hyd. Minimum Burst Fluid Pressure	4250 psig/29 304 kPa minimum per SAE J214
Hyd. Fluid Filtration Required	10–15 µm absolute
Trip Time	Less than 0.250 s
Slew Time	**Part Number** / **Slew Time** 9904-598/-599/-630/-631: 1 +/-0.150 s opening, 1.150 +/- 0.150s closing / 1 +/-0.150 s (opening & closing) All other part numbers: 0.1 to 0.8 s (opening & closing)
Design Availability Objective	Better than 99.5% over an 8760 hour period
Hydraulic Fluid Connections	Trip relay pressure—1.062-12 UNF straight thread port (–12) Supply pressure—0.750-14 UNF straight thread port (–8) Drain pressure—1.312-20 UNF straight thread port (–16)
Sound Level	<100 dB at max flow conditions
Vibration Test Level	0.5 gp 5–100 Hz sine wave Random 0.01500 gr²/Hz from 10 to 40 Hz ramping down to 0.00015 gr²/Hz at 500 Hz
Shock	Limited to 30 g by servo valve
Servo Input Current Rating	–7.2 to +8.8 mA (null bias 0.8 ± 0.32 mA)
Hydraulic Fluid Contamination Level	Per ISO 4406 code 18/16/13 max Code 16/14/11 preferred
Materials	Woodward certifies that our SonicFlo line of gas fuel control valves is designed and manufactured such that all wetted materials that experience a tensile stress are compliant with the thermo-mechanical requirements of NACE MR0175/ ISO15156 and MR0103.

	Standard Recovery Design	**High Recovery Design**
Trim Configuration	Linear	Modified Equal Percentage
Maximum Gas Pressure	3999 kPa (580 psig)	3999 kPa (580 psig)
Gas Temperature	–18 to +204 °C (0 to 400 °F)	SA216-WCB body: –18 to +204 °C (0 to 400 °F) SA351-CF8M body: –18 to +130 °C (0 to 266 °F)
Valve Port Sizes	See below	See below
Flow Characteristics	±3% Cg deviation of point from 10% to 100% stroke	±3% Cg deviation of point from 10% to 100% stroke
Hydraulic Fluid Temperature	10 to 66 °C (50 to 150 °F)	10 to 66 °C (50 to 150 °F)

Regulatory Compliance

European Compliance for CE Marking:
These listings are limited only to those units bearing the CE Marking.

EMC Directive: Declared to 2004/108/EC COUNCIL DIRECTIVE of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and all applicable amendments. 2004/108/EC is met by evaluation of the physical nature to the EMC protection requirement. Electromagnetically passive or "benign" devices are excluded from the scope of the Directive 2004/108/EC; however, they also meet the protection requirement and intent of the directive.

Pressure Equipment Directive: Certified to Pressure Equipment Directive 97/23/EC of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment, Categories II and III, TUV Rheinland Certificate 01 202 USA/Q-11 6617, Module H

ATEX – Potentially Explosive Atmospheres Directive: Declared to 94/9/EEC COUNCIL DIRECTIVE of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres.
Zone 2, Category 3, Group II G, Ex nA IIC T3X Gc, IP54
See below for special conditions for safe use.

Valves with Intrinsically Safe Components Only—
ATEX Potentially Explosive Atmospheres Directive: Declared to 94/9/EC COUNCIL DIRECTIVE of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres.
Zone 2, Category 3, Group II G, Ex nA IIC T3X Gc, IP54

Special Conditions for Safe Use:
The LVDT and servo valve must be wired using barrier wiring drawings shown in Figure 1-5.
Servo valve must not be replaced with one that has previously been installed in 'nA' applications.

Other European Compliance:
Compliance with the following European Directives or standards does not qualify this product for application of the CE Marking:

Machinery Directive: Compliant as partly completed machinery with Directive 2006/42/EC of the European Parliament and the Council of 17 May 2006 on machinery.

ATEX: Exempt from the non-electrical portion of the ATEX Directive 94/9/EC due to no potential ignition sources per EN 13463-1.

Other International Compliance

TIIS: Applicable to the servo valve and LVDT. Where a customer has requested TIIS compliance, the servo valve and LVDT are TIIS-marked, and must be installed with barriers as shown in the wiring diagrams in Chapter 1.

GOST R: Certified for use in explosive atmospheres within the Russian Federation per GOST R certificate POCC US. МЛ14.B00144 as ExnAIIT3 X.

North American Compliance:
Suitability for use in North American Hazardous Locations is the result of compliance of the individual components:

Servo Valve: FM Certified for Class I, Division 2, Groups A, B, C, D for use in the United States only per FM 4B9A6.AX.

CSA Certified for Class I, Division 2, Groups A, B, C, D for use in Canada per CSA 1072373.

Junction Box: UL Listed for Class I, Zone 1: AEx e II, Ex e II, T6 for use in the United States and Canada per UL E203312.

Dual Coil LVDT: CSA Certified for Class I, Divisions 1 and 2, Groups A, B, C, D, T4 for use in the United States and Canada per
CSA 151336-1090811.

Triple Coil LVDT: ETL Certified for Class I, Division 2, Groups A, B, C, D, T3 for use in the United States and Canada per ETL J98036083-003.

Special Conditions for Safe Use—All Valves
Wiring must be in accordance with North American Class I, Division 2, or European Zone 2 Category 3 wiring methods as applicable, and in accordance with the authority having jurisdiction.

Field wiring must be suitable for at least 100 °C.

The wiring junction box provides earth ground terminals if needed for a separate earth ground to meet wiring requirements.

T3 reflects conditions without process fluid. The surface temperature of this valve approaches the maximum temperature of the applied process media. It is the responsibility of the user to ensure that the external environment contains no hazardous gases capable of ignition in the range of the process media temperatures.

Compliance with the Machinery Directive 2006/42/EC noise measurement and mitigation requirements is the responsibility of the manufacturer of the machinery into which this product is incorporated.

The risk of electrostatic discharge is reduced by permanent installation of the valve, proper connection to the protective earth (PE) terminals, and care when cleaning. The valve should not be cleaned unless the area is known to be non-hazardous.

Standard Recovery SonicFlo Installation Drawings

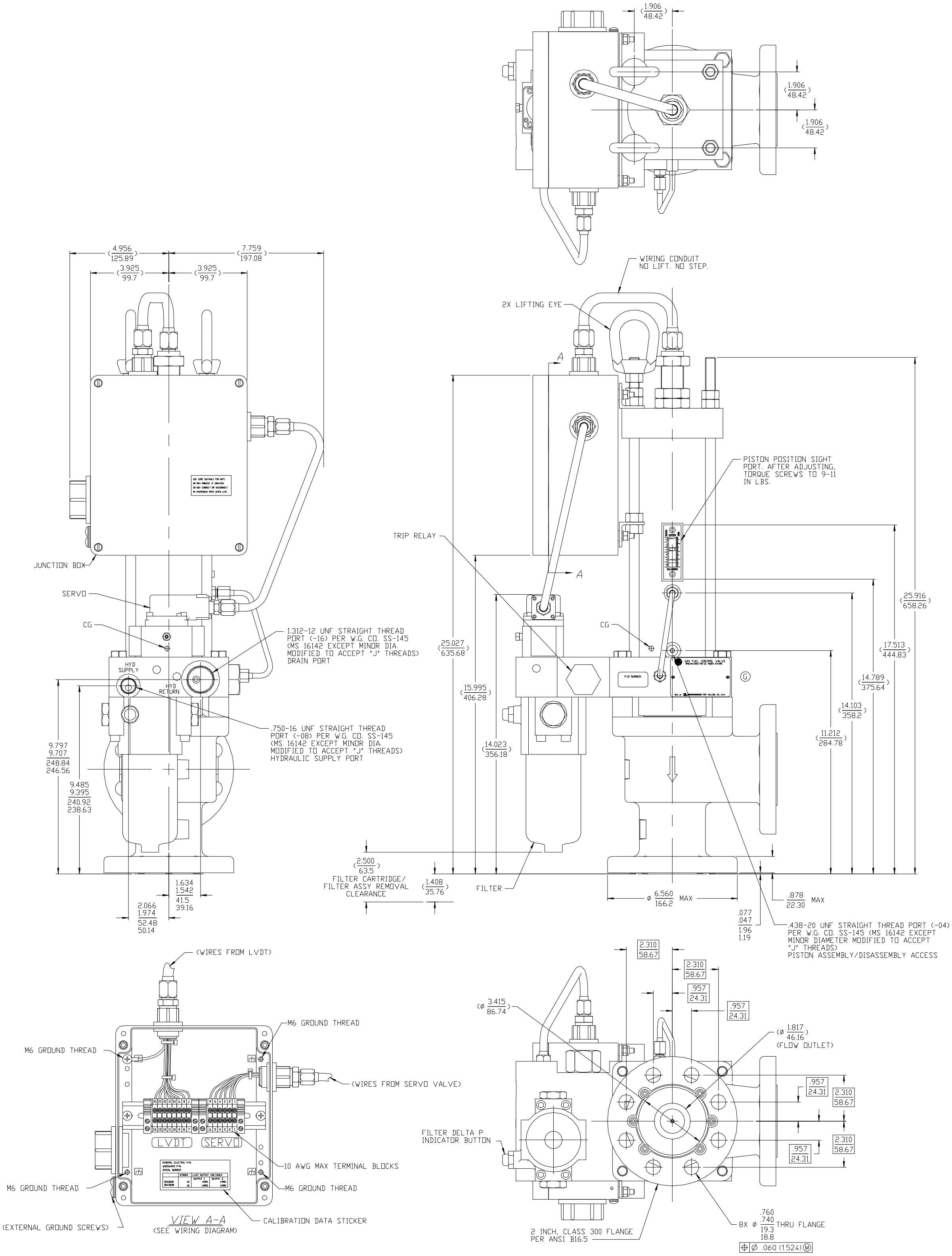


Figure 3-2a. Outline Drawing 2” Standard Recovery Control Valve (View Showing Dual Coil LVDT)

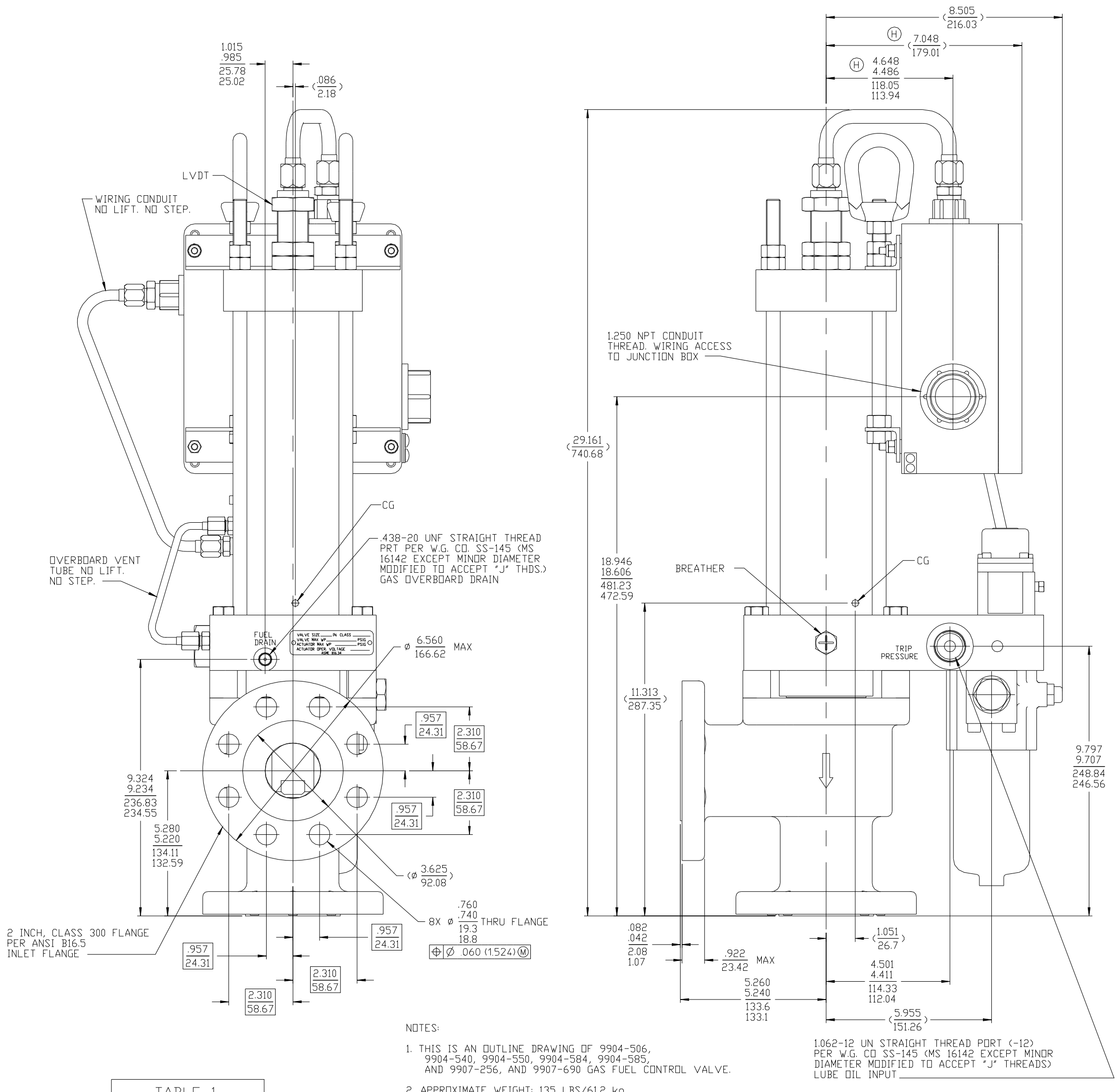


TABLE 1

VALVE P/N	CE APPROVAL
9904-506	NONE
9904-540	NONE
9904-550	CE
9904-584	CE
9904-585	CE
9907-256	NONE
9907-690	CE

Figure 3-2b. Outline Drawing 2” Standard Recovery Control Valve

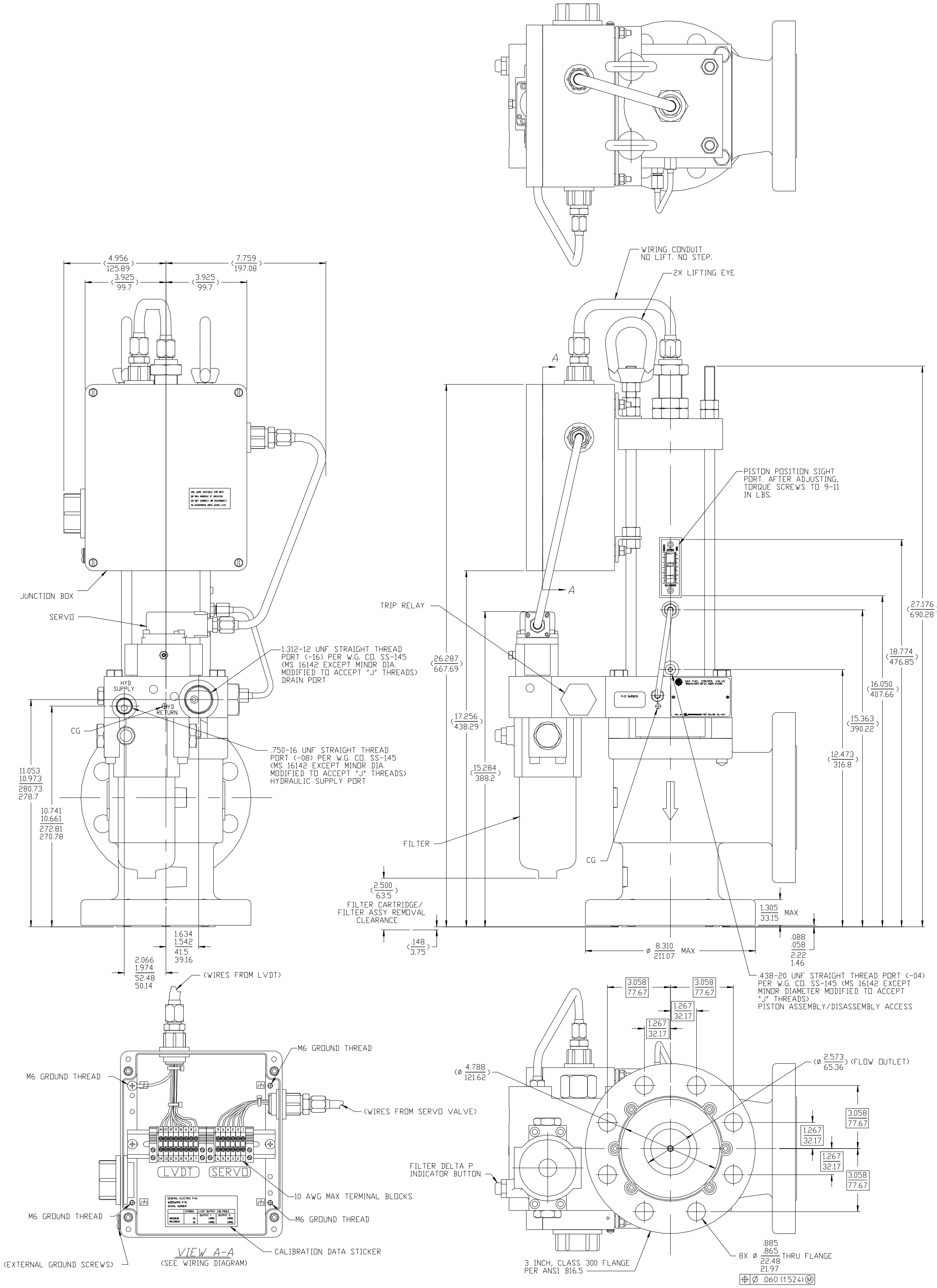


Figure 3-3a. Outline Drawing 3" Standard Recovery Control Valve (View Showing Dual Coil LVDT)

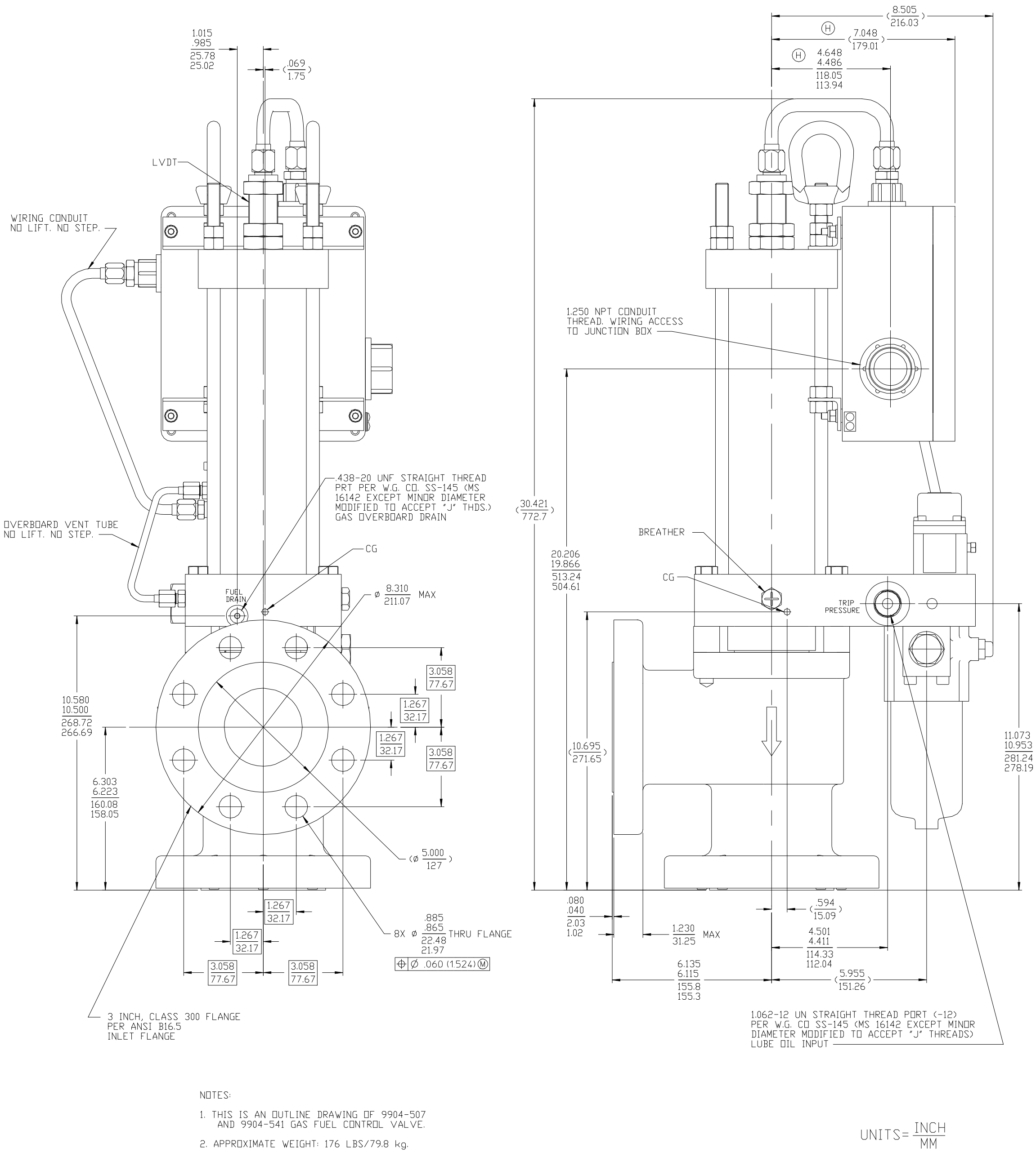


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Figure 3-3b. Outline Drawing 3" Standard Recovery Control Valve

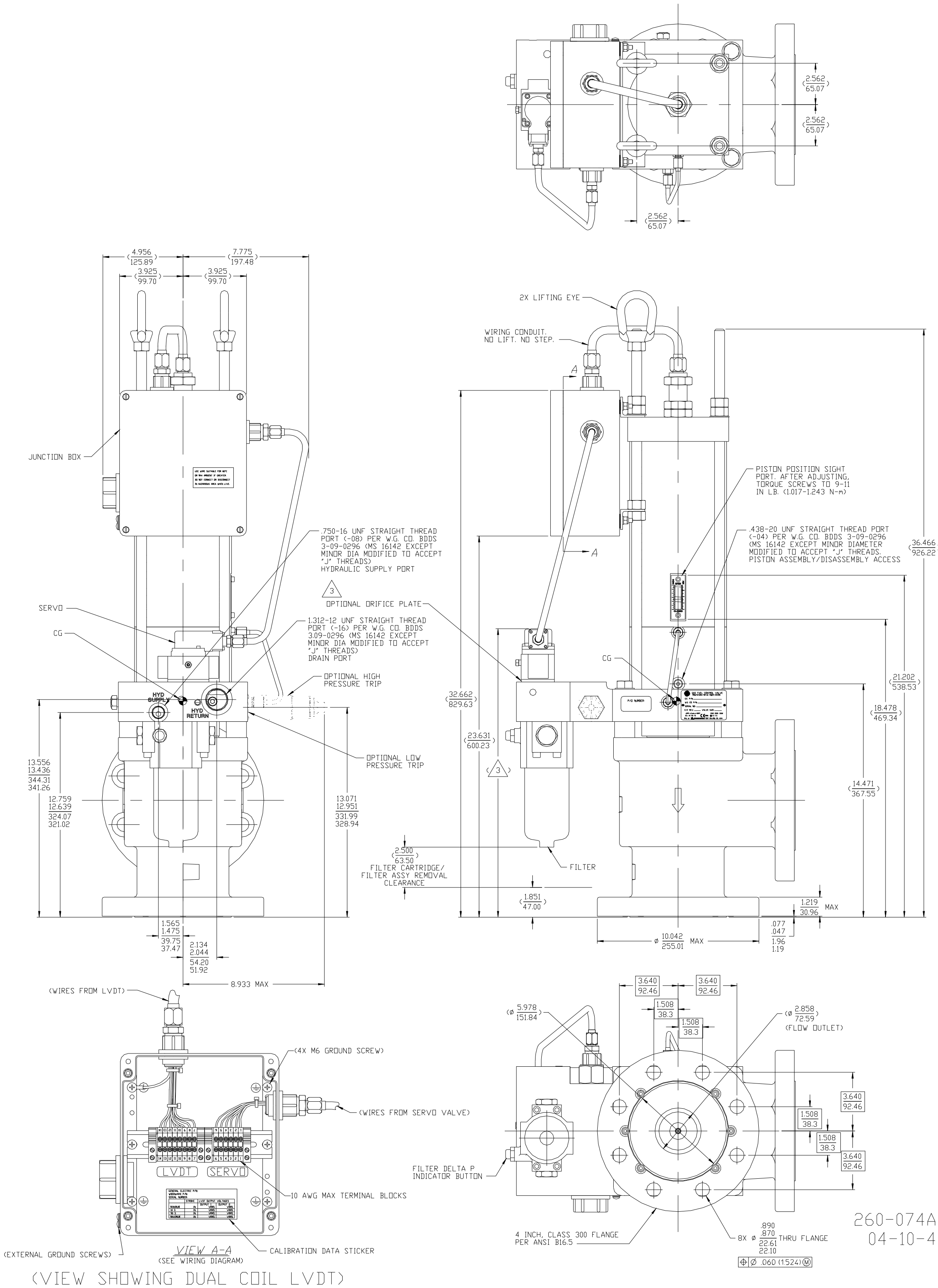


Figure 3-4a. Outline Drawing 4" Standard Recovery Control Valve (View Showing Dual Coil LVDT)

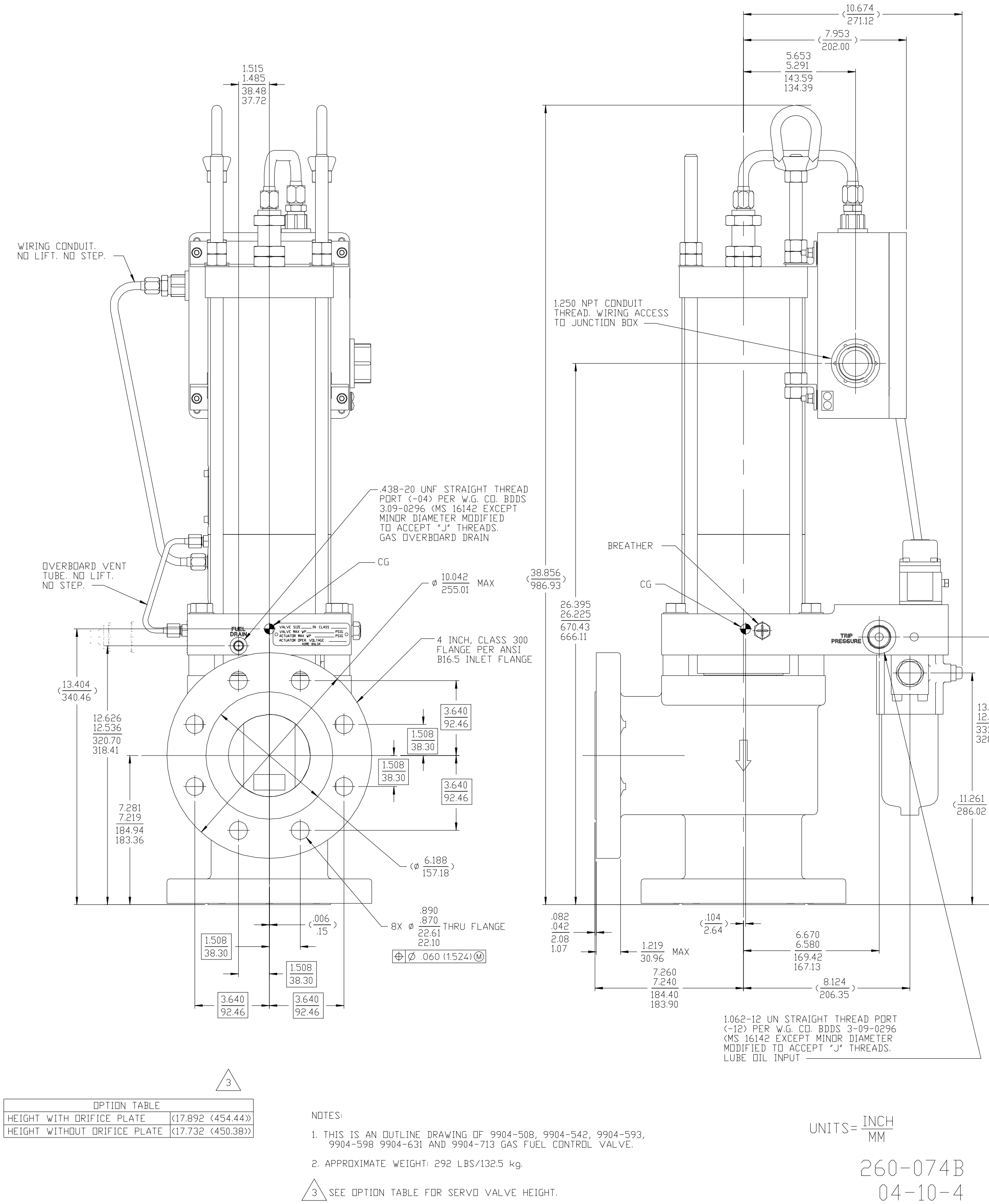


Figure 3-4b. Outline Drawing 4" Standard Recovery Control Valve

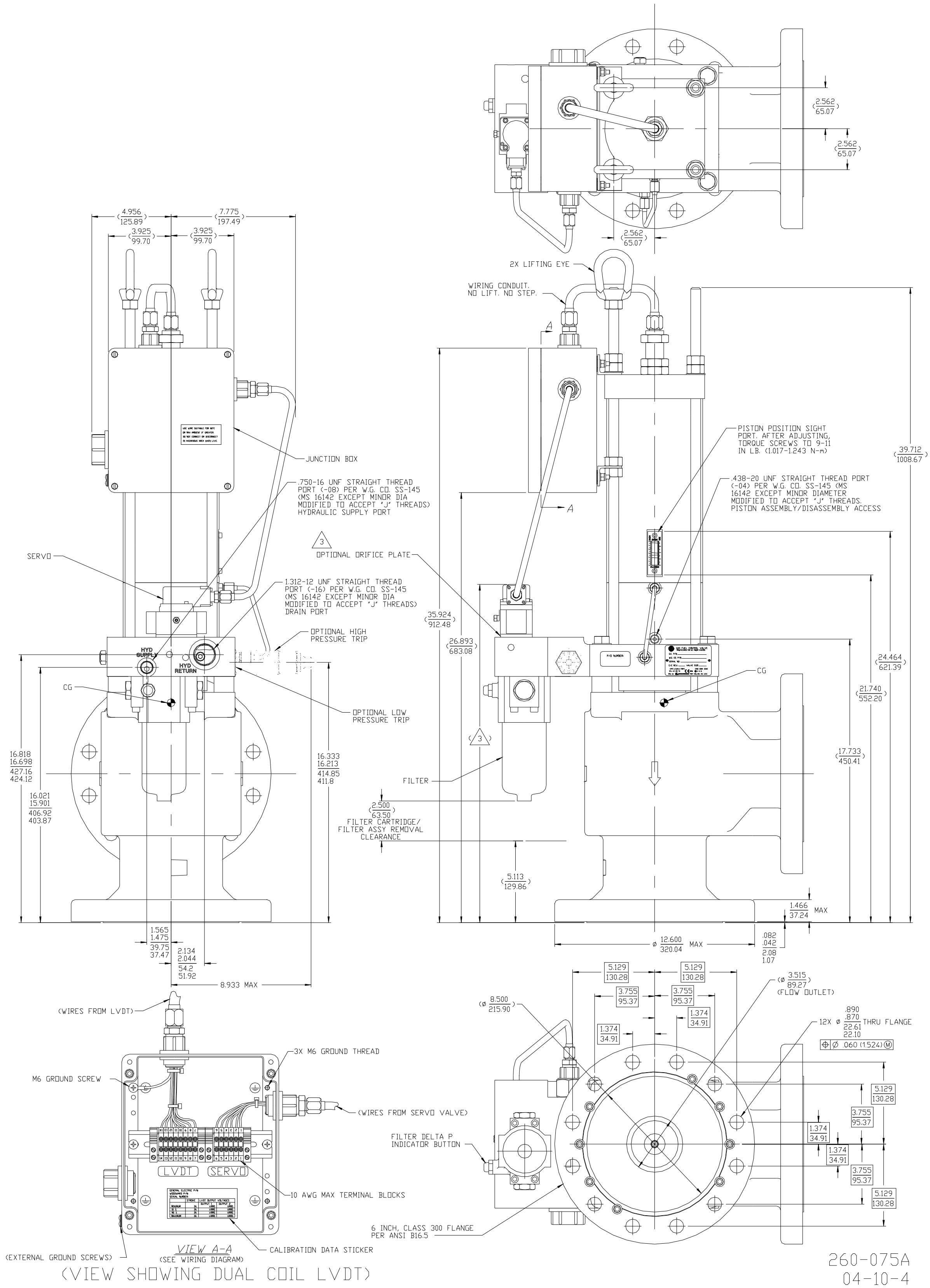
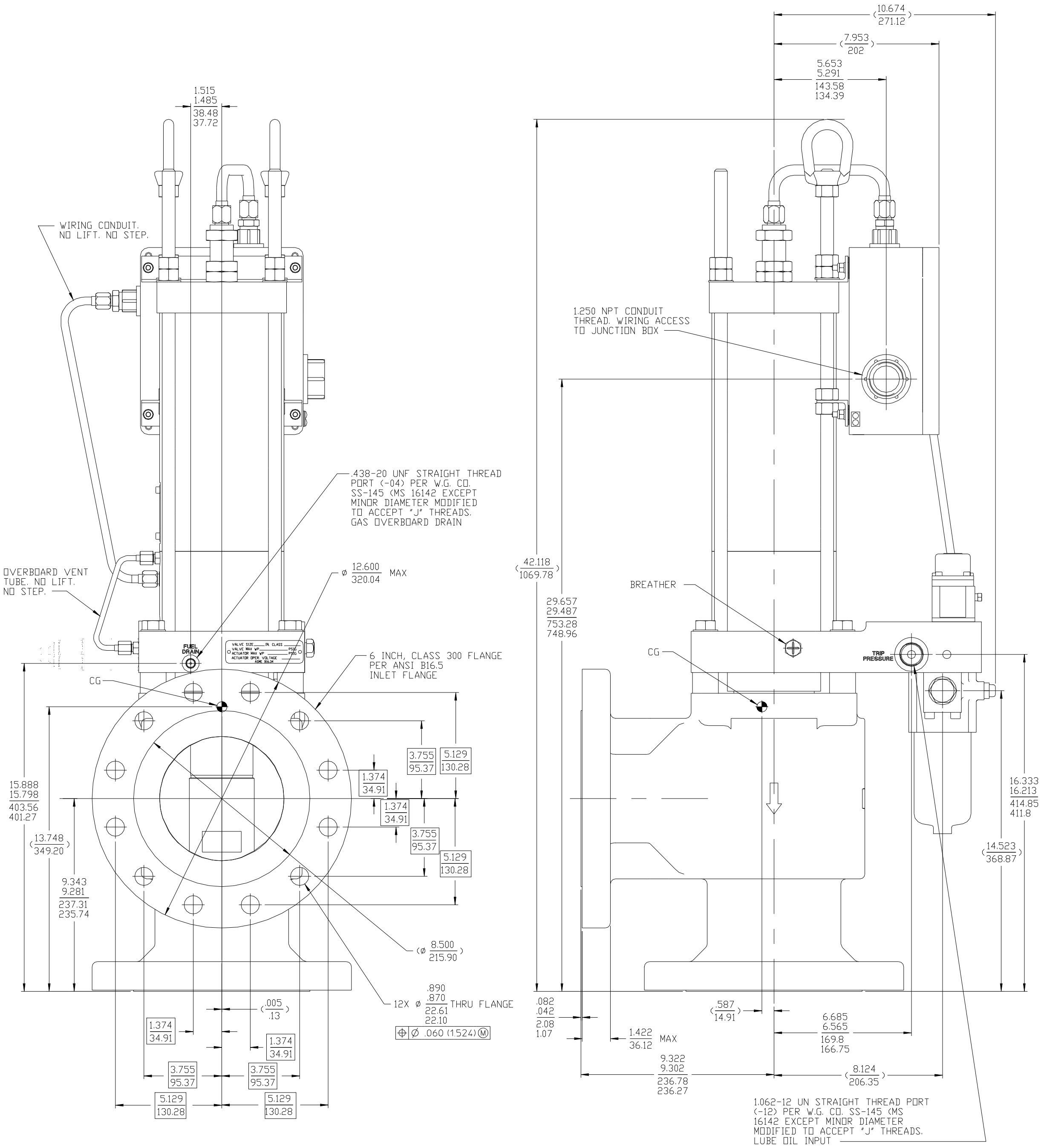


Figure 3-5a. Outline Drawing 6" Standard Recovery Control Valve (View Showing Dual Coil LVDT)



OPTION TABLE	
HEIGHT WITH ORIFICE PLATE	(21.154 (537.30))
HEIGHT WITHOUT ORIFICE PLATE	(20.994 (533.23))

NOTES:

1. THIS IS AN OUTLINE DRAWING OF 9904-513, 9904-543, 9904-582, 9904-587, 9904-599, 9904-630, 9904-707 AND 9904-714 GAS FUEL CONTROL VALVES.
2. APPROXIMATE WEIGHT: 375 LBS/170.1 kg.
3. SEE OPTION TABLE FOR SERVO VALVE HEIGHT.

Figure 3-5b. Outline Drawing 6" Standard Recovery Control Valve

High Recovery SonicFlo Installation Drawings

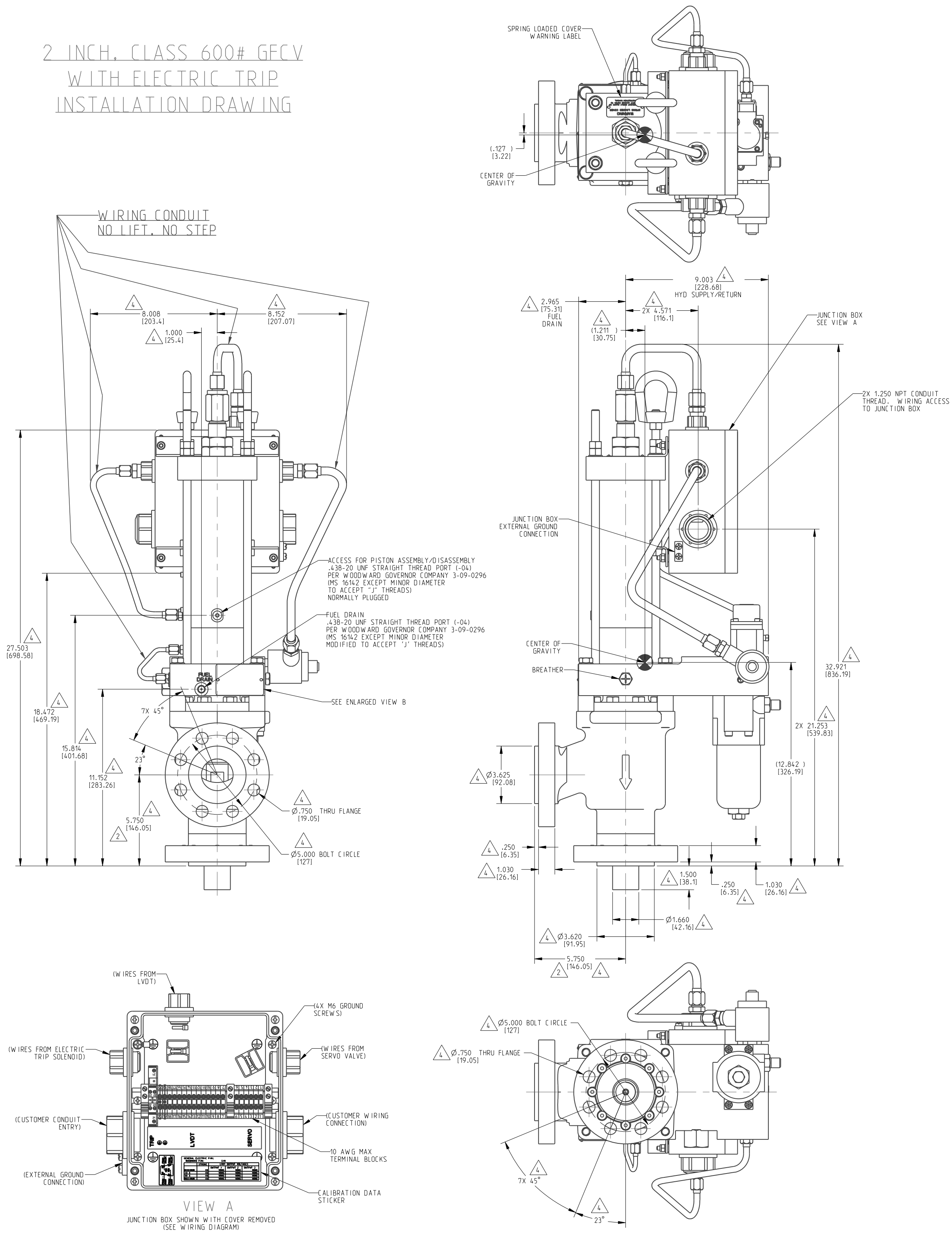


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Figure 3-6a. Outline Drawing 2” High Recovery Control Valve (Left View)

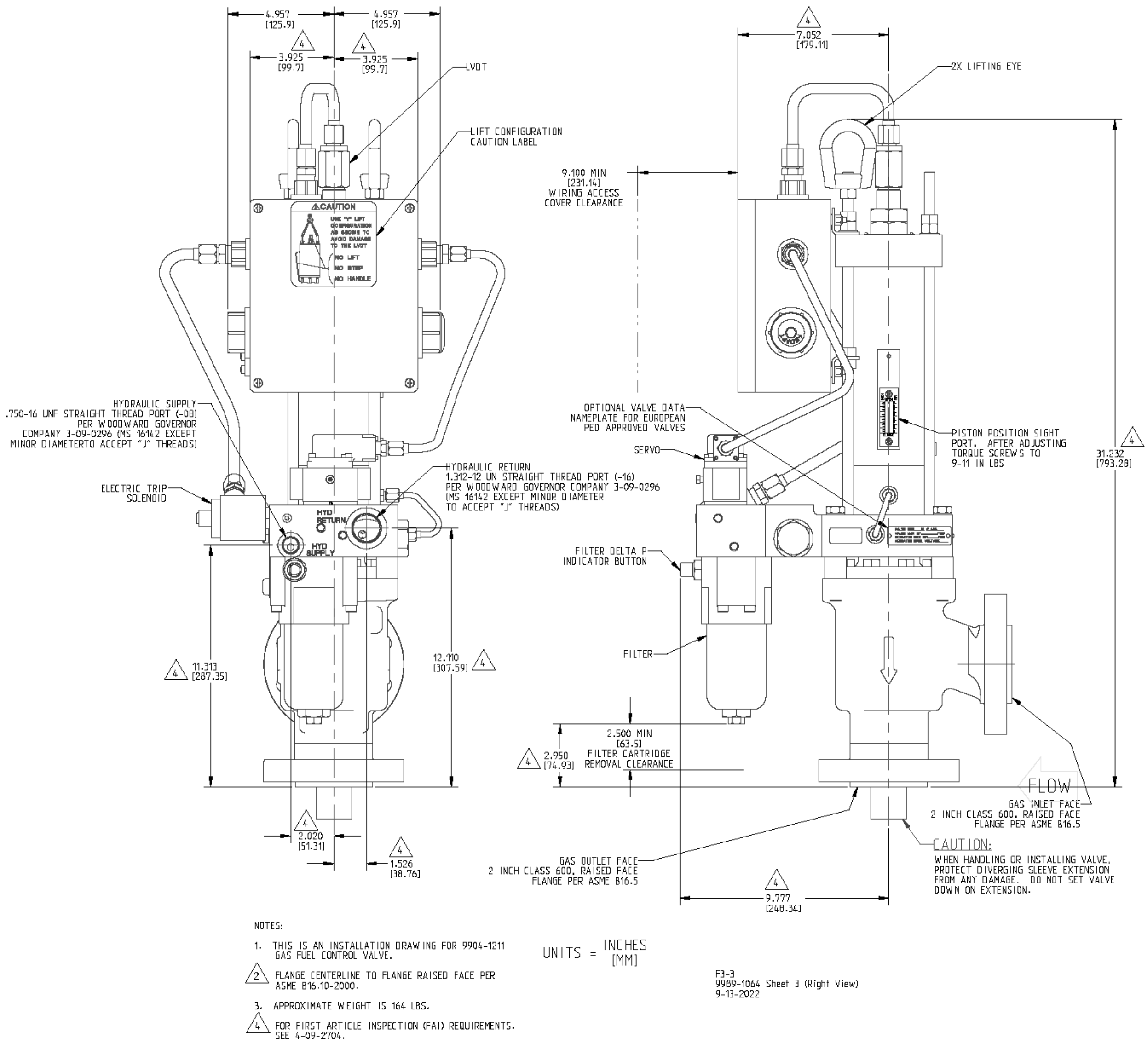

Figure 3-6b. Outline Drawing 2" High Recovery Control Valve (Right View)

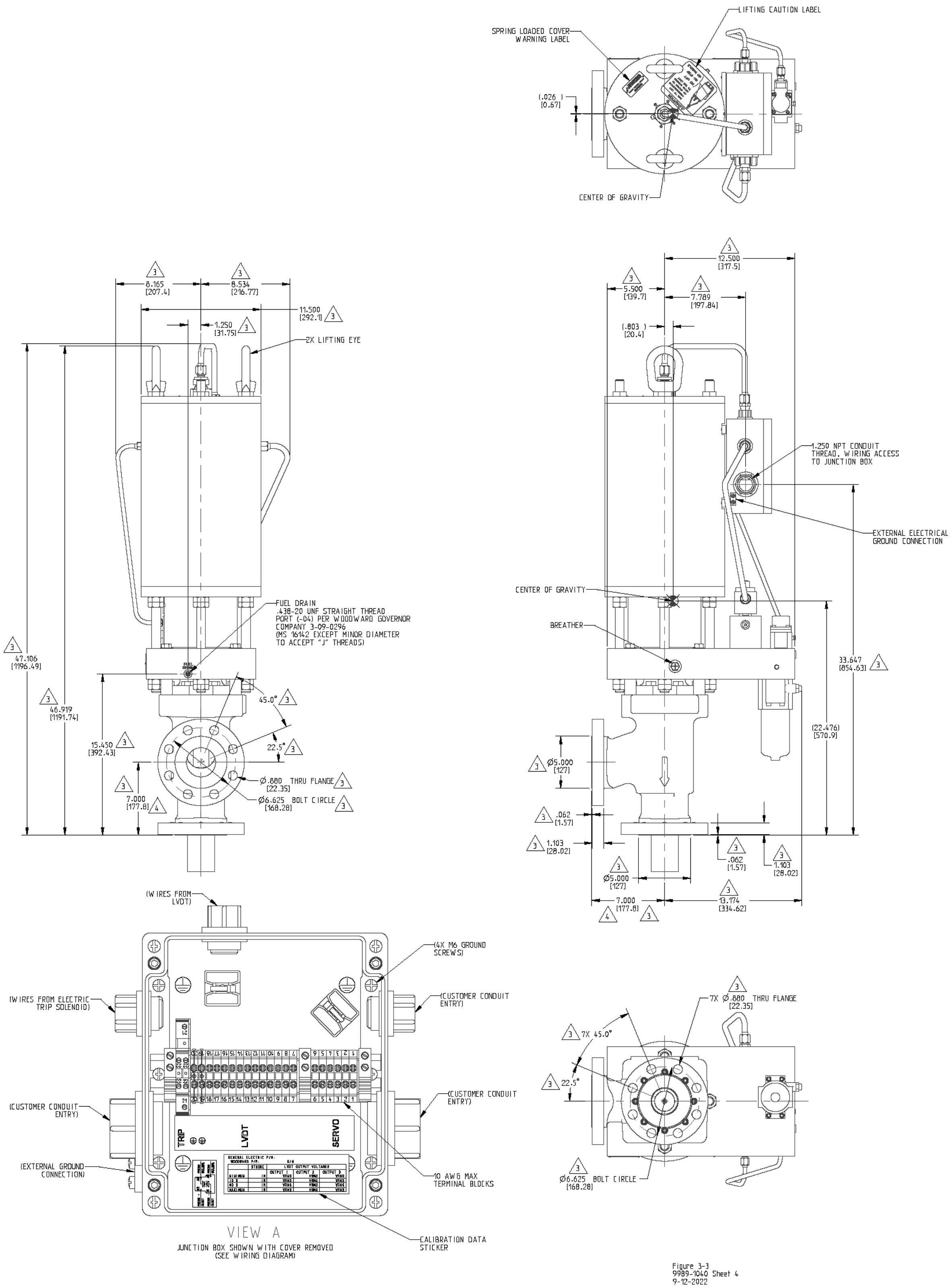

Figure 3-7a. Outline Drawing 3" High Recovery Control Valve (Left View)

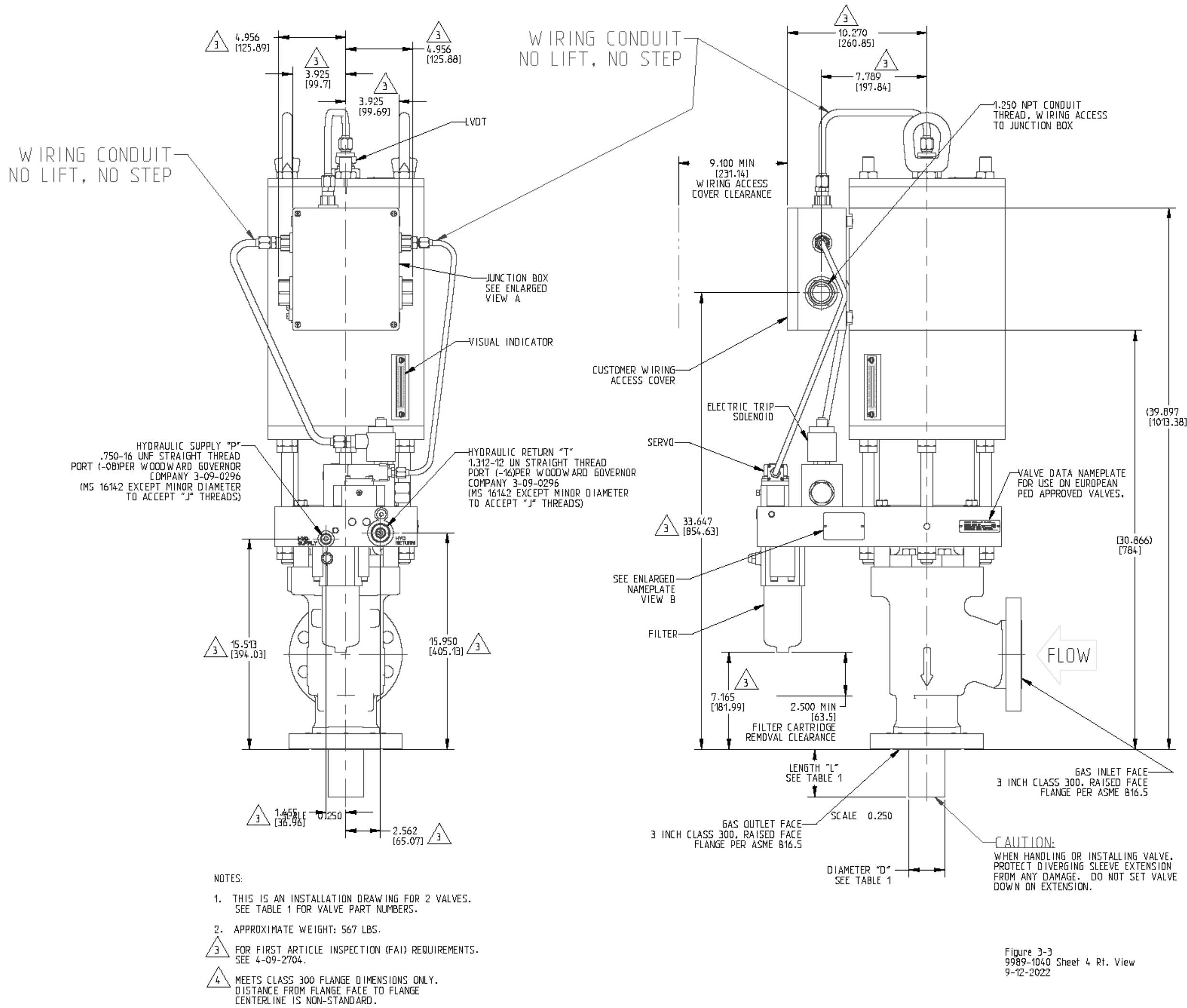

Figure 3-7b. Outline Drawing 3" High Recovery Control Valve (Right View)

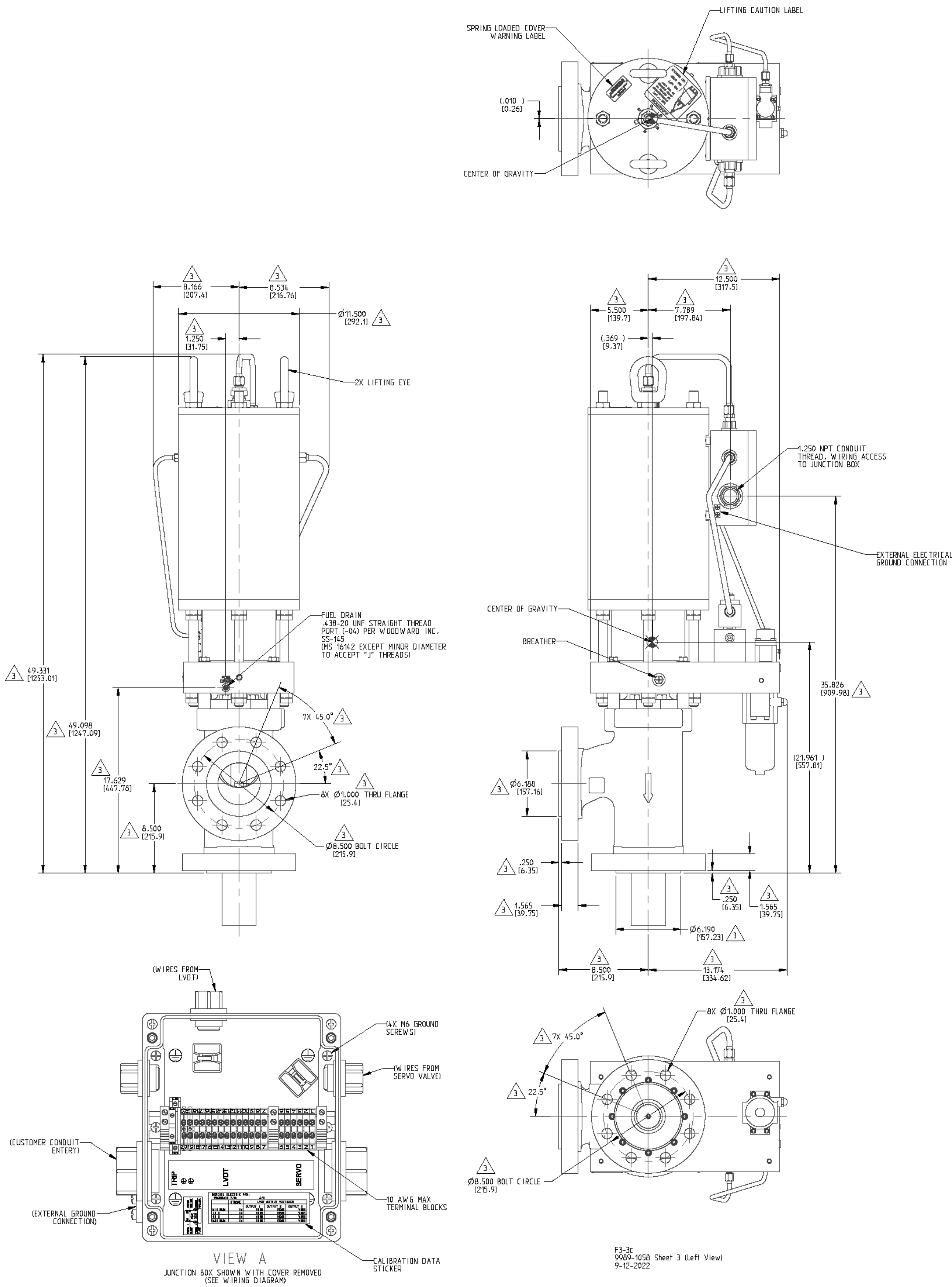

Figure 3-8a. Outline Drawing 4” High Recovery Control Valve (Left View)

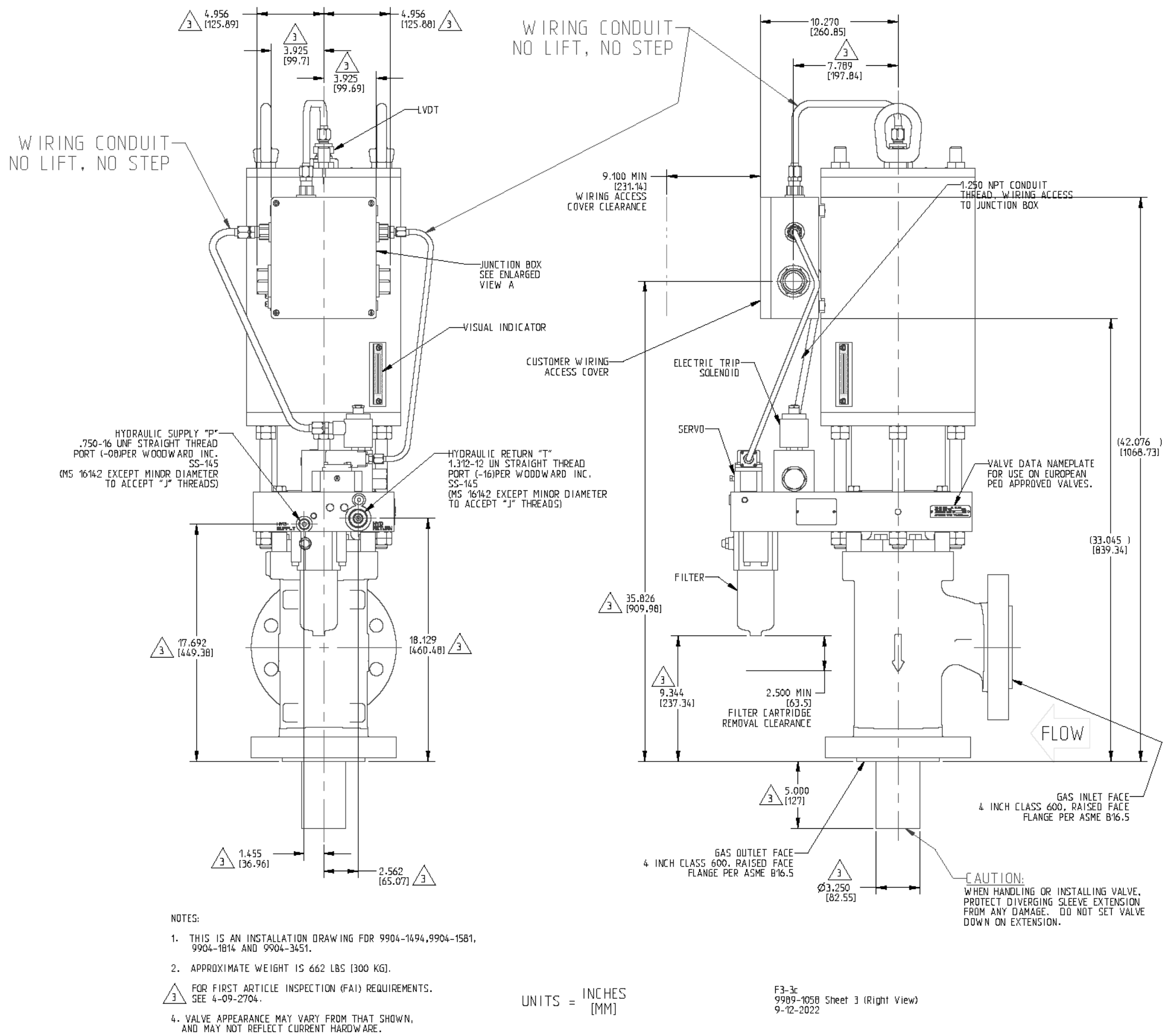

Figure 3-8b. Outline Drawing 4” High Recovery Control Valve (Right View)

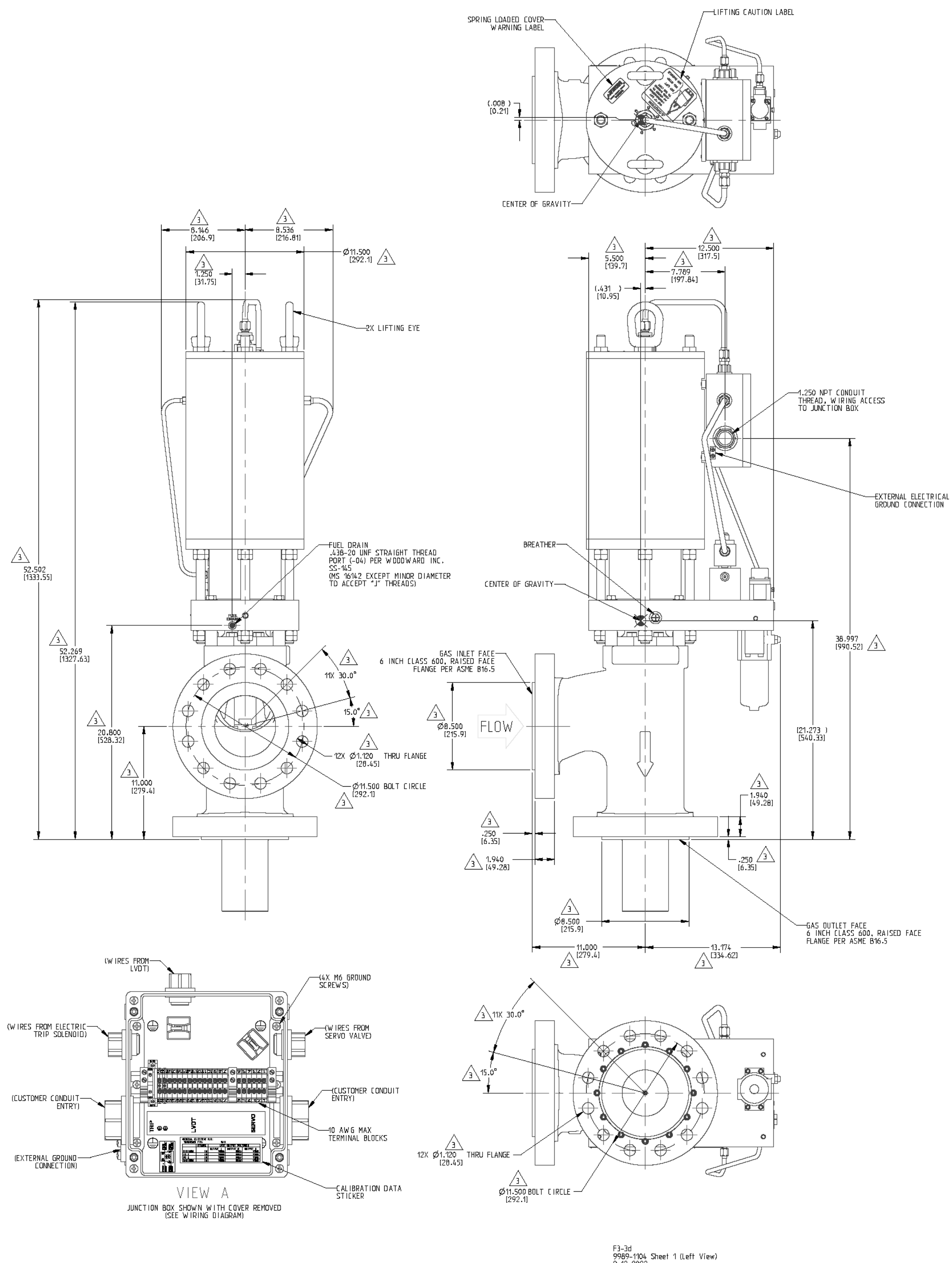

Figure 3-9a. Outline Drawing 6” High Recovery Control Valve (Left View)

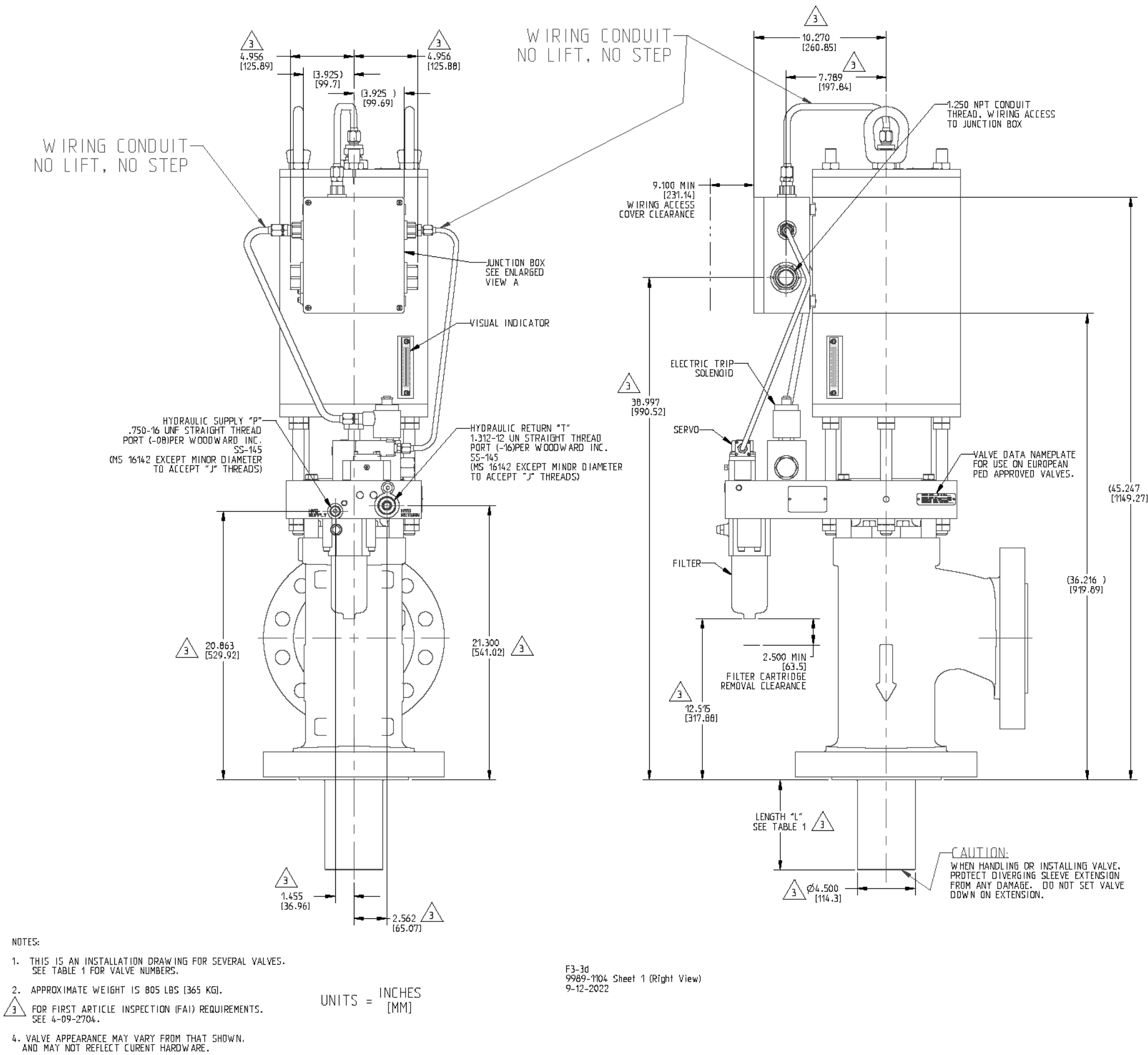

Figure 3-9b. Outline Drawing 6" High Recovery Control Valve (Right View)

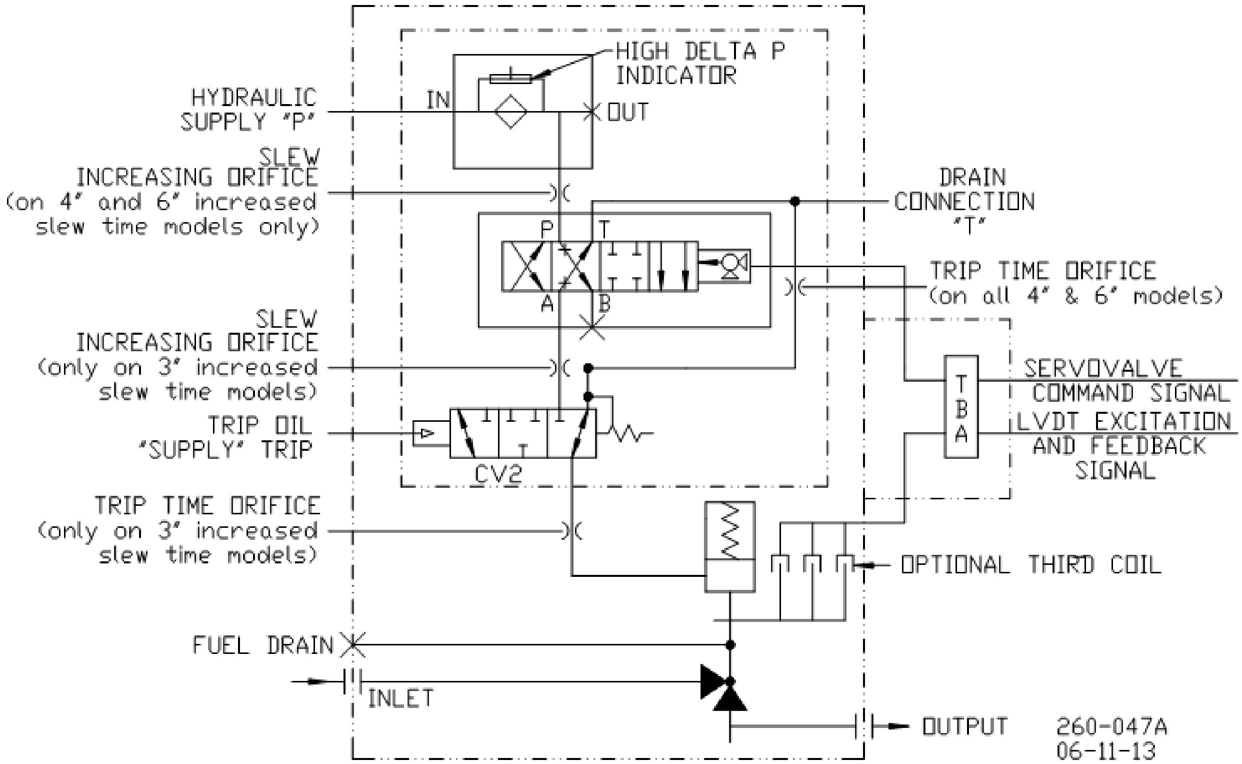

Figure 3-10. Hydraulic Schematic Circuit

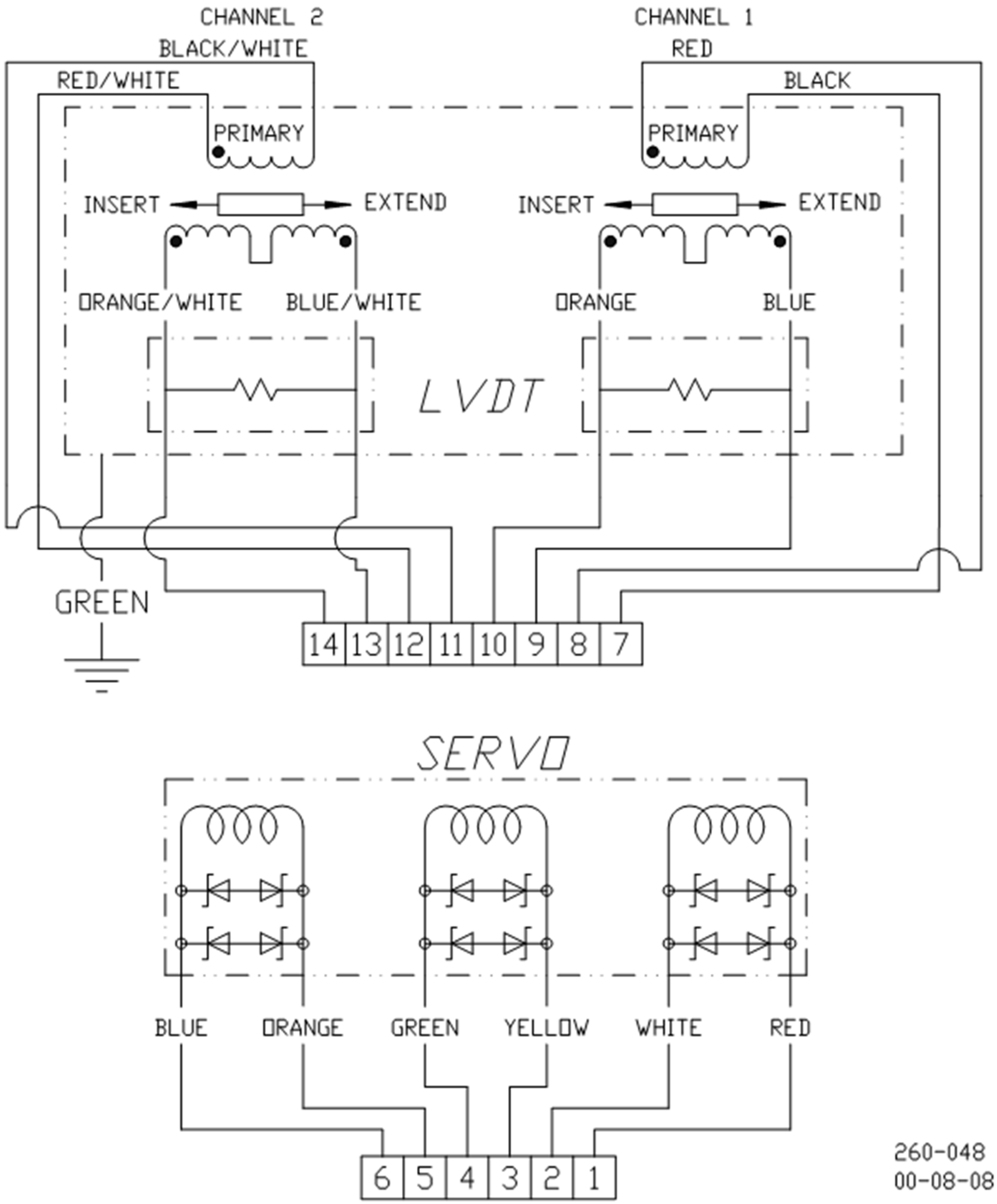

Figure 3-11. Wiring Diagram (Dual Coil LVDT)

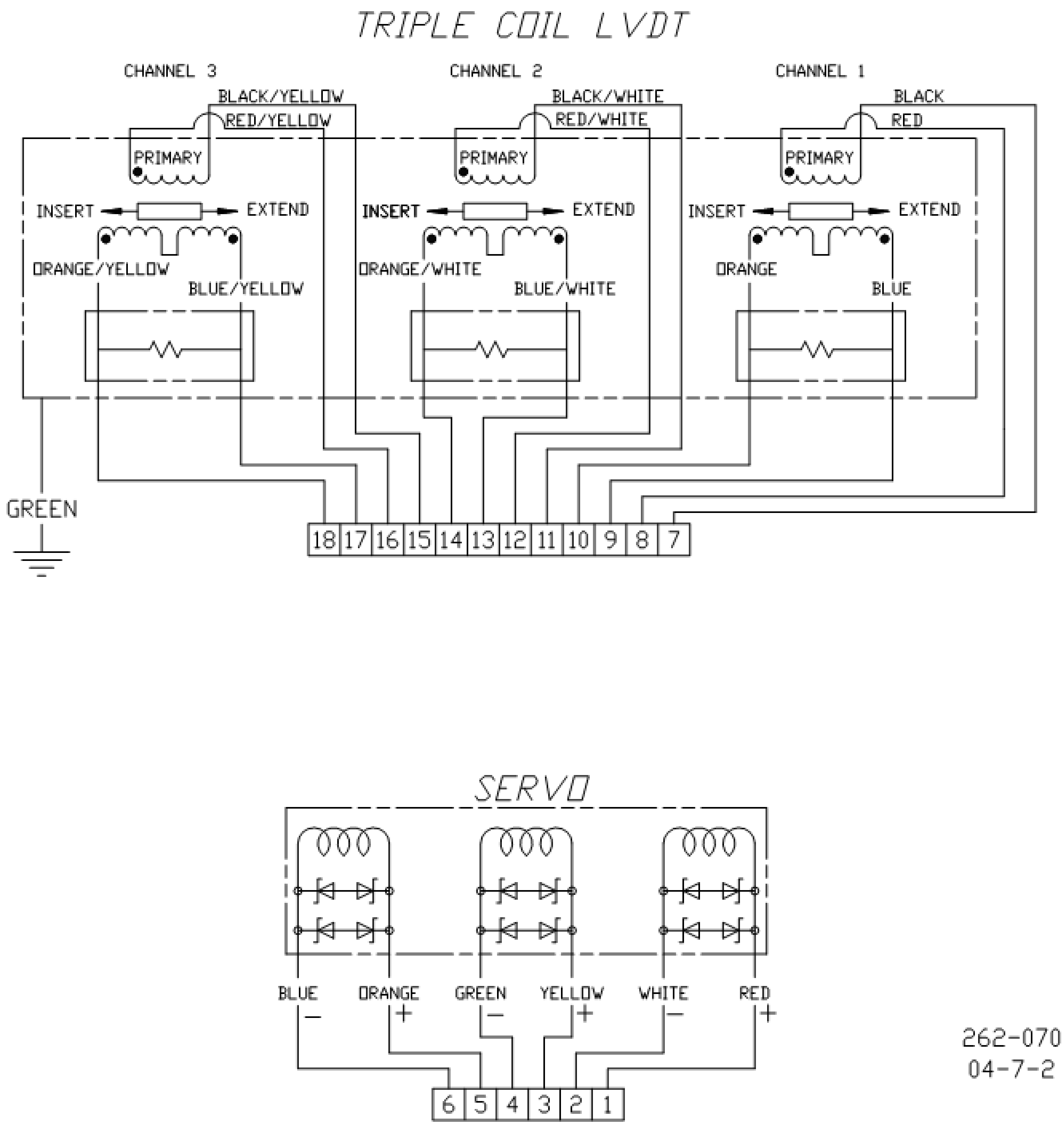

Figure 3-12. Wiring Diagram (Triple Coil LVDT)

Hydraulic Actuator Component Description

Triple Coil Electrohydraulic Servo Valve Assembly

The hydraulic actuator assembly uses a two-stage hydraulic servo valve to modulate the position of the actuator output shaft and thereby control the gas fuel valves. The first stage torque motor utilizes a triple-wound coil, which controls the position of the first and second stage valves in proportion to the total electric current applied to the three coils.

If the control system requires a rapid movement of the valve to send more fuel to the turbine, total current is increased well above the null current. In such a condition, control port PC1 is connected to supply pressure. The flow rate delivered to the piston cavity of the actuator is proportional to the total current applied to the three coils. Thus, the opening velocity is also proportional to the current (above null) supplied to the torque motor.

If the control system requires a rapid movement to close the gas fuel valve, the total current is reduced well below the null current. In such a condition, port PC1 is connected to the hydraulic drain circuit. The flow rate from the piston cavity to drain is proportional to the magnitude of the total current below the null value. Thus, the closing velocity is also proportional to the current (below null) supplied to the torque motor.

Near the null current, the four-landed valve isolates the control port from the hydraulic supply and drain, balancing the piston pressure against the spring to maintain a constant position. The control system, which regulates the amount of current delivered to the coils, modulates the current supplied to the coil to obtain proper closed loop position of the valve.

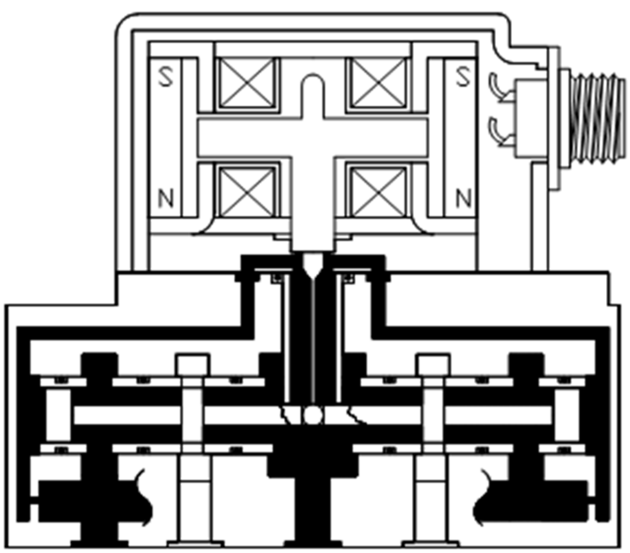

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Figure 3-13. Servo Valve Cutaway

Trip Relay Valve Assembly

The SonicFlo valve uses a three-way, two-position, hydraulically-operated valve to switch the position of the stop valve. When the trip circuit pressure increases above 18–30 psig (124–207 kPa; low-pressure trip) or 650–850 psig (4482–5861 kPa; high-pressure trip), the three-way relay valve shifts position so that the common port is connected to supply pressure and isolated from the hydraulic drain circuit. Actuation pressure is routed from the control pressure circuit of the relay valve to the lower piston cavity of the actuator. This moves the piston upward and allows the control valve to function. As the trip circuit supply pressure reduces below 16–28 psig (110–193 kPa; low-pressure trip) or 650–850 psig (4482–5861 kPa; high-pressure trip), the three-way relay valve shifts position so that the common port is connected to the hydraulic drain circuit, and isolated from the hydraulic supply. As the pressure falls within the lower piston cavity, the return spring will rapidly return the valve plug to the downward position, closing the control valve and shutting off fuel to the engine.

Hydraulic Filter Assembly

The valve is supplied with an integrated, high-capacity filter. The broad range filter protects the internal hydraulic control components from large oil-borne contaminants that might cause the hydraulic components to stick or operate erratically. The filter is supplied with a visual indicator which shows when the recommended pressure differential has been exceeded and thus replacement of the element is necessary.

LVDT Position Feedback Sensors

The SonicFlo control valves use either a dual-coil, dual-rod LVDT or a triple-coil, single-rod LVDT for position feedback. The LVDT is factory set to give 0.7 Vrms feedback at minimum position and 3.5 Vrms feedback at maximum position, when supplied with 7 Vrms excitation at 3000 Hz.

Chapter 4.
Electric SonicFlo Valves (LESV)

Introduction

This section describes Woodward's Large Electric Sonic Valve (LESV) and Digital Valve Positioner (DVP), which are used to control the flow of gas fuel to the combustion system of an industrial or utility gas turbine. The key attributes of the LESV's electric actuator are safe turbine fuel shutoff (fail closed design), repeatable dynamic response, and reliable valve positioning.

Note: This manual is for reference only. Always follow all instructions provided in LESV Installation and Operation manual 26419; LESV, Characterized Version for DLE Applications, Installation and Operation manual 26465; DVP Digital Valve Positioner manual 26329; and LESV, SIL-2 Version, manual 26745.

LESV General Specifications

Description	2, 3, 4, & 6-Inch (51, 76, 102, 152 mm) electrically actuated natural gas sonic metering valve.	
Mean Time Between Failure (MTBF)	149 000 hrs. operation combined metering valve per valve/actuator/DVP/cable subsystem.	
Ambient Temperature Range	–40 to +93 °C (–40 to +200 °F)	
Approximate Weights	Class 300 LESV 2-Inch - 113 kg / 250 lb. 3-Inch - 161 kg / 356 lb. 4-Inch - 195 kg / 430 lb. 6-Inch - 256 kg / 565 lb.	Class 600 LESV 2-Inch – 113 kg / 250 lb. 3-Inch – 167 kg / 368 lb. 4-Inch – 207 kg / 456 lb. 6-Inch – 278 kg / 613 lb.
ACTUATOR		
Description	Brushless dc motor with dual position feedback sensors.	
Coil	Class H insulation	
Failure Mode	Spring type to drive valve to safe position with loss of signal (Fail Close).	
Bandwidth	35 rad/s with no more than 6 dB attenuation and less than 180 degrees phase loss at ±2% magnitude and minimum supply voltage at DVP.	
Visual Position Indication	Yes	
Ingress Protection	IP55	
Characteristic	High Recovery LESV	Ultra-High Recovery LESV
Response Time	2-Inch—200 ms 3-Inch—350 ms 4-Inch—700 ms 6-Inch—700 ms	2-Inch—400 ms 3-Inch—700 ms 4-Inch—700 ms 6-Inch—700 ms
DVP Input Voltage (typical)	125 Vdc	220 Vdc
DVP Input Voltage (Max)	150 Vdc	300 Vdc
DVP Input Voltage (min) (for full dynamic performance)	112.5 Vdc	112.5 Vdc

Valve Specifications

VALVE			
Operating Fluid	Natural Gas		
Gas Filtration	25 µm absolute at 75 beta requirement		
Valve flange connection	Class 300 Flange High Recovery LESV	Class 600 Flange High Recovery LESV	Class 600 Flange Ultra High Recovery LESV
Min Fluid Temperature	–29 °C (–20 °F)	–29 °C (–20 °F)	–29 °C (–20 °F)
Max Fluid Temperature	232 °C (450 °F)	260 °C (500 °F)	260 °C (500 °F)
Min Fluid Pressure	0 kPa (0 psig)	0 kPa (0 psig)	0 kPa (0 psig)
Max Fluid Pressure	3902 kPa at 38 °C (566 psig at 100 °F) 3434 kPa at 232 °C (498 psig at 450 °F)	4000 kPa at 38 °C (580 psig at 100 °F) 4000 kPa at 260 °C (580 psig at 500 °F)	4171 kPa at 38 °C (605 psig at 100 °F) 4171 kPa at 260 °C (605 psig at 500 °F)
Proof Test Pressure/ Production	7584 kPa / 1100 psig	9136 kPa / 1325 psig	9480 kPa / 1375 psig
Burst Pressure	5x maximum operating pressure.		
Overboard Leakage	<50 cm³/min as shipped (see Fuel Overboard Vent Port section).		
Trim Sizes	Contact Woodward for various Cg trim sizes.		

Regulatory Compliance

European Compliance for CE Marking:
These listings are limited only to those units bearing the CE Marking.

Low Voltage Directive (Motor):	Declared to 73/23/EEC COUNCIL DIRECTIVE of 10 February 1973 on the harmonization of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits.
EMC Directive:	Declared to 2004/108/EC COUNCIL DIRECTIVE of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and all applicable amendments.
Pressure Equipment Directive:	Certified to Pressure Equipment Directive 97/23/EC of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment, Category II and III TUV Rheinland Module H Certificate 01 202 USA/Q-11 6617
ATEX – Potentially Explosive Atmospheres Directive:	Declared to 94/9/EEC COUNCIL DIRECTIVE of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres. Zone 2, Category 3, Group II G, Ex nA IIC T3 X Gc IP55

Other European and International Compliance:
Compliance with the following European Directives or standards does not qualify this product for application of the CE Marking:

Machinery Directive:	Compliant as partly completed machinery with Directive 2006/42/EC of the European Parliament and the council of 17 May 2006 on machinery.
GOST R:	Certified for use in explosive atmospheres within the Russian Federation per GOST R certificate POCC US.МЛ14.B00192 as ExnAIIT3 X

North American Compliance:
These listings are limited only to those units bearing the CSA Marking.

CSA (Actuator):	CSA Certified for Class I, Division 2, Groups A, B, C, & D, T3 at 93 °C Ambient For use in Canada and the United States Certificate 1635932

Actuator is certified for North America as on-engine systems component connected to the certified Digital Valve Positioner.

Wiring must be in accordance with North American Class I, Division 2, or European Zone 2, Category 3 wiring methods as applicable, and in accordance with the authority having jurisdiction.

Electric SonicFlo Installation Drawings

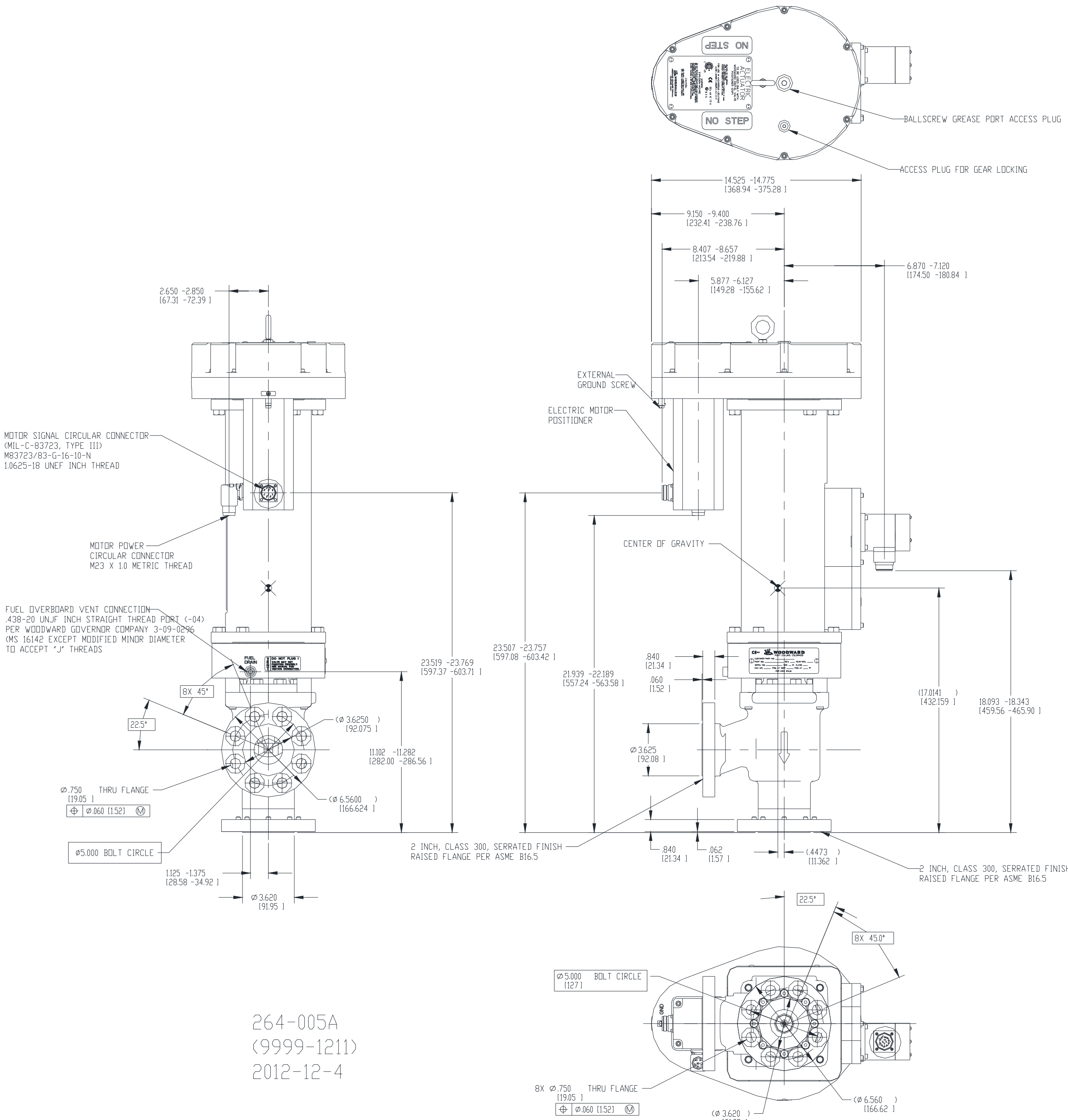

Figure 4-1a. Outline Drawing 2” LESV (Left View)

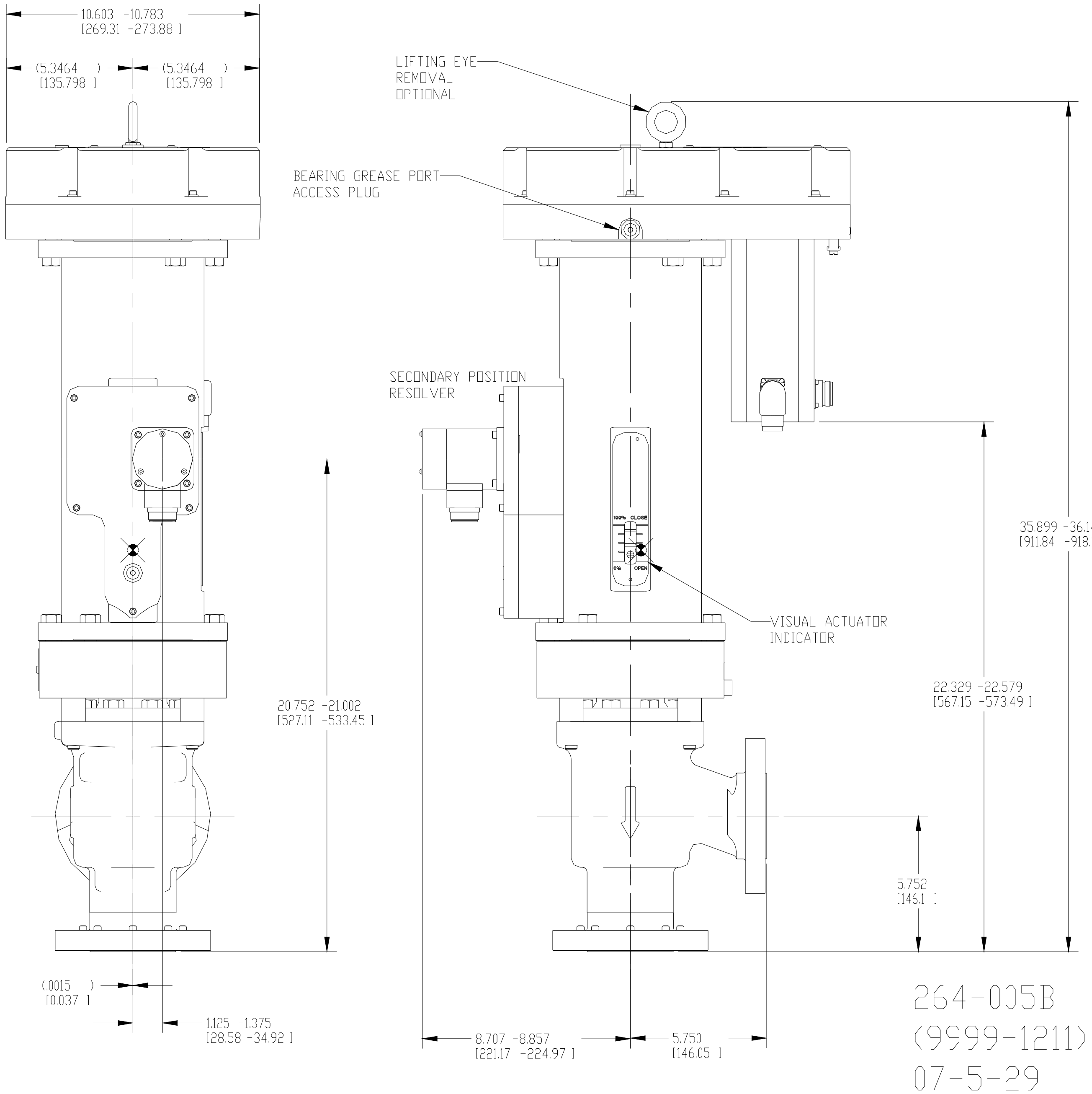

Figure 4-1b. Outline Drawing 2" LESV (Right View)

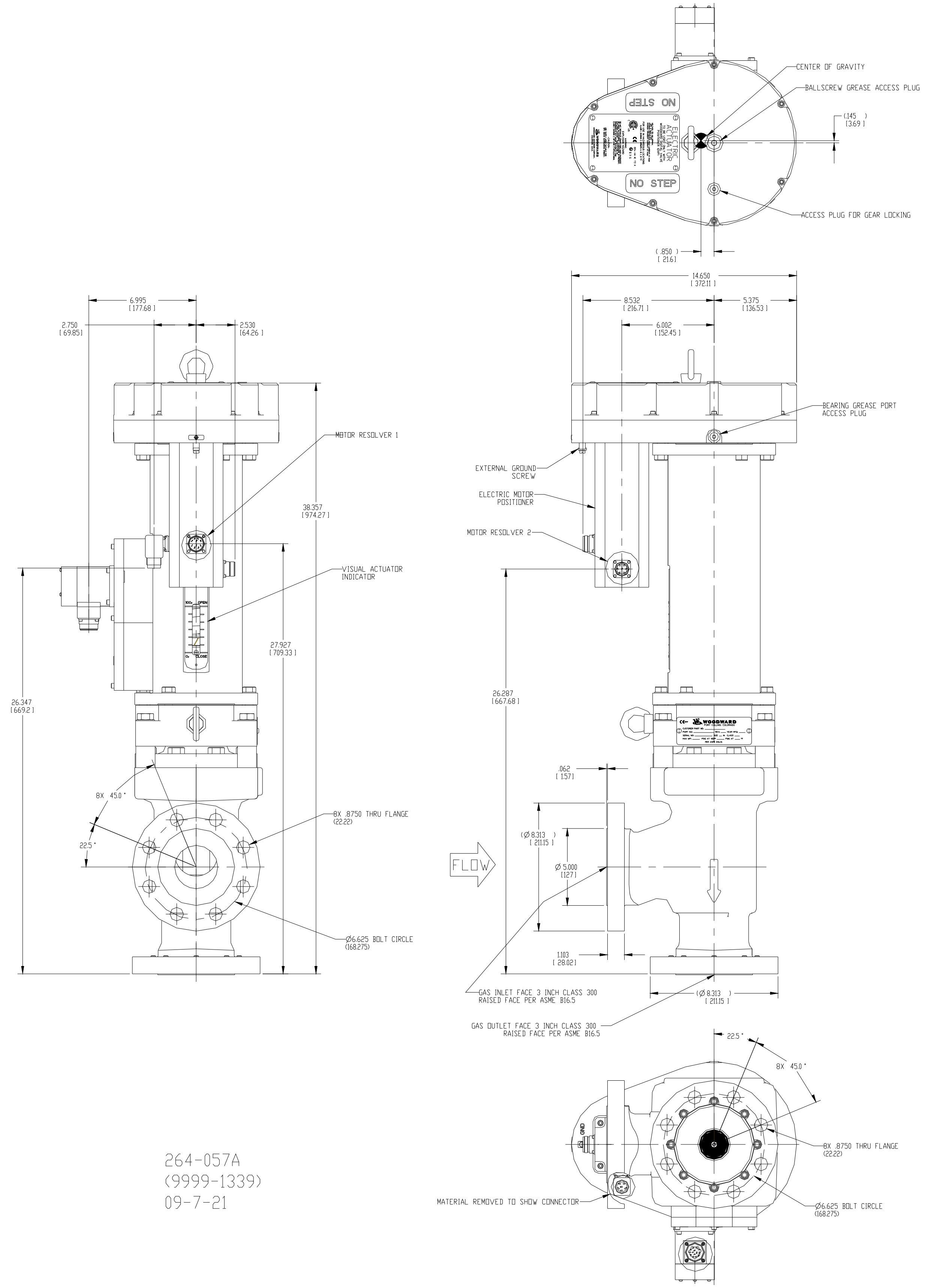

Figure 4-2a. Outline Drawing 3” LESV (Left View)

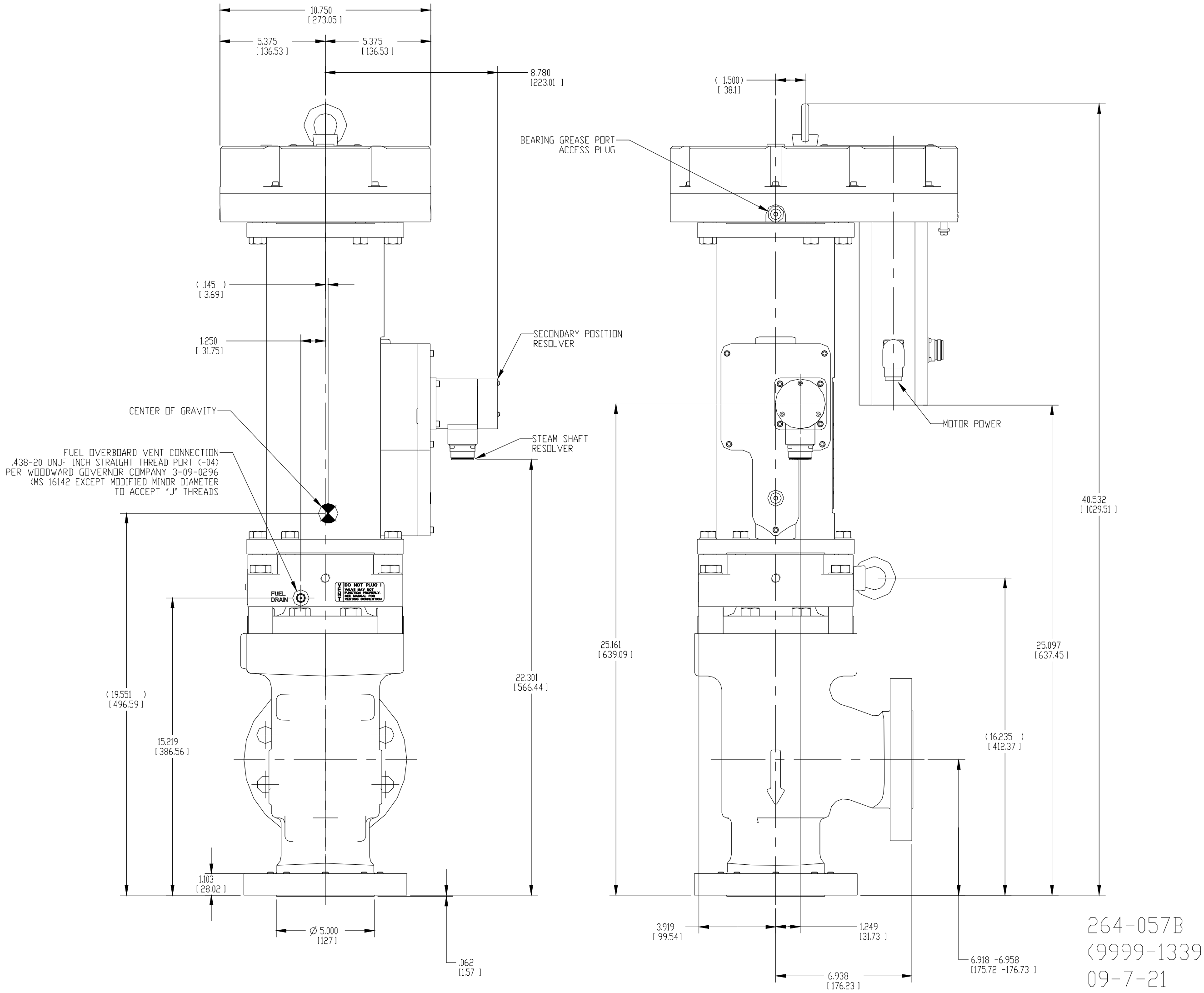

Figure 4-2b. Outline Drawing 3" LESV (Right View)

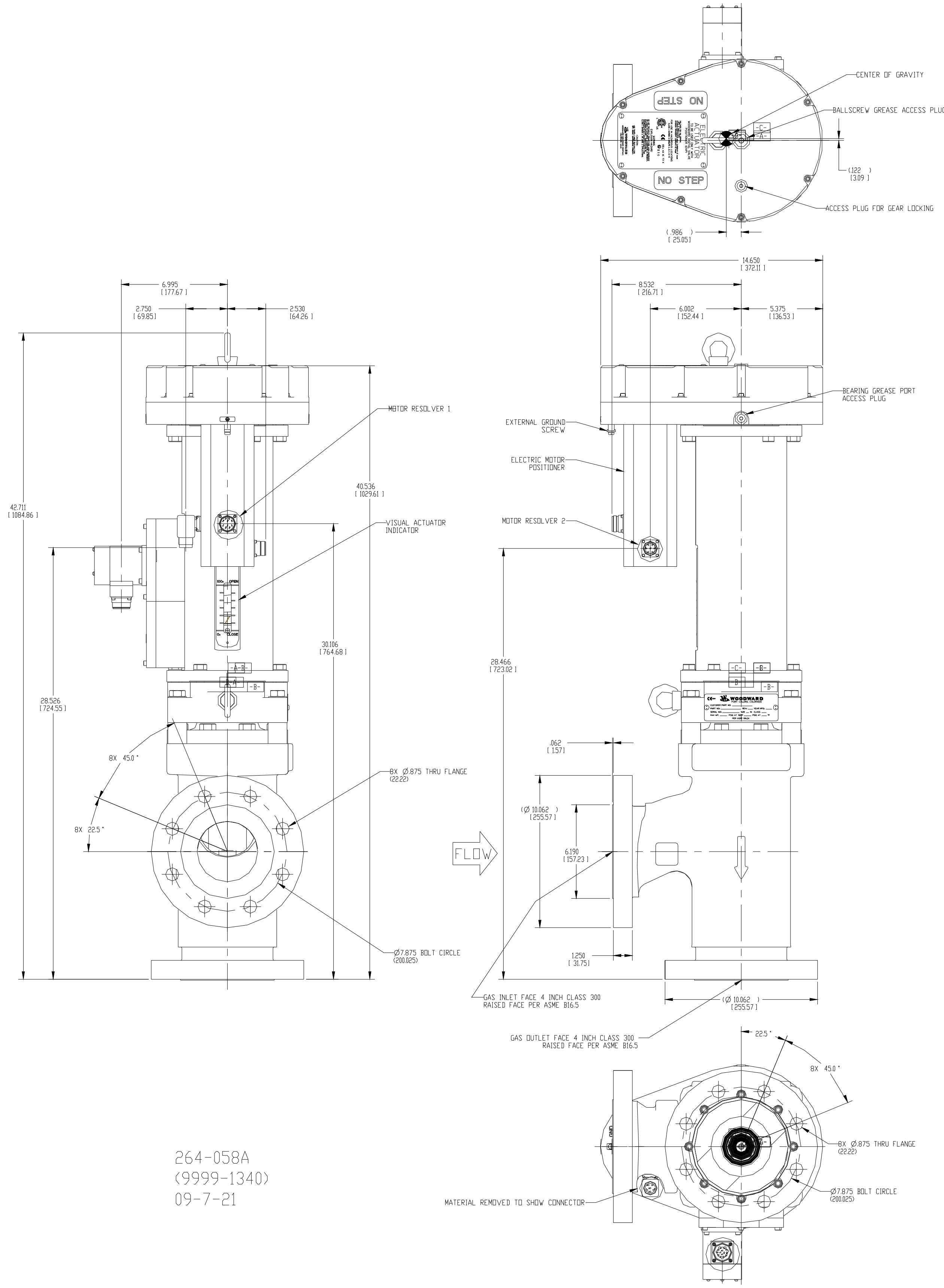

Figure 4-3a. Outline Drawing 4" LESV (Left View)

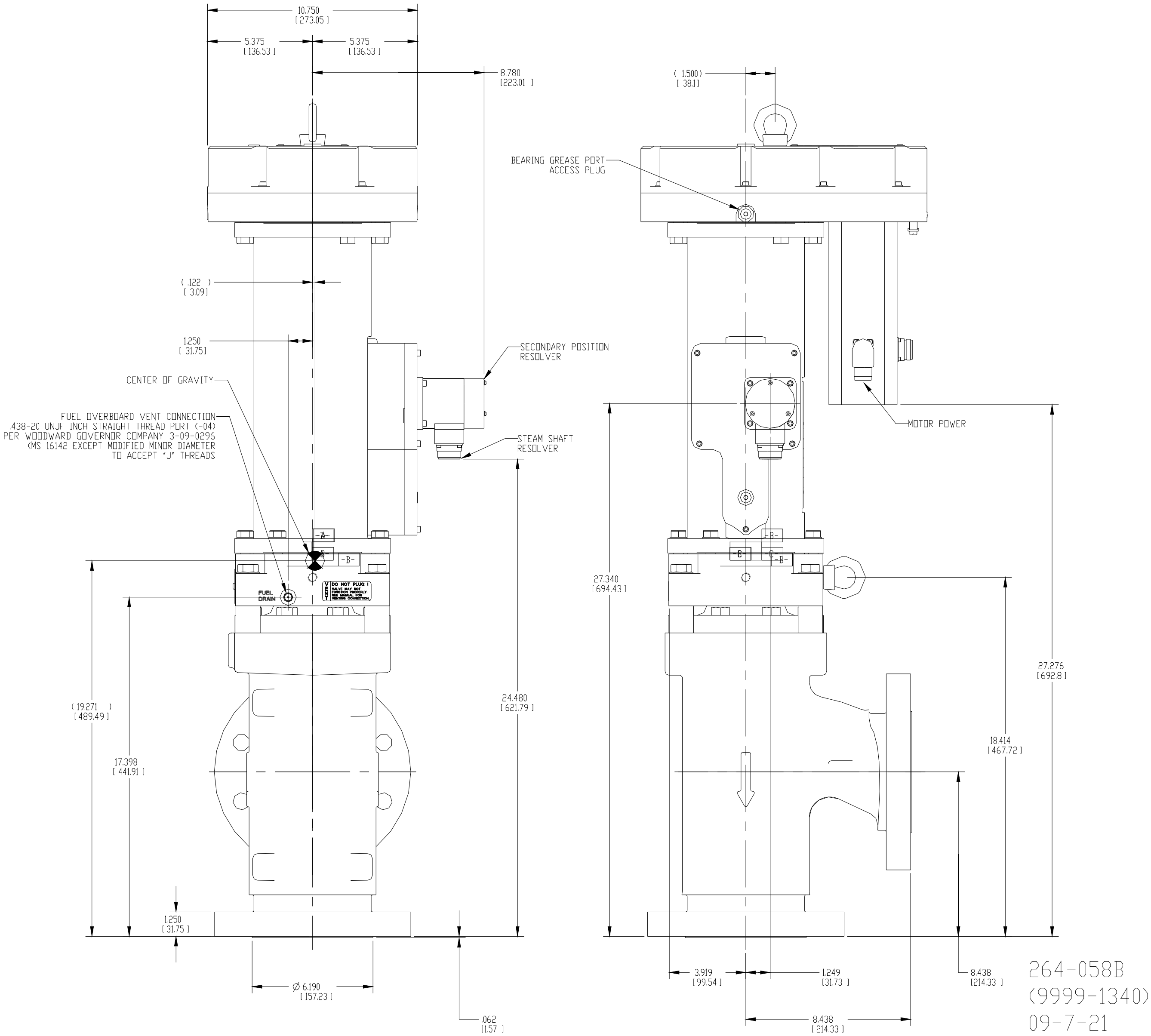

Figure 4-3b. Outline Drawing 4" LESV (Right View)

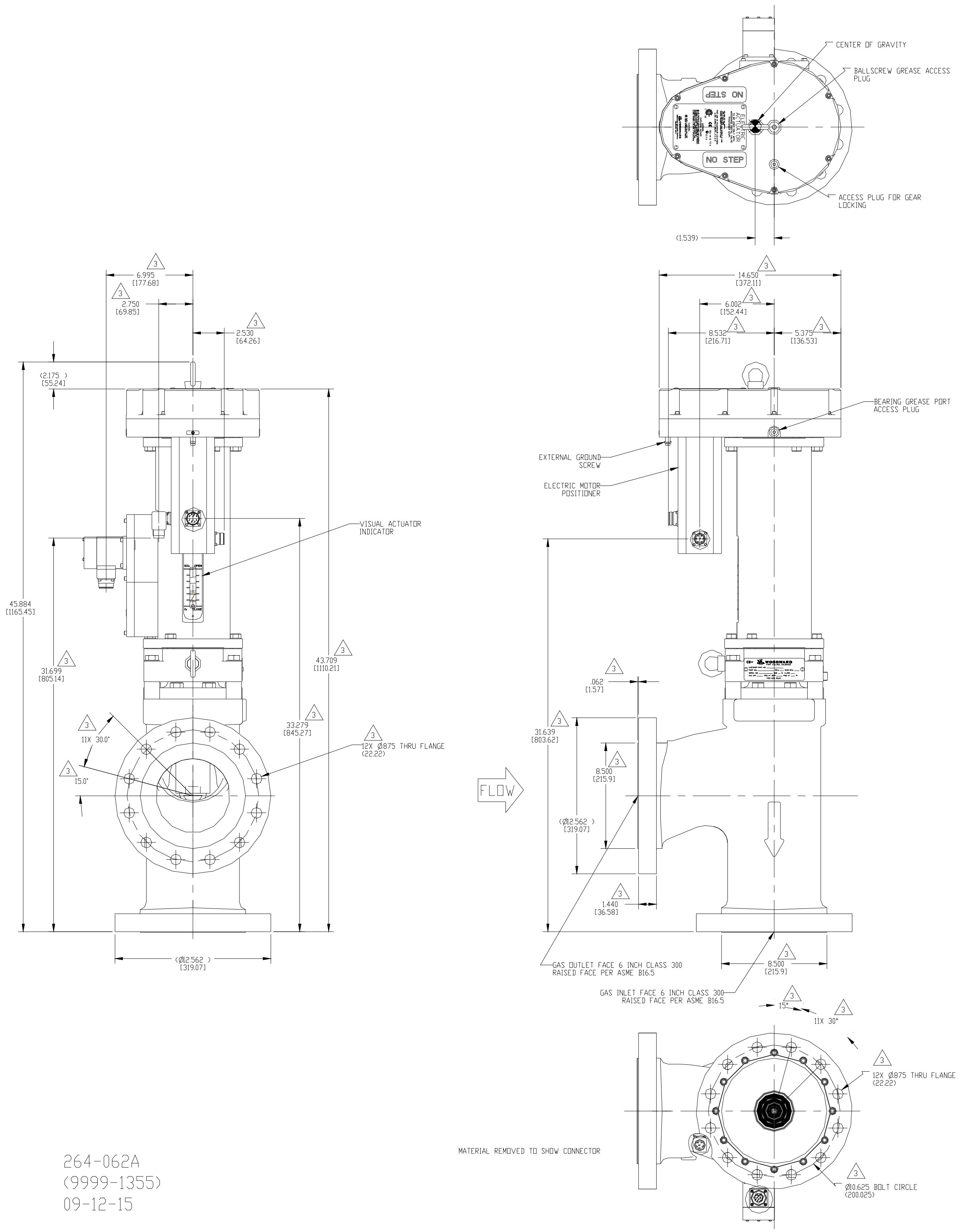

Figure 4-4a. Outline Drawing 6" LESV (Left View)

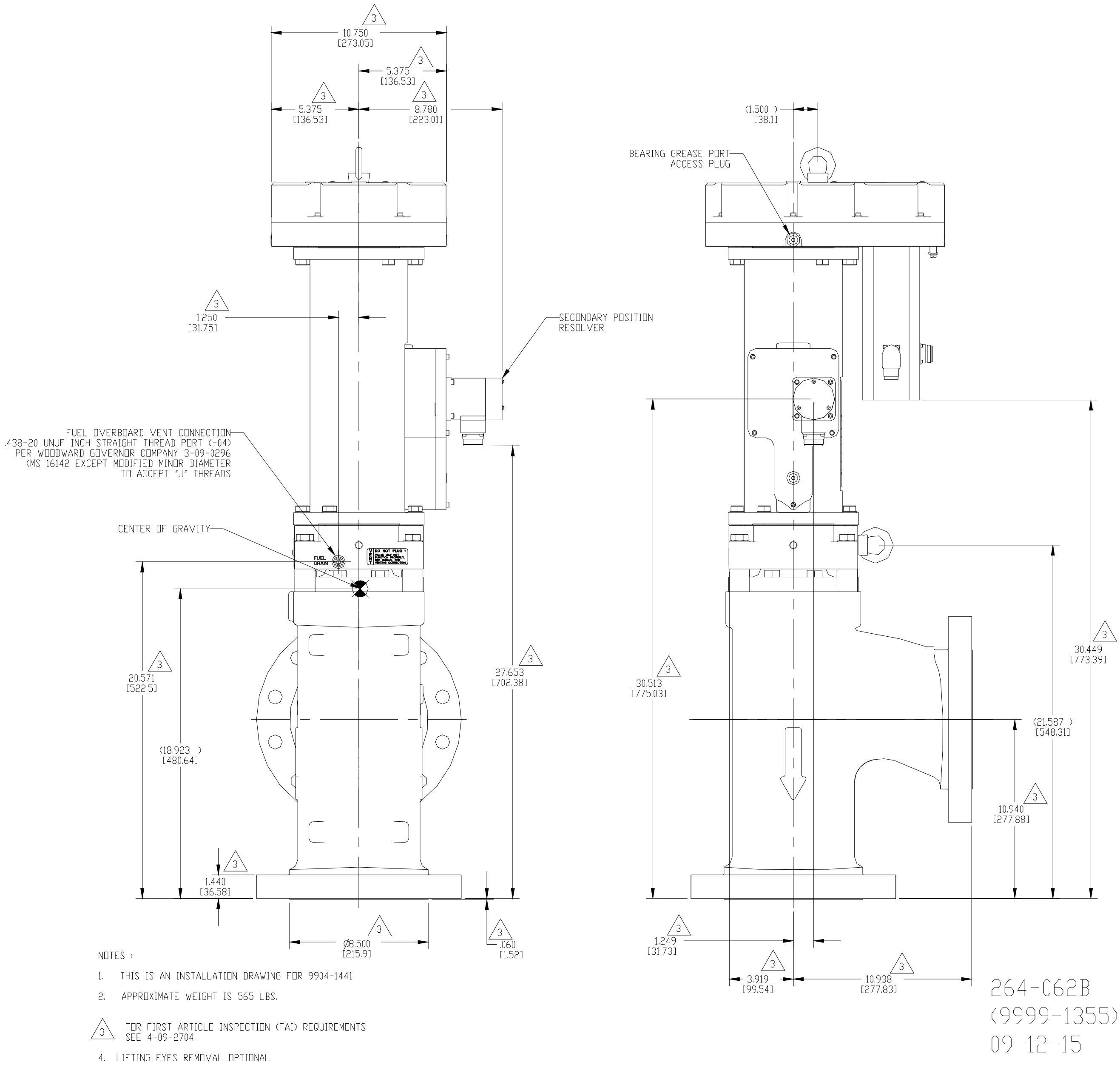

Figure 4-4b. Outline Drawing 6” LESV (Right View)

High Recovery Valve installation Considerations

In the event the valves supplied are considered High Recovery, the following feature (extension) is added in addition to the outline drawing dimensions for the outlet flange. Take care not to damage the extension and do not use the extension to support the valve.

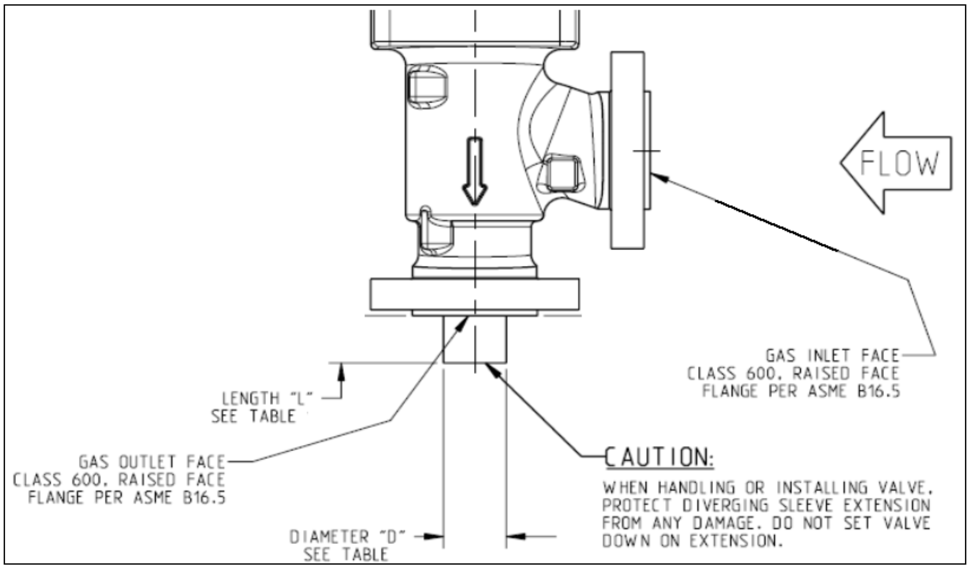

Figure 4-3. Representative Outline Deviation of High Recovery Valves

Table 1. Dimensions “L” and “D” per Figure 1-5 for High Recovery LESVs

Valve Size	Dimension “L” (Inches)	Dimension “D” (Inches)	Recovery Factor
2-Inch	1.500	1.670	1.08
3-Inch	3.700	2.620	1.08
4-Inch	5.000	3.250	1.08
6-Inch	7.000	4.500	1.08

Table 2. Dimensions “L” and “D” per Figure 1-5 for Ultra High Recovery LESVs

Valve Size	Dimension “L” (Inches)	Dimension “D” (Inches)	Recovery Factor
2-Inch	4.000	1.880	1.06
3-Inch	6.000	2.810	1.06
4-Inch	8.000	3.960	1.06
6-Inch	12.000	5.580	1.06

LESV Functional Description

The electrical-mechanical actuator consists of a brushless dc motor that provides torque, an integral resolver for motor commutation and position feedback to the controller, a valve stem resolver for motor resolver verification, and a high-efficiency ball screw for rotary-to-linear motion conversion. The actuator also contains a fail-safe spring designed to extend the actuator if power is removed from the actuator.

- A soft-stop spring to dissipate motor rotor inertia during fail-safe shutdown and prevent ball screw damage
- A cam follower to provide apposing torque during slew operations
- A lifting eye to aid installation

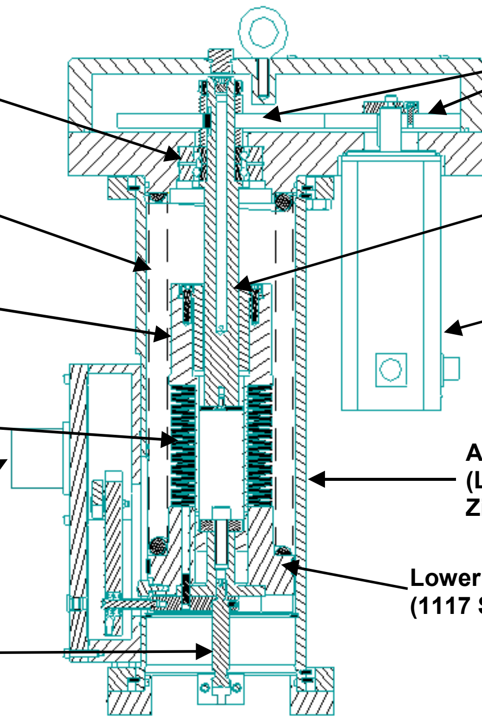

Figure 4-4. Electrical Mechanical Actuator

Brushless DC Motor

The motor used on the LESV is a permanent magnet, electrically commutated, brushless dc motor. The components used in the motor are rated for service from –40 to +155 °C (–40 to +311 °F). The motor is a permanently lubricated assembly with a sealed enclosure rating of IP55.

Resolver Position Feedback Sensors

The primary position feedback transducer is the resolver that is integral to the dc brushless motor. Dual resolver motors are used on standard trim sizes. The actuator also has a valve stem resolver. This resolver is used as a watchdog function of the primary motor control, to prevent runaway conditions and to ensure that the primary motor resolver is reading correctly. Linear shaft motion is converted to angular rotation for the valve stem resolver through a linkage. Parameter files are loaded onto the DVP to specifically match the valve characteristics in order to obtain the most accurate position sensing.

Soft Stop Spring

Integral to the actuator is a soft stop spring. This provides a bumper like action if the actuator is driven hard into the fully extended position. This will occur only on loss of power, certain wiring faults, and in rare cases, internal fault conditions within the positioner. The soft stop mechanism is not used when the positioner is controlling the actuator. Although the positioner will rapidly drive the actuator towards the minimum position, it also decelerates the actuator as the actuator approaches the mechanical minimum stop. Under the control of the positioner, the actuator should not reach the mechanical minimum stop at a high velocity.

Valve

The SonicFlo contoured plug valve consists of a valve housing, metering plug, diverging sleeve, pilot sleeve/bonnet, and actuator adapter. The metering elements of this valve are a contoured plug and a hardened seat. The plug is contoured to provide various Cg versus position flow characteristics from 0% to 100% stroke. Please contact Woodward for available trim sizes and Cg profiles.

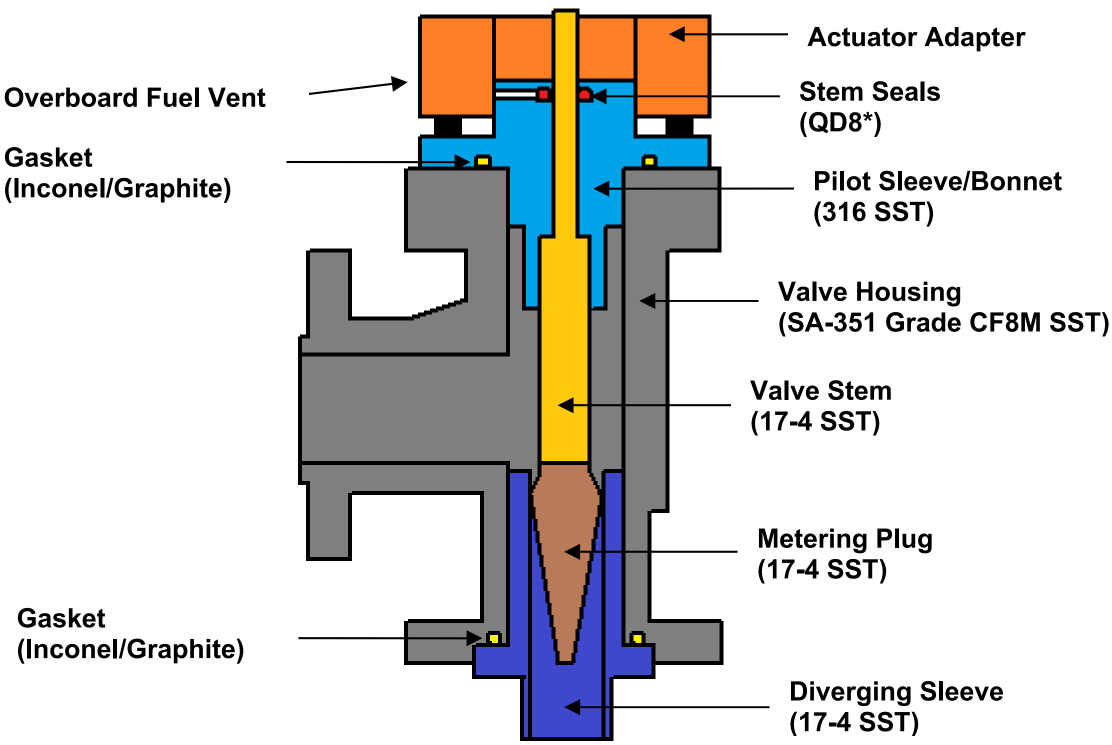

Figure 4-5. Valve Cross Section
*Material will vary depending on specification and item number

Fuel Overboard Vent Connection

There is a fuel overboard vent port that must be vented to a safe location. In normal operation, this vent should have very low leakage.

Digital Valve Positioner (DVP)

The Digital Valve Positioner (DVP) is a digital electronic position driver used to control actuation systems on reciprocating engines and turbines. The DVP is designed to control valves and actuators with either limited angle torque (LAT) or brushless DC (BLDC) motor types. The driver provides position output based on resolver feedback located on the valve or actuator. The DVP uses the latest in Woodward control architecture and a robust controller to provide high-speed precise valve control.

The DVP is designed for plug-and-play installations on many valve types. Woodward has integrated smart technology into the new generation of valves and actuators called an ID (identification) module. Upon connection to a valve or actuator equipped with an ID module, the DVP will automatically read critical valve-specific information to set up the driver. After this auto-detection and customer interface configuration, the DVP is ready for use.

The DVP is designed to accept many different types of input commands, including Ethernet, Analog Input (4–20 mA or 0–5 V), CAN, or PWM. Woodward also provided a Service Tool that allows users to manipulate, configure, and monitor the DVP operation status.

The Woodward DVP is suitable for +24 VDC or +125 VDC input power supply operation and meets IP30 or IP56 environments. (Contact Woodward for more details and/or reference the Digital Valve Positioner Installation and Operation manual number 26329.)

Production Testing

Production testing for each shipped LESV includes, but is not limited to:

1) Bench Testing:
    - Forward and reverse seat leakage
    - Proof/hydrostatic test
    - Valve stem seal leakage/overboard vent leakage

2) End of Line Testing:
    - Load product identification settings
    - Scale resolvers
    - Fail safe test
    - Slew open and slew closed test
    - Valve stem seal leakage/overboard vent leakage
    - ID module programming

3) Flow Testing:
    - Cg verification
    - Recovery verification

Chapter 5.
Product Maintenance

Component Maintenance Recommendations

The following recommendations regarding Woodward designed and manufactured auxiliary components have been developed to properly ensure the reliability, availability, and "safety of operation" expectations established for turbine engines. These recommendations include Woodward gas valves, actuators and mechanical controls. While there are electronic control systems designed to monitor and diagnose the operational performance of these components, control monitoring cannot replace normal preventative maintenance practices. It is important to follow these recommendations in order to avoid unnecessary and unscheduled shutdowns.

A detailed analysis has compared repair records of returned units, field data and design criteria to determine the following recommendations. An overhaul of the component should be completed on or before the unit reaches the recommended range of "Operating Hours" not to exceed 6 years in service. Recommendations are appropriately aligned with the standard OEM turbine maintenance schedules which are based on "normal" operating conditions, environment, fuel quality, and past maintenance history. Installations that do not meet "normal" operating conditions may require customized maintenance cycles to maximize reliability, performance and asset life. Contact your local Woodward representative for a detailed evaluation of your site conditions to determine the right maintenance cycles for your installation.

Woodward's overhaul services will return the unit to "like new" condition ready for another full operating cycle to your next planned maintenance outage. Upon reaching the recommended maintenance cycle of the auxiliary component, please contact either the sites turbine OEM service representative, local Woodward Distributor or Woodward Authorized Independent Service Facility to facilitate services. A directory of your local Woodward authorized distributor or service facility can be found on the Woodward website at www.woodward.com/support/directory.cfm.

Woodward Product Maintenance Recommendations (Revision 3)

Product Name	Maintenance Recommendation	
	Operating Hours*	Years in Service
AERO DERIVATIVE:		
Hydraulic Control Unit	50,000 Hours	6 years
Variable Geometry Hydromechanical Control	50,000 Hours	6 years
Variable Geometry Electromechanical Control	50,000 Hours	6 years
Variable Stator Vane Actuators	50,000 Hours	6 years
1907 Small Liquid Valves	25,000 Hours	3 years
1907 Large Liquid Valves	50,000 Hours	6 years
Liquid Shutoff Valves	50,000 Hours	6 years
LQ25 & LQ25T Liquid Metering Valves	50,000 Hours	6 years
1907 Small Gas Valves	25,000 Hours	3 years
3103/3171 Gas Valve with Hydraulic Actuator	50,000 Hours	6 years
3103/3171 Gas Valve with Electric Actuator	50,000 Hours	6 years
Gas Shutoff Valve	50,000 Hours	6 years
GS3/GS10 Gas Metering Valve	25,000 Hours	6 years
GS6/GS16 Gas Metering Valve	50,000 Hours	6 years
3151 Water Metering Valve	50,000 Hours**	6 years**
CIT/CDP Sensor	50,000 Hours	6 years
2057 Pump	50,000 Hours	6 years

HEAVY FRAME:		
Globe Gas Fuel Control Valve (Hydraulic and Electric Actuated)	50,000 Hours	6 years
SonicFlo Gas Fuel Control Valve (Hydraulic and Electric Actuated)	50,000 Hours	6 years
Rotary Gas Fuel Control Valve (Hydraulic and Electric Actuated)	50,000 Hours	6 years
3-Way Liquid Fuel Control Valve (Hydraulic Actuated)	50,000 Hours	6 years
2 - Way Liquid Fuel Valve (Hydraulic and Electric Actuated)	50,000 Hours	6 years
2 – Way Water Metering Valve (Hydraulic and Electric Actuated)	50,000 Hours	6 years
Inlet Guide Vane (IGV) Actuator	50,000 Hours	6 years
Variable Guide Vane (VGV)	50,000 Hours	6 years

*Woodward considers its valves and actuators as key components in the overall fuel efficiency, emissions control, and safety of the gas turbine. Therefore, we recommend that our products be overhauled at the same regular intervals that the gas turbine “Hot Section” or “Major Inspections” occur. Please consult the Gas Turbine OEM guidelines for recommended service intervals for your turbine.

** Per the product maintenance manual complete sleeve indexing maintenance procedure as recommended.

Manual 40120 “3151A Water Valve/TM-40LP Actuator Assembly for Gas Turbine Water Injection System”

Manual 40181 “3151A Water Valve EML100 Actuator Assembly for Gas Turbine Water Injection System”

Chapter 6. Product Support and Service Options

Product Support Options

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see “How to Contact Woodward” later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM or Packager Support: Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

Woodward Business Partner Support: Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

A current list of Woodward Business Partners is available at www.woodward.com/directory.

Product Service Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in “like-new” condition and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:

- return authorization number;
- name and location where the control is installed;
- name and phone number of contact person;
- complete Woodward part number(s) and serial number(s);
- description of the problem;
- Instructions describing the desired type of repair.

Packing a Control

Use the following materials when returning a complete control:

- protective caps on any connectors;
- antistatic protective bags on all electronic modules;
- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

NOTICE	**To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Replacement Parts

When ordering replacement parts for controls, include the following information:

- the part number(s) (XXXX-XXXX) that is on the enclosure nameplate;
- the unit serial number, which is also on the nameplate.

Engineering Services

Woodward offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- Technical Support
- Product Training
- Field Service

Technical Support is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

Field Service engineering on-site support is available, depending on the product and location, from many of our worldwide locations or from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact us via telephone, email us, or use our website: **www.woodward.com**.

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at **www.woodward.com**, which also contains the most current product support and contact information.

You can also contact the Woodward Customer Service Department at one of the following Woodward facilities to obtain the address and phone number of the nearest facility at which you can obtain information and service.

Products Used in Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany:	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (32) 422-5551
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Products Used in Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+ 82 (32) 422-5551
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Products Used in Industrial Turbomachinery Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+ 82 (32) 422-5551
The Netherlands	+31 (23) 5661111
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Technical Assistance

If you need to contact technical assistance, you will need to provide the following information. Please write it down here before contacting the Engine OEM, the Packager, a Woodward Business Partner, or the Woodward factory:

General

Your Name ______________________

Site Location ______________________

Phone Number ______________________

Fax Number ______________________

Prime Mover Information

Manufacturer ______________________

Turbine Model Number ______________________

Type of Fuel (gas, steam, etc.) ______________________

Power Output Rating ______________________

Application (power generation, marine, etc.) ______________________

Control/Governor Information

Control/Governor #1

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #2

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #3

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Symptoms

Description ______________________

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If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.

Revision History

Changes in Revision —

- New Application Note

Woodward appreciates your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 51548.

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Complete address / phone / fax / email information for all locations is available on our website.