WOODWARD

Product Manual 26374
(Revision L, 5/2016)
Original Instructions

IGV (Inlet Guide Vane) Actuator

9FA / 9FB Turbines

Installation and Operation Manual

General Precautions	**Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.** **Practice all plant and safety instructions and precautions.** **Failure to follow instructions can cause personal injury and/or property damage.**

Revisions	**This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, on the *publications page* of the Woodward website:** **www.woodward.com/publications** **The latest version of most publications is available on the *publications page*. If your publication is not there, please contact your customer service representative to get the latest copy.**

Proper Use	**Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.**

Translated Publications	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. Be sure to check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.**

Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

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Illustrations and Tables

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Important Definitions

⚠ This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER** - Indicates a hazardous situation, which if not avoided, will result in death or serious injury.
- **WARNING -** Indicates a hazardous situation, which if not avoided, could result in death or serious injury.
- **CAUTION** - Indicates a hazardous situation, which if not avoided, could result in minor or moderate injury.
- **NOTICE** - Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT** - Designates an operating tip or maintenance suggestion.

⚠WARNING **Overspeed / Overtemperature / Overpressure**	**The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.** **The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.**

⚠WARNING **Personal Protective Equipment**	**The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:** • **Eye Protection** • **Hearing Protection** • **Hard Hat** • **Gloves** • **Safety Boots** • **Respirator** **Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.**

⚠WARNING **Start-up**	**Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.**

Electrostatic Discharge Awareness

NOTICE

Electrostatic Precautions

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:

- **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).**
- **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.**
- **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.**

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*.

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Regulatory Compliance

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

ATEX – Potentially Explosive Atmospheres Directive: Declared to Directive 2014/34/EU on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.

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

EMC Directive: Not applicable to this product. Electromagnetically passive devices are excluded from the scope of the 2014/30/EU Directive.

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.

Pressure Equipment Directive: Compliant as "SEP" per Article 4.3 to Pressure Equipment Directive 2014/68/EU on the harmonisation of the laws of the Member States concerning pressure equipment.

ATEX: Exempt from the non-electrical portion of the ATEX Directive 2014/34/EU due to no potential ignition sources per EN 13463-1.

Other International Compliance:

IECEx: This suitability is the result of IECEx compliance of the individual components as follows:
Servo Valve per IECEx KEM 10.0041X Ex nA IIC T3 Gc
LVDT per IECEx ITS 10.0032X Ex nAc II T3
Trip solenoid per IECEx ETL 13.0020X Ex nA IIC T3 Gc
Woodward QAR for assembly: DE/TUR/QAR/11.0002/00
Refer to individual component certificates for special conditions of safe use.

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 per 4B9A6.AX for use in the United States. CSA Certified for use in Canadian Class I, Division 2, Groups A, B, C, D as a component for use in other equipment subject to acceptance by CSA or Inspection Authority having jurisdiction, per CSA 1072373.

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

Electric Trip Solenoid: ETL Certified for Class I, Division 2, Groups A, B, C, D per 3168365CRT-004 for use in the United States and Canada.

Special Conditions for Safe Use

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.

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 121 °C.

The risk of electrostatic discharge is reduced by permanent installation of the actuator and care when cleaning. The actuator should not be cleaned unless the area is known to be non-hazardous.

⚠WARNING

EXPLOSION HAZARD—Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2 or Zone 2 applications.

⚠AVERTISSEMENT

RISQUE D'EXPLOSION—Ne pas raccorder ni débrancher tant que l'installation est sous tension, sauf en cas l'ambiance est décidément non dangereuse.

La substitution de composants peut rendre ce matériel inacceptable pour les emplacements de Classe I, applications Division 2 ou Zone 2.

Chapter 1.
General Information

Introduction

The Woodward IGV (Inlet Guide Vane) actuator provides highly accurate position control of the inlet guide vanes on large industrial gas turbines. This actuator is a double-acting design that will close the guide vane on loss of electrical or hydraulic signals. An on-board hydraulic filter is designed into the manifold to augment the reliability of the servo valve and actuator. The servo valve is an electrically redundant triple-coil design. Dual- or triple-redundant ac-powered LVDTs provide feedback for the actuator.

The IGV actuator performs a dual function for the gas turbine. One function provides accurate position control of the turbine inlet guide vanes during normal engine operation. The other function rapidly closes the guide vanes in a “trip” situation, rapidly reducing the air flow through the compressor stages.

The Woodward IGV actuator features a modular design which allows the actuator platform to meet critical control characteristics on a variety of large turbines with various force output and mechanical interface requirements. The electrical and mechanical interfaces have been designed for quick and easy assembly or removal of service components at the factory or in the field. These components include an on-board hydraulic filter, electrohydraulic servo valve, trip valves, and dual or triple LVDTs.

Optimum control of the inlet guide vane requires that the actuator accurately and quickly track the demand signals transmitted by the control. The Woodward IGV actuator has been designed to provide output forces that exceed the opening and closing requirements. The additional margin helps ensure that the system moves rapidly even under service conditions where the system has been contaminated or worn. The hydraulic trip relay valves have been selected to provide high operating force margins, and to ensure the desired closure rate of the actuator under trip conditions.

Three different trip systems are available on the Frame 9F actuators—low pressure trip for simple cycle turbines or those with separate trip systems, high pressure trip for single-shaft STAG units sharing the trip oil system with the steam turbine, and electric trip for simple cycle turbines with separate electric trip system. The high pressure trip versions also include connections for an optional accumulator and built-in cartridge type check valve.

IGV Actuator Functional Characteristics

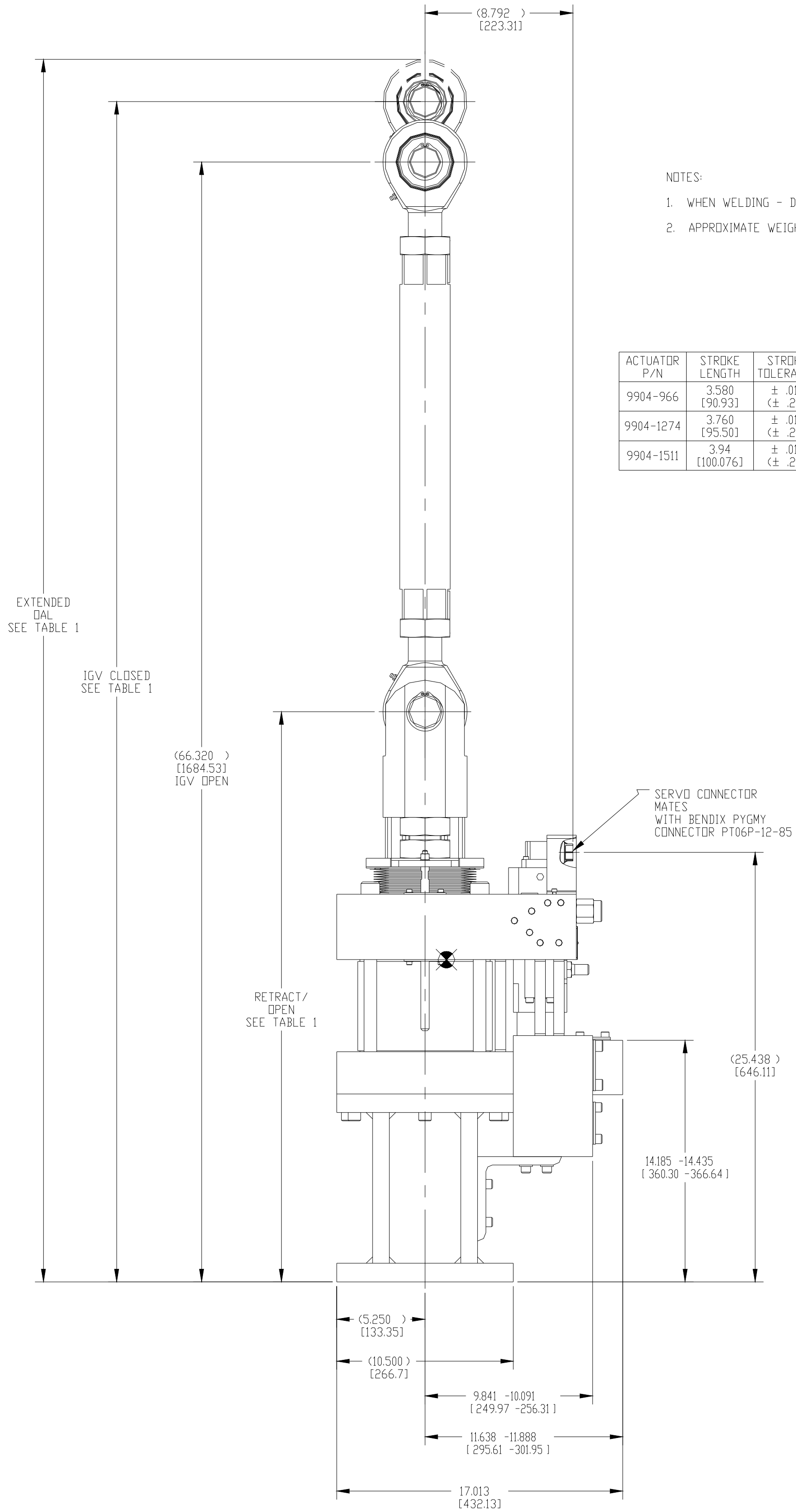
Functional Requirement		IGV Actuator
Position Accuracy		±1 % full scale (over ±14 °C/±25 °F deviation from calibration)
Position Repeatability		±0.5 % of point over the range of 10 % to 100 %
Hydraulic Fluid Type		Petroleum-based hydraulic fluids as well as fire resistant hydraulic fluids such as Fyrquel EHC
Maximum Operating Hydraulic Supply Pressure		(9653 to 12 411) kPa / (1400 to 1800) psig (design at 11 722 kPa/1700 psig)
Proof Test Fluid Pressure Level		18 616 kPa (2700 psig) minimum per SAE J214 (Prod Test)
Minimum Burst Fluid Pressure		31 264 kPa (4500 psig) minimum per SAE J214
Fluid Filtration Required		10 µm to 15 µm at 75 Beta
Hydraulic Fluid Contamination Level		Per ISO 4406 code 18/16/13 max, code 16/14/11 preferred
Hydraulic Fluid Temperature		(+10 to +71) °C / (+50 to +160) °F
Actuator Ambient Temperature		(–40 to +121) °C / (–40 to +250) °F
Vibration Test Level		0.5 gp 5 Hz to 100 Hz sine wave Random 0.01500 gr²/Hz from 10 Hz to 40 Hz ramping down to 0.00015 gr²/Hz at 500 Hz
Shock		Limited to 30 G by servo valve
Trip Time		Less than 5 seconds at 11 032 kPa (1600 psi) supply pressure, 38 °C / 100 °F oil temperature and (13 to 22) kN / (3000 to 5000) lbf load (100 % to 0 % stroke)
Slew Time	For 9FA Turbine	0 % to 100 % in (4.5 ± 1.5) seconds and 100 % to 0 % in (5.0 ± 1.5) s. Exception for 3.94 inch stroke units: 0 % to 100 % in (5.0 ± 1.5) s and 100 % to 0 % in (5.0 ± 1.5) s
	For 9FB Turbine	0 % to 100 % in (5.0 +1.0/–1.5) seconds and 100 % to 0 % in (5.0 +1.0/–1.5) s. Exception for 3.94 inch stroke units: 0 % to 100 % in (5.0 ± 1.5) s and 100 % to 0 % in (5.0 ± 1.5) s
Trip Pressure (Low Press Hyd Trip Option)		Pick up and drop out pressures to be ≤207 kPa (30 psid) (relative to hydraulic return)
Trip Pressure (High Press Hyd Trip Option)		Pick up ≤8274 kPa (1200 psid) (relative to hyd return) Drop out ≤4137 kPa (600 psid) (relative to hyd return)
Hydraulic Fluid Connections	For 9FA Turbine (Low Press Hyd. Trip Option, Electric Trip Option)	Trip Relay Pressure (only for actuator with hydraulic trip relay)—-0.500 SAE Code 61 flange port (-8) Supply Pressure–0.750 SAE Code 61 flange port (-12) Return Port–1.250 SAE Code 61 flange port (–20)
	For 9FB Turbine (Low Press Hyd. Trip Option, Electric Trip Option)	Trip Relay Pressure (only for actuator with hydraulic trip relay)—-0.500 SAE Code 61 flange port (-8) Supply Pressure(only for actuator with hydraulic trip relay) –0.750 SAE Code 61 flange port (-12) Return Port(only for actuator with hydraulic trip relay) –1.250 SAE Code 61 flange port (–20)
		Supply Pressure(only for actuator with Electric Trip Solenoid) —-1.062-12 UN straight thread port (-12) Return Port(only for actuator with Electric Trip Solenoid) —-1.000-11.5 NPTF
	For 9FB Turbine (High Press Hyd. Trip Option)	Trip Relay Pressure—-0.750-16 UNF straight thread port (-08) Supply Pressure—-1.062-12 UN straight thread port (-12) Return Port–1.000-11.5 NPTF Hydraulic Drain Accumulator —-0.562-18 UNF straight thread port (-06) Hydraulic Supply Accumulator —-.750-16 UNF straight thread port (-08)
Servo Input Current Rating		–7.2 mA to +8.8 mA (null bias 0.8 mA ± 0.32 mA)
Paint		Two part Epoxy
Actuation Forces (opening and closing at 11 722 kPa / 1700 psig		Retract Force (open)—253 887 N / 57 079 lb Extend Force—291 006 N / 65 424 lb
Design Availability Objective		Better than 99.5 % over an 8760 hour period

NOTES:

1. WHEN WELDING – DO NOT USE ELECTRICAL COMPONENTS AS WELDING GROUND.
2. APPROXIMATE WEIGHT: 500 LBS.

TABLE 1

ACTUATOR P/N	STROKE LENGTH	STROKE TOLERANCE	RETRACT/ OPEN	EXTENDED OAL	IGV CLOSED	LINKAGE LENGTH
9904-966	3.580 [90.93]	± .010 (± .25)	33.639-33.889 [854.44-860.78]	72.400 [1838.96]	69.900 [1775.46]	32.056-33.056 [814.23-839.62]
9904-1274	3.760 [95.50]	± .010 (± .25)	33.459-33.709 [849.86-856.21]	72.580 [1843.53]	70.080 [1780.03]	32.236-33.236 [818.79-844.19]
9904-1511	3.94 [100.076]	± .010 (± .25)	33.279-33.529 [845.28-851.63]	72.76 [1848.1]	70.26 [1784.6]	32.416-33.416 [823.36-848.76]



263-050A
(9999-3056)
2010-2-18

Figure 1-1a. 9F IGV Actuator, Low Pressure Trip (left side view)

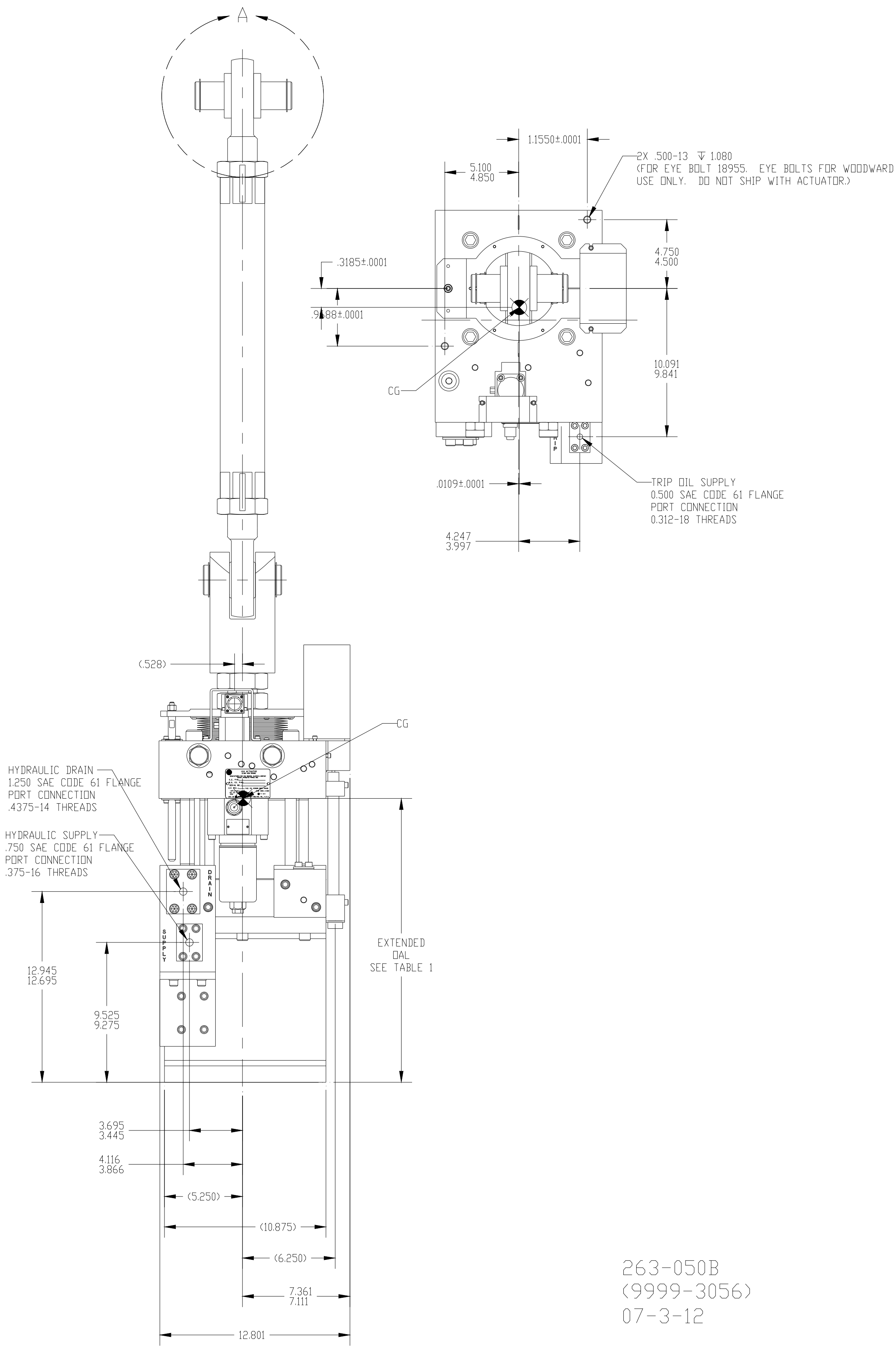


Figure 1-1b. 9F IGV Actuator, Low Pressure Trip (front and top views)

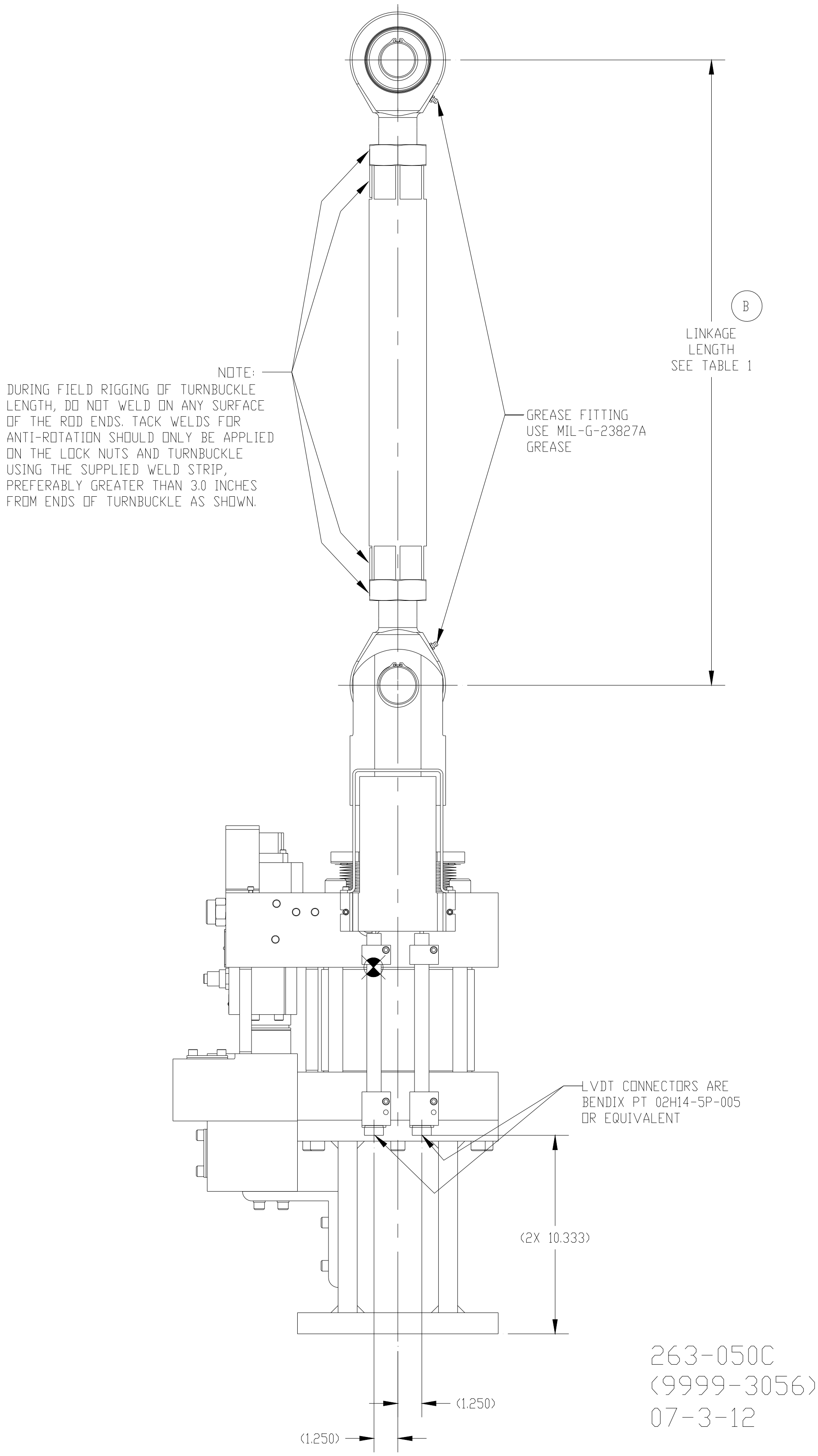


Figure 1-1c. 9F IGV Actuator, Low Pressure Trip (right side view)

NOTES:

1. THIS IS AN INSTALLATION DRAWING OF THE ACTUATORS LISTED IN TABLE 1.
2. APPROXIMATE WEIGHT: 507 LBS
3. WHEN WELDING, DO NOT USE ELECTRICAL COMPONENTS AS WELDING GROUND.

TABLE 1

	STROKE LENGTH	STROKE TOLERANCE	(RETRACTED /OPEN)	LINKAGE LENGTH	EXTENDED OAL	EXTENDED CONNECTION PIN	RETRACTED CONNECTION PIN
9904-1206	3.580 [90.93]	± .010 (± .25)	33.764 [857.61]	30.076 [763.93]	69.920 [1775.97]	67.420 [1712.47]	63.840 [1621.54]
9904-1207	3.760 [95.50]	± .010 (± .25)	33.584 [853.03]	32.736 [831.49]	72.400 [1838.96]	70.080 [1780.032]	66.320 [1684.53]
9904-1512	3.94 [100.076]	± .010 (± .25)	33.404 [848.46]	30.39 [771.91]	70.23 [1783.84]	67.73 [1720.34]	63.79 [1620.27]
9904-1980	3.94 [100.076]	± .010 (± .25)	33.404 [848.46]	30.39 [771.91]	70.23 [1783.84]	67.73 [1720.34]	63.79 [1620.27]

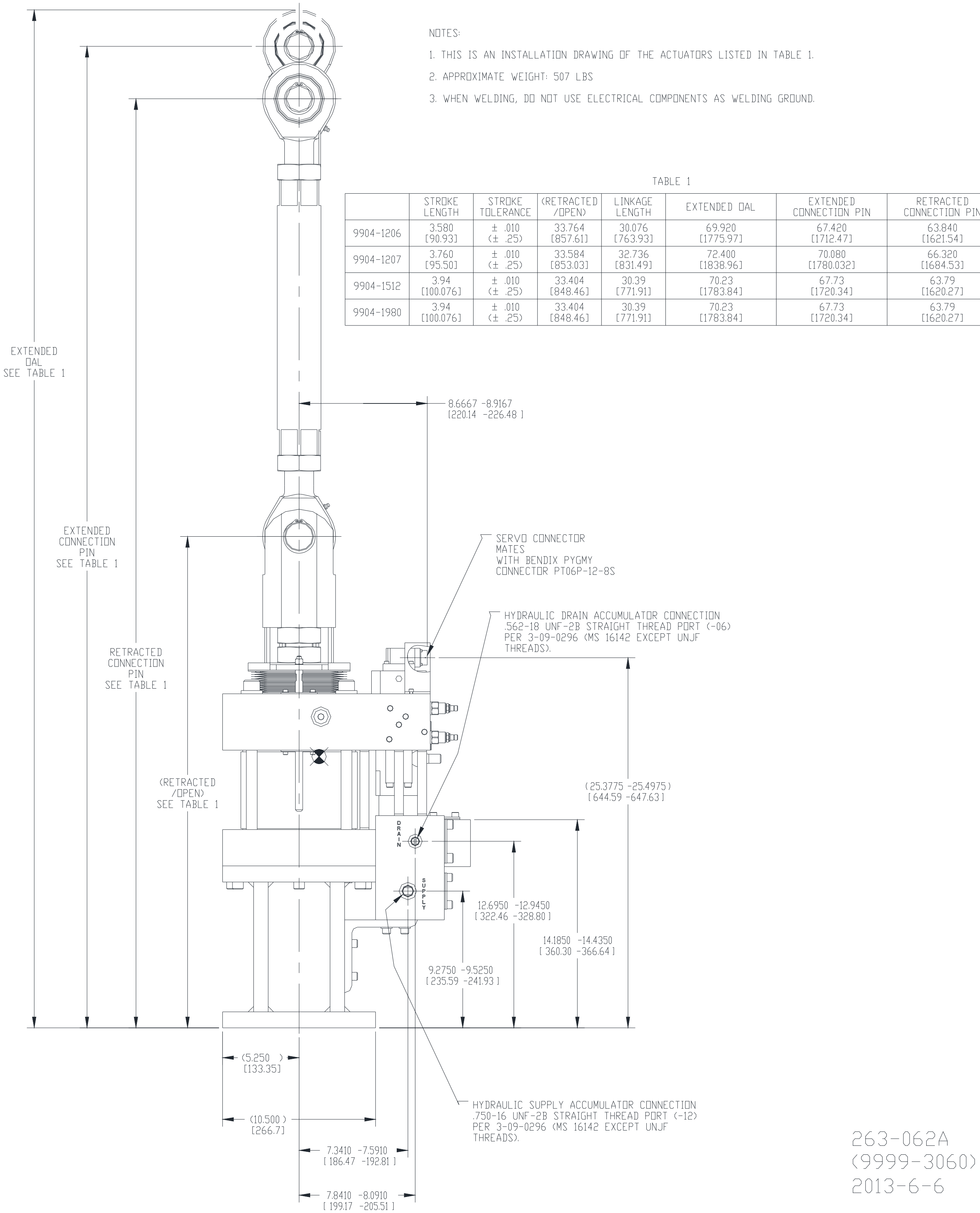


Figure 1-2a. 9F IGV Actuator, High Pressure Trip without internal check valve (left side view)

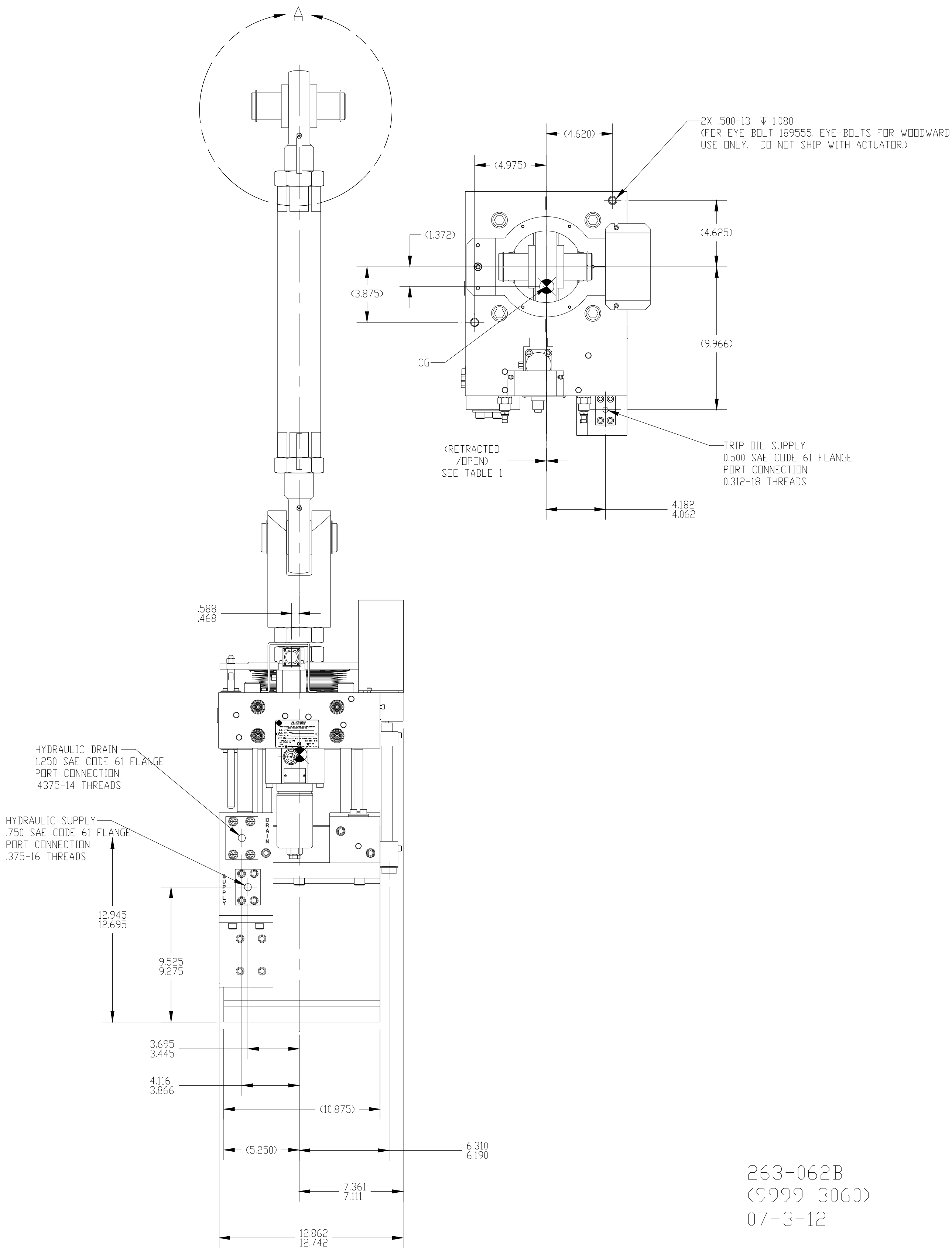


Figure 1-2b. 9F IGV Actuator, High Pressure Trip without internal check valve (front and top views)

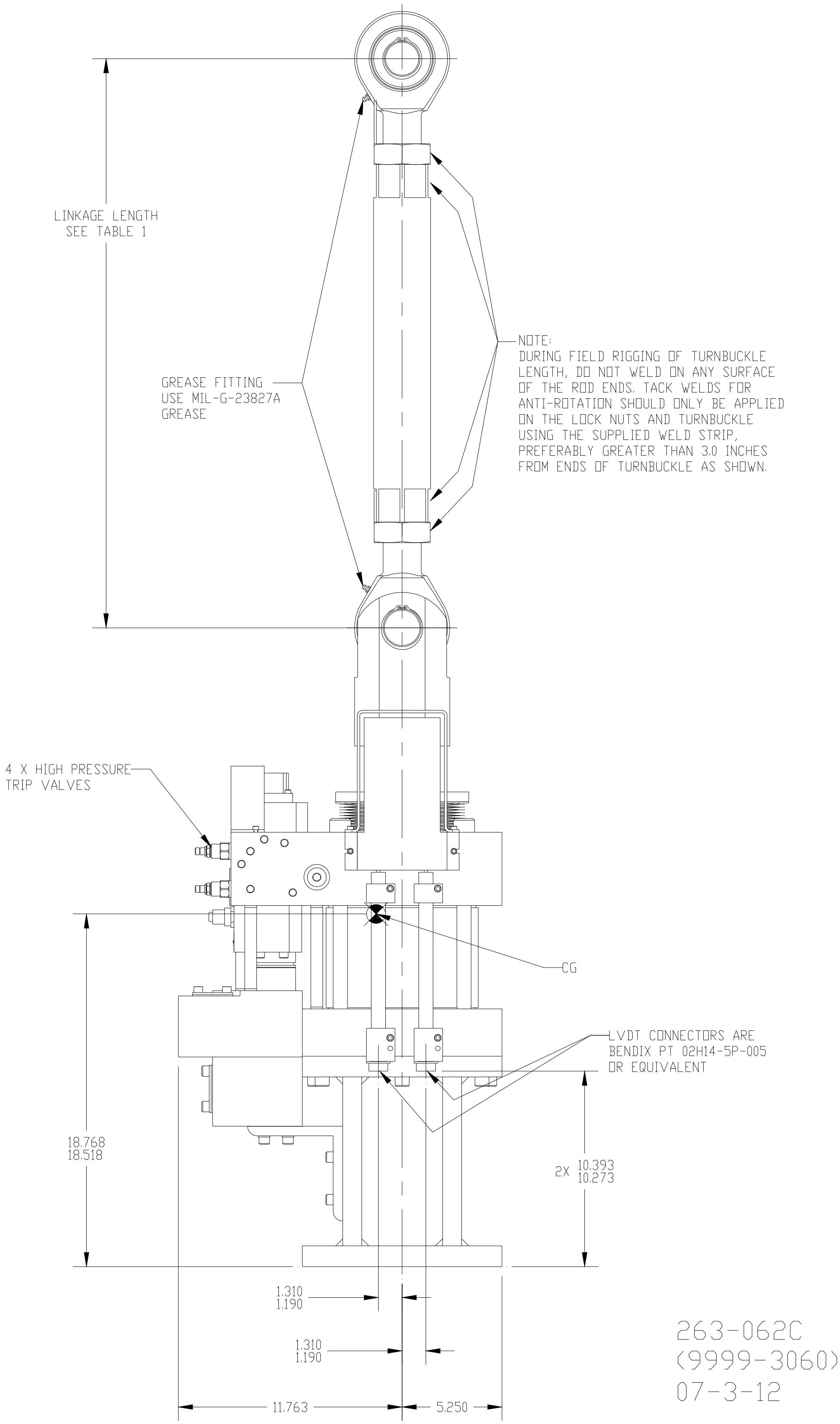
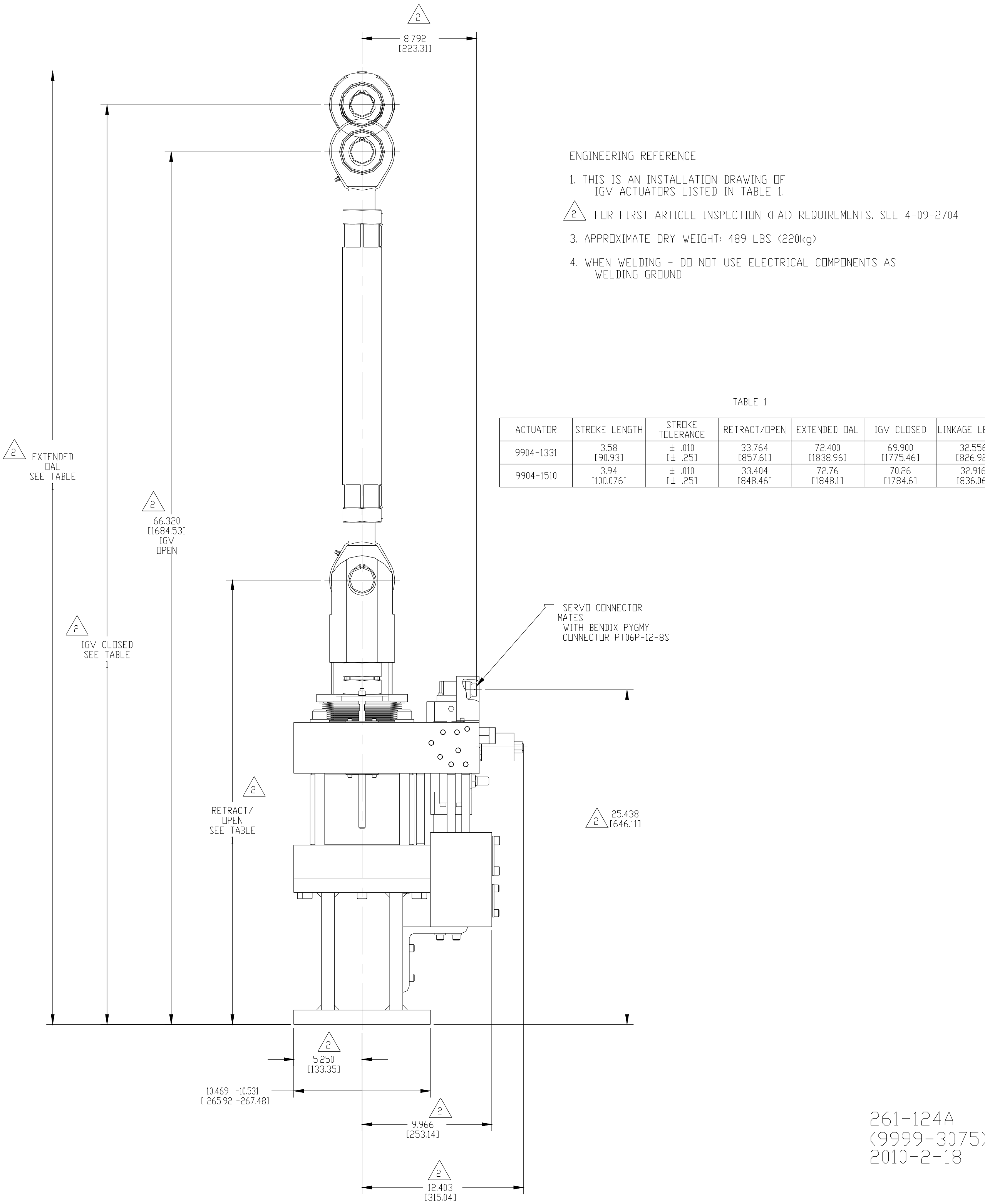


Figure 1-2c. 9F IGV Actuator, High Pressure Trip without internal check valve
(right side view)



ENGINEERING REFERENCE

1. THIS IS AN INSTALLATION DRAWING OF IGV ACTUATORS LISTED IN TABLE 1.
2. FOR FIRST ARTICLE INSPECTION (FAI) REQUIREMENTS. SEE 4-09-2704
3. APPROXIMATE DRY WEIGHT: 489 LBS (220kg)
4. WHEN WELDING - DO NOT USE ELECTRICAL COMPONENTS AS WELDING GROUND

TABLE 1

ACTUATOR	STROKE LENGTH	STROKE TOLERANCE	RETRACT/OPEN	EXTENDED OAL	IGV CLOSED	LINKAGE LENGTH
9904-1331	3.58 [90.93]	± .010 [± .25]	33.764 [857.61]	72.400 [1838.96]	69.900 [1775.46]	32.556 [826.92]
9904-1510	3.94 [100.076]	± .010 [± .25]	33.404 [848.46]	72.76 [1848.1]	70.26 [1784.6]	32.916 [836.06]

Figure 1-3a. 9F IGV Actuator with Electric Trip and SAE CODE 61 flange type connection (left side view)

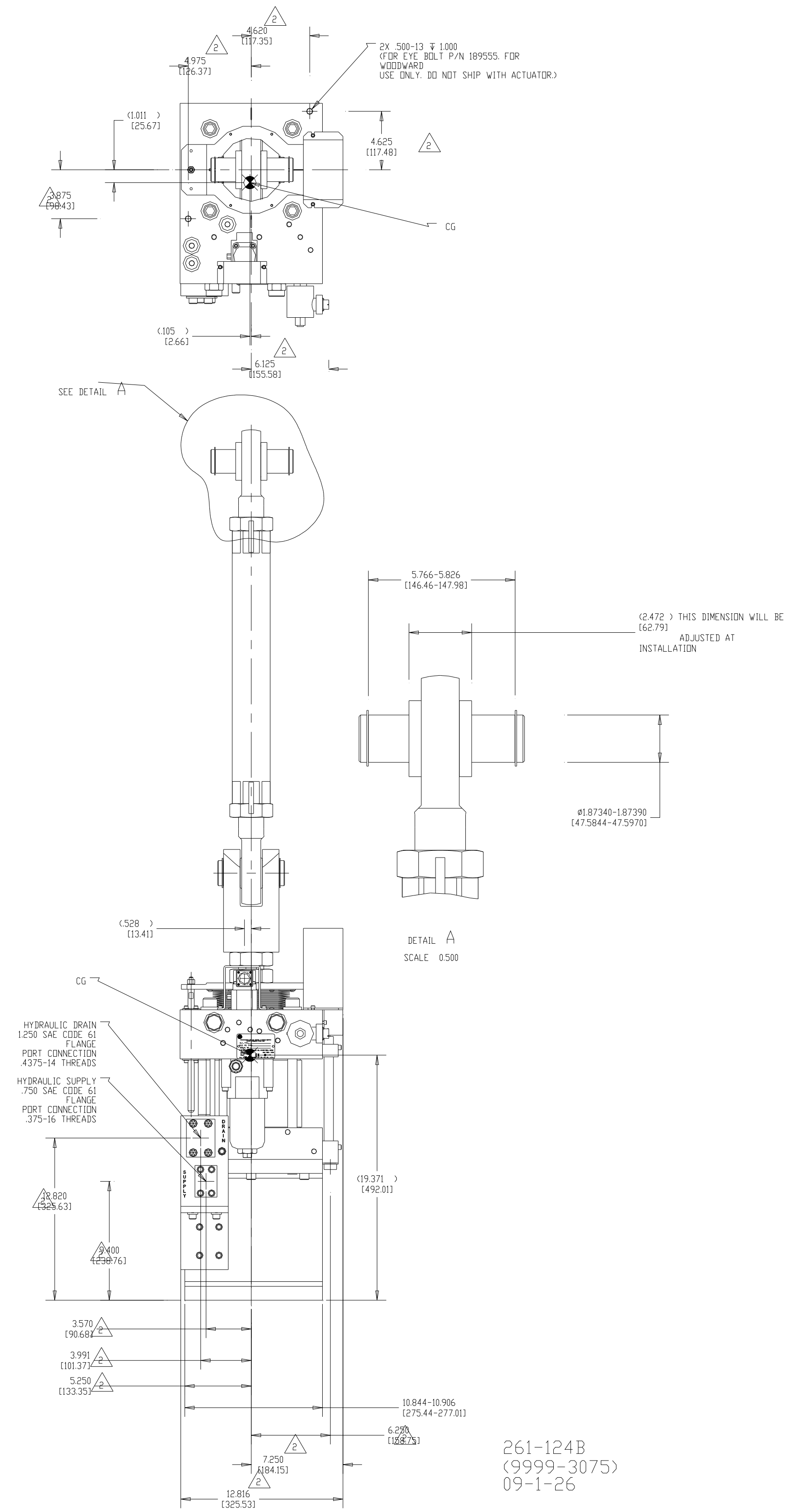


Figure 1-3b. 9F IGV Actuator with Electric Trip and SAE CODE 61 flange type connection (front and top views)

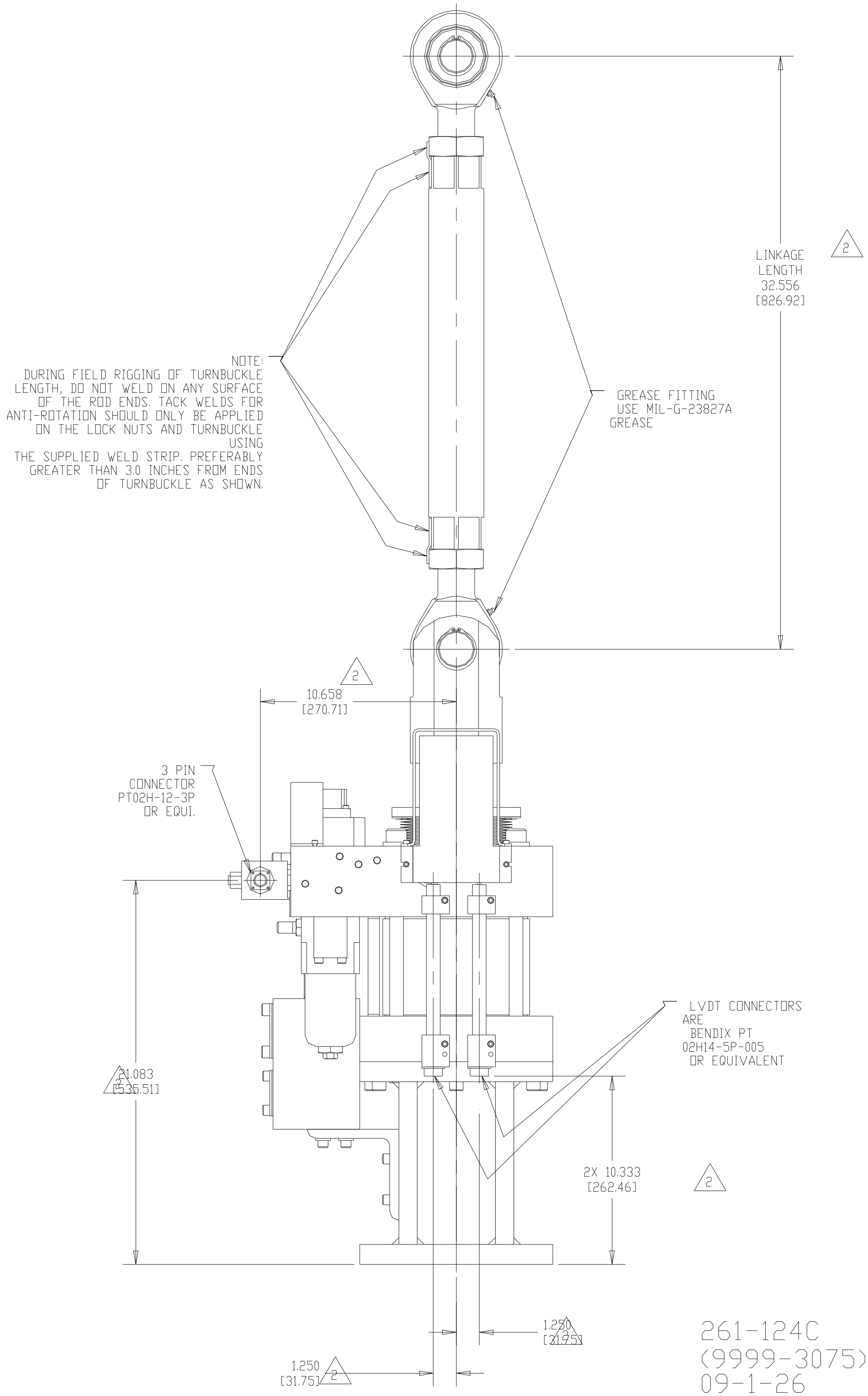


Figure 1-3c. 9F IGV Actuator with Electric Trip and SAE CODE 61 flange type connection (right side view)

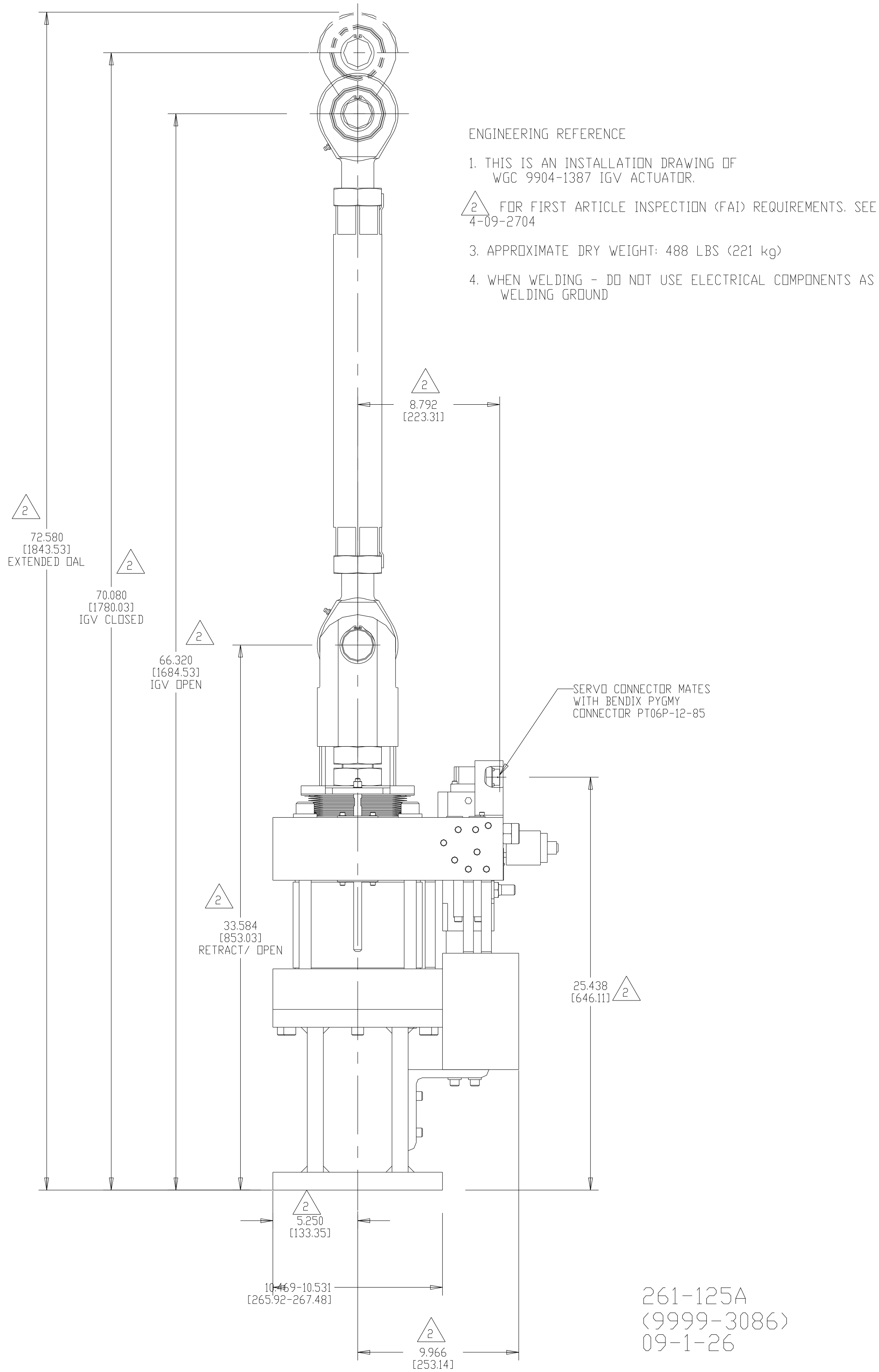


Figure 1-4a. 9F IGV Actuator with Electric Trip and SAE O-ring Thread Type Connection (left side view)

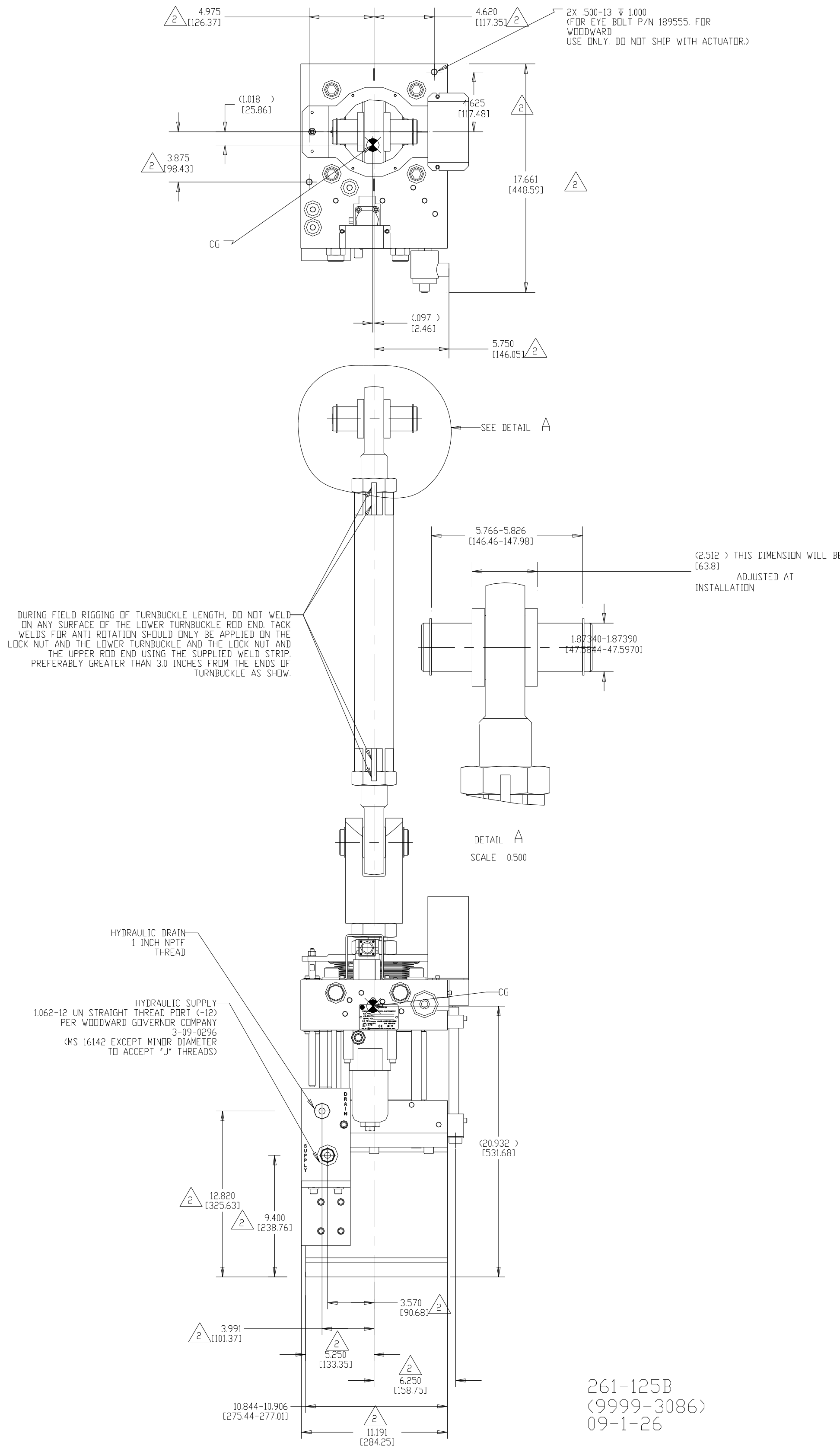


Figure 1-4b. 9F IGV Actuator with Electric Trip and SAE O-ring Thread Type Connection (front and top views)

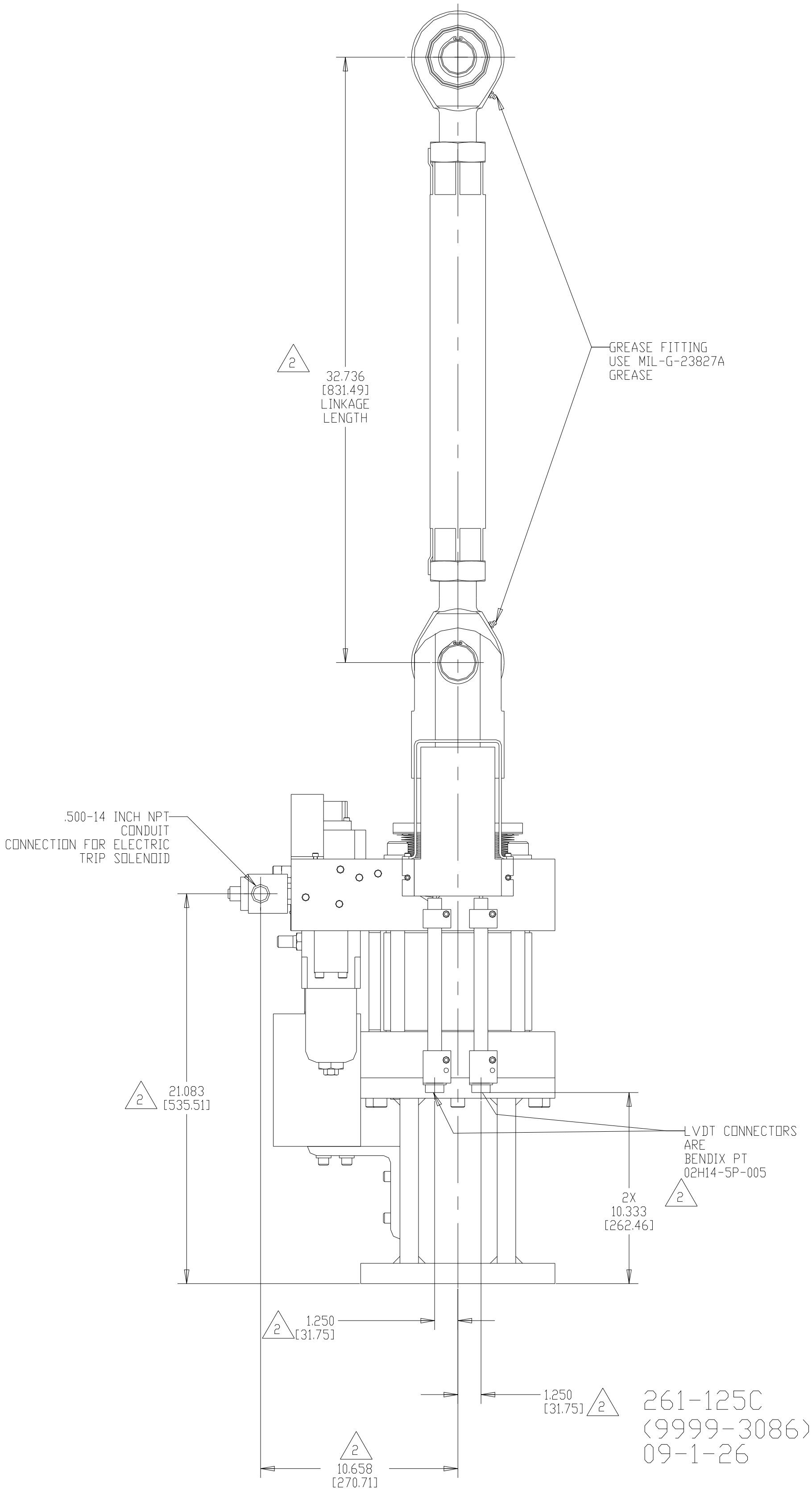


Figure 1-4c. 9F IGV Actuator with Electric Trip and SAE O-ring Thread Type Connection (right side view)

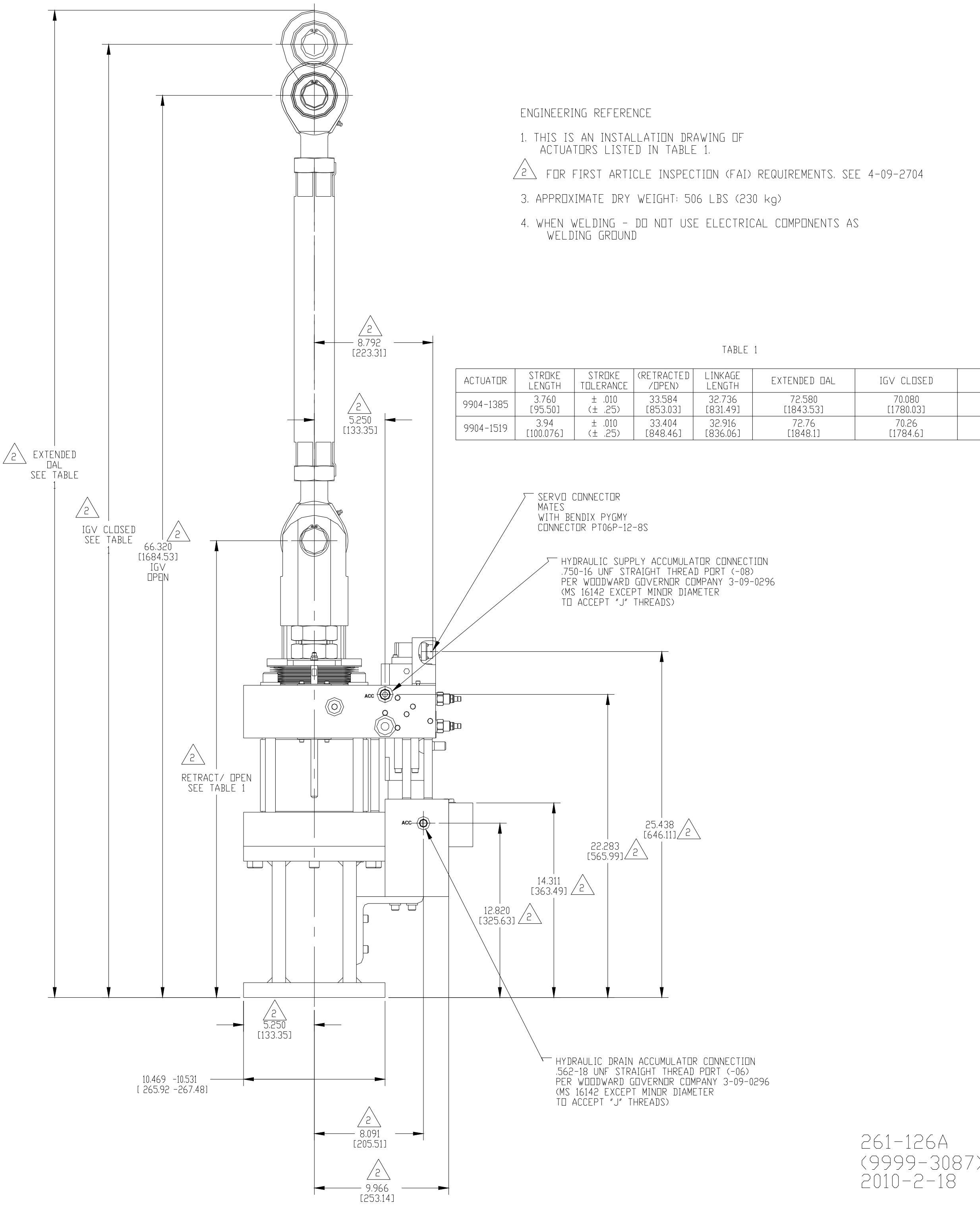


TABLE 1

ACTUATOR	STROKE LENGTH	STROKE TOLERANCE	(RETRACTED /OPEN)	LINKAGE LENGTH	EXTENDED OAL	IGV CLOSED	IGV OPEN
9904-1385	3.760 [95.50]	± .010 (± .25)	33.584 [853.03]	32.736 [831.49]	72.580 [1843.53]	70.080 [1780.03]	66.320 [1684.53]
9904-1519	3.94 [100.076]	± .010 (± .25)	33.404 [848.46]	32.916 [836.06]	72.76 [1848.1]	70.26 [1784.6]	66.320 [1684.53]

Figure 1-5a. 9F IGV Actuator, High Pressure Trip with Internal Check Valve (left side view)

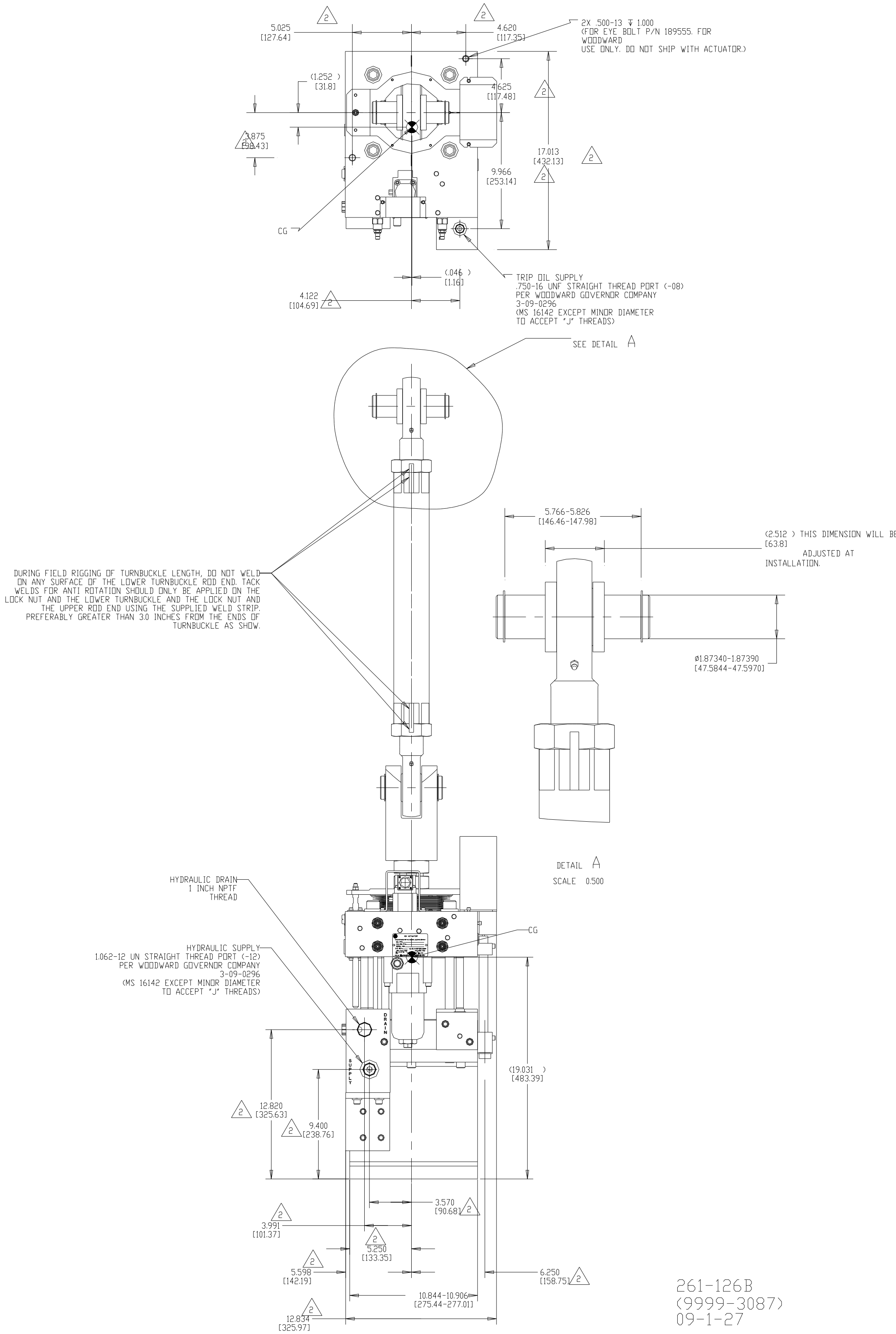


Figure 1-5b. 9F IGV Actuator, High Pressure Trip with Internal Check Valve (front and top views)

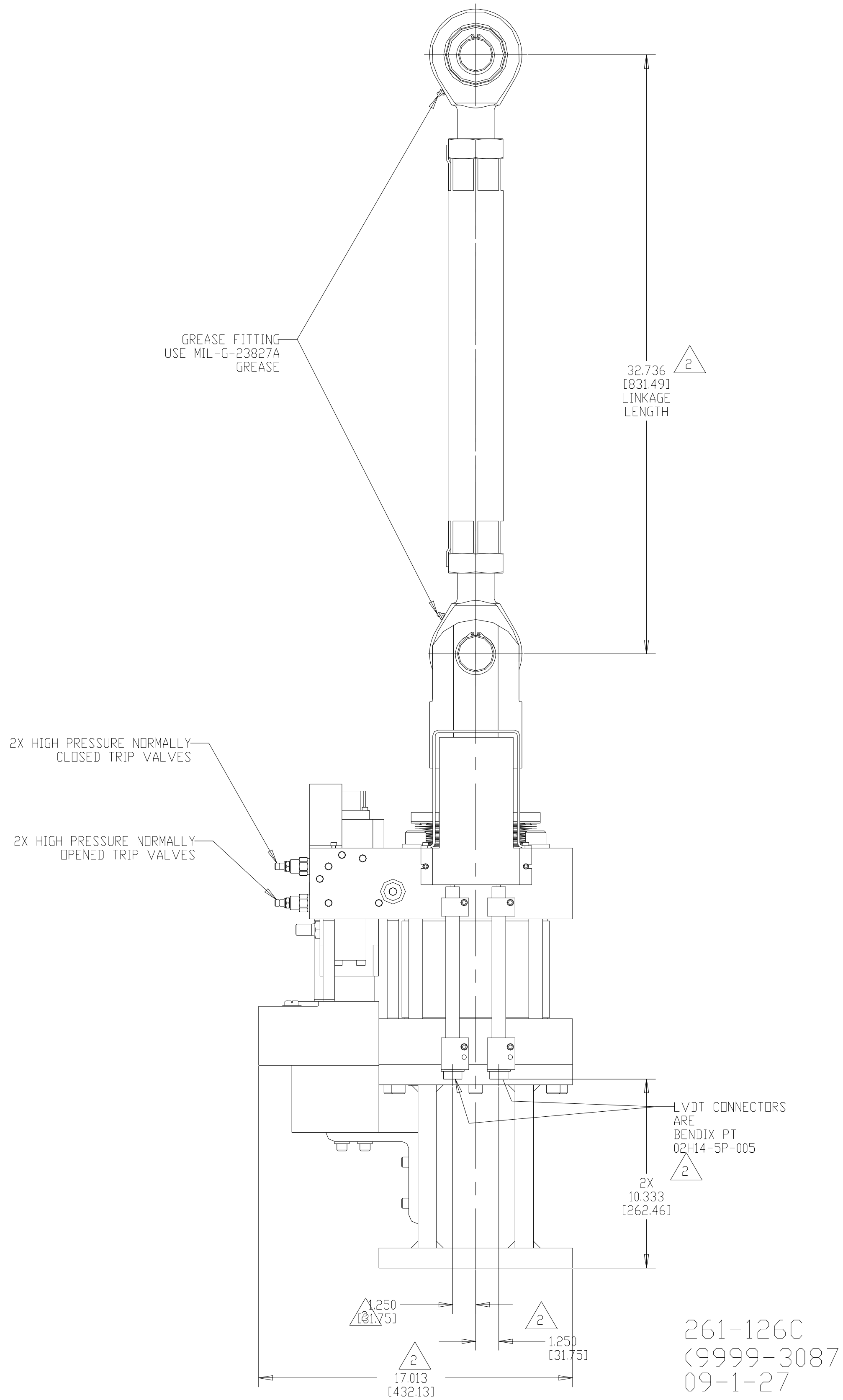


Figure 1-5c. 9F IGV Actuator, High Pressure Trip with Internal Check Valve (right side view)

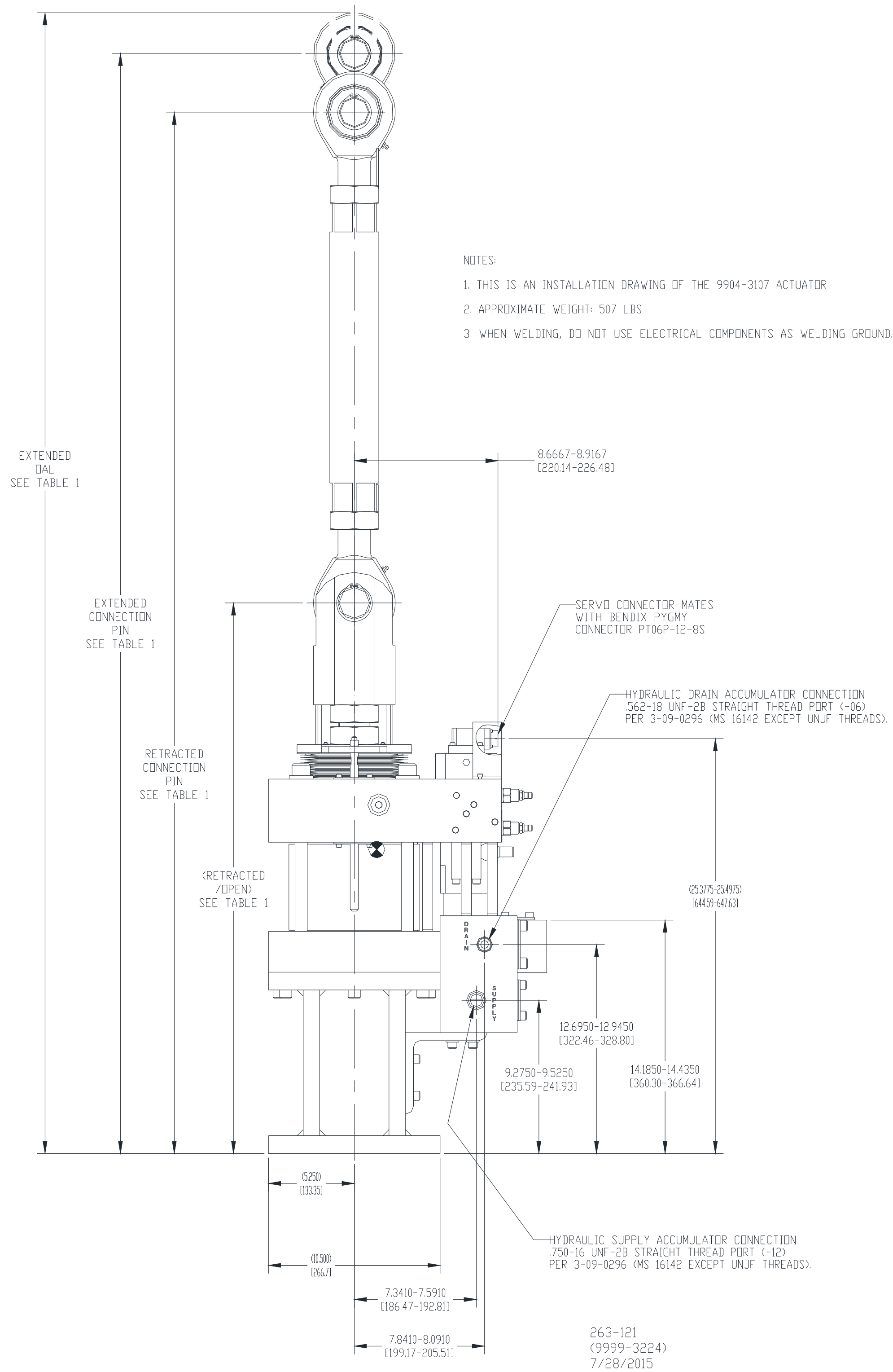


TABLE 1

ACTUATOR	STROKE LENGTH	STROKE TOLERANCE	(RETRACTED /OPEN)	LINKAGE LENGTH	EXTENDED OAL	EXTENDED CONNECTION PIN	RETRACTED CONNECTION PIN
9904-3107	3.94 [100.076]	± .010 (± .25)	33.404 [848.46]	30.39 [771.91]	70.23 [1783.84]	67.73 [1720.34]	63.79 [1620.27]

Figure 1-6a. 9F IGV Actuator, High Pressure Trip, Triple LVDT without Internal Check Valve (left side view)

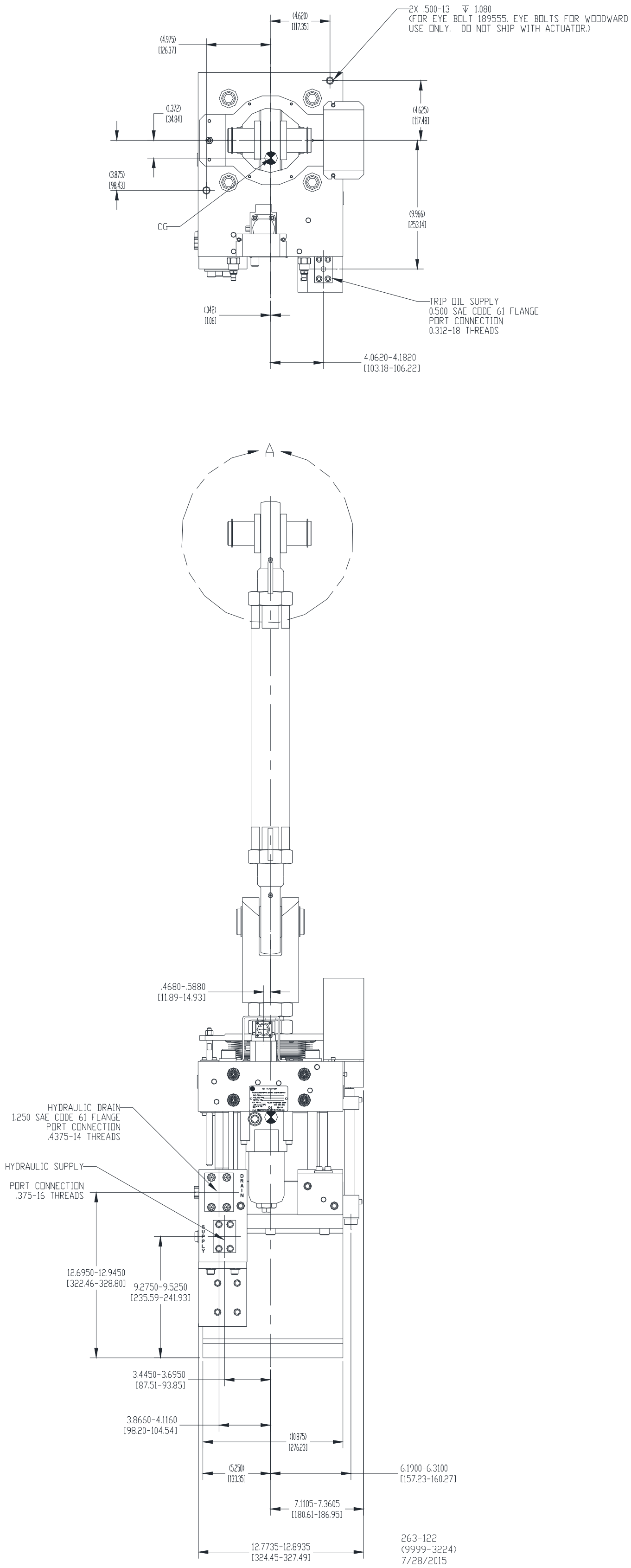


Figure 1-6b. 9F IGV Actuator, High Pressure Trip, Triple LVDT without Internal Check Valve (front and top views)

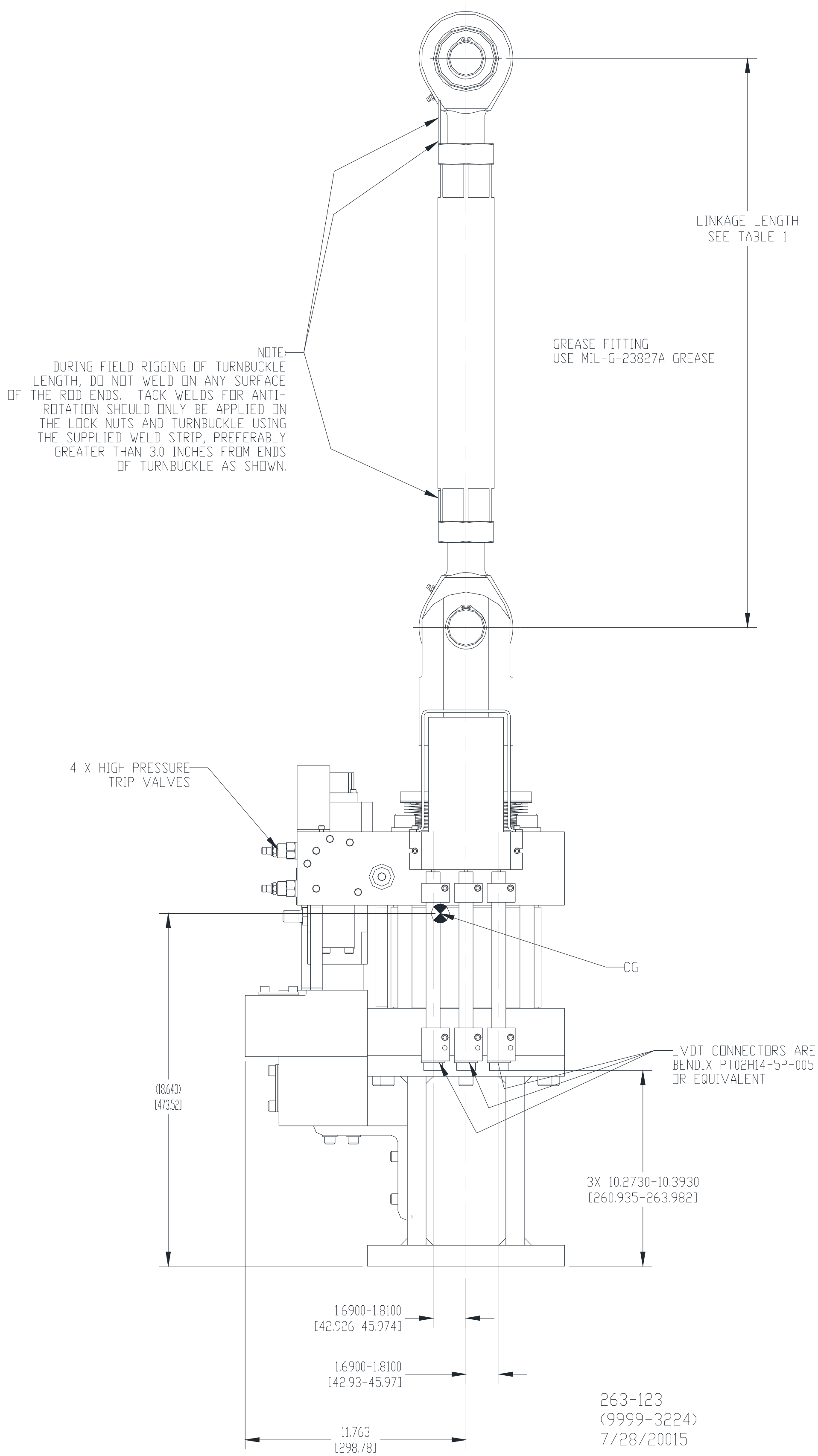


Figure 1-6c. 9F IGV Actuator, High Pressure Trip, Triple LVDT without Internal Check Valve (right side view)

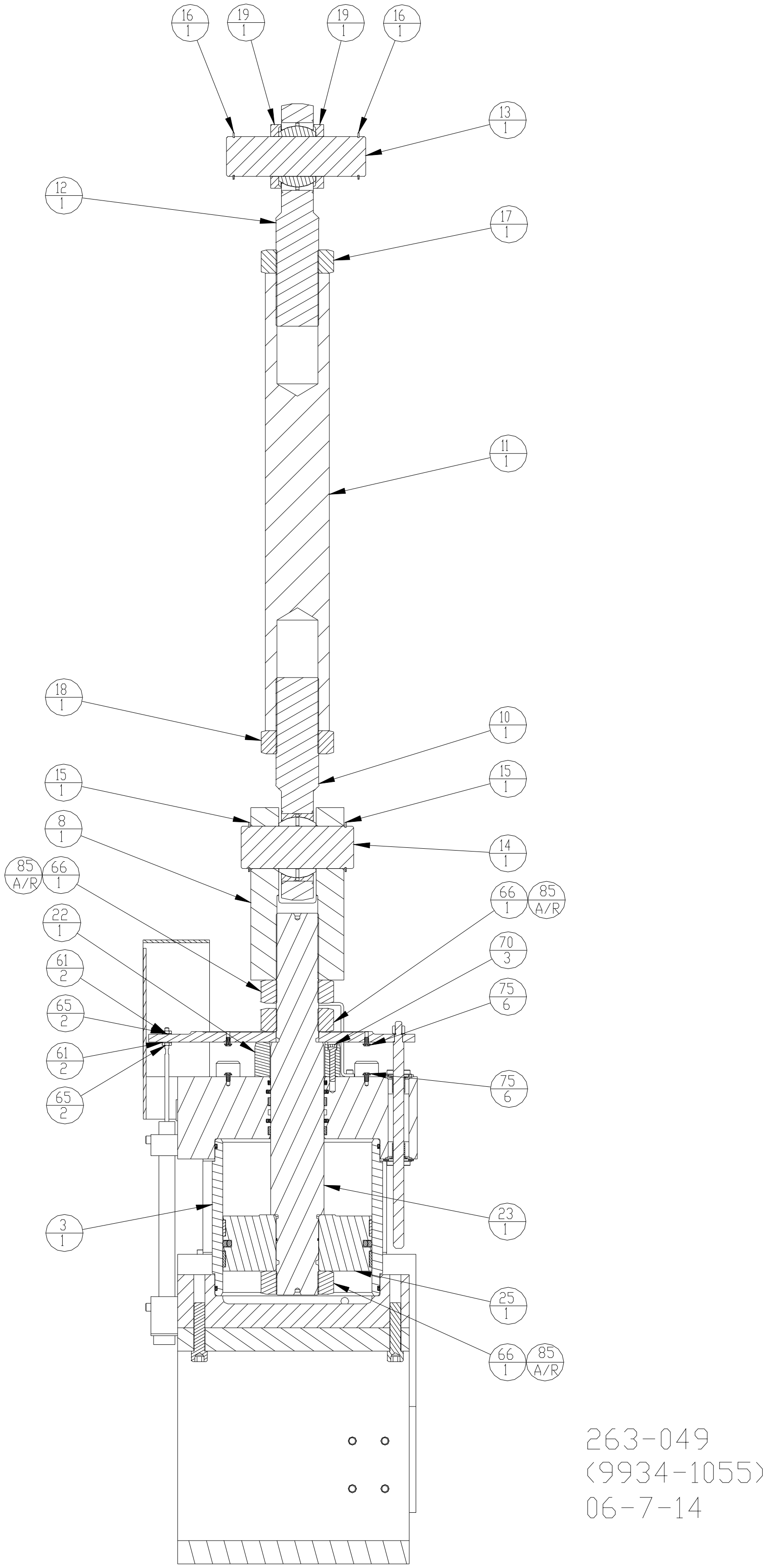


Figure 1-7. Typical 9F IGV Actuator (partial cutaway with reference numbers)
(electric trip solenoid not shown—number 1734-1033/1734-1031)

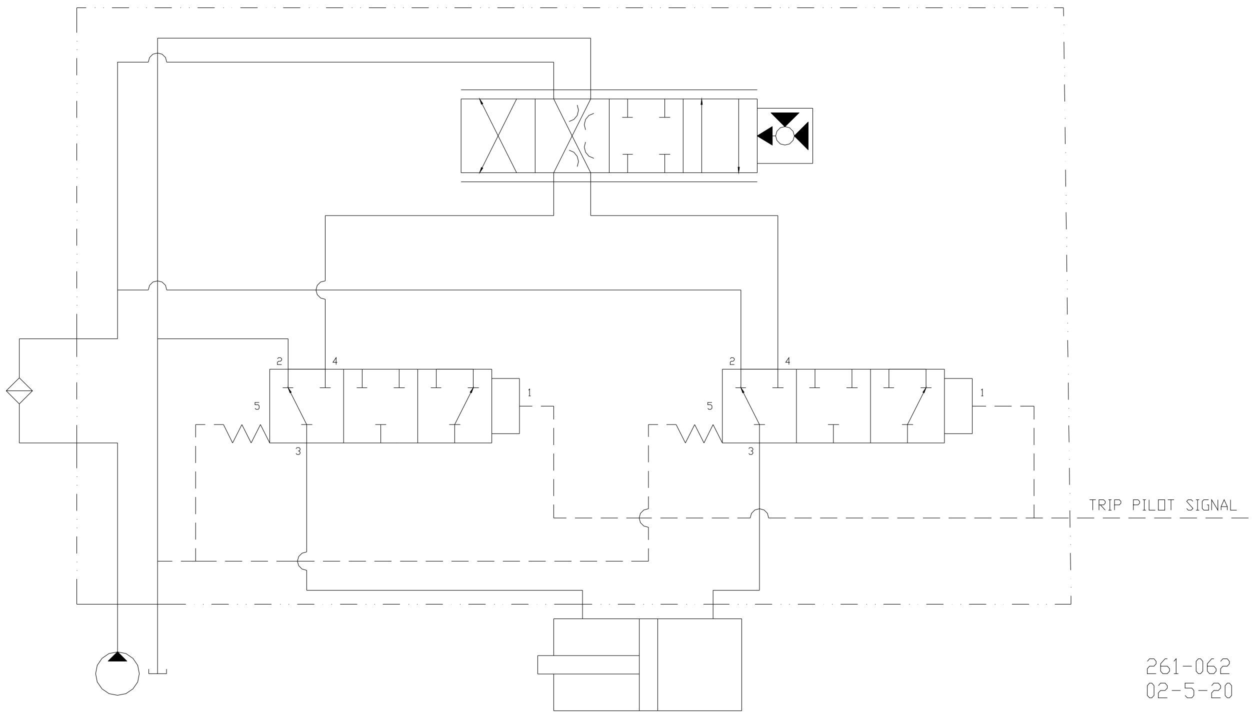


Figure 1-8a. IGV Hydraulic Schematic—Low Pressure Trip

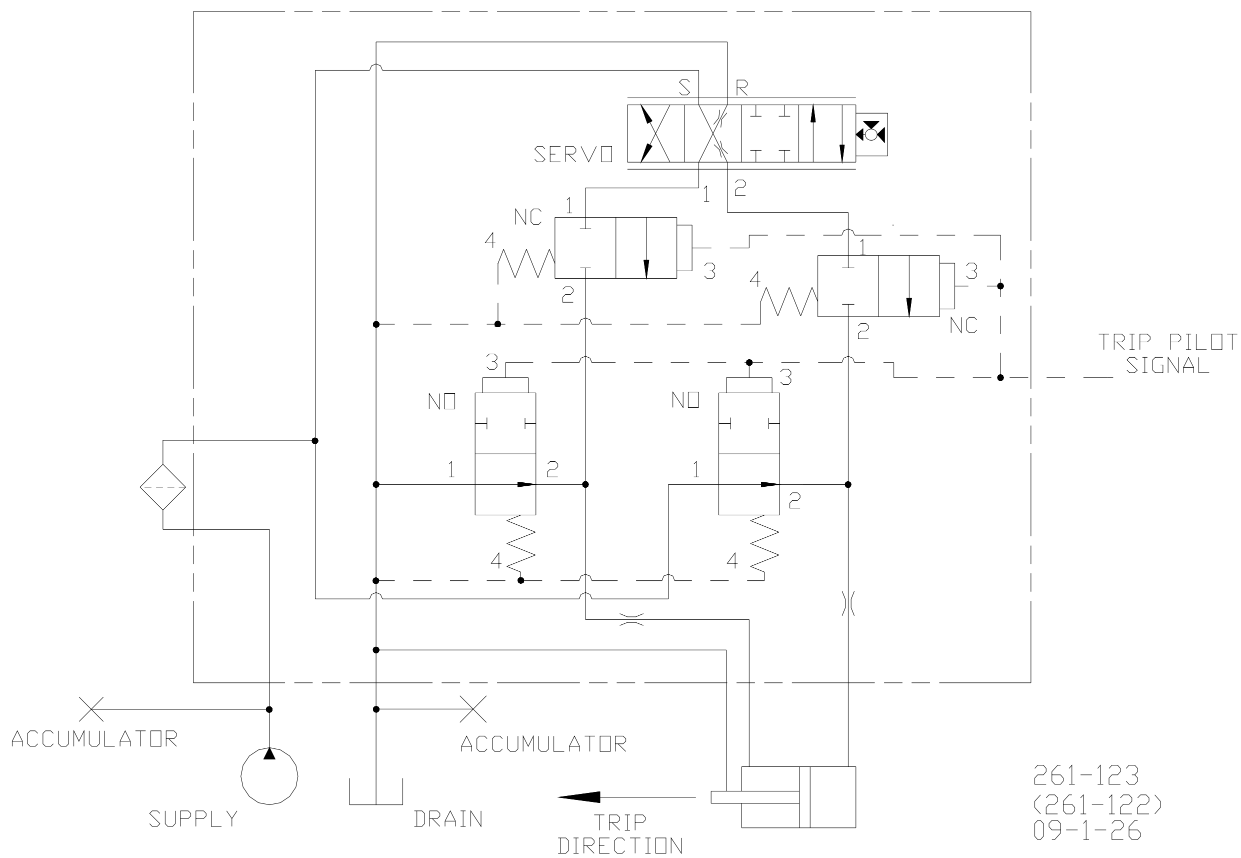


Figure 1-8b. IGV Hydraulic Schematic—High Pressure Trip without Internal Check Valve

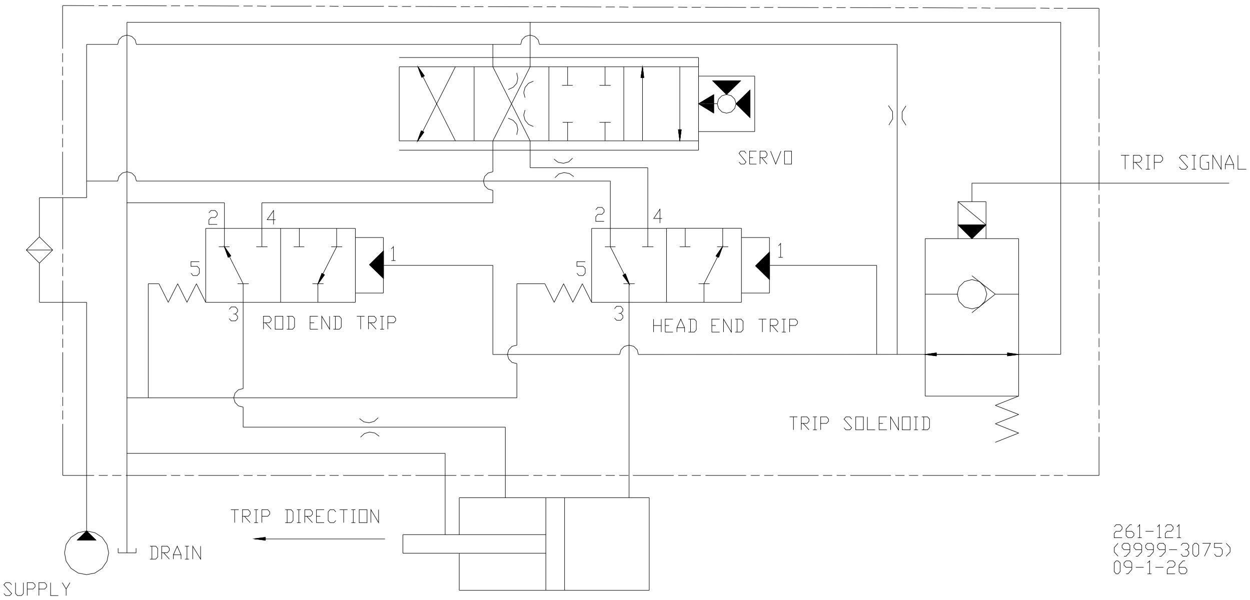


Figure 1-8c. IGV Hydraulic Schematic—Electric Trip

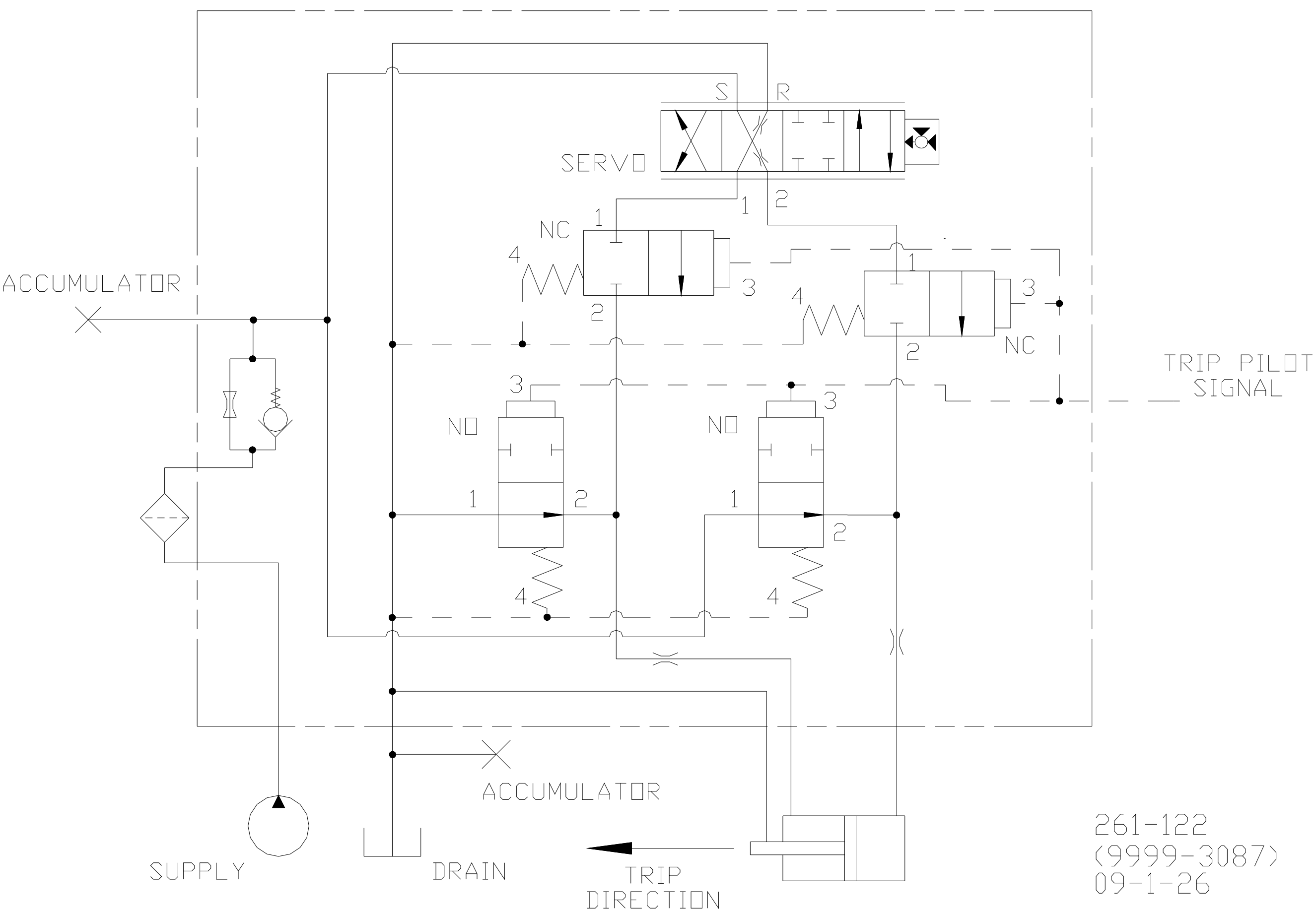


Figure 1-8d. IGV Hydraulic Schematic—High Pressure Trip with Internal Check Valve

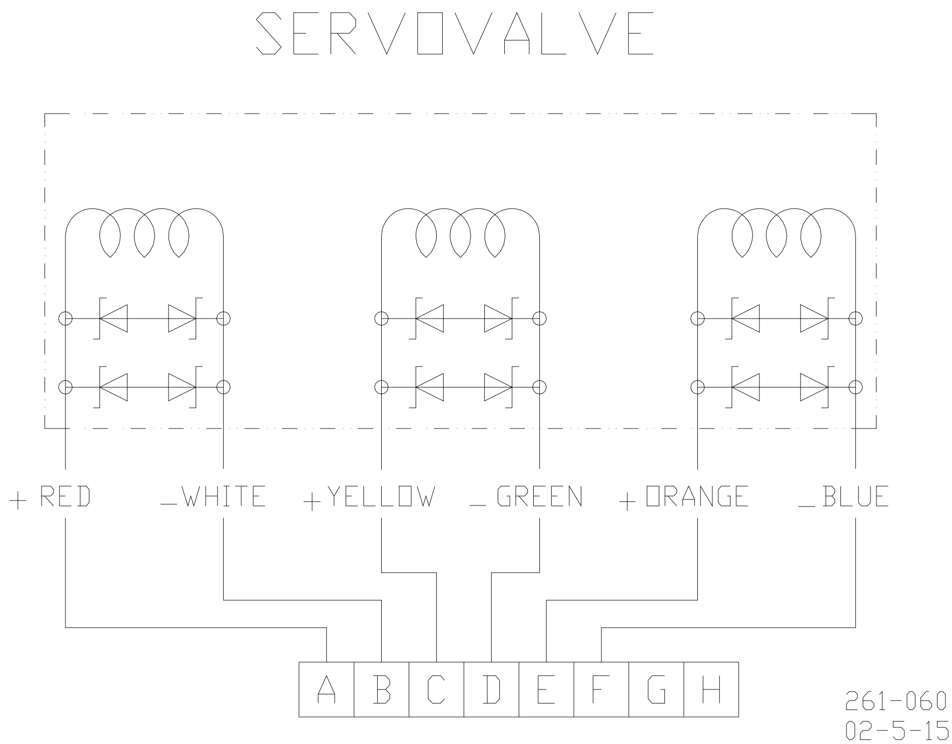


Figure 1-9. Servo Valve Electrical Schematic and Wiring Diagram

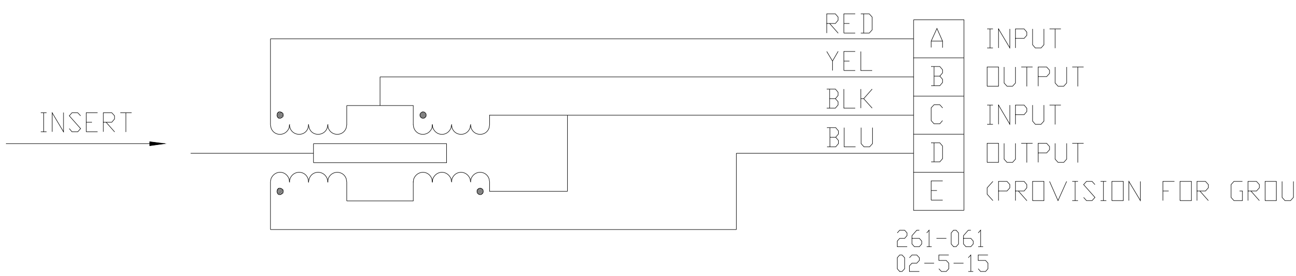


Figure 1-10. LVDT Electrical Schematic and Wiring Diagram

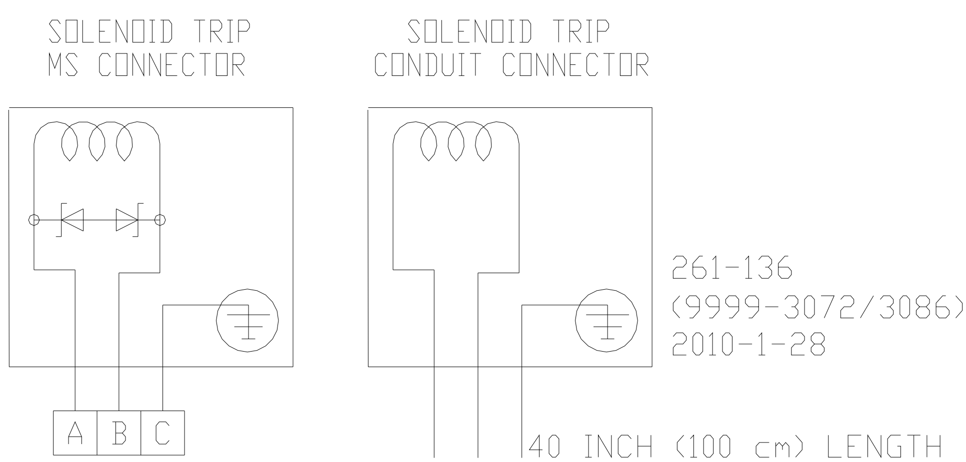


Figure 1-11. Solenoid Valve Electrical Schematic and Wiring Diagram

NOTES

1. These general reference outline drawings apply to Woodward 9F IGV actuators only. Consult Woodward for the latest outline drawing.
2. Installation Orientation — Orientation vertical approximately as shown
   See elsewhere in this manual for other installation recommendations
3. Approximate Weight — 227 kg / 500 lb
4. Service Manual Replacement Parts
   Servo Valve—consult Woodward for part number
   O-rings for servo valve—consult Woodward for part number
   Filter element—consult Woodward for part number
   Manual—consult Woodward for part number
   LVDT—consult Woodward for part number
   Trip relay valve—consult Woodward for part number
   Seal kit for trip relay valve—consult Woodward for part number
   Solenoid Valve—consult Woodward for part number
5. Description of IGV Actuator

Process fluid	hydraulic fluid
Temperature range	hydraulic fluid (10 to 66) °C / (50 to 150) °F ambient (–40 to +121) °C / (–40 to +250) °F
External leakage	(none)

6. Actuation

Cylinder bore	7.000 inch diameter (177.80 mm)
Rod diameter	2.500 inch diameter (63.50 mm)
Stroke	3.58 inch (90.9 mm) or 3.76 (95.5 mm) or 3.94 inch (100.1 mm)
Static seals	Elastomer per US MIL-R-83248 (Viton)
Operating fluid	Petroleum-based hydraulic fluid as well as fire resistant hydraulic fluids such as Fyrquel EHC
Operating hydraulic pressure	(8274 to 11 722) kPa / (1400 to 1800) psig

7. Servo Valve Flow Rating — 38 L/min (10.0 US gal/min) at 6895 kPa (1000 psid) valve drop, 4-way

Electrical input rating	±8 mA (sum of three coils)
First stage null bias	10 % ± 4 % Rated Flow Cylinder Port 1 to Drain and Pressure to Port 2
Null Internal Leakage at 1600 psid	1.6 L/min (0.42 US gal/min) (New) 2.8 L/min (0.75 US gal/min) (R+R)
Electrical connection	Mates with Bendix PYGMY Connector PT06P-12-8S, PT02H14-5P-005, PT02H-12-3P

IMPORTANT

These general reference outline drawings apply to various Woodward IGV actuators. Consult Woodward for the latest outline drawing for your particular IGV actuator.

Chapter 2.
IGV Actuator Operation

The IGV actuator is controlled by an electronic servo-control system (not included), which compares the demanded and actual actuator positions. The control system modulates the input current signal to the electrohydraulic servo valve to minimize the positioning system error. See Figure 1-8a for a functional schematic of the low pressure trip actuator, Figure 1-8b for a functional schematic of the high pressure trip actuator without internal check valve, Figure 1-8c for a functional schematic of the electric trip actuator, and Figure 1-8d for a functional schematic of the high pressure trip actuator with internal cartridge check valve.

Hydraulic oil enters the actuator via a removable element filter with integral high ∆P indicator and is directed to a four-way electrohydraulic servo valve used in a three-way configuration. The PC1 control pressure output from the servo valve is directed to the upper cavity (rod end) of the hydraulic piston. When the force exerted by the hydraulic pressure exceeds the force of the opposing IGV force, the output piston retracts, rotating the Inlet Guide Vane unison ring in the opening direction.

Low pressure trip versions utilize two trip relay valves interposed between the electrohydraulic servo control valve and the servo output stage. Loss or reduction of the externally supplied trip signal pressure causes the trip relay valves to shift position. This connects the lower cavity (head end) of the actuator piston directly to the hydraulic supply pressure and the upper cavity (rod end) to drain. The pressure differential forces the actuation piston up to the extended position, rotating the Inlet Guide Vane unison ring to the closed position. High pressure trip versions utilize four “logic element” cartridges to produce the same effect. On the high pressure system, the two upper cartridges control the passages to the servo valves, and the two lower cartridges control the direct connections between the hydraulic cylinder and the supply and drain passages. In the electric trip system, the removal of voltage from the trip solenoid allows pressure to the trip relay valve to be reduced, causing the trip relay valve to shift position.

Two or three redundant LVDT position feedback transducers are mounted within each actuator. The LVDT sensor cores and support rods are connected to the main actuator output rod by an anti rotation plate which is also coupled to a rod which is guided in a bushing. This guide bushing maintains LVDT alignment to minimize core damage due to sliding wear and the associated loss of sensing accuracy.

Chapter 3.
Standard Component Details

Triple Coil Electrohydraulic Servo Valve Assembly

The IGV actuator uses a two stage hydraulic servo valve to modulate the position of the output shaft and thereby control the inlet guide vane. The first stage torque motor uses a triple-wound coil, which controls the position of the first- and second-stage valves in proportion to the total electrical current applied to the three coils.

If the control system requires a rapid movement of the actuator, the total current is increased well above the null current. In such a condition, supply oil is admitted to the appropriate actuator piston cavity. The flow rate delivered to the piston cavity is proportional to the total current applied to the three coils. Thus, the actuator stroke velocity and the valve opening are also proportional to the current (above null) supplied to the torque motor above the null point.

If the control system requires a rapid movement to close the IGV actuator, the total current is reduced well below the null current. In such a condition, the actuator piston cavity is connected to the hydraulic drain circuit. The flow rate returning from the upper piston cavity of the valve is proportional to the magnitude of the total current below the null value. The flow rate and closing velocity of the valve is in this case proportional to the total current below the null point.

Near the null current, the servo valve essentially isolates the piston cavities from the hydraulic supply and drain, and the piston pressure is balanced 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 operation of the system.

Trip Relay Valve Assembly

Depending on whether the actuator is low pressure trip, high pressure trip, or electric trip, it utilizes either two hydraulically operated three-way cartridge valves or four hydraulically operated logic element valves to switch the position of the IGV actuator.

Low Pressure Trip System

On the low pressure system, one valve connects a servo port to the actuator rod end, and the other connects the other servo port to the actuator head end with pilot pressure applied. With no pilot pressure, the pump is connected to the actuator head end port, and the drain port is connected to the actuator rod end port. The valves are designed to ensure that pickup and drop-out points occur <40 psid. When the trip circuit pressure increases to its pickup pressure, the three-way relay valves shift position. The servo valve control ports are then connected to the actuator ports. Depending on the command signal, one actuator port is connected to pump pressure while the other is connected to tank, allowing the actuator to function.

When the trip circuit pressure decreases to its drop-out point, the three-way trip valves shift position so that the rod end actuator port is connected to the hydraulic drain circuit, and the head end actuator port is connected directly to supply pressure. As the pressure increases to the actuator head end cavity, and pressure falls off in the actuator rod end cavity, the actuator rapidly extends the piston to the vane closed position, closing the inlet guide vanes of the turbine.

High Pressure Trip System

On the high pressure system, when trip pressure is applied to the pilot port of the upper logic element cartridges, they shift and allow the servo ports to connect to the respective ends of the hydraulic cylinders. When trip pressure is applied to the pilot ports of the lower logic element cartridges, they close off the direct connections from the upper end of the cylinder to drain, and from the lower end of the cylinder to supply pressure. With the cartridges in this position, the servo valve can modulate the cylinder for normal operation of the actuator.

When the trip pressure falls below 2068 kPa (300 psig) at the cartridge pilot ports, the upper cartridges both close, thereby isolating the servo valve from the hydraulic cylinder. The lower cartridge valves open when the trip pressure is removed from the cartridge pilot ports. This connects the upper end of the hydraulic cylinder directly to drain and the lower end of the cylinder directly to hydraulic line pressure, causing the cylinder to fully extend regardless of the servo valve control signal.

Electric Trip System

In the electric trip system, the trip pilot pressure is made available internally from the manifold. This system includes an electric trip solenoid controlled by the customer. When the solenoid is powered, pilot pressure is provided to the trip valves, and the actuator is under servo valve control as described above. Tripping action is effected by removing power from the solenoid that results in reducing trip circuit pressure. When the trip circuit pressure decreases to its drop-out point, the three-way trip valves shift position so that the rod end actuator port is connected to the hydraulic drain circuit, and the head end actuator port is connected directly to supply pressure. As the pressure increases to the actuator head end cavity, and pressure falls off in the actuator rod end cavity, the actuator rapidly extends the piston to the vane closed position, closing the inlet guide vanes of the turbine.

Hydraulic Filter Assembly

The IGV actuator is supplied with an integrated, high-capacity filter. This 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 indicates when the pressure differential exceeds the recommended value, indicating that replacement of the element is necessary.

LVDT Position Feedback Sensors

The IGV actuator uses dual or triple LVDTs for position feedback. The LVDTs are factory set to give (0.7 ± 0.1) Vrms feedback in extended position.

Chapter 4. Installation

General

See the outline drawings (Figures 1-1, 1-2, 1-3, 1-4, 1-5, 1-6) for:

- Overall dimensions
- Hydraulic connections and fitting sizes
- Electrical connections
- Lift points
- Weight of the actuator

The design of the IGV actuator requires that the output shaft be mounted vertically. Additionally, a vertical actuator position is generally preferred to conserve floor space as well as ease of making electrical, fuel, and hydraulic connections and changing the hydraulic filter element.

The IGV actuator is designed for support by an actuator base. Additional supports are neither needed nor recommended.

⚠WARNING	**Due to typical noise levels in turbine environments, hearing protection should be worn when working on or around this product.**

⚠WARNING	**The surface of this product can become hot enough or cold enough to be a hazard. Use protective gear for product handling in these circumstances. Temperature ratings are included in the specification section of this manual.**

⚠WARNING	**Woodward recommends lifting the IGVA by installing two lifting eyes in the 0.500 x 13 tapped holes shown in Figures 1-1b, 1-2b, 1-3b, 1-4b, 1-5b, 1-6b. If the unit must be lifted by slings, Woodward recommends running a strap through the 2 inch (51 mm) diameter hole on the yoke. This will extend the IGV rod as the unit is lifted. If installing straps on any other location, observe the center of gravity noted in Figure 1-1b, 1-2b, 1-3b, 1-4b, 1-5b, 1-6b, and take care that the straps do not press against other components such as the LVDTs, servo valve, or anti-rotation rod.**

⚠WARNING	**External fire protection is not provided in the scope of this product. It is the responsibility of the user to satisfy any applicable requirements for their system.**

Unpacking

The actuator is shipped with the turnbuckle linkage disconnected from the output shaft but included in the same shipping container along with necessary mounting hardware. Check the shipping container for all components before removing it from the area.

Hydraulic Connections

For the hydraulic trip system IGVA, there are three hydraulic connections that must be made to each actuator: supply, return, and trip. The connections to the actuator used on GE Frame 9F with low pressure trip system turbines use SAE Code 61 4-bolt flanges connections for the trip, main supply and drain port. The connections to the actuator used on GE Frame 9F with high pressure trip system turbines use SAE straight thread O-ring connections for the trip and main supply ports and a 1 inch NPTF connection for the drain port.

IMPORTANT	**Actuators featuring the High Pressure Trip option also include extra SAE straight-thread O-ring supply and drain connections for hydraulic accumulators.**

For the IGVA used on GE Frame 9F with electric trip system turbines, there are only two hydraulic connections, supply and return. Type of connection depends on specific IGVA version. The IGVA 9FA version uses SAE Code 61 4-bolt flange connections for the main supply ports and a connection for the drain port. The IGVA 9FB version uses SAE straight thread O-ring connections for the main supply ports and a 1 inch NPTF connection for the drain port.

The tubing up to the actuator must be constructed to eliminate any transfer of vibration or other forces into the actuator.

Make provisions for proper filtration of the hydraulic fluid that will supply the actuator. The system filtration should be designed to assure a supply of hydraulic oil with a maximum ISO 4406 contamination level of 18/16/13 and a preferred level of 16/14/11. The filter element included with the actuator is not intended to provide adequate filtration over the entire life of the actuator.

The hydraulic supply to the actuator is to be 19.05 mm (0.750 inch) tubing capable of supplying 38 L/min (10 US gal/min) at (9653 to 12 411) kPa / (1400 to 1800) psig.

The hydraulic drain should be 32 mm (1.25 inch) tubing or larger and must not restrict the flow of fluid from the actuator. The drain pressure must not exceed 207 kPa (30 psig) under any condition.

The trip pressure supply should be 12.70 mm (0.500 inch) tubing. For the low pressure trip versions, the trip system pressure should be above 276 kPa (40 psig) for normal operation of the actuator. During a trip, the pressure should fall below 138 kPa (20 psig) to insure that the unit trips in the specified time. For high pressures trip versions, the trip system pressure should be above 6206 kPa (900 psig) for normal operation of the actuator. During a trip, the pressure should fall below 2068 kPa (300 psig) to ensure the unit trips in the specified time.

Electrical Connections

⚠WARNING	**Due to the hazardous location listings associated with this product, proper wire type and wiring practices are critical to operation.**

NOTICE	**Do not connect any cable grounds to “instrument ground”, “control ground”, or any non-earth ground system. Make all required electrical connections based on the wiring diagrams (Figures 1-9, 1-10, 1-11).**

Use MS3116F-14-5S or Bendix PT02H14-5P-005 or equivalent mating connector for the LVDT. Eliminate or reduce the gap at the cable entry side of the mating connector such that objects greater than 1 mm (0.039 inch) diameter cannot enter, to assure ingress protection IP4X.

The use of cable with individually-shielded twisted pairs is recommended. All signal lines should be shielded to prevent picking up stray signals from nearby equipment. Installations with severe electromagnetic interference (EMI) may require shielded cable run in conduit, double-shielded wire, or other precautions. Connect the shields at the control system side or as indicated by the control system wiring practices, but never at both ends of the shield such that a ground loop is created. Wires exposed beyond the shield must be less than 50 mm (2 inches). The wiring should provide signal attenuation to greater than 60 dB.

The servo valve cable should consist of three individually shielded twisted pairs. Each pair should be connected to one coil of the servo valve as indicated in Figure 1-9 (wiring diagram).

The LVDT cable must consist of four individually shielded twisted pairs. Two separate pairs should be used for each of the excitation voltages to the LVDT, and two separate pairs used for each of the feedback voltages from the LVDT, as indicated in Figure 1-10 (wiring diagram).

The electric trip solenoid valve must use wire suitable for at least 300 V.

Electronic Settings

Dynamic Tuning Parameters

It is imperative that the correct dynamic characteristics of this actuator be input into the control system to ensure that the operation of the actuator/control system is within acceptable limits.

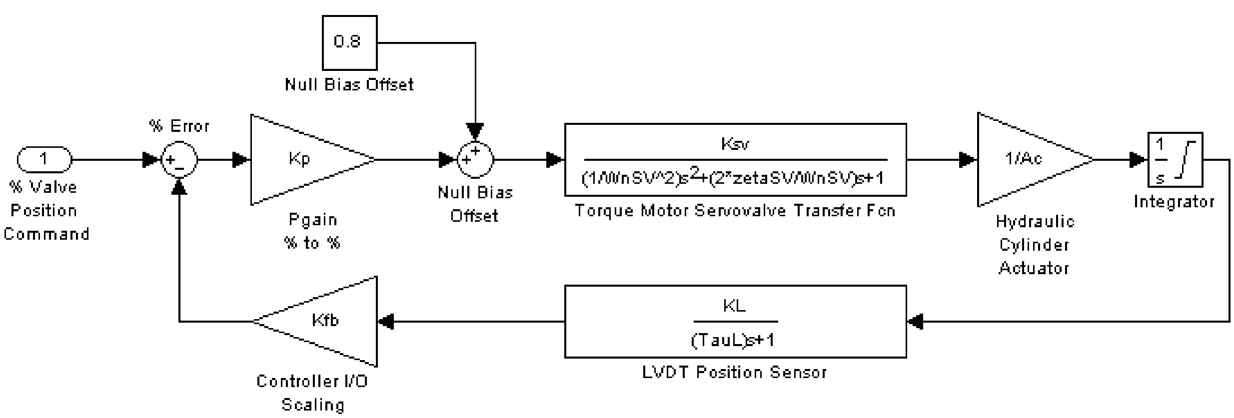


Figure 4-1. IGV Actuator Block Diagram

A_c Hydraulic cylinder working area (in^2) 38.48 in^2 extend area, 33.58 in^2 retract area
K_{SV} Servo valve flow gain (in^3/s) = 6.1 $in^3/s/mA$
K_L LVDT gain (Vrms/inch). Gain = 0.799 Vrms/inch
ξ servo valve damping ratio = 0.7
ω_n servo valve natural frequency (rad/s) = 520 rad/s (83 Hz)
τ_L LVDT time constant (s) = 0.005 (depends on excitation/demodulation)

[in^2 = square inches; 1 in^2 = 645.16 mm^2]
[in^3 = cubic inches; 1 in^3 = 16.387 mm^3]

Null Current Adjustment

Every IGV actuator shipped contains documentation that gives the actual null current as measured by Woodward. It is imperative that the control system null current match the as-measured current for each IGV actuator in the system. Incorrect null current setting (with proportional control only) will result in position error.

Rigging Procedure

The actuator is shipped with documentation which contains the appropriate LVDT feedback signals for each LVDT in the fully extended and retracted positions (assuming 7.0 Vrms excitation at 3000 Hz).

Once the control system is connected to the actuator and control of the actuator is established, set the command position to 0 % of full stroke. Measure the feedback voltage from each LVDT. Adjust the Offset in the feedback loop until the feedback voltage matches the documented values for that position. Adjust the command position to 100 % of full stroke. Adjust the Gain of the feedback loop until the LVDT feedback voltage matches the documented values. Set the command position to close the vane (actuator extend). Visually verify that the vane (actuator) is opened and that the feedback voltage from the LVDT is (0.7 ± 0.1) Vrms. This process may have to be repeated to ensure the feedback voltages at both the 0 % and 100 % command positions match the documented values.

NOTICE

During field rigging of turnbuckle length, do not weld on any surface of the rod ends. Tack welds for anti-rotation should only be applied on the lock nuts and turnbuckle using the supplied weld strip, preferably more than 75 mm (3 inches) from the ends of the turnbuckle as shown in Figure 1-1c, 1-2c, 1-3c, 1-5c, 1-6c.

Chapter 5.
Maintenance and Hardware Replacement

Maintenance

The IGV actuator requires no maintenance or adjustment in preparation for normal operation. The grease fitting on each rod end should be re-greased after the first 24 months of operation, and every 12 months thereafter, with grease meeting US MIL-G-23827A.

Woodward recommends routine checks of the DP gauge on the filter assembly to verify that the filter is not partially clogged. If the DP indicator shows red, the filter element needs to be replaced.

Woodward recommends a yearly removal and cleaning of the Trip Relay Valves or Logic Element Cartridges to prevent build-up of oil varnish or contaminants which may prevent proper operation of the Trip Relay Valves.

Remove each valve as described below and soak in a solvent (Stoddard or kerosene based) compatible with the fluorocarbon O-rings. Actuate the valve by hand and blow clean with compressed air. Verify smooth operation of the Trip Relay Valve and ensure no sticking or binding is present.

In the event that any of the standard components of the actuator become inoperative, field replacement of components is possible. Contact a Woodward representative for assistance.

⚠WARNING **Any cleaning by hand or with water spray must be performed while the area is known to be non-hazardous to prevent an electrostatic discharge in an explosive atmosphere.**

Hardware Replacement

⚠WARNING **To prevent possible serious personal injury, or damage to equipment, be sure all electric power, hydraulic pressure, and vane force have been removed from the actuator before beginning any maintenance or repairs.**

⚠WARNING **Due to typical noise levels in turbine environments, hearing protection should be worn when working on or around the IGV actuator.**

See the outline drawings (Figures 1-1, 1-2, 1-3, 1-4, 1-5, 1-6) for the location of items.

Hydraulic Filter Assembly/Cartridge

The hydraulic filter is located on the hydraulic manifold, hanging directly under the top manifold directly under the servo valve.

Replacement of Filter Assembly

1. Remove four 0.312-18 UNC socket head cap screws.
2. Remove the filter assembly from the manifold block.

IMPORTANT **The filter contains a large amount of hydraulic fluid that may be spilled during filter removal.**

3. Remove the two O-rings present in the interface between the filter and the manifold.
4. Obtain a new filter assembly.
5. Place two new O-rings in the new filter assembly.
6. Install the filter onto the manifold assembly. Be sure to place the filter in the correct orientation. See the outline drawings (Figures 1-1, 1-2, 1-3, 1-4, 1-5, 1-6).
7. Install four 0.312-18 cap screws through the filter into the manifold, and torque to (27 to 37) N·m / (20 to 27) lb-ft.

Replacement of Filter Cartridge

IMPORTANT **The filter contains a large amount of hydraulic fluid that may be spilled during filter removal.**

1. Using a 1-5/16 inch (~33+ mm) wrench, loosen the bowl from the filter assembly.
2. Remove the filter element by pulling it downward.
3. Obtain a new filter element.
4. Lubricate the O-ring on the ID of the cartridge with hydraulic fluid.
5. Install the cartridge into the assembly by sliding the open end of the cartridge upward onto the nipple.
6. Install the filter bowl. Tighten to (34 to 41) N·m / (25 to 30) lb-ft.

Trip Relay Valve or Logic Element Cartridge Replacement

The trip relay valve or logic element cartridges are located in the hydraulic manifold block (Figures 1-1, 1-2, 1-3, 1-4, 1-5, 1-6).

IMPORTANT **Hydraulic fluid may spill during cartridge removal.**

1. Using a 1.25-inch (~32– mm) wrench, loosen the trip relay valves from the hydraulic manifold.
2. Slowly remove the cartridges from the manifold.
3. Obtain a new trip relay valve or logic element cartridge and verify part number and revision with the existing unit.
4. Verify that all O-rings and backup rings are present on new cartridge.
5. Lubricate the O-rings with hydraulic fluid or petroleum jelly.
6. Install the cartridge into the manifold housing.
7. Torque low pressure trip relay valves to (45 to 50) N·m / (33 to 37) lb-ft.
8. Torque high pressure trip logic elements to (41 to 47) N·m / (30 to 35) lb-ft.

Servo Valve Replacement

The servo valve is located on the hydraulic manifold directly above the filter assembly. Refer to the outline drawings (Figures 1-1,1-2, 1-3, 1-4, 1-5, 1-6).

1. Disconnect the servo valve cable from the servo valve.
2. Remove the four #10-32 UNF socket head cap screws holding the servo valve to the manifold.
3. Discard the four O-rings between the servo valve and the manifold.
4. Obtain a replacement servo valve and verify part number and revision with the existing unit.
5. Remove the protective plate from the replacement servo valve and verify that O-rings are on all four counter bores of the servo valve.
6. Place the servo valve onto the hydraulic manifold. Be sure to orient the servo valve to match the original orientation. Be sure that all four O-rings remain in their proper location during assembly.
7. Install four #10-32 UNF socket head cap screws and torque to (6.3 to 8.5 N·m / (56 to 75) lb-in.

LVDT Replacement

⚠CAUTION

Use care and follow all instructions after removal of supply pressure and blocking the actuator in extended position. Significant weight is being supported, and the potential to cause bodily injury is high if all safety precautions are not followed.

The LVDTs are located on the right side of the upper and lower manifolds when viewing the front (hydraulic port connections) of the actuator. Refer to the outline drawings (Figures 1-1, 1-2, 1-3, 1-4, 1-5, 1-6).

1. Shut off the hydraulic supply to the IGV actuator and ensure that the actuator is in the fully extended position. You may need to block it in this position.
2. Remove the LVDT covers by removing the four #10-32 UNF screws holding the access covers on the top and side of the LVDTs.
3. Disconnect both sets of LVDT connectors.
4. Remove the #10-32 UNF locknuts and washers (Figure 1-7 items 61 and 65) from the defective LVDT rod holding the 0.250 inch flats on the rod.
5. Lower the rod from the anti-rotation plate and allow it to rest on the LVDT.
6. Remove the two 0.250-20 UNC socket head cap screws holding the LVDT bracket to the upper and lower manifolds.
7. Carefully remove the LVDT assembly from the actuator by vertically lowering it away from the IGV. Take care not to damage the good LVDT housing and rod.
8. Obtain a replacement LVDT and verify part number and revision with the existing unit.
9. Install the bottom #10-32 UNF locknut and washer on the replacement LVDT rod. Install the new rod into the anti-rotation plate, positioning the rod height to approximately match the other LVDT rod height.
10. Install the #10-32 UNF locknut and washer onto the LVDT rod but do not torque the nut at this time.
11. Carefully slide the replacement LVDT over the LVDT rod. ***Be very careful not to force the LVDT at any time since this could damage the LVDT rod.***
12. Install the two 0.250-20 UNC socket head cap screws holding the LVDT bracket to the upper and lower manifolds and torque to (13.6 to 18.1) N·m / (120 to 160) lb-in.
13. Connect the LVDT cable to the new LVDT.
14. Reattach the hydraulic drain connection.

15. Once the LVDT is installed, it must then be calibrated as described below.
16. Covers will be attached after calibration.

LVDT Calibration

1. Whenever an LVDT is replaced, or whenever its core rod adjustment is disturbed, the LVDT output voltage must be calibrated in the following way.

> ⚠CAUTION
>
> **Use care and follow all instructions after removal of supply pressure and blocking the actuator in extended position. Significant weight is being supported and the potential to cause bodily injury is high if all safety precautions are not followed.**

2. If not replacing an LVDT but calibrating:
   a. Ensure that the actuator it is in its fully extended position. Shut off the hydraulic supply to the IGV actuator and block it in this position.
   b. Remove the LVDT covers by removing the four #10-32 UNF screws holding the access covers on the top and side of the LVDTs.
3. Adjust the LVDT rod so that the output of the replaced LVDT is (0.7 ± 0.1) Vrms with the IGV actuator fully extended (inlet guide vane closed).
4. Tighten the #10-32 UNF locknut to (3.6 to 4.0) N·m / (32 to 35) lb-in.
5. Attach an accurate stroke measurement device (dial indicator or equivalent), capable of measuring 4 inches (102 mm) of stroke, to the IGV actuator body.
6. Apply hydraulic pressure to the IGV actuator and manually command the actuator to retract stroke [(69.3 ± 0.3) mm / (3.58 ± 0.01) inches] / [(95.5 ± 0.3) mm / (3.76 ± 0.01) inches] / [(100.1 ± 0.3) mm / (3.94 ± 0.01) inches] by manipulating the electronic controller.
7. Note and record the LVDT output voltages at this [(90.9 ± 0.3) mm / (3.58 ± 0.01) inches] / [(95.5 ± 0.3) mm / (3.76 ± 0.01) inches] / (100.1 ± 0.3) mm / (3.94 ± 0.01) inches] stroke position.
8. Remove the actuator control command, returning the actuator to its rest (inlet guide vane closed) position.
9. Shut off the IGV actuator hydraulic supply.
10. Update the IGV actuator control logic with the new LVDT output voltage value.

Troubleshooting Charts

Faults in the IGV control may be associated with speed variations of the prime mover, but such speed variations may not always indicate system faults. Therefore, when improper IGV operation occurs, check all components, including the turbine for proper operation. Refer to applicable electronic control manuals for assistance in isolating the trouble. The following steps describe troubleshooting for the IGV actuator.

Disassembly of the core IGV actuator parts in the field is ***not*** recommended due to the special tools and procedures required. Under unusual circumstances where disassembly becomes necessary, all work and adjustments should be made by personnel thoroughly trained in the proper procedures and tools.

When requesting information or service help from Woodward, it is important to include the part number and serial number of the actuator assembly in your communication.

Symptom	Possible Causes	Remedies
External hydraulic leakage	Static O-ring seal(s) missing or deteriorated	Replace O-rings fitted to user-serviceable components (filter, servo valve, trip relay valve) as needed. Otherwise, return actuator to Woodward for service.
	Dynamic O-ring seal missing or deteriorated	Return actuator to Woodward for service.
Internal hydraulic leakage	Servo valve internal O-ring seal(s) missing or deteriorated	Replace servo valve.
	Servo valve metering edges worn	Replace servo valve.
	Piston seal missing or deteriorated	Return actuator to Woodward for service.
Actuator will not open (actuator retract)	Servo valve command current incorrect. (The sum of the current through the three coils of the servo valve must be greater than the null bias of the servo valve for the actuator to open.)	Trace and verify that all wiring is in accordance with the electrical schematic (Figures 1-9, 1-10, 1-11) and the GE system wiring schematic(s). Pay special attention to the polarity of the wiring to the servo valve and LVDT.
	Servo valve failure	Replace servo valve.
	Hydraulic supply pressure inadequate	Supply pressure must be greater than 9653 kPa / 1400 psig (11 032 kPa / 1600 psig preferred).
	Trip relay pressure inadequate	Trip pressure must be greater than 276 kPa (40 psig).
	Trip solenoid voltage inadequate (electric trip system IGVA)	Trip solenoid voltage must be (90 to 140) V (dc).
	Trip Relay Valve Cartridge or logic element failure	Remove the Trip Relay Valves or Logic Elements from the actuator as described previously. Visually inspect the cartridges and check for evidence of contamination, sticky operation, or binding. Clean or replace as described in the Maintenance section.
Actuator will not close	Servo valve command current incorrect. (The sum of the current through the three coils of the servo valve must be less than the null bias of the servo valve for the actuator to close.)	Trace and verify that all wiring is in accordance with the electrical schematic (Figure 1-9, 1-10, 1-11) and the GE system wiring schematic(s). Pay special attention to the polarity of the wiring to the servo valve and LVDT.
	Servo valve failure	Replace servo valve.
	LVDT failure	Replace LVDT.
	Linkage broken	Return actuator to Woodward for service.
	Trip Relay Valve Cartridge failure	Remove the two Trip Relay Valves from the actuator as described previously. Visually inspect and actuate by hand. Check for contamination, sticky operation, or binding. Clean as described in the Maintenance section, or replace the Trip Valves.
Actuator will not respond smoothly	Hydraulic filter clogged	Check the differential pressure indicator on the filter housing.
	Servo valve spool sticking	Verify hydraulic contamination levels are within recommendations of Chapter 1. The use of dither may improve performance in contaminated systems.
	Servo valve internal pilot filter clogged	Replace servo valve.
	Rod-end(s) worn out	Return actuator to Woodward for service.
	Piston seal worn out	Return actuator to Woodward for service.
	Trip Relay Valve Cartridge or logic element failure	Remove the two Trip Relay Valves (or four logic element cartridges) from the actuator as described previously. Visually inspect and actuate by hand. Check for contamination, sticky operation, or binding. Clean as described in the Maintenance section, or replace the valves.

Symptom	Possible Causes	Remedies
Actuator seals wear out prematurely	Hydraulic contamination level is excessive	Verify hydraulic contamination levels are within recommendations of Chapter 1. The use of excessive dither may reduce life in contaminated systems.
	System is oscillating (seal life is proportional to distance traveled). Even small oscillations (on the order of ±1 %) at slow frequencies (on the order of 0.1 Hz) cause wear to accumulate rapidly.	Determine and eliminate the root cause of oscillation.

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/directory**, 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) 6762 6727
Germany:	
Kempen	+49 (0) 21 52 14 51
Stuttgart	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
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) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
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) 6762 6727
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
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 ____________________

____

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 L—
- Updated Regulatory and Compliance Section
- Replaced DOC and DOI

Changes in Revision K—
- Updated to include triple LVDT version of IGV including drawings 1-6a, 1-6b, 1-6c

Changes in Revision J—
- Updated IECEx compliance information

Changes in Revision H—
- Updated Compliance information
- Added cleaning warning to Chapter 5 Maintenance section
- Added new Declarations

Changes in Revision G—
- Updated Regulatory Compliance information to latest, including IECEx and GOST R

Declarations

EU DECLARATION OF CONFORMITY

EU DoC No.:	00212-04-EU-02-03
Manufacturer's Name:	WOODWARD INC.
Manufacturer's Contact Address:	1041 Woodward Way Fort Collins, CO 80524 USA
Model Name(s)/Number(s):	Inlet Guide Vane (IGV) Actuator with electrical connectors: 9904-533 and similar
The object of the declaration described above is in conformity with the following relevant Union harmonization legislation:	Directive 2014/34/EU on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres
Markings in addition to CE marking:	Ex Category 3 Group II G, Ex nA IIC T3 Gc, IP54
Applicable Standards:	EN 60079-0:2012/A11:2013 - Explosive atmospheres - Part 0: Equipment - General requirements EN 60079-15:2010 - Explosive atmospheres -- Part 15: Equipment protection by type of protection "n"

This declaration of conformity is issued under the sole responsibility of the manufacturer
We, the undersigned, hereby declare that the equipment specified above conforms to the above Directive(s).

MANUFACTURER

[signature]
Signature

Christopher Perkins
Full Name

Engineering Manager
Position

Woodward, Fort Collins, CO, USA
Place

02 - MAY - 2016
Date

5-09-1183 Rev 26

DECLARATION OF INCORPORATION
Of Partly Completed Machinery
2006/42/EC

File name:	00212-04-EU-02-01
Manufacturer's Name:	WOODWARD INC.
Manufacturer's Address:	1041 Woodward Way. Fort Collins, CO, 80524 USA
Model Names:	Inlet Guide Vane (IGV) Actuators
This product complies, where applicable, with the following Essential Requirements of Annex I:	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7

The relevant technical documentation is compiled in accordance with part B of Annex VII. Woodward shall transmit relevant information if required by a reasoned request by the national authorities. The method of transmittal shall be agreed upon by the applicable parties.

The person authorized to compile the technical documentation:

Name: Dominik Kania, Managing Director
Address: Woodward Poland Sp. z o.o., ul. Skarbowa 32, 32-005 Niepolomice, Poland

This product must not be put into service until the final machinery into which it is to be incorporated has been declared in conformity with the provisions of this Directive, where appropriate.

The undersigned hereby declares, on behalf of Woodward Governor Company of Loveland and Fort Collins, Colorado that the above referenced product is in conformity with Directive 2006/42/EC as partly completed machinery:

MANUFACTURER

Signature

Christopher Perkins
Full Name

Engineering Manager
Position

Woodward Inc., Fort Collins, CO, USA
Place

03-MAY-2016
Date

Document: 5-09-1182 (rev. 16) **PAGE** 1 of 1

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 26374.

B26374:L

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Email and Website—www.woodward.com

**Woodward has company-owned plants, subsidiaries, and branches,
as well as authorized distributors and other authorized service and sales facilities throughout the world.**

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