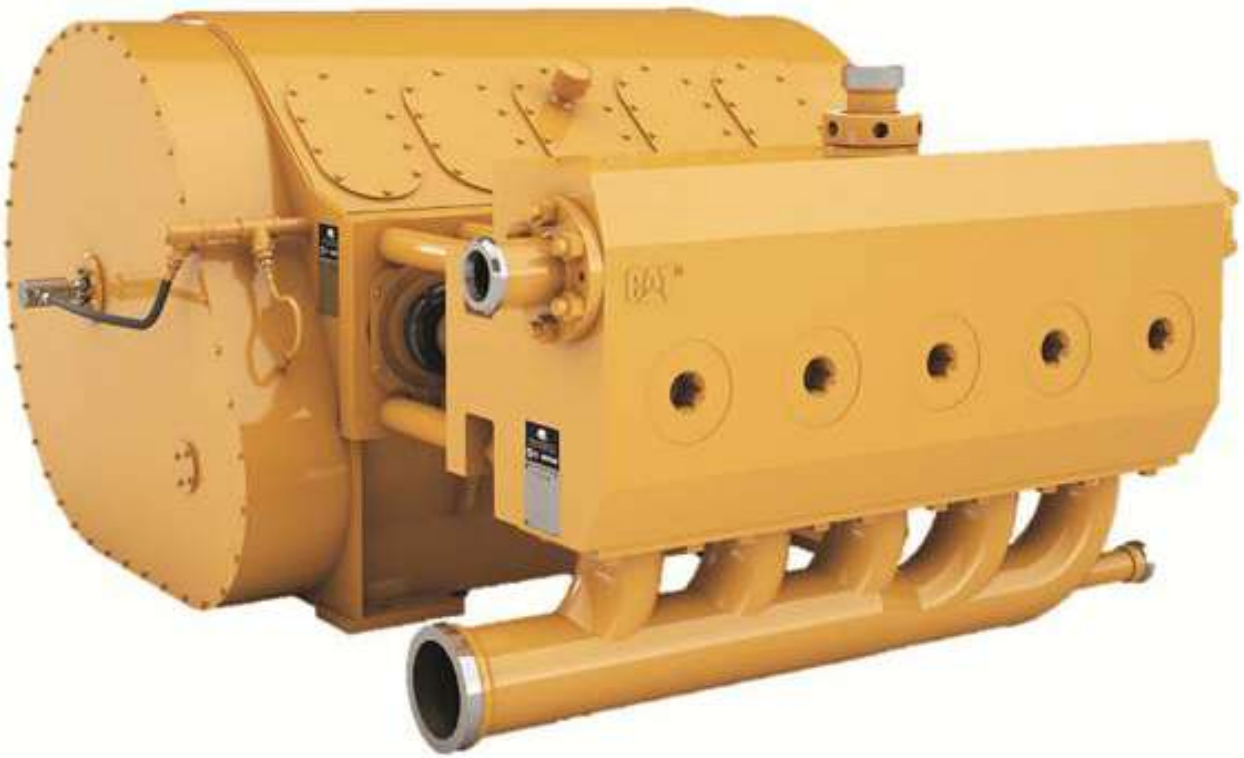
WS223 WS255 WS273 and WS305

Well Stimulation Pump Project Guide



1 Introduction

This document is intended to provide the necessary information for the correct application and installation Cat® Well Stimulation pumps. This document shall act as the resource for installation procedures for the customer. Contact the Application Support Center (ASC) for questions related to the Well Stimulation pumps which are not specifically addressed in this guide.

1.1 Applicable Products (Serial Number Prefixes)

Petroleum Well Stimulation Pumps:

WS223 .....(S/N: SR31 – UP)

WS223XD .....(S/N: SR41 – UP)

WS223SS…….(S/N: BM31 – UP)

WS255 .....(S/N: SR51 – UP)

WS255XD .....(S/N: SR61 – UP)

WS255SS..... (S/N: BM51 – UP)

WS273XD…….(S/N: DG21 – UP)

WS305XD .....(S/N: EA21 – UP)

2 Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools in order to perform these functions properly.

The information in this publication was based upon current information at the time of publication. Check for the most current information before you start any job. Cat dealers will have the most current information. Improper operation, maintenance or repair of this product may be dangerous and may result in injury or death. Do not operate or perform any maintenance or repair on this product until you have read and understood the operation, maintenance and repair information. Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are not all inclusive.

WARNING

Do not operate or work on this equipment unless you have read and understand the instructions and warnings in the Operation and Maintenance Manuals. Failure to follow the instructions or heed the warnings could result in serious injury or death.

If a tool, a procedure, a work method or an operating technique that is not specifically recommended by Caterpillar is used, you must be sure that it is safe for you and for other people. You must also be sure that the product will not be damaged. You must also be sure that the product will not be made unsafe by the procedures that are used.

WARNING: Could cause serious injury or death. Do not operate or work on this equipment unless you have read and understand the operation and maintenance manuals.

2.1 Warning – Replacement Parts

When replacement parts are required for this product, Caterpillar recommends using Cat replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

2.2 Guarding

Serious injury can be prevented with proper guards around the pump input pinion shaft and plunger rod area. Caterpillar strongly recommends installing fixed guards to these areas. It is the responsibility of the OEM or installer of this pump to ensure that guards

are installed that meet all applicable industry standards and all applicable governmental, environmental, and safety guidelines, practices, regulations, and mandates.

WARNING

To avoid personal injury due to entanglement with moving components, keep all guards and covers in place. Install pump guard when system is not in use.

3 Mounting

This section contains general information on mounting of the Well Stimulation pump. For additional information or questions related to mounting or isolation that are not specifically addressed in this guide, contact the Cat ASC.

3.1 Mounting Overview

Longevity and trouble-free service of the Well Stimulation pump are functions of proper installation. Careful consideration must be devoted to the following:

A. Power Source: The rating of the prime mover, most commonly an 1800 to 2100 rpm diesel engine, should not exceed the rating of the pump at intermittent service, whether 2250 bhp, 2500 bhp, 2700 bhp or 3000 bhp.

B. Drivetrain: The connecting drivetrain between the pump and prime mover should include a transmission with a broad usable gear range, universal joints, and a slip joint to maximize the effective pump range of pressure and flow characteristics. The transmission should be of power-shift type, including an

3.2 Weight and CG

The following center of gravity coordinates are with reference to an origin (0,0,0) at the intersection of the pinion shaft

4 Power End

4.1 System Overview

Proper lubrication is critical to successful pump operation. The lubrication system of a pump accomplishes the following functions:

- Lubricates surfaces to minimize friction losses
- Cools internal components
- Cleans the pump by flushing away wear particles
- Cushions the pump's bearings from the compression in the cylinders
- Seals the pump's metal surfaces to prevent rust

Cat Well Stimulation Pump standard components:

- Housing – from fabricated steel that is stress relieved and line bored
- Crankshaft – machined from a heat treated steel forging. Has journals that are precision ground and supported by robust design cylindrical main roller bearings.
- Bull Gears – double opposing, helical type gears of AGMA #8 quality for high horsepower. These are precision machined from alloy steel castings of high strength grade. The gear teeth are induction hardened, and crankshaft extensions rigidly supported the gears at each end of the pump.
- Pinion Shaft - based on a heat-treated alloy steel shaft and has double opposing, helical type gears integrally machined at its ends. Gears are of AGMA #8 quality for high horsepower. The gear teeth are induction hardened. The shaft is supported near its ends by two (2) robust design spherical main roller bearings.
- Gear Ratio – (6.353:1 for the WS223 and WS255) (5.55:1 for the WS273 and WS305) ratios allow for direct drive by a 1800 to 2100 rpm diesel engine coupled with a power shift transmission, without pump over-speed.
- Pony Rods – replaceable nature with clamped connections at the plunger end of the rod. These are machined from steel castings, and have a precision ground hard overlay (60 Rc) seal surface.
- Stay Rod Assemblies – based on high-strength heat treated alloy steel that is precision machined. Tensile loading on the stay rod is maintained by the two-piece assembly design.
- Connecting Rods – based on steel castings that are precision machined. Full rod load is supported by large diameter concentric head supports rather than wrist pins.
- Crossheads – based on fully cylindrical castings from high strength ductile iron that is precision machined.
- Crosshead Guides – based on fully cylindrical bronze castings that are precision machined and designed for replace ability.
- Wrist Pins - based on heat treated steel that is precision machined.

- Lubrication – the pumps are configured for pressurized lubrication to all moving parts, using a Dry Sump system by others.

4.2 System Requirements

Reliability and service life of Cat® Well Stimulation pumps are strongly functions of the design quality and proper maintenance of the power end lubrication system. The pump characteristic of high pump pressures with high load conditions at the lowest pump speeds requires employment of an engine-driven lubrication pump to maintain lubrication oil flow rate based on the engine speed rather than the pump speed.

Due to this characteristic of the pump and additional variations in configuration, the power end lubrication external system must be designed and provided by others. Compatibility of the engine, transmission and auxiliaries on the packaged assembly must be analyzed by the equipment manufacturer when designing the external power end lubrication system.

The following criteria will apply to a correctly designed power end lubrication system:

4.2.1 Oil Reservoir

A. Size range from 189 Liter (50 gallon) minimum capacity to 379 Liter (100 gallon) preferred nominal capacity.
B. The suction outlet should be 51 mm (2 in.) minimum and be located as deeply as feasible.
C. The distance between suction outlet and return inlets should be maximized.
D. Minimum fittings are 76 mm (3 in.) for the return fitting for drain back and 25 mm (1 in.) for relief valve line.
E. A magnet with serviceable configuration is recommended, to be installed near the 76 mm (3 in.) return port.
F. A breather/filler cap with 40-micron filtration and 0.71 m^3/min (25 CFM) minimum flow rate should be installed on the reservoir; the cap should include a built-in strainer to prevent entry of foreign debris.
G. A dipstick or sight glass should be employed to monitor reservoir oil level.
H. The reservoir must be located at an elevation lower than the lowest drain port on the power end and as close to the power end as possible, preferably directly beneath the power end.

4.2.2 Lube System Suction Piping

A. This piping must have minimum I.D. 51 mm (2 in.) throughout to maintain suction flow velocity below 0.6 to 0.9 meters (2 feet to 3 feet) per second.
B. A suction strainer must be included with:
- Minimum port size 51 mm (2 in.)
- Wire cloth of 40 to 100 mesh (400-150 micron)
- Minimum element area of 5806 cm^2 (900 in^2)
- A build-in bypass rated at 341 Liters/minute (90 gpm) minimum flow and 21 to 34 kPa (3 to 5 psi, 6 to 10 in-Hg). Cleaning the element is facilitated by use of an in-line canister type strainer design.

C. If the lubrication pump is located at an elevation higher than the fluid level in the reservoir, the suction line may employ a minimum 51 mm (2 in.) swing type check valve.

D. Suction line design should be so that it has minimum length, radiused so as to be free of radical bends, and with wire reinforcement to prevent collapse of the line. Line size of 2.5 to 3.0 inch minimum I.D. should be used to mitigate friction losses if the suction line length exceeds 3 meters (10 feet).

4.2.3 Lube Pump

A. A gear type pump design must be employed with minimum rating of 189 Liters/minute (50 gpm) at its installed maximum rpm.

B. At maximum rpm, the minimum oil pressure should be at least 414 kPa (60 psi). At low idle speed only (~700 engine rpm), 138 kPa (20 psi) is allowable, but only at this low idle condition. Under no circumstance should maximum pressure exceed 862 kPa (125 psi). These targets should be achievable with a 50 gpm pump. The lubrication oil pressure requirements are to be measured and maintained at the lubrication oil inlet port on the power end.

C. Lubrication oil ports at the inlet and outlet of the power end should be as large as possible, with preferred minimums of 51 mm (2 in.) inlet and 25.4 mm (1 in.) outlet. If the inlet port to the gear pump suction inlet is smaller than 51 mm (2 in.), a swage connection should be used on the suction port in order to maintain 51 mm (2 in.) suction line size as close to the gear pump as possible.

D. A vacuum gauge of liquid-fill type with range 0 to 762 mm-Hg (0 to 30 in-Hg) should be installed as close to the gear pump suction port as possible so that suction flow conditions can be monitored. This is an especially valuable feature during cold startups of the pump in low ambient conditions.

E. Direct coupling of the gear pump is possible using an accessory drive location on the engine or to the transmission using a pump-mount type power take-off (PTO). Typical advantages of the transmission/PTO mount are lower mounting elevation and improved suction conditions. The lubrication pump mounted must be a direct-coupled positive drive arrangement, with speed corresponding to the engine speed.

4.2.4 Lube System Pressure Lines and Oil Filter

A. A minimum flow velocity of 3.0 to 3.7 meters (10 to 12 feet) per second must be maintained by use of pressure lines with minimum I.D. of 25.4 mm (1 in.).

B. The pressure lines should have minimum operating pressure rating of 5516 kPa (800 psi) and be wire reinforced.

C. The following specifications apply to the oil filter:

- Minimum rating of 341 L/min / 1379 kPa (90 gpm / 200 psi)
- A built in relief valve of 103 to 173 kPa (15 to 25 psi) must be employed
- Elements of 25 to 33 micron
- The filter element types may be spin-on or canister-enclosed throwaways
- Filter location must be readily serviceable and have a built-in bypass indicator (service indicator)
- The pressure drop associated with filtering 90W gear oil and the service interval of the filter elements may be improved by use of a dual element filter with minimum rating 341 L/min (90 gpm)
- **Caution:** filter protection should never be based on an external relief valve

D. A pressure gauge with range 1379 kPa (200 psi) must be located at the 1 inch NPT lubrication inlet on the power end. For units with remote control consoles, employment of an auxiliary oil pressure gauge is recommended.

4.2.5 Lube System Relief Valve and Relief Return Line

A. The relief valve for the system should be 1 in., 30 to 40 gpm, with ratings of 60 psi minimum / 200 psi maximum, and be of adjustable non-chattering nature.

B. The relief valve must be located at the 1 inch NPT lubrication port on the opposite side of the lubrication inlet on the power end, so that oil flow is distributed throughout the power end internals prior to reaching the relief valve.

C. The relief return line must be 1 inch minimum I.D., have minimum rating 800 psi, be wire reinforced, and return directly to the lubrication oil reservoir.

4.2.6 Lube Drain Lines (from plunger pump to reservoir)

A. The WS223 is equipped with a single 3 inch NPT drain port in the bottom of the power end housing. The WS255, WS273, and WS305 are equipped with dual 3 inch NPT drain ports in the bottom of the power end housing. The power end drain lines should never be smaller than the drain ports, and should have minimum possible lengths while allowing for radiuses free of radical bends. The drain lines should flow along a continual decrease in elevation to the reservoir.

B. An oil temperature gauge with 0 to 121°C (0 to 250°F) capability should be installed in the primary drain line so that its sensor will be submerged in the power end return oil. This temperature gauge should be located so that it is viewed easily. For units with remote control consoles, employment of an auxiliary oil temperature gauge is recommended.

4.2.7 Optional Lube System Equipment

A. For extreme high ambient temperature conditions, an oil cooler may be used to prevent high oil temperatures and decrease in oil viscosity. If so employed, the oil cooler should be of “air to oil” or “forced air” nature and should be located downstream of the oil filter. The cooler should have minimum ratings of 341 L/min / 1724 kPa (90 gpm / 250 psi), and should have minimum 25.4 mm (1 in.) inlet and outlet connections. If the packaged unit may be utilized in extreme cold ambient conditions as well, the oil cooler must be piped so as to allow the oil to bypass the cooler during said low ambient condition.

B. For extreme low ambient temperature conditions, an electric sump heater or a “shell and tube” type heat exchanger may be required to prevent poor lubrication oil suction, lubrication pump damage, and power end damage due to unacceptably high oil viscosity.

C. The electric sump heater, if used, should be installed near the suction outlet of the lubrication oil reservoir and be capable of heating the lubrication oil to approximately 27° to 38°C (80° to 100°F) over an 8 to 12 hour duration. Thermostatic control of the sump heater must be used to prevent overheating of the lubrication oil.

D. The “shell and tube” heater, if used with heat recovery from engine jacket water, should have a heat exchanger with minimum rating 341 L/min / 1724 kPa (90 gpm / 250 psi), and have minimum 25.4 mm (1 in.) inlet and outlet lubrication oil passage connections. The oil cooler must be piped so as to allow the oil to easily bypass the cooler if the power end lubrication oil temperature exceeds 82°C (180°F).

4.3 Power End Lubrication Oil Selection and Recommendations

Gear oils with extreme pressure additives are recommended for the plunger pump. In order to achieve optimum performance, follow the recommendations below.

4.3.1 General Service Gear Oils

The use of synthetic gear oils is recommended in order to achieve optimum oil film thickness, reduced friction, improved startup of the pump and optimal wear protection. The temperature of the pump should not exceed 79°C (175°F) during use. The following characteristics are required:

- Viscosity grade: 75W - 90, rated for extreme service
- Viscosity Index: 135 minimum
- Viscosity of 80 SUS minimum at 99°C (210°F)
- Pour point: 1.7°C (35°F)
- Timken test rating: 50 lbs for non-SAE grades only

4.3.2 Alternate Seasonal Conventional (Non-Synthetic) Gear Oils

Alternate seasonal conventional (non-synthetic) gear oils can be used in the plunger pumps if both of the following conditions are met:

- The oils must have an extreme pressure additive.
- The oils must have a viscosity index of 93 or higher.

Non-SAE grade gear oils must have a Timken test rating of 45 lbs minimum.

4.4 Hub Compatibility

Determine the power end assembly model and corresponding hub part numbers using the table below.

Power End Model Number	Serial Number Prefix	Power End Pump Group Part Numbers	Hub Spec	Applicable Hub Part Number / Quantity 1 each	Applicable Assembly Part Numbers / Quantity 1 each
WS223	FNJ	434-9860	390.60 4"	462-0819	443-8607 key and 476-3491 set screw
			390.65 4"	462-0820	443-8607 key and 476-2855 set screw
WS255	FNK	434-9912 or 457-8377 or 441-6768	390.65 4"	462-0820	443-8607 key and 476-2855 set screw
WS273	DG3	434-9985	390.70 4.5"	462-0821	443-8607 key and 476-2855 set screw
WS305	EA3	435-0063	390.70 4.5"	462-0821	443-8607 key and 476-2855 set screw

Table 3

TABLE 3 – Hub Compatible Cat Power End Assembly Options

5 Fluid End

5.1 System Overview

5.1.1 Fluid End Design

- Fluid Cylinder - Durable low maintenance monoblock design. Precision machined from high strength heat-treated alloy steel forging.
- Plungers - “Quick Disconnect” clamp disconnection. Machined from steel w/precision ground hard overlay (60 Rc) acid resistant packing surface.
- Plunger Packing- “Self-adjusting” type packing assemblies. Precision molded fiber reinforced V-type pressure rings. Supported by precision machined bronze adapter rings. Various compositions available for all common well service fluid media such as hydrocarbons, toluene, etc. and for a wide range of ambient temperatures.
- Valve Covers - Threaded “knockout” type valve covers for ease of maintenance.
- Valve Assemblies - Wing guided well service type valves. Tapered well service type valve seats w/auxiliary seal ring.
- Valve Springs - Long lasting coil springs engineered for a wide range of well service applications. Designed for spring loads, and valve cracking pressures unique to well service pumps.
- Suction Valve Keepers - Combination cage and replaceable valve stop button.
- Discharge Flanges - Dual (RH and LH) outlet design. Replaceable type discharge flanges precision machined from heat-treated alloy steel. Available in male or female with a variety of common well service connections such as integral hammer, union male or female subs (fig. 1502).
- Suction Manifold - Replaceable type manifold fabricated from steel, precision machined, and pressure tested.
- Fluid Seals - Precision molded high-pressure acid resistant fluid seals made from a superior Polyurethane/Molydisulfide seal compound.
- Packing Lubrication - Equipped for a pressurized oil based packing lube system.

5.2 System Requirements

Cat® Well Stimulation pumps are designed for packing lubrication with oil rather than grease. Exceptionally long packing life can be expected providing proper lubrication is supplied to the plunger packing lube port above each plunger bore. Ample plunger and packing lubrication can be achieved with an inexpensive relatively trouble-free low-pressure air operated “lubricant pump” type system. Mechanically driven plunger lubricators are not recommended due to the Well Stimulation pump’s extreme variations in pump speeds.

Proper lubrication is critical during the start-up of the plunger pump. Lubricant for the plunger must begin to flow freely to the stuffing box lube inlet prior to the start-up of the pump and prior to the stoking of the plungers.

Note: Start-up is a critical time for the plunger packing. Lubrication should flow freely to the plunger prior to stoking the pump. Stoking dry plungers may cause the header ring and the packing to tear and to fail.

For all styles of packing, the plunger lube is critical for good packing life and plunger life. Failing to provide adequate or appropriate lube may cause the packing to fail and damage mating components.

A properly designed packing lube system will meet the following specifications:

5.2.1 Oil Reservoir

A. Should be a minimum of 5-gallon capacity.

B. Should be equipped for the vertical installation of an air-operated pump.

C. Should be equipped with a sight glass or dipstick.

D. Should be equipped with a breather/filler cap that has a built-in strainer to prevent trash from entering the reservoir.

5.2.2 Air Operated Lubricant Pump

A. Vertical air operated 12 oz. per minute / 150 psi / 40:1 ratio lubricant pump.

B. Must be equipped with a 1/4 inch adjustable air pressure regulator in order to adjust the pump speed and packing lubricant flow rate.

C. Should be installed so that the bottom of the pump is no closer than 25.4 mm (1 in) to the bottom of the reservoir.

5.2.3 Packing Lubricant Flow Lines

A. Should be 1/4 inch I.D./1250 psi minimum/fiber or wire reinforced hose to prevent crimping.

B. Should be a common line from the lubricant pump to the plunger pump at which point it will branch off to each individual packing lube port.

5.2.4 Flow Control Needle Valves

A. Should be a 1/4 inch needle valve which can be locked at any given setting after adjustment.

B. Must be installed in each lubricant flow line which leads to the individual packing lube ports in the plunger pump fluid cylinder.

5.2.5 High Pressure Check Valves

A. Must be rated at or above the Well Stimulation pump’s maximum pressure rating.

B. Must be installed in the packing lube port so that the direction of flow is into the fluid cylinder.

5.2.6 Packing Lube System Flow Requirements/Adjustments

A. After filling with the proper grade of packing lube oil, and before rotating the Well Stimulation pump, the lube system should be adjusted to supply oil to each plunger and packing assembly.

B. Recommended minimum consumption rate 1.0 pint per plunger per hour.

C. It is recommended that you set your lubricators at 25 psi. This will provide adequate lubrication to the packing and not blow out the wiper seal. Users

pumping a CO2 job will need to increase the oil lubrication to roughly 40 psi to avoid ice crystal build up.

D. During commissioning of the pump it is recommended that the pressure vs. flow curve is measured so that the pressure requirements can be used during operation knowing the minimum flow rate is achieved. The pressure is easier to measure on location and will make stage preparation faster.

E. Rates as high as 3 times the minimum recommended have been reported, and this should be considered when sizing the lube reservoir.

5.3 Fluid End Lubrication Oil Selection

5.3.1 Recommended Plunger Lube Oils

The use of an optimal plunger lubricant is critical to the achievement of full performance and service life that is designed and built into the pump. The use of the recommended oils can reduce horsepower robbing friction, reduce fuel consumption and increase the net amount of hydraulic horsepower delivered by the pump. The use of a modern machine tool Way Oil for improved lubrication of the plungers and packing is highly recommended by Caterpillar. In an area where a Way Oil is not available, a suitable Rock Drill oil may be substituted.

The use of Cat HYDO™ Advanced oils, SAE 10 and SAE 20 are acceptable for this application.

Note: The use of lubricants that do not meet these recommendations is unacceptable and may result in shorter plunger life, shorter packing life and premature failure of these components.

Refer to the follow table for the specifications that must be met by an acceptable Way Oil or Rock Bit plunger pump oil. The use of lubricants that fail to meet these specifications is not allowed. The use of used crankcase oil is unacceptable.

Specifications for Plunger Lube Oils		
Characteristic	Requirements for Ambient Conditions	
	0°C (32°F)	< 0°C (32°F)
ISO Grade	32	68
CPS No.	232500	232511
AGMA Grade	-	2
API Gravity	21.4	25.6
cSt at 40°C (1)	30.4	64.6
cSt at 100°C(1)	4.9	7.3
SUS at 100°F(2)	158	338
SUS at 210°F(2)	42.7	50.8
Viscosity Index	74	61
Flash Point, C(F)	170°C (338°F)	200°C (389°F)
Pour Point, C(F)	-44°C (-48°F)	-24°C (-11°F)
(1) Viscosity, Kinematic (2) Viscosity, Saybolt.		

Table 4

Lubricants that fail to meet these specifications, and especially “used crankcase oils”, are unacceptable.

Startup is a critical time for plunger packing. Lubrication should flow freely to plunger prior to stroking the pump. Stroking dry plungers can cause the header ring and packing to tear and fail.

5.4 Suction Manifold Compatibility

The below table addresses the Suction Manifolds and their compatibility with the various Cat fluid end horsepower ratings, flow sizing and coupling configurations, and climate requirements.

Fluid End HP	Description	Centers	Part Number
2250	Tri 6" Dual hole Victaulic log	12"	434-9803
2250	Tri 6" Dual hole log - 6" Fig. 206/6" Fig. 206	12"	434-9852
2250	Tri 6" Dual hole Zoomie - 6" Fig. 206/2" Fig. 200	12"	434-9895
2250	Tri 6" Low Profile - 6" Victaulic/2" Fig 200 (cold weather)	12"	455-5452
2500	Quint 6" Victaulic log (bolts)	10"	434-9854
2500	Quint 6" Zoomie – 6" Fig. 206/2" Fig 200	10"	434-9855
2500	Quint 8" Zoomie - 8" Fig. 206/2" Fig. 200	10"	434-9857
2500	Quint 6” log – 6” Fig. 206/6” Fig. 206 (cold weather)	10”	455-5463
2500	Quint 5" Low Profile - 6" Fig. 206/2" Fig. 206 (cold weather)	10"	434-9859
2500	Quint Zoomie 6" Fig. 206 (cold weather) (2" end port)	10"	450-7596
2500	Quint Zoomie 6" Fig. 206 (cold weather) (4" end port)	10"	450-7597
2700	Tri 6" Victaulic	13"	435-0038
2700	Tri 6" Zoomie - 6" Fig. 206/2" Fig. 200	13"	455-5447
3000	Quint 8" Victaulic	13"	435-0059
3000	Quint 6" Victaulic	13"	435-0049
3000	Quint 6" Zoomie - 6" Fig 206/2" Fig 200	13"	455-5449
3000	Quint 6" Zoomie - 6" Fig 206/2" Fig 200 (cold weather)	13"	469-4733

Table 5

TABLE 5 – Suction Manifold Compatible Options

5.5 Gage Port Compatibility

Table 6 details the fluid end serial numbers and prefixes corresponding to the relevant gage port assembly components.

WC	Details	Prefix	RELEVANT COMPLETE PUMP WS code	Applicable Gage Port
WC001	2500 hp 8 in stroke 4.5" bore 5 cyl XD fluid end	P23	WS255	462-9801
WC002	2500 hp 8 in stroke 4.0" bore 5 cyl XD fluid end	FN2	WS255	462-9801
WC003	2250 hp 8 in stroke 4.5" bore 3 cyl XD fluid end	FN3	WS223	462-9801
WC004	2250 hp 8 in stroke 4.5" bore 3 cyl standard fluid end	FN4	WS223	462-9802
WC005	2500 hp 8 in stroke 4.0" bore 5 cyl standard fluid end	FN5	WS255	462-9801
WC006	2500 hp 8 in stroke 4.5" bore 5 cyl standard fluid end	FN6	WS255	462-9802
WC007	2500 hp 8 in stroke 5.0" bore 5 cyl standard fluid end	FN7	WS255	462-9802
WC008	2500 hp 10 in stroke 4.5" bore 3 cyl XD fluid end	FN8	WS253	462-9801
WC009	2400 hp 10 in stroke 4.5" bore 3 cyl XD fluid end	FN9	WS243	462-9801
WC010	2700 hp 10 in stroke 4.5" bore 5 cyl XD fluid end	FNB	WS275	462-9801
WC011	2400 hp 10 in stroke 4.0" bore 3 cyl XD fluid end	FNC	WS243	462-9801
WC012	2400 hp 10 in stroke 5.0" bore 3 cyl XD fluid end	FND	WS243	462-9802
WC013	2400 hp 10 in stroke 5.5" bore 3 cyl XD fluid end	FNE	WS243	462-9802
WC014	2700 hp 10 in stroke 4.0" bore 5 cyl XD fluid end	FNF	WS275	462-9801
WC015	2700 hp 10 in stroke 5.0" bore 5 cyl XD fluid end	FNG	WS275	462-9802
WC016	2700 hp 10 in stroke 5.5" bore 5 cyl XD fluid end	FNH	WS275	462-9802
WC019	2250 hp 3 cyl power end and fluid end	SR3	WS223	462-9802
WC020	2500 hp 5 cyl power end and fluid end	SR5	WS255	462-9801 or 462-9802
WC021	2250 hp 3 cyl power end and fluid end XD	SR4	WS223	462-9801 or 462-9802
WC022	2500 hp 5 cyl power end and fluid end XD	SR6	WS255	462-9801
WC023	2700 hp 3 cyl power end and fluid end XD	DG2	WS273	462-9801
WC025	2700 hp 10 in stroke 4.0" bore 3 cyl XD fluid end	DG4	WS273	462-9801
WC026	2700 hp 10 in stroke 4.5" bore 3 cyl XD fluid end	DG5	WS273	462-9801
WC027	2700 hp 10 in stroke 5.0" bore 3 cyl XD fluid end	DG6	WS273	462-9801

Table 6

Table 6 continues on following page

WC	Details	Prefix	RELEVANT COMPLETE PUMP WS code	Applicable Gage Port
WC028	3000 hp 5 cyl complete power end and fluid end XD	EA2	WS305	462-9801 or 462-9802
WC030	3000 hp 10 in stroke 4.0" bore 5 cyl XD fluid end	EA4	WS305	462-9801
WC031	3000 hp 10 in stroke 4.5" bore 5 cyl XD fluid end	EA5	WS305	462-9801
WC032	3000 hp 10 in stroke 5.0" bore 5 cyl XD fluid end	EA6	WS305	462-9801
WC033	3000 hp 10 in stroke 5.5" bore 5 cyl XD fluid end	EA7	WS305	462-9802
WC040	2250 hp 3 cyl complete fluid end and power ends SS	BM3	WS223	462-9801 or 462-9802
WC041	2250 hp 8 in stroke 4.5" bore 3 cyl XD SS fluid end	BM4	WS223	462-9801
WC042	2500 hp 5 cyl complete fluid end and power end pumps SS XD	BM5	WS255	462-9801
WC043	2500 hp 8 in stroke 4.0" bore 5 cyl XD SS fluid end	BM6	WS255	462-9801
WC044	2500 hp 8 in stroke 4.5" bore 5 cyl XD SS fluid end	BM7	WS255	462-9801
WC045	2500 hp 10 in stroke 5.0" bore 3 cyl XD SS fluid end	RWD	WS253	462-9801
WC046	2500 hp 10 in stroke 4.5" bore 3 cyl XD SS fluid end	RWC	WS253	462-9801
WC047	2400 hp 10 in stroke 4.0" bore 3 cyl XD SS fluid end	RX2	WS243	462-9801
WC048	2400 hp 10 in stroke 4.5" bore 3 cyl XD SS fluid end	RX3	WS243	462-9801
WC049	2400 hp 10 in stroke 5.0" bore 3 cyl XD SS fluid end	RX4	WS243	462-9802
WC050	2400 hp 10 in stroke 5.5" bore 3 cyl XD SS fluid end	RX5	WS243	462-9802
WC051	2700 hp 10 in stroke 4.0" bore 3 cyl XD SS fluid end	RX6	WS273	462-9801
WC052	2700 hp 10 in stroke 4.5" bore 5 cyl XD SS fluid end	RX7	WS275	462-9801
WC053	2700 hp 10 in stroke 5.0" bore 5 cyl XD SS fluid end	RX8	WS275	462-9802
WC054	2700 hp 10 in stroke 5.5" bore 5 cyl XD SS fluid end	RX9	WS275	462-9802
WC055	2500 hp 10 in stroke 5.0" bore 3 cyl XD fluid end	FNT	WS253	462-9801
WC056	2250 hp 8 in stroke 5.0" bore standard fluid end	FNL	WS223	462-9802
WC057	2250 hp 8 in stroke 5.0" bore 3 cyl XD fluid end	FNM	WS223	462-9802
WC058	2250 hp 8 in stroke 5.0" bore 3 cyl XD SS fluid end	BM8	WS223	462-9802
WC059	2500 hp 8 in stroke 5.0" bore 5 cyl XD fluid end	FNP	WS255	462-9802
WC060	2500 hp 8 in stroke 5.0" bore 5 cyl XD SS fluid end	BM9	WS255	462-9802

Table 6

TABLE 6 – Gage Port Compatible Options

6 Supercharging System

6.1 Supercharging System Requirements

Due to the pumping of heavy slurries at a variety of flow rates, a well-designed supercharging system is required for reliable operation of the Cat Well Stimulation Pump. The supercharging system must maintain proper fluid flow and pressure supply to the suction manifold to prevent cavitation and fallout of solids suspended in the fluid slurry.

A properly designed supercharging system will satisfy the following criteria:

6.1.1 Suction piping and hoses

6.1.1.1 Primary Suction Piping and Hoses

These are the piping and hoses located where the fluid first begins to flow from its source only under the influence of gravity or atmospheric pressure. This section of the system is typically a pipe or hose connecting the fluid reservoir to the charge pump or blender suction pump. The flow velocity (a function of the fluid end's maximum flow rating at a given plunger diameter) in this section must not exceed 1.2 meters (4 feet) per second so as to flow under natural influences. Additional guidelines are as follows:

A. Hoses must have minimum rating of 122 in-Hg (60 psi), be oil and chemical resistant, and be wire reinforced combination vacuum/discharge type hose.
B. With steel piping, prevention of air traps in the system is essential. All piping runs must be installed so that they are level or progressively higher toward the fluid end. Reducer fittings, if employed, should be of eccentric type and be installed "belly down". Any welded connections must be both air and fluid tight.
C. For this section of the system, all piping or hoses should be of minimum necessary length, with minimum number of turns, radiused so that they are free of radical bends, and have total maximum length of 3 meters (10 feet).

6.1.1.2 Secondary Suction Piping and Hoses:

These are the piping and hoses located where the pressurized fluid is carried from the discharge of the centrifugal pump to another location in the flow system. This piping also connects the centrifugal charge pump to the fluid end suction manifold inlet, and may also be piping which connects the centrifugal mixing pump discharge to a mixing tub inlet. The recommended range of flow velocity for this portion of the system, as a function of fluid end plunger diameter, is 2.4 to 3.7 meters (8 to 12 feet) per second. Additional guidelines are as follows:

A. Hoses must have minimum rating of 204 in-Hg (100 psi), be oil and chemical resistant, and be wire reinforced combination vacuum/discharge type hose.
B. With steel piping, prevention of air traps in the system is essential. All piping runs must be installed so that they are level or are progressively higher toward the fluid end. Reducer fittings, if employed, should be of eccentric type and be installed "belly down". Any welded connections must be both air and fluid tight.
C. For this section of the system, all piping or hoses should be of minimum necessary length, with minimum number of turns, radiuses so that they are free of radical bends, and have total maximum length of 4.6 meters (15 feet).

6.1.2 Pump

For some well servicing operations, the use of two centrifugal units is required, one for mixing of slurry and the other for supercharging. Use of two centrifugal units requires that together they satisfy the following criteria:

A. Must maintain 345 kPa (50 psi, 115 ft. head) at the fluid end suction manifold inlet, and be capable of delivering the maximum rated flow of the fluid end.
B. Must be sized so as to overcome any piping friction losses in the section between the centrifugal pump discharge and the fluid end suction manifold inlet. As an example, the centrifugal may need to be designed to deliver the required flow at a pressure 50 % higher than at the fluid end suction manifold inlet.
C. Must operate at a speed which delivers the required flow within the upper quartile of its efficiency range, so as to ensure adequate fluid acceleration upon demand from the fluid end.
D. Must have sufficient power to deliver the fluid end flow requirements of volume and pressure as well as the specific gravity of the fluid or slurry.

6.1.3 Suction Pulsation Dampener

A harmonic fluid rhythm is generated in the supercharge system due to fluid starting and stopping under each cycle of the suction valves. This pressure signal must be dampened from the system in order to maintain effectiveness of the charge pump, and this dampening is assisted by a suction pulsation dampener.

Recommended characteristics of a suction pulsation dampener are as follows:

A. A Nitrogen charged bladder type with minimum rating of 690 kPa (100 psi).
B. Installed location of the dampener should be above the fluid flow path to mitigate settling and packing of solids around the bladder.
C. Installed location of the dampener should be as close to the fluid end suction manifold inlet as possible.
D. The damper must be pre-charged according to the manufacturer's recommendations; typically 30 to 40 % of the anticipated supercharge pressure.

6.1.4 Supercharge Pressure Gauge

The system should always include a supercharge pressure gauge which satisfies the following criteria:

A. Pressure gauge should be a liquid filled with range 0 to 690 kPa (0 to 100 psi).
B. Installed location of the gauge should be as close to the fluid end suction manifold inlet as possible.
C. Gauge should be used with a gauge snubber or a needle valve that can be adjusted to function as a snubber.

6.2 Operational Parameters

6.2.1

Recommended Supercharge Pressure at Plunger Pump Suction Inlet	
Minimum	50 psi (115 ft. head)
Maximum	80 psi (185 ft. head)

Table 7

Note: the pressure of the supercharge must always exceed the vapor pressure of the working fluid in the system.

6.2.2

Number of 4 Inch Suction Hoses Required to Maintain 4 Feet Per Second Maximum Fluid Velocity in "Gravity Feed" Portion of the System		
GPM Flow	**BPM Flow**	**Number of 4 Inch Hoses Required**
Up to 157	3.7	One
Up to 313	7.5	Two
Up to 470	11.2	Three
Up to 626	14.9	Four
Up to 783	18.6	Five
Up to 940	22.4	Six
Up to 1096	26.1	Seven
Up to 1253	29.8	Eight
Up to 1409	33.5	Nine
Up to 1566	37.3	Ten

Table 8

6.2.3

Steel Pipe Size Required to Maintain 4 Feet Per Second Maximum Fluid Velocity in "Gravity Feed" Portion of the System		
GPM Flow	**BPM Flow**	**Pipe Size Required**
Up to 156	3.7	4 inch I.D.
Up to 250	5.9	5 inch I.D.
Up to 353	8.4	6 inch I.D.
Up to 626	14.9	8 inch I.D.
Up to 979	23.3	10 inch I.D.
Up to 1410	33.6	12 inch I.D.
Up to 1719	40.9	14 inch I.D.

Table 9

6.2.4

Number of 4 Inch Suction Hoses Required to Maintain 12 Feet Per Second Maximum Fluid Velocity in the "Pressurized" Portion of the System		
GPM Flow	**BPM Flow**	**Number of 4 inch Hoses Required**
Up to 470	11.1	One
Up to 940	22.3	Two
Up to 1409	33.5	Three
Up to 1879	44.7	Four

Table 10

6.2.5

Steel Pipe Size Required to Maintain 12 Feet Per Second Maximum Fluid Velocity in the "Pressurized" Portion of the System		
GPM Flow	**BPM Flow**	**Pipe Size Required**
Up to 264	6.2	3 inch I.D.
Up to 470	11.1	4 inch I.D.
Up to 734	17.4	5 inch I.D.
Up to 1057	25.4	6 inch I.D.

Table 11

7 System Limits

Pump Model	Plunger Diameter (in)	Max Rod Load (lbs)	Maximum Discharge Pressure (psi)	Maximum Flow Rate (GPM)	Max horsepower input (BHP)
WS223	4.5	225,000	14,147	545	2250
	5.0	225,000	11,459	673	
WS255	4.0	192,325	15,315	716	2500
	4.5	192,325	12,100	908	
	5.0	192,325	9,800	1,122	
WS273	4.0	275,000	21,885	449	2700
	4.5	275,000	17,290	568	
	5.0	275,000	14,005	701	
WS305	4.0	250,000	19,900	747	3000
	4.5	250,000	15,725	946	
	5.0	250,000	12,730	1168	
	5.5	250,000	10,525	1414	

Table 12

8 Performance Data

8.1 WS223 Performance Data

Plunger Diameter	Output per Revolution	Displacement at Pump Plunger Per Minute / Pinion RPM									
		75/476		115/731		200/1271		300/1906		330/2096	
in	Gal/rev	GPM	psi	GPM	psi	GPM	psi	GPM	psi	GPM	Psi
4.5 inch	1.65	124	14147	190	14147	330	10502	496	7002	545	6365
5.0 inch	2.04	153	11459	235	11459	408	8507	612	5671	673	5156
Input Power: BHP		1137		1743		2250		2250		2250	

1. Based on 90% ME and 100% VE -Intermittent Service Only.
2. Pumps with pressures in excess of 15,000 psi require special gauge and discharge flanges.

Table 3

8.2 WS255 Performance Data

Plunger Diameter	Output per Revolution	Displacement at Pump Plunger Per Minute / Pinion RPM									
		111/705		115/731		200/1271		300/1906		330/2096	
in	Gal/rev	GPM	psi	GPM	psi	GPM	psi	GPM	psi	GPM	Psi

8.4 WS305 Performance Data

Plunger Diameter	Output per Revolution	Displacement at Pump Plunger Per Minute / Pinion RPM									
		75/416		115/638		150/832		200/1110		275/1526	
in	Gal/rev	GPM	psi	GPM	psi	GPM	psi	GPM	psi	GPM	Psi
4 inch	2.72	204	19990	312	16450	408	12615	543	9460	747	6875
4.5 inch	3.44	258	15725	396	12985	516	9960	688	7450	946	5425
5 inch	4.25	319	12730	489	10520	637	8065	850	6050	1168	4400
5.5 inch	5.14	386	10525	591	8695	771	6665	1028	5000	1414	3635
Input Power: BHP		2368		3000		3000		3000		3000	

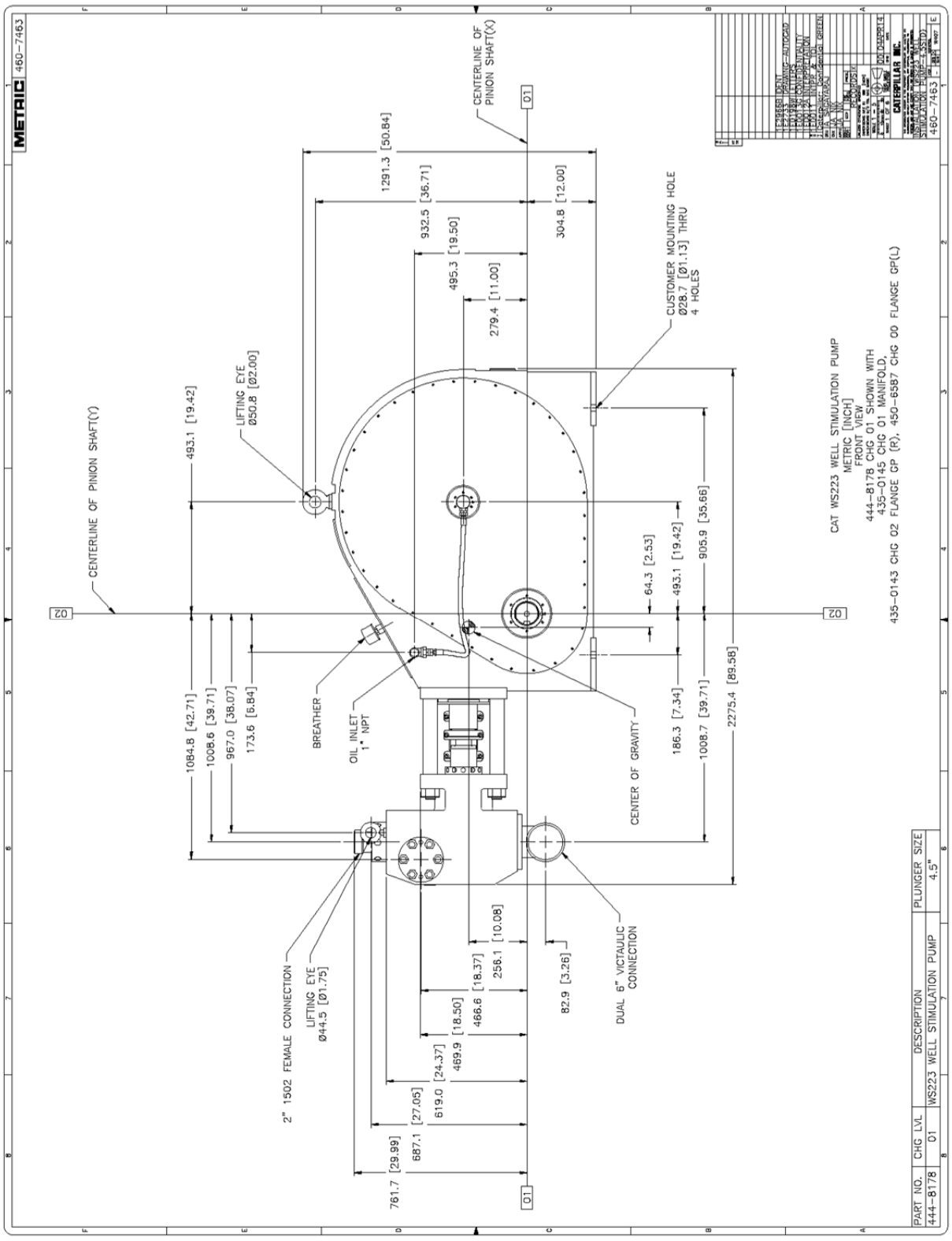
5. Based on 90% ME and 100% VE -Intermittent Service Only.
6. Pumps with pressures in excess of 15,000 psi require special gauge and discharge flanges.

Table 16

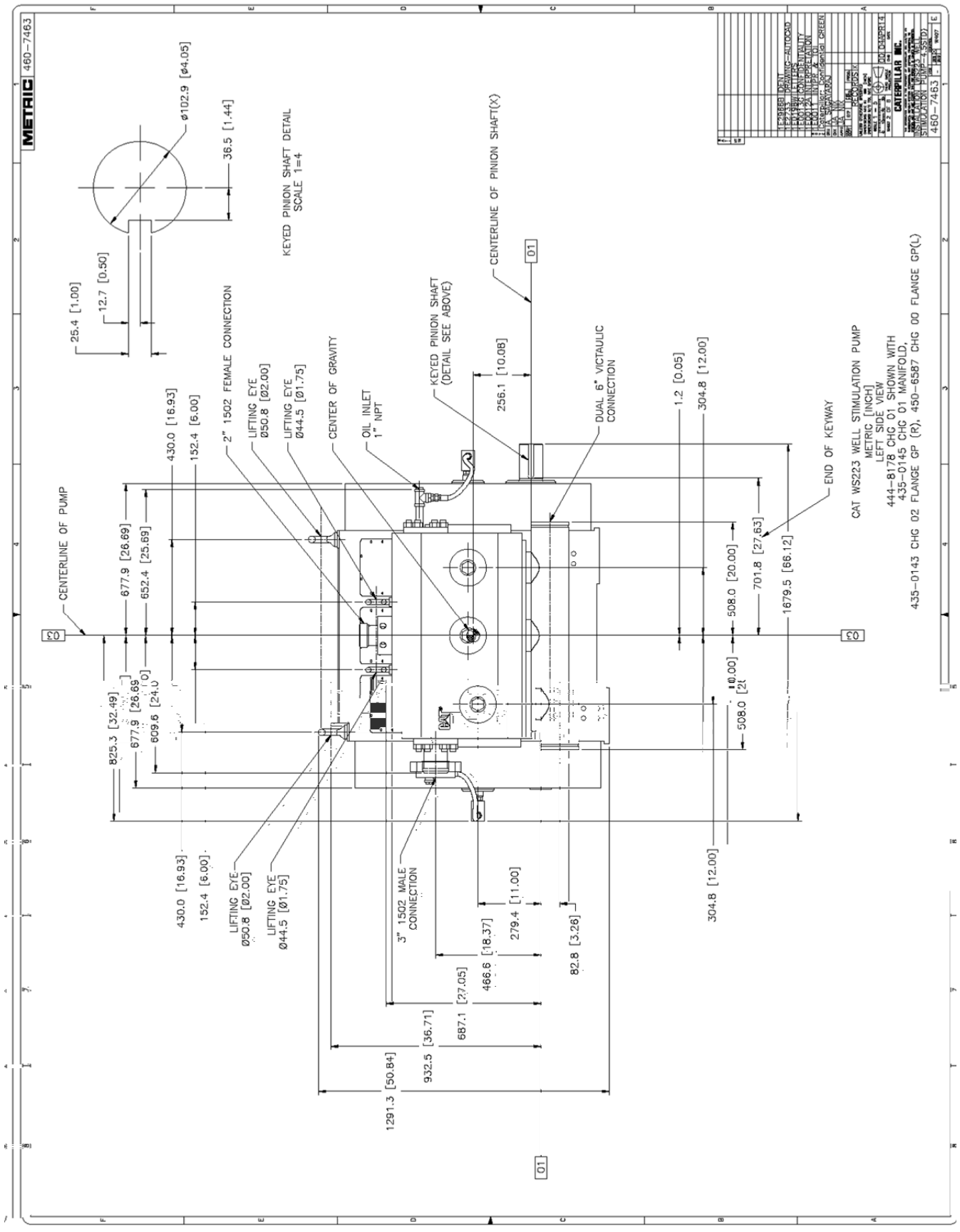
Appendix – Installation Drawings

WS223 Drawings – # 460-7463

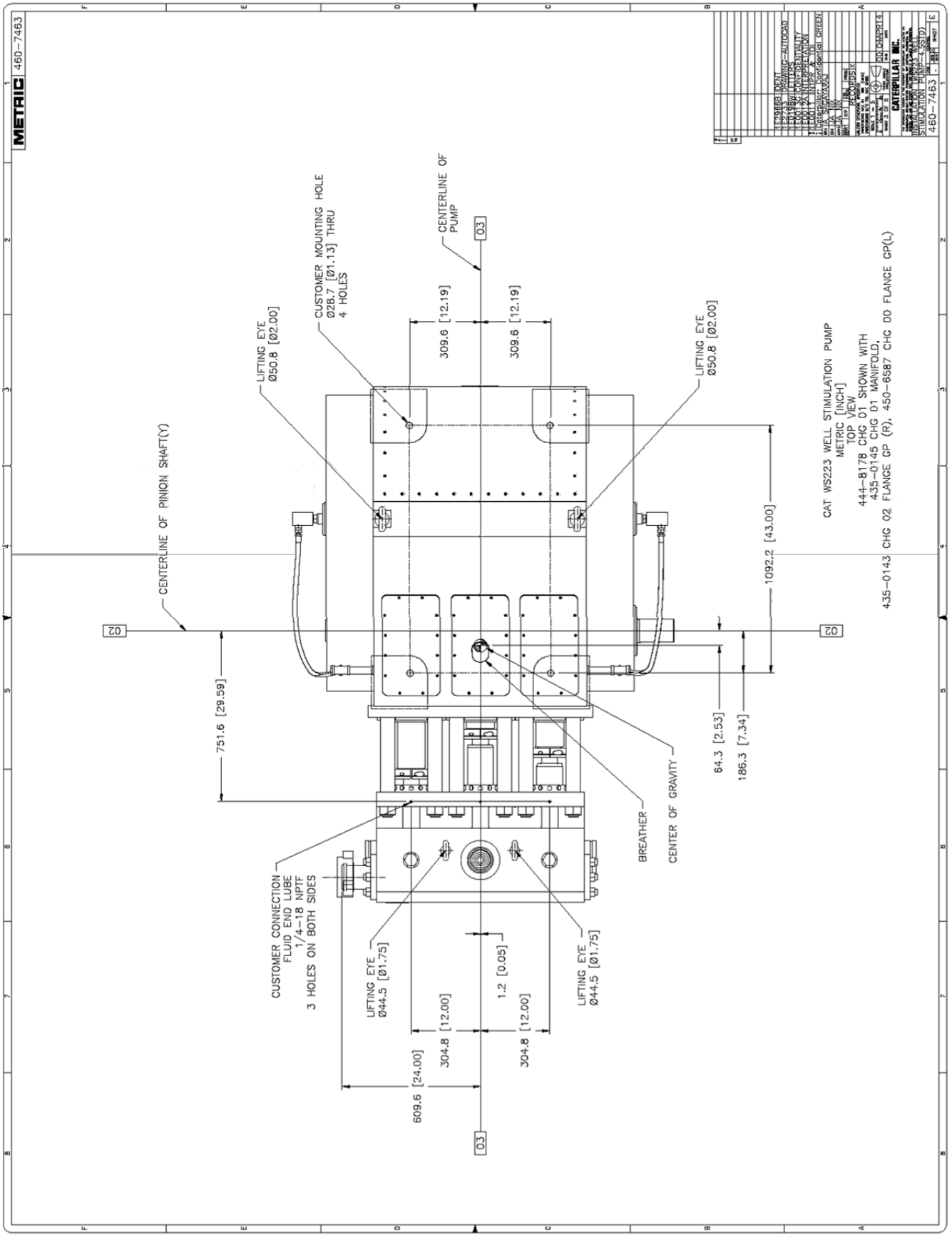
WS223 Front View



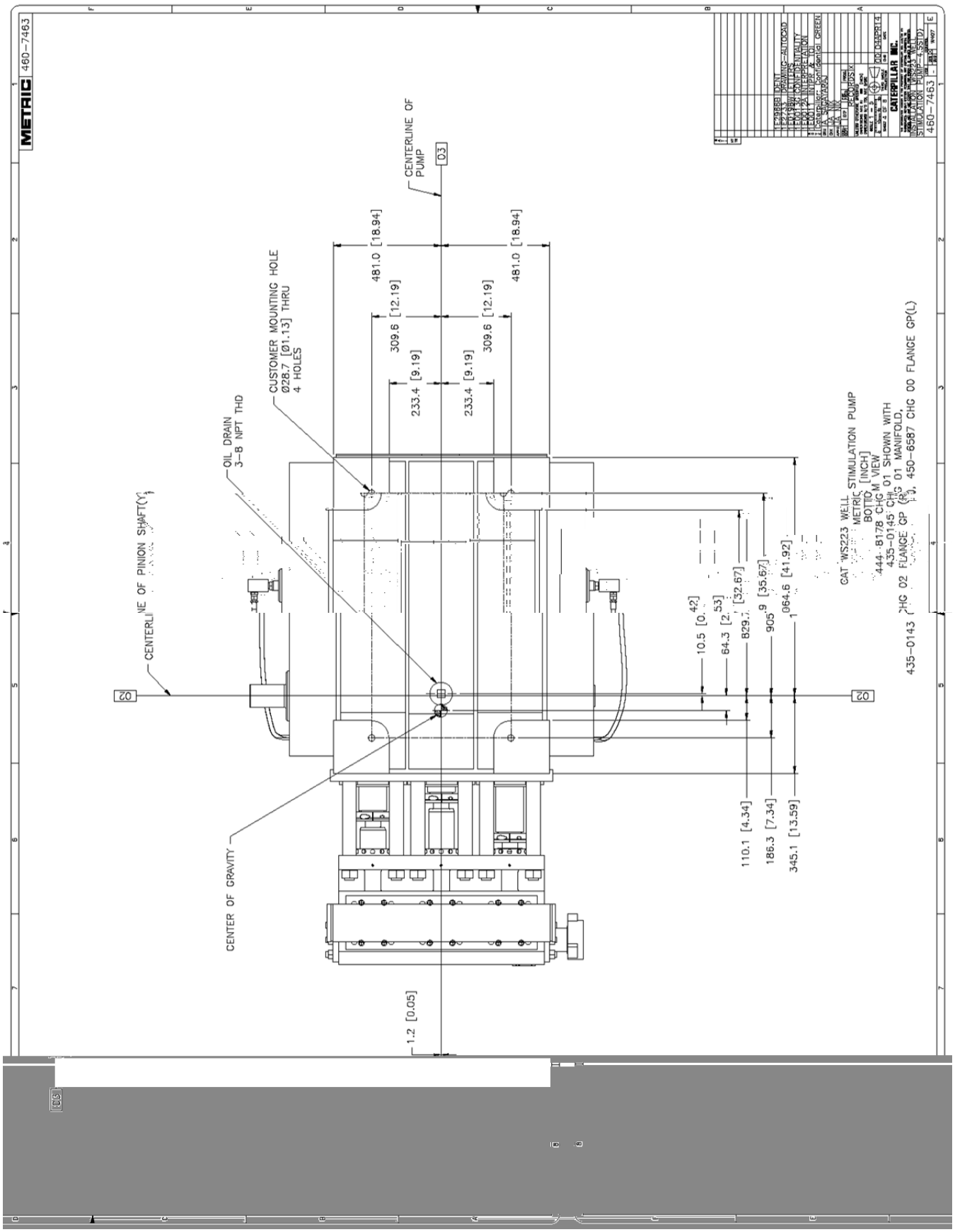
WS223 Left Side View



WS223 Top View



WS223 Bottom View



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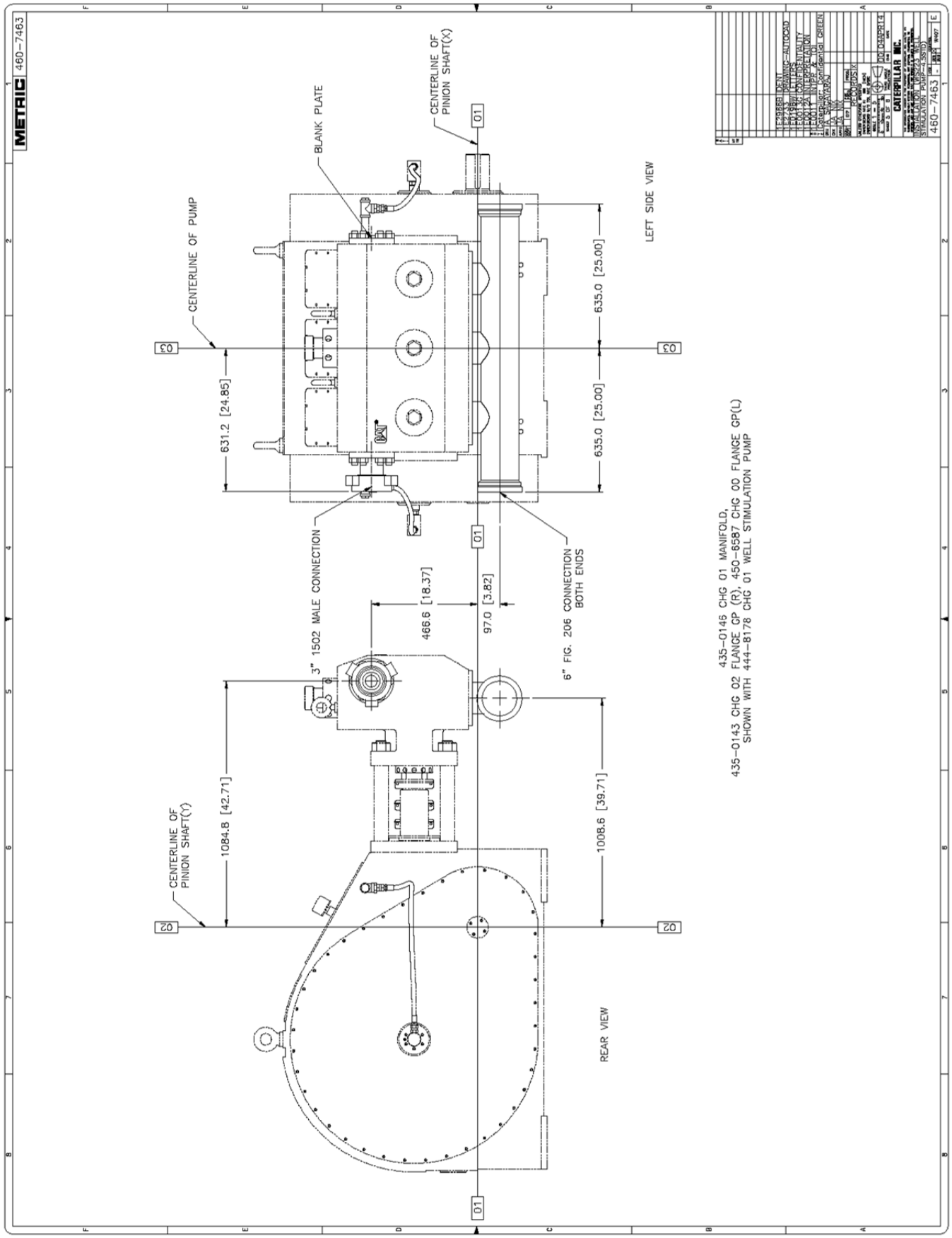

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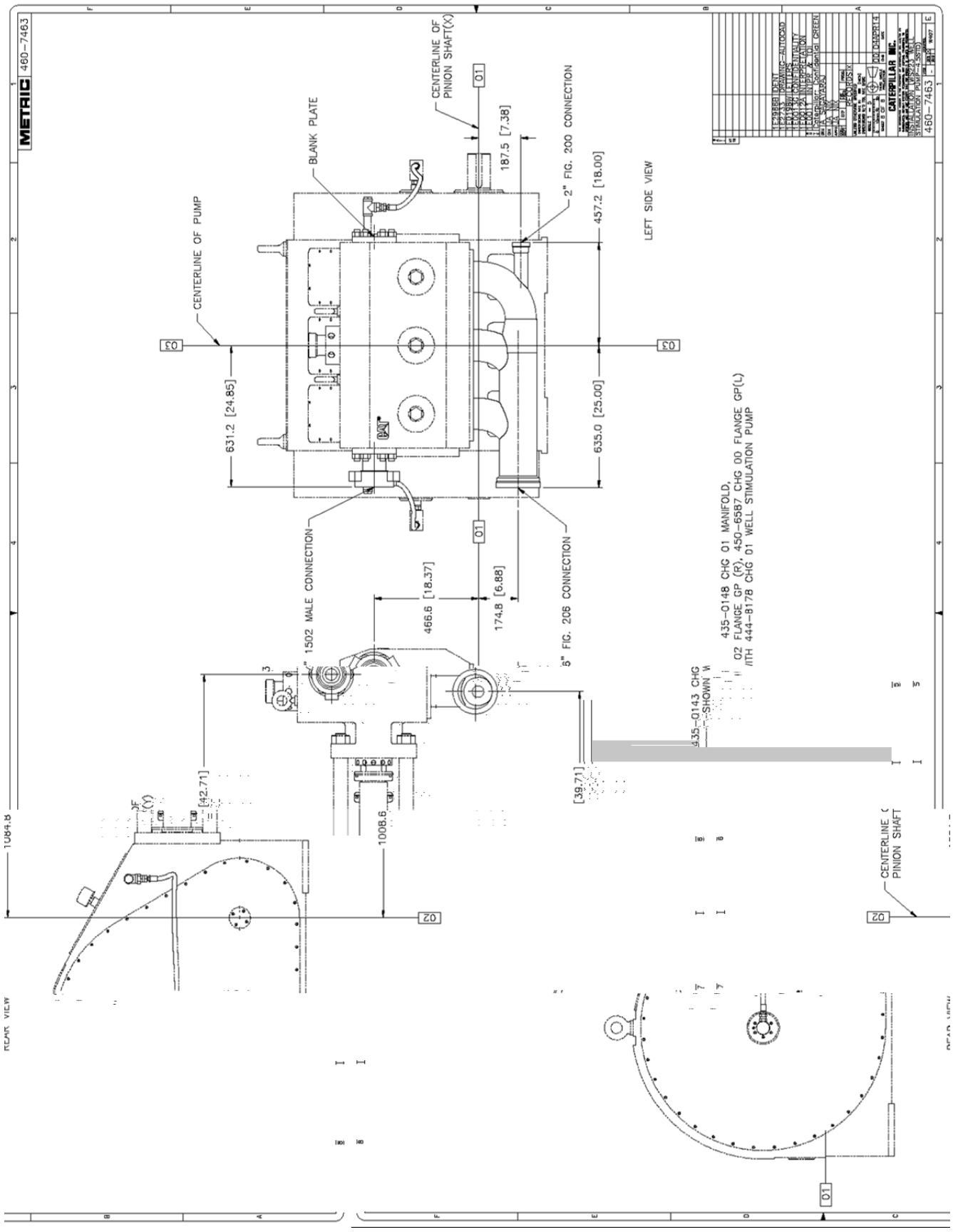
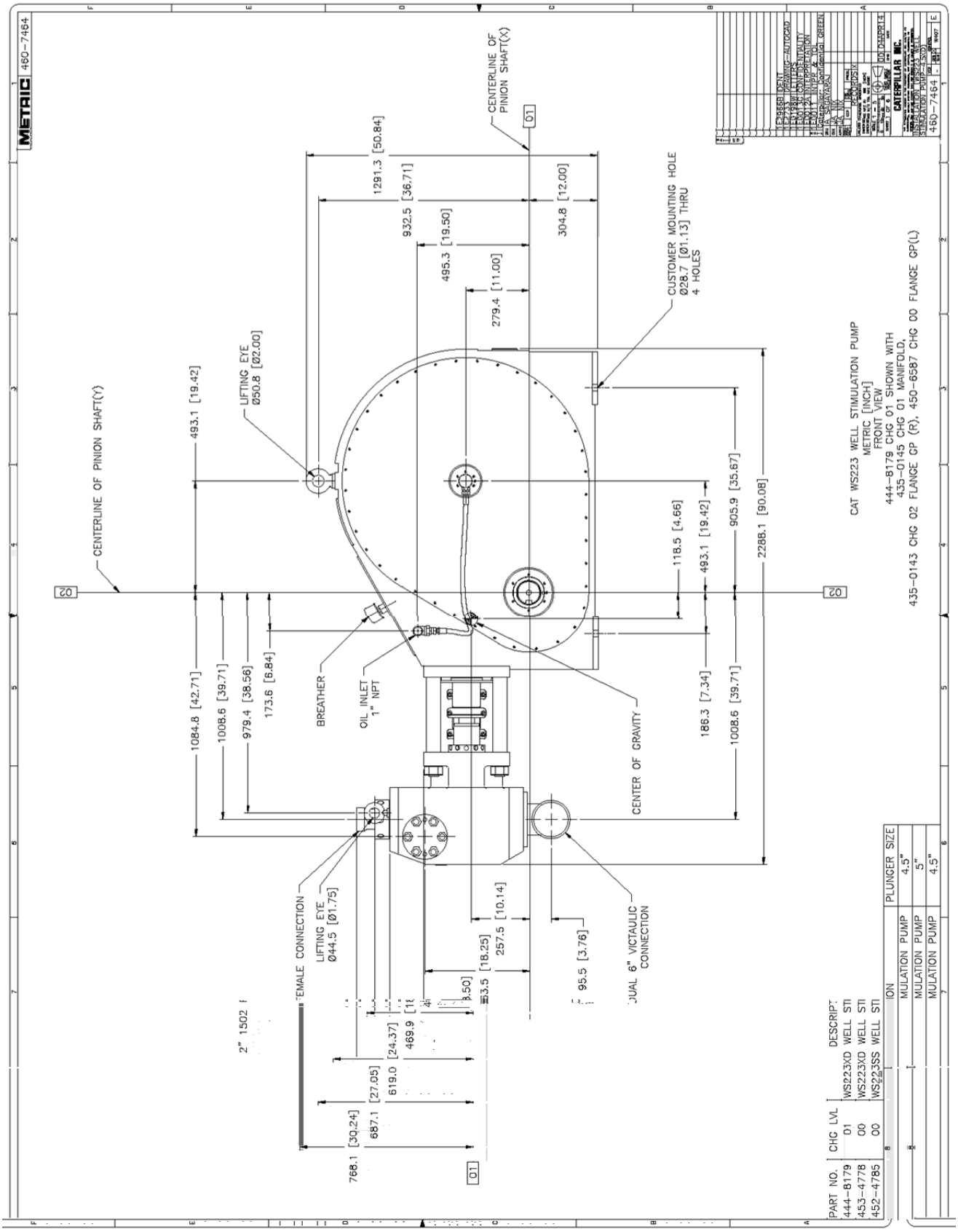
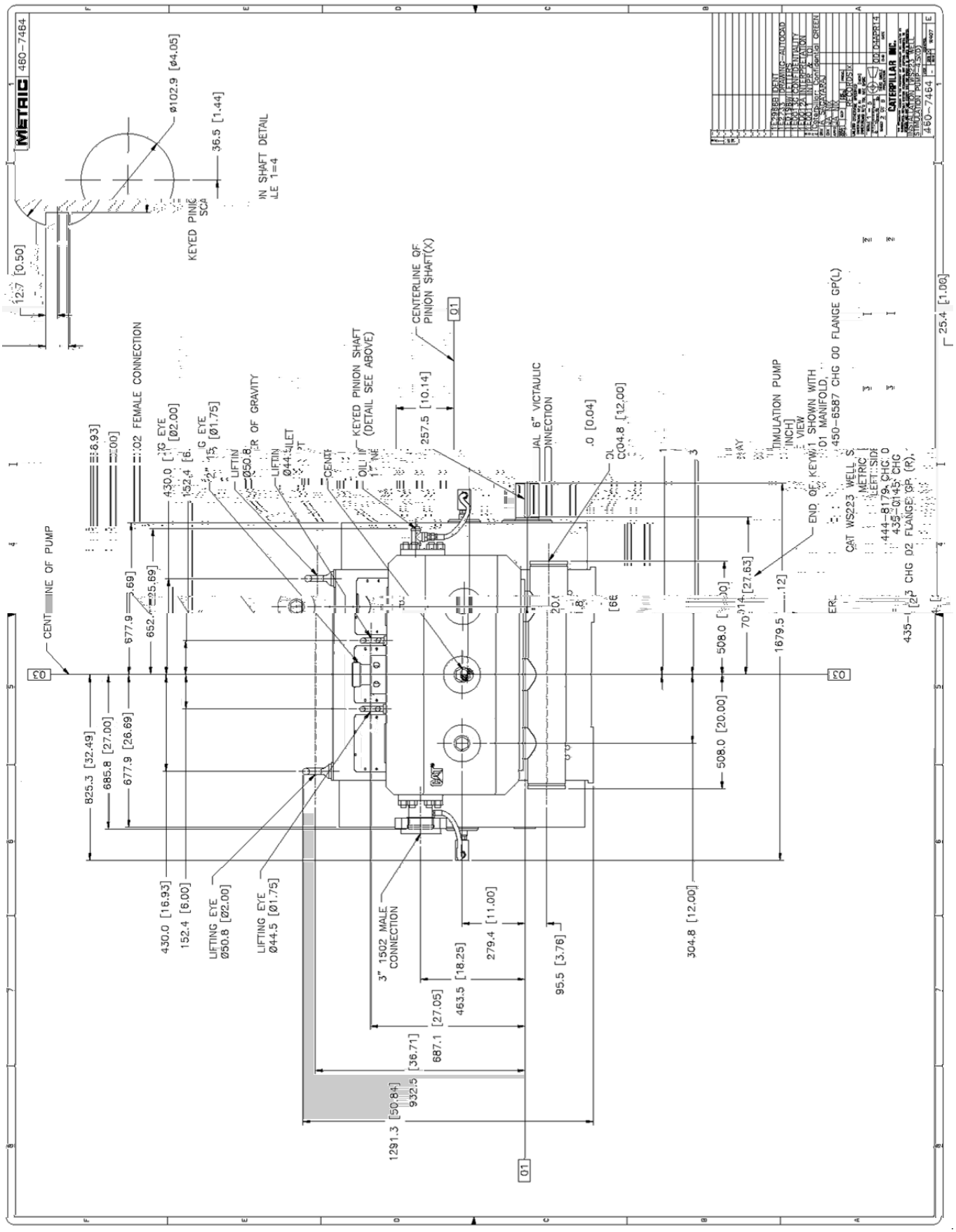


WS223XD and SS Drawings – 460-7464

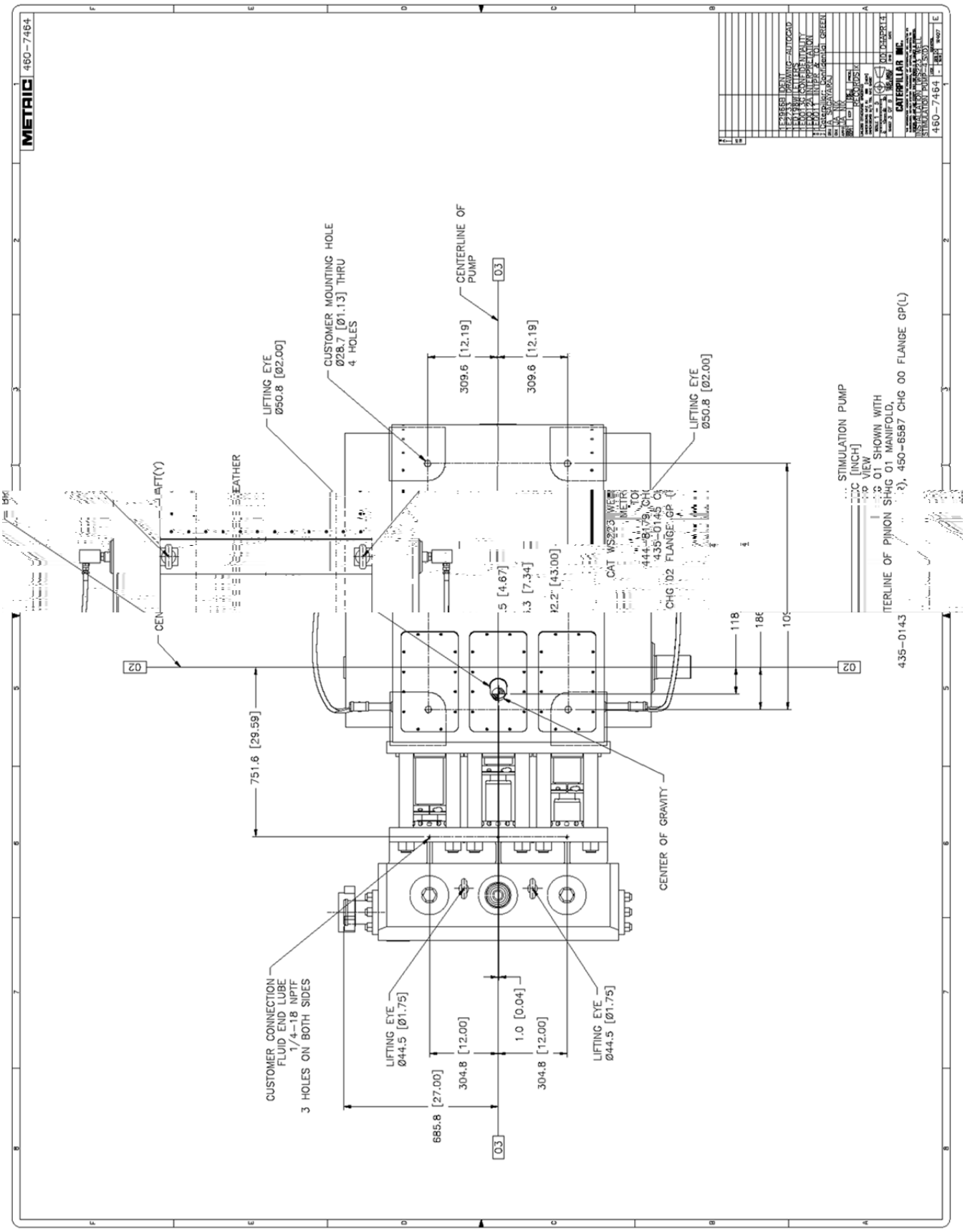
WS223XD & SS Front View



WS223XD & SS Left Side View



WS223XD & SS Top View



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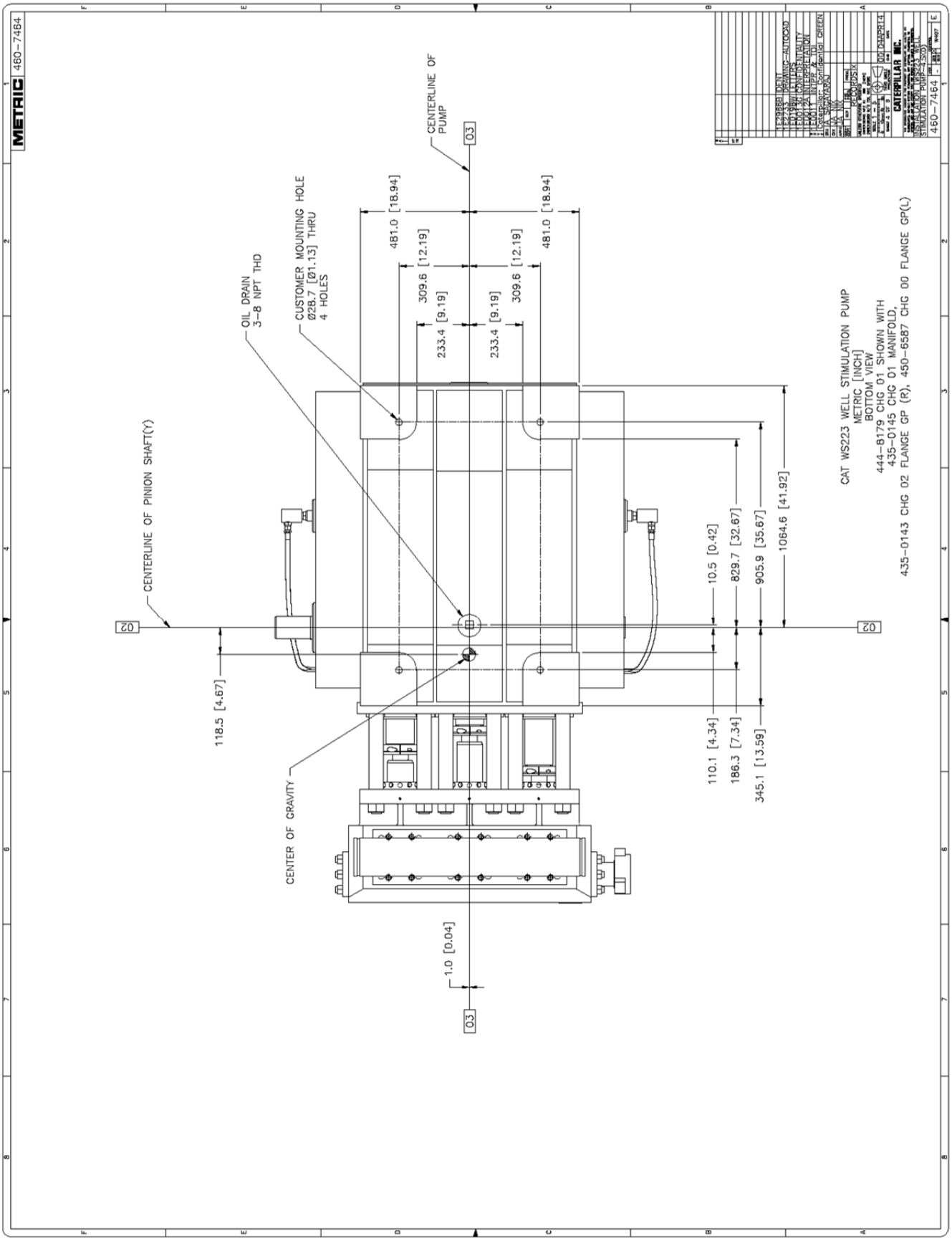

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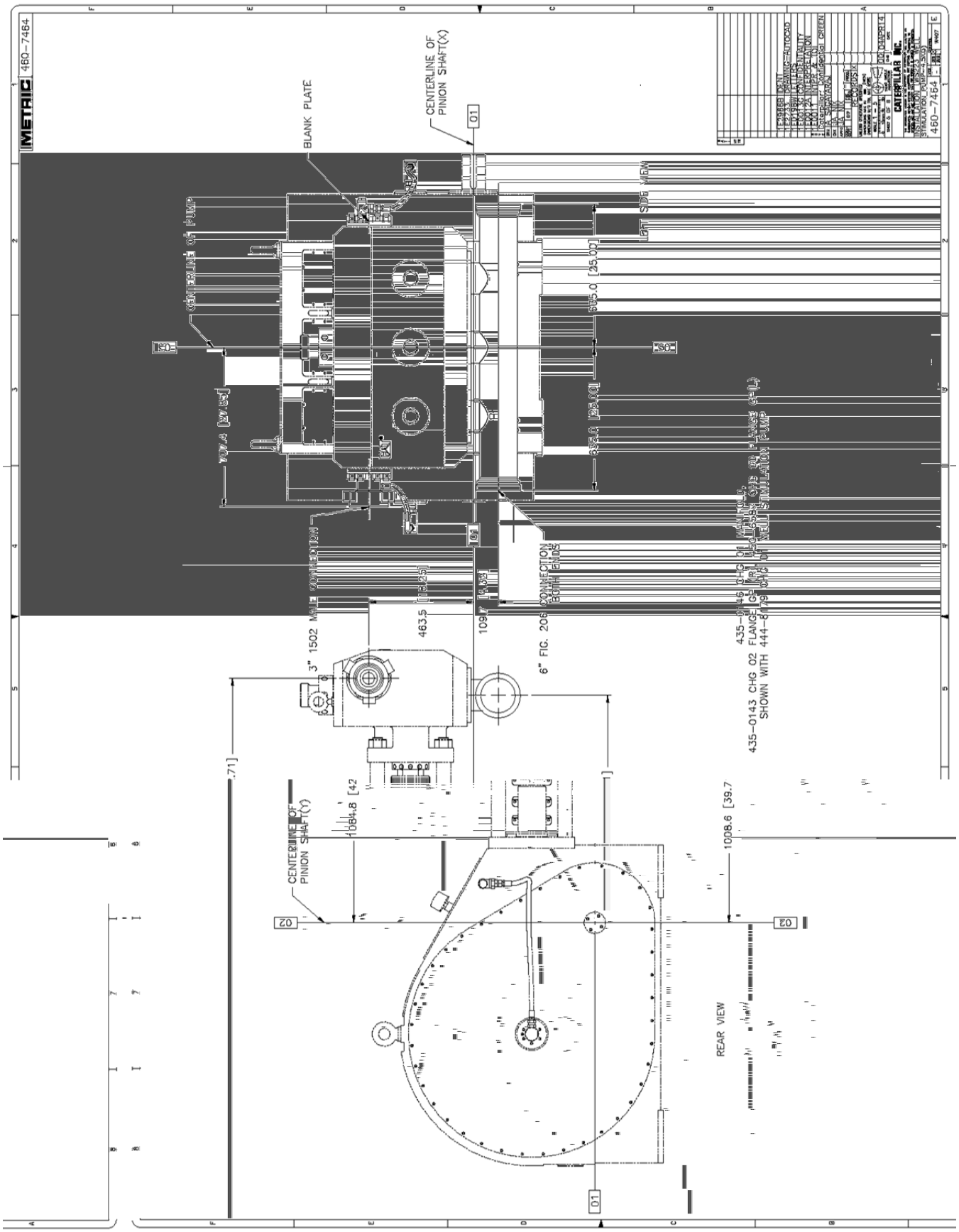

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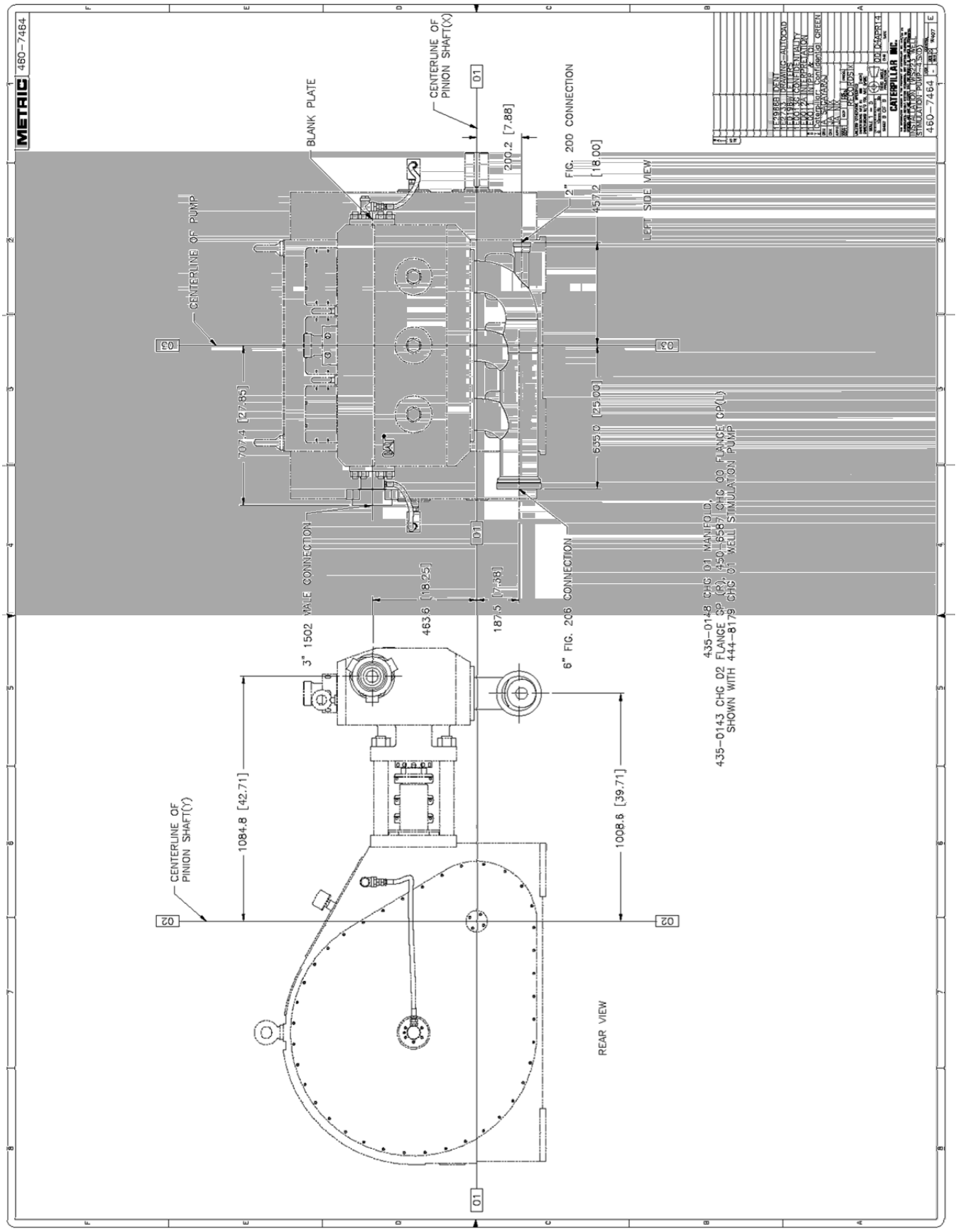
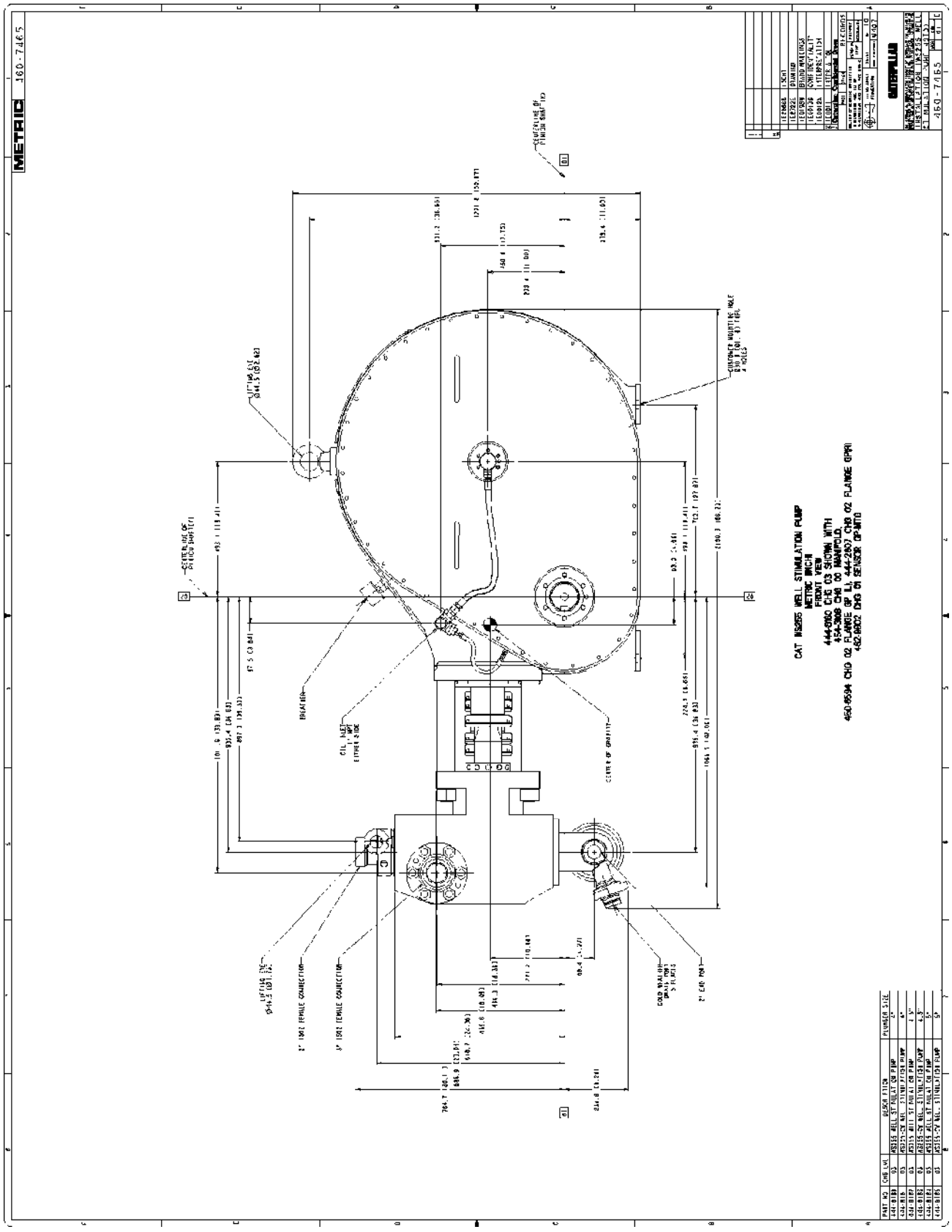
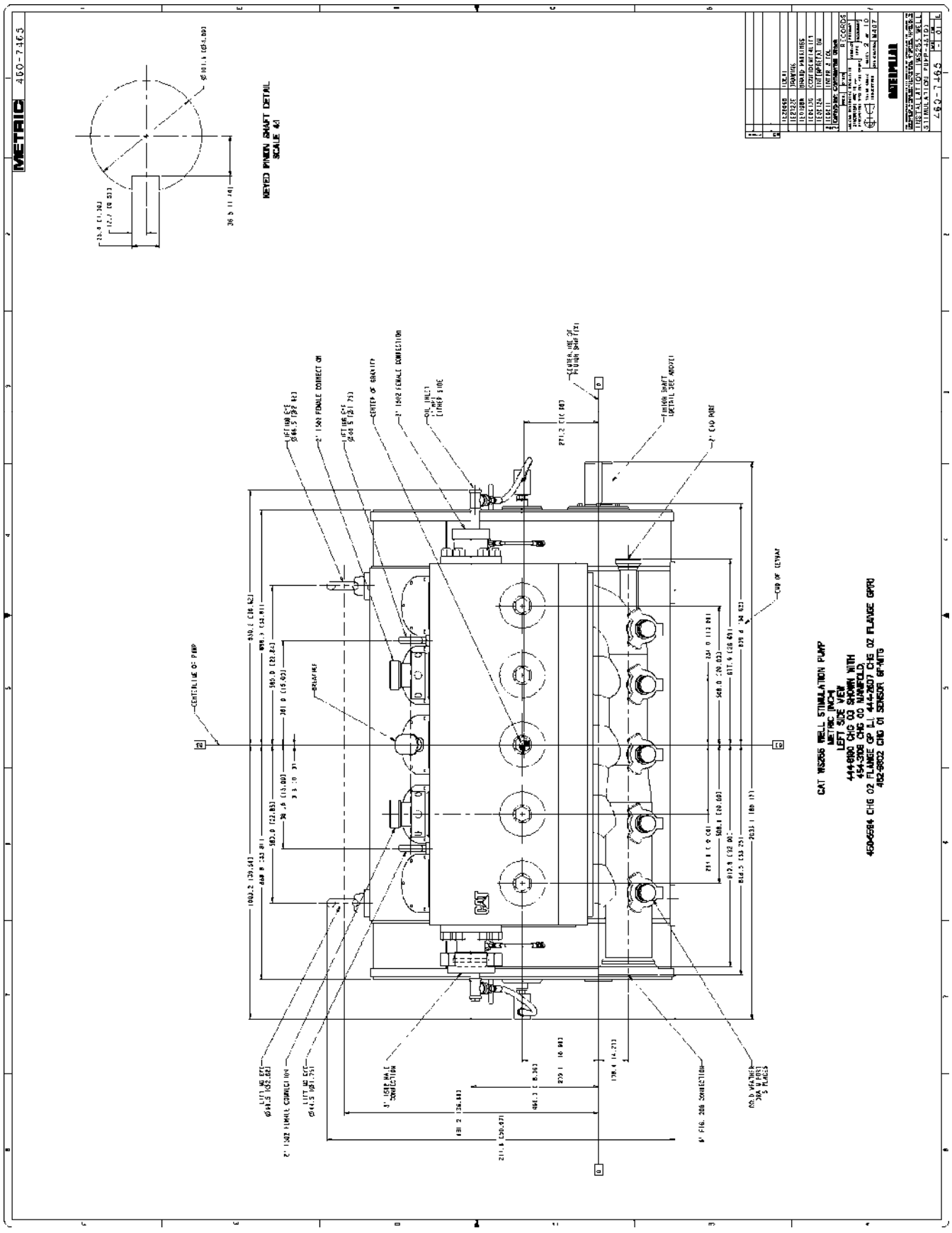


WS255 Drawings – 460-7465

WS255 Front View



WS255 Left Side View



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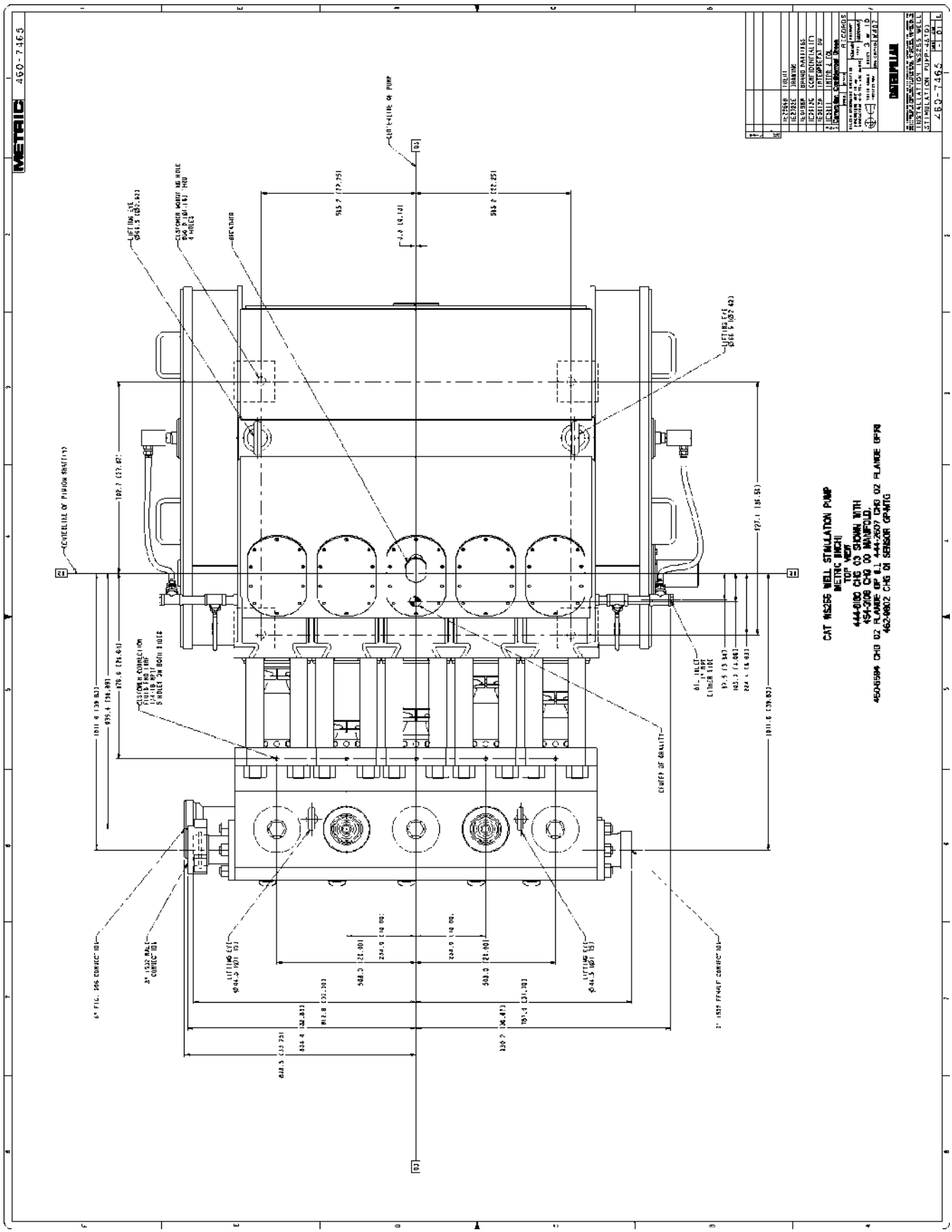
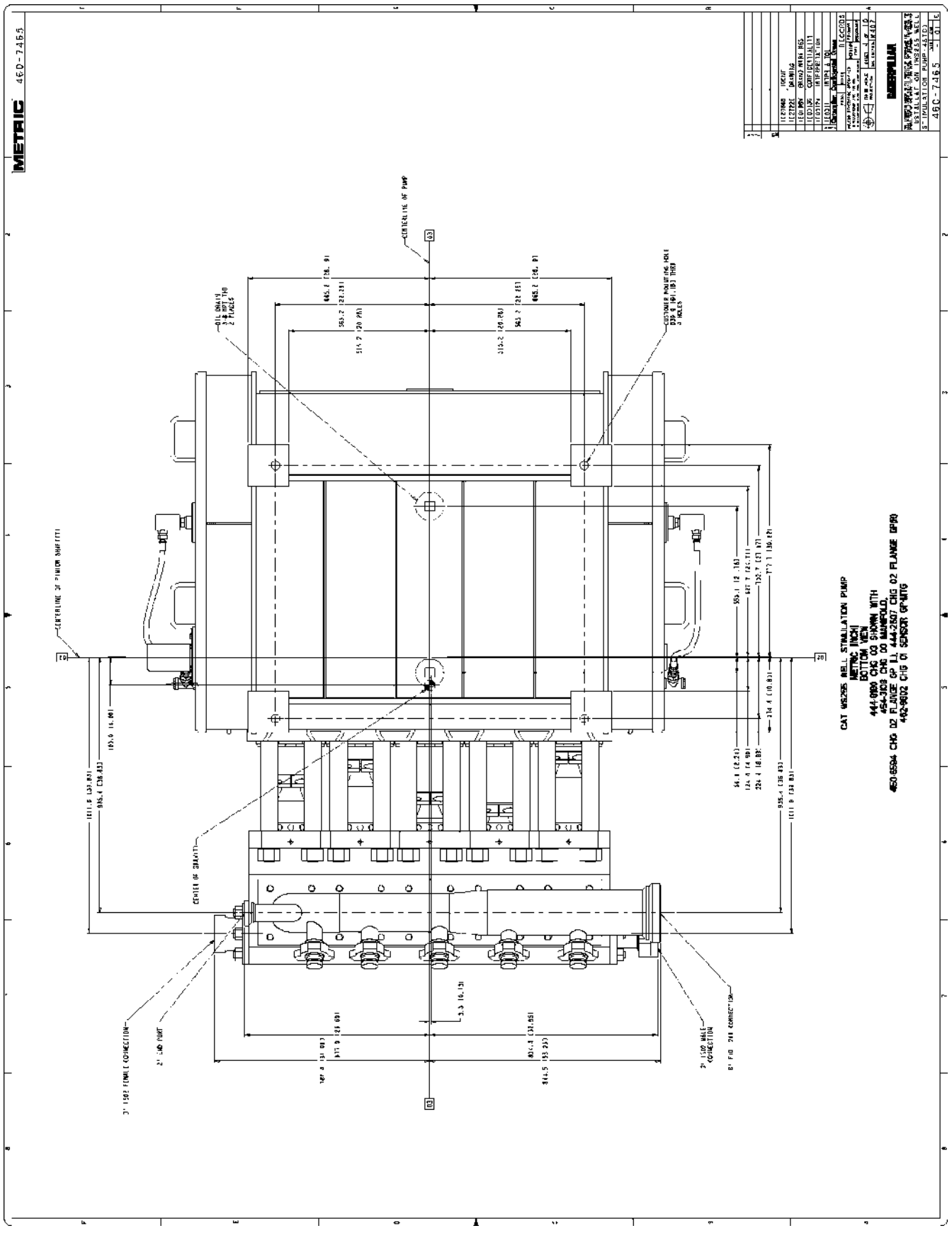


WS255 Bottom View



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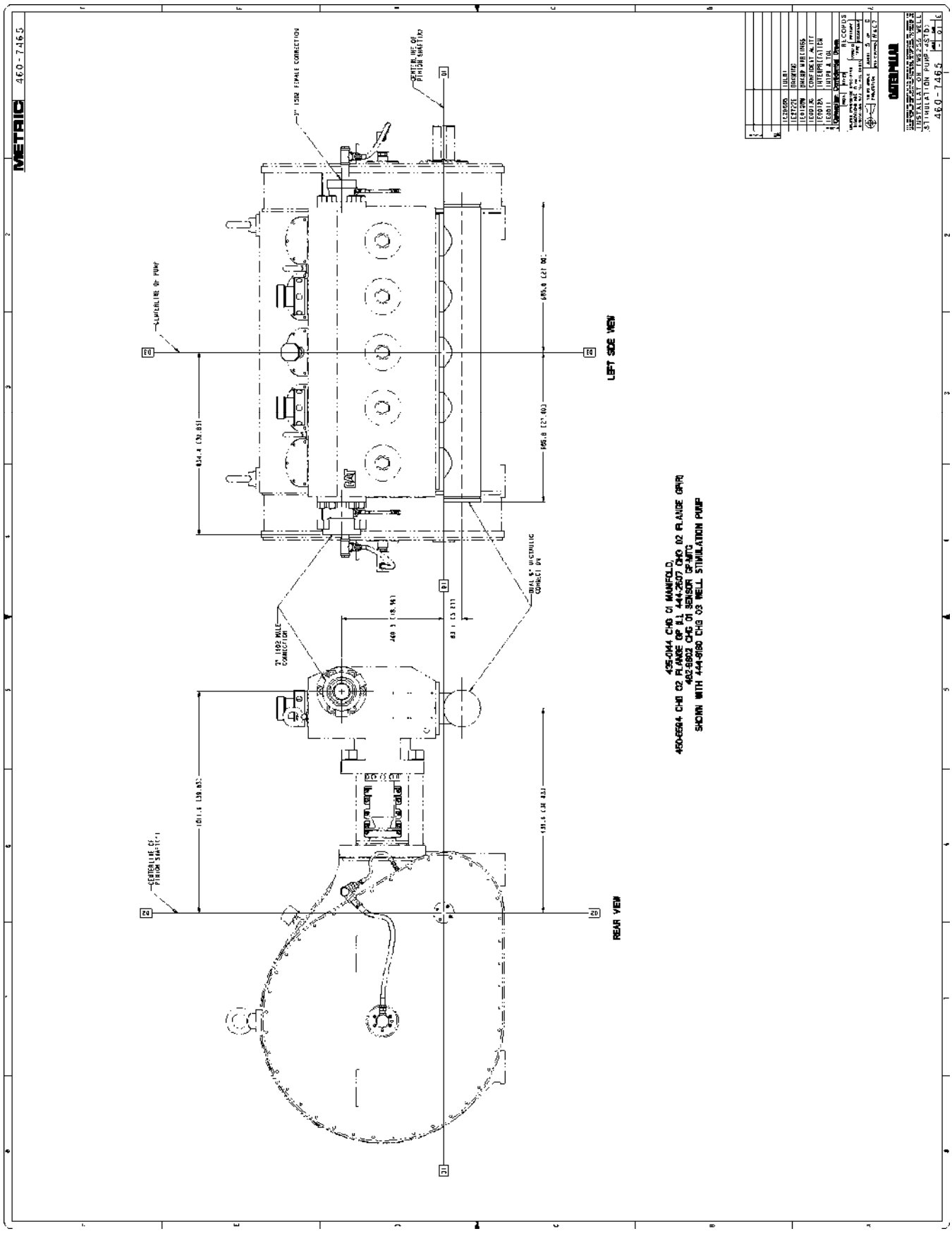

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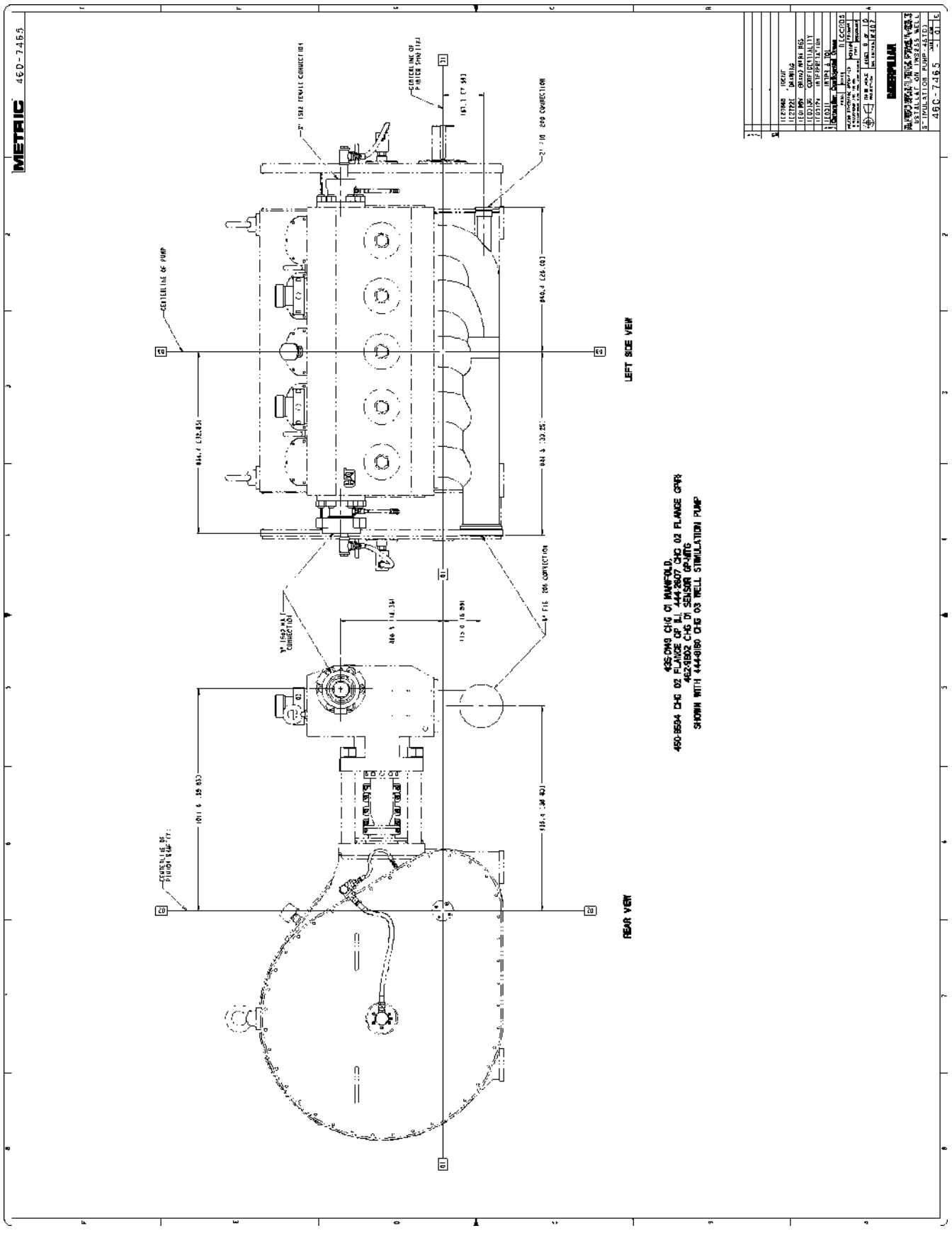

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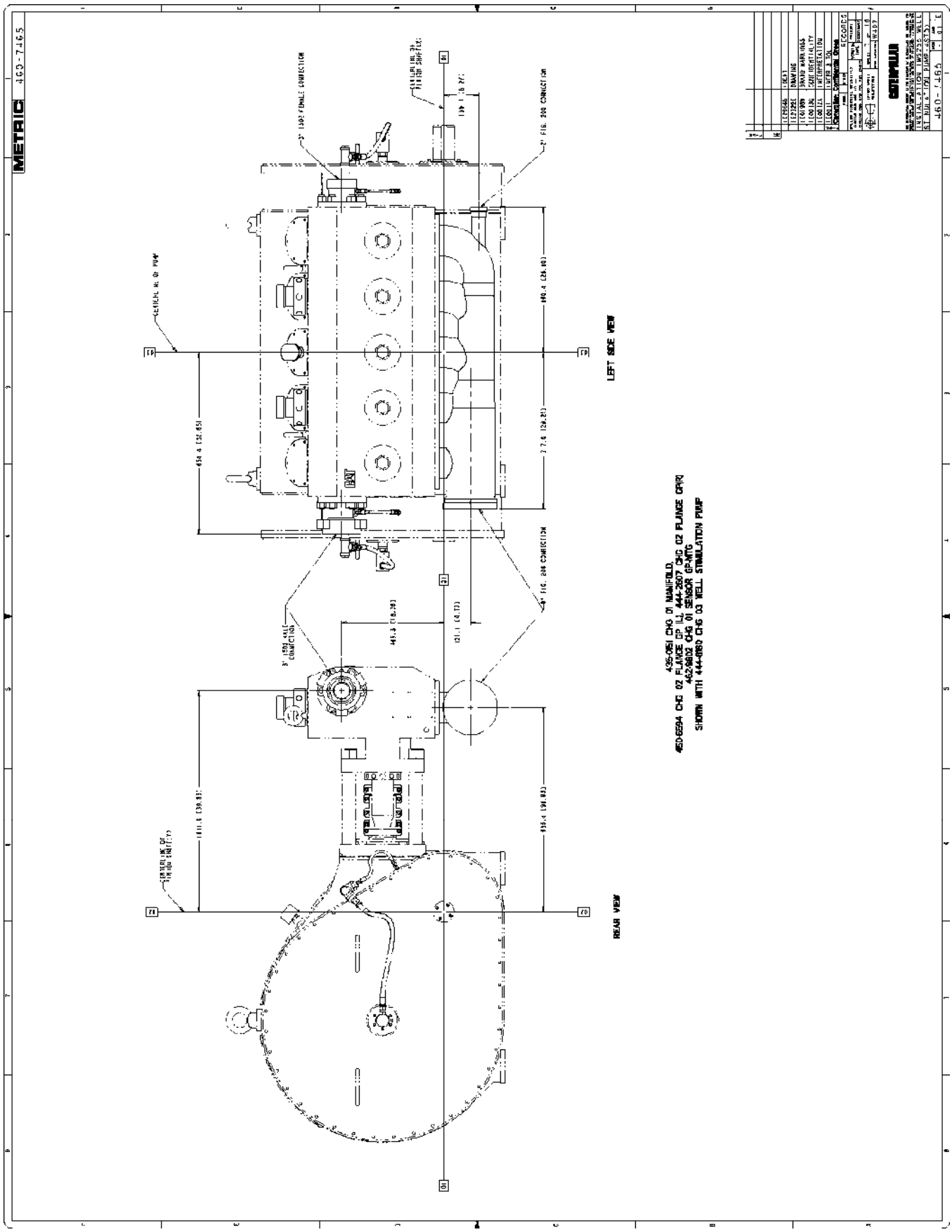

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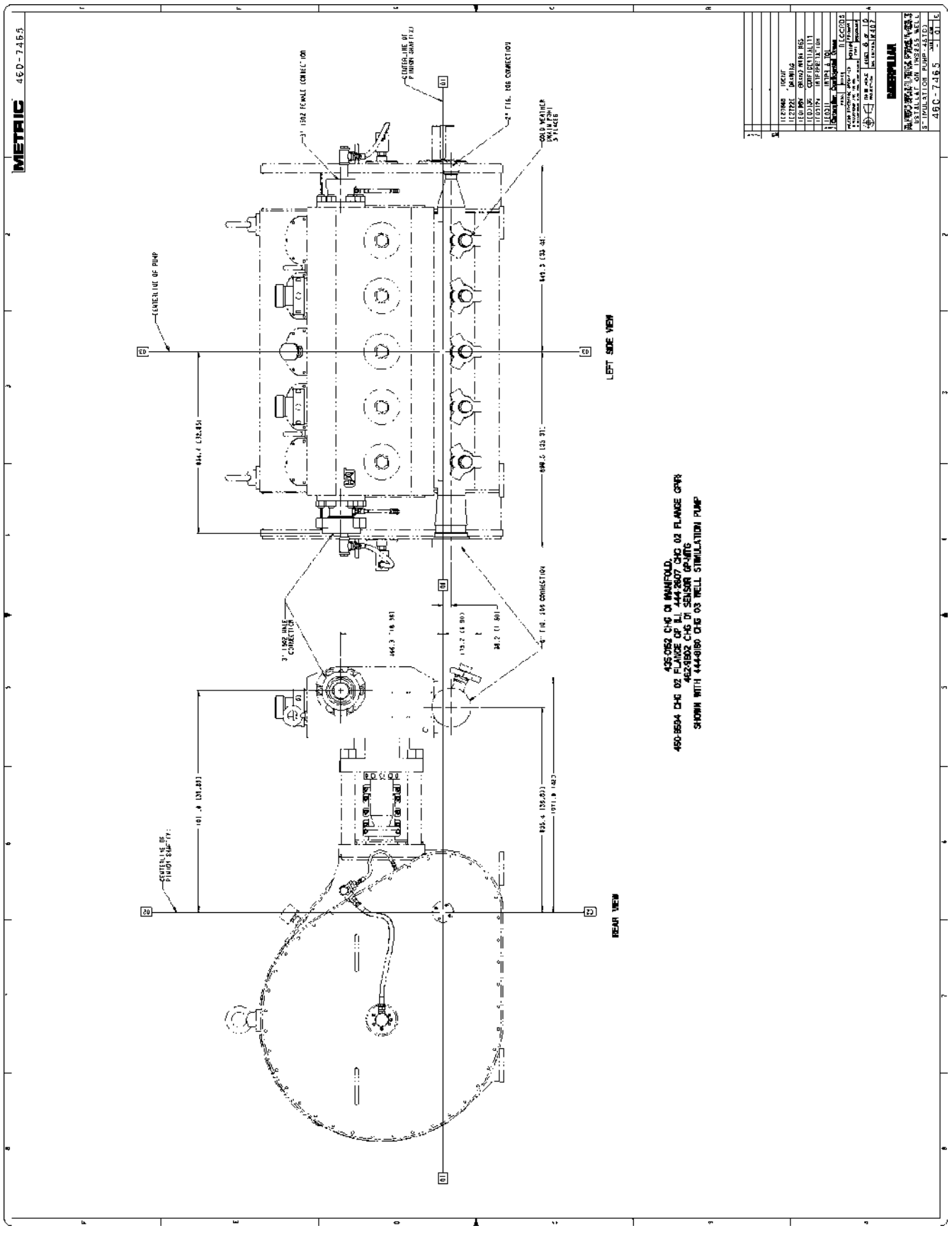

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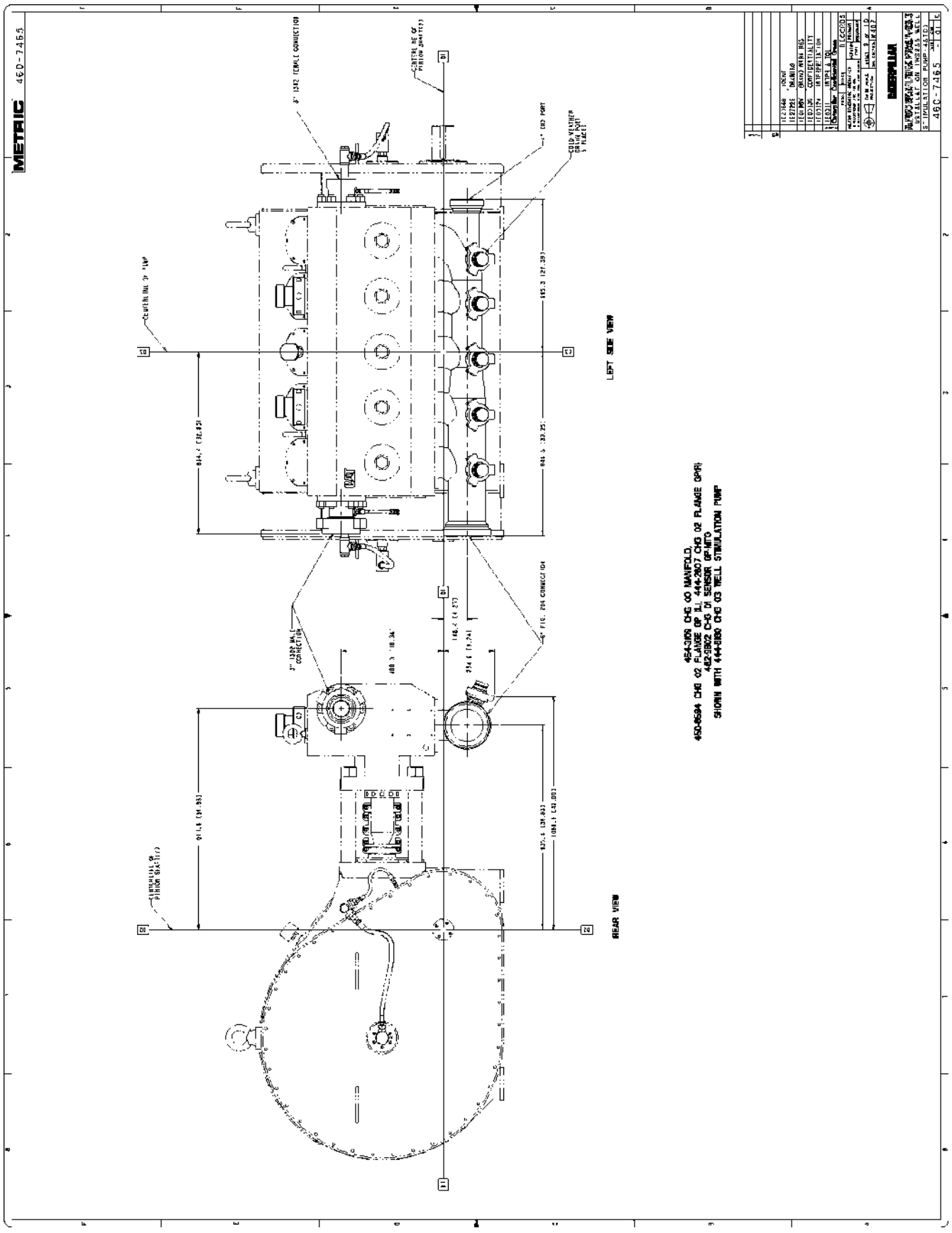

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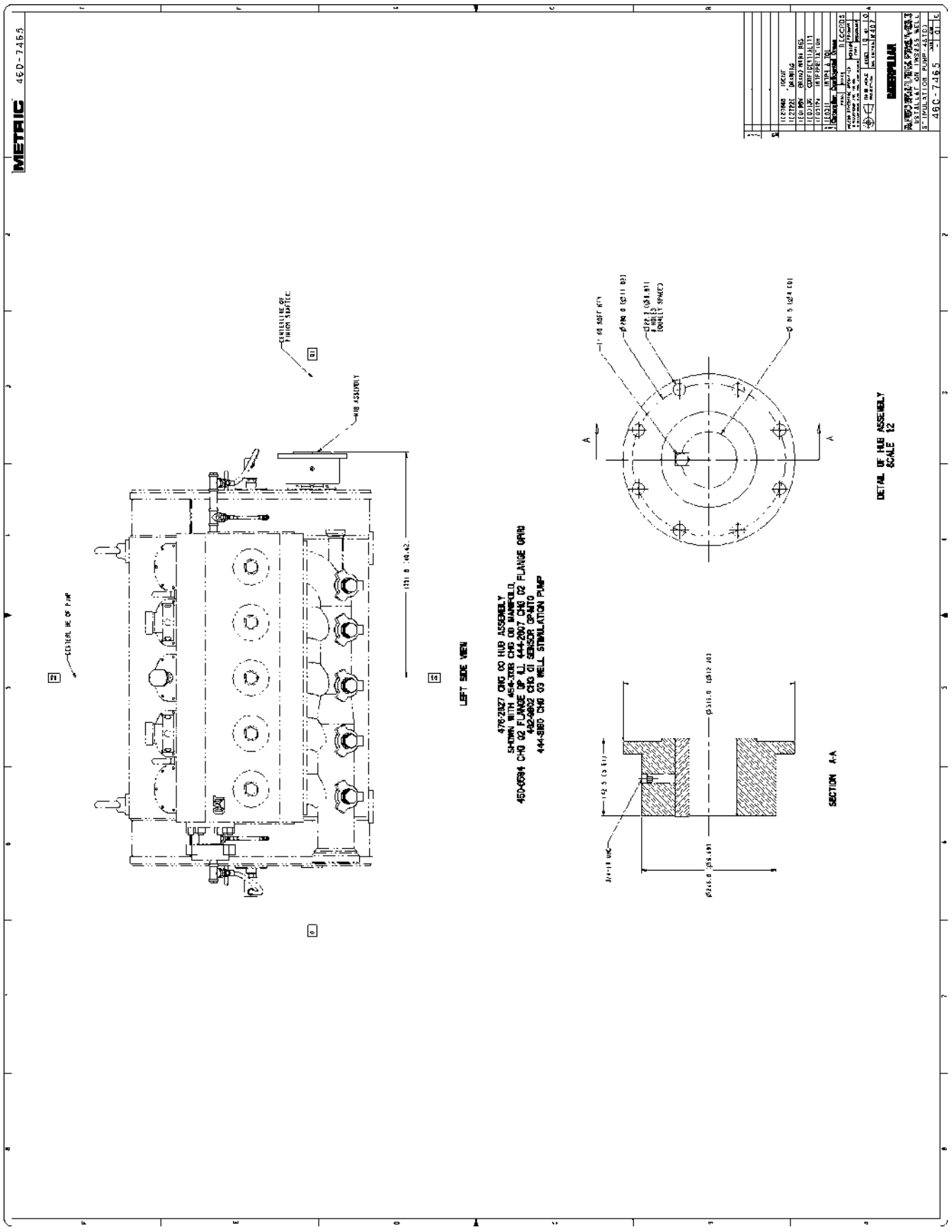
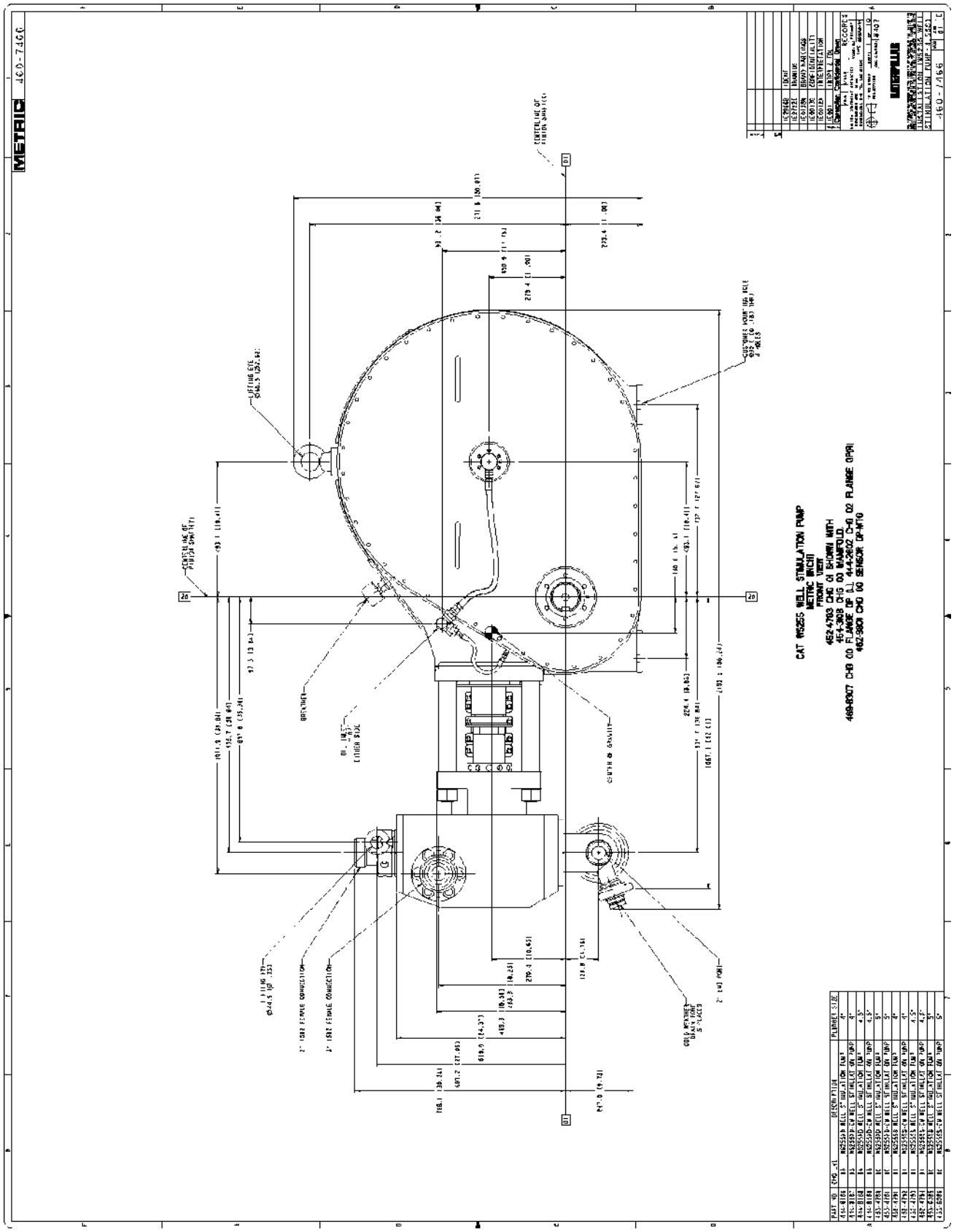
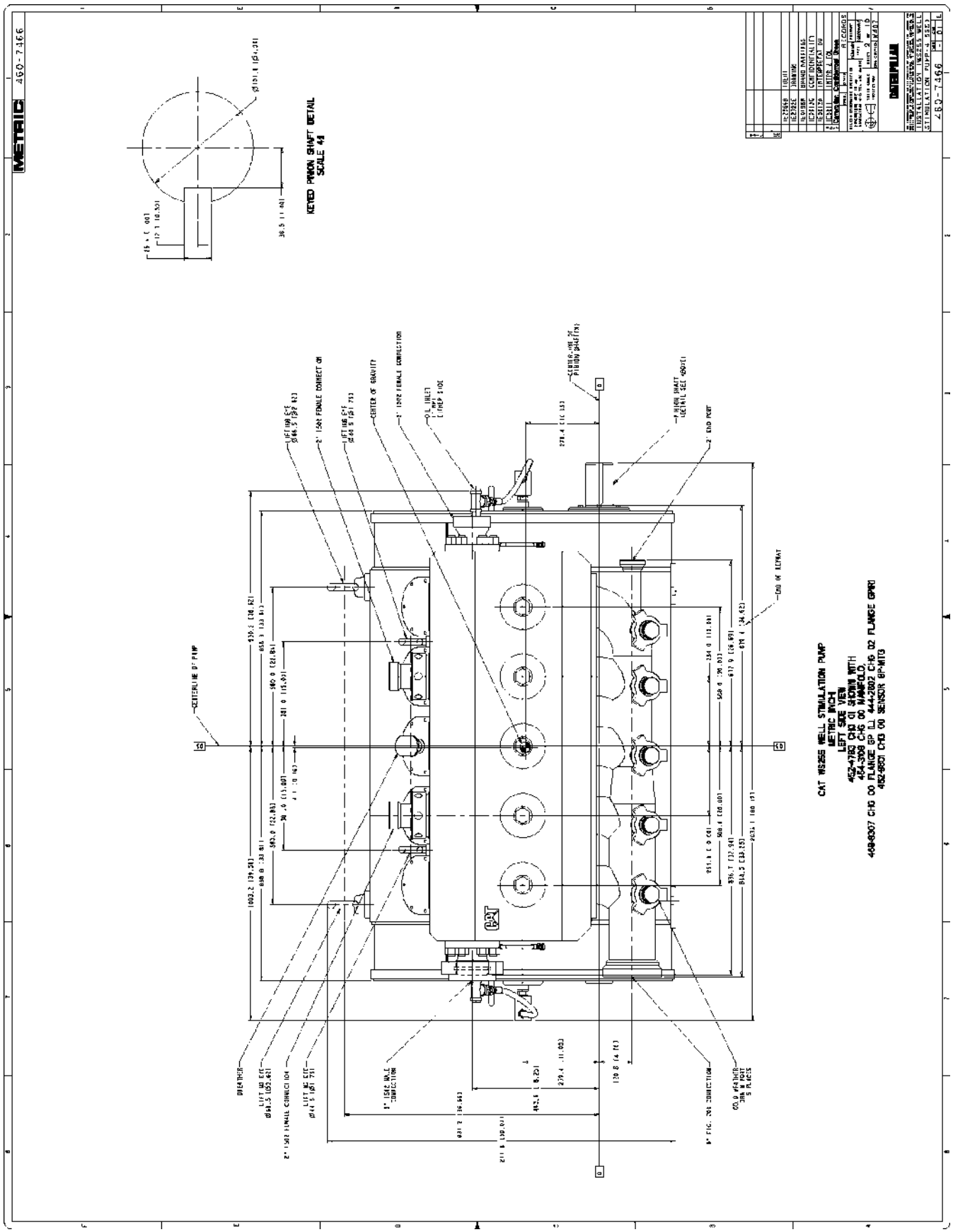


WS255XD and SS Drawings – 460-7466

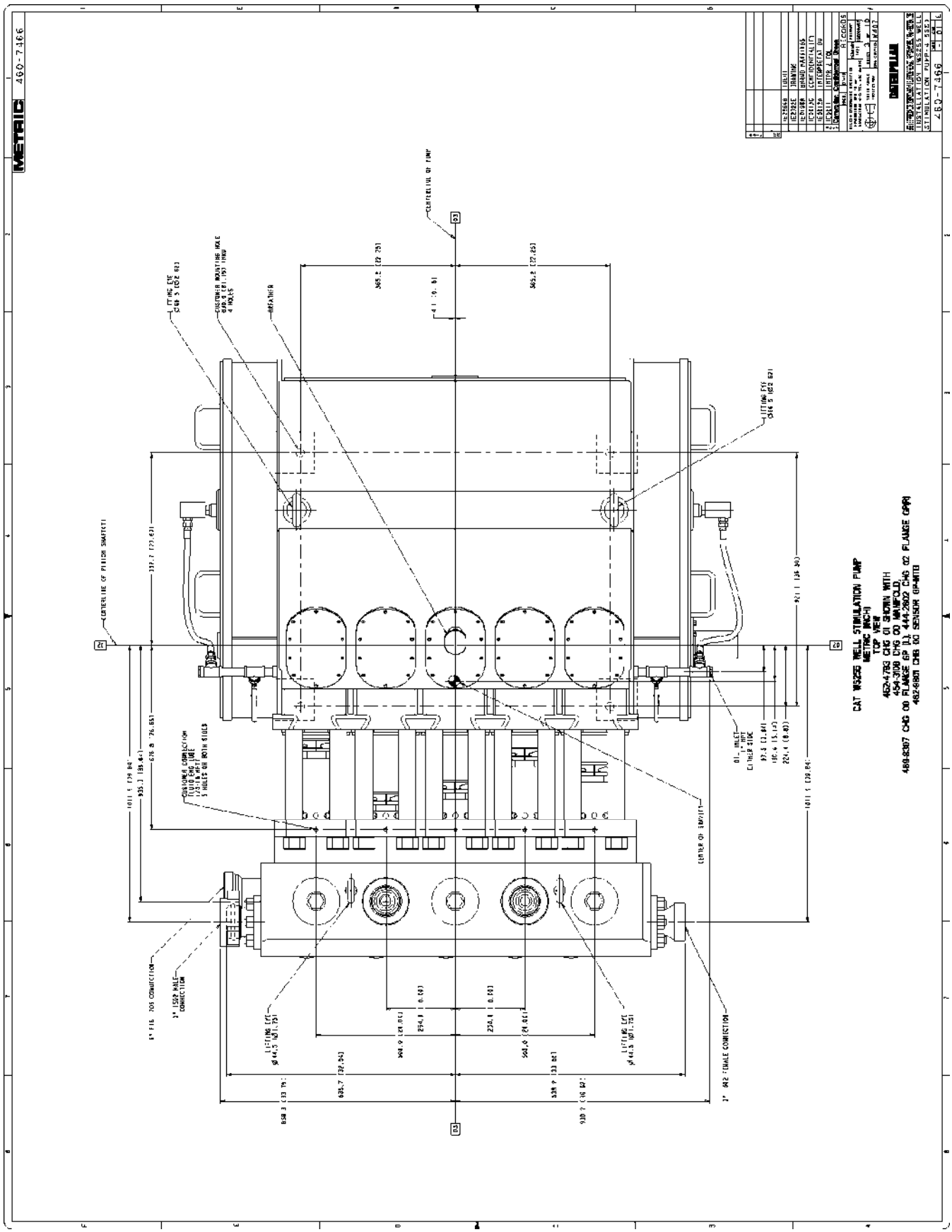
WS255XD & SS Front View



WS255XD & SS Left Side View



WS255XD & SS Top View



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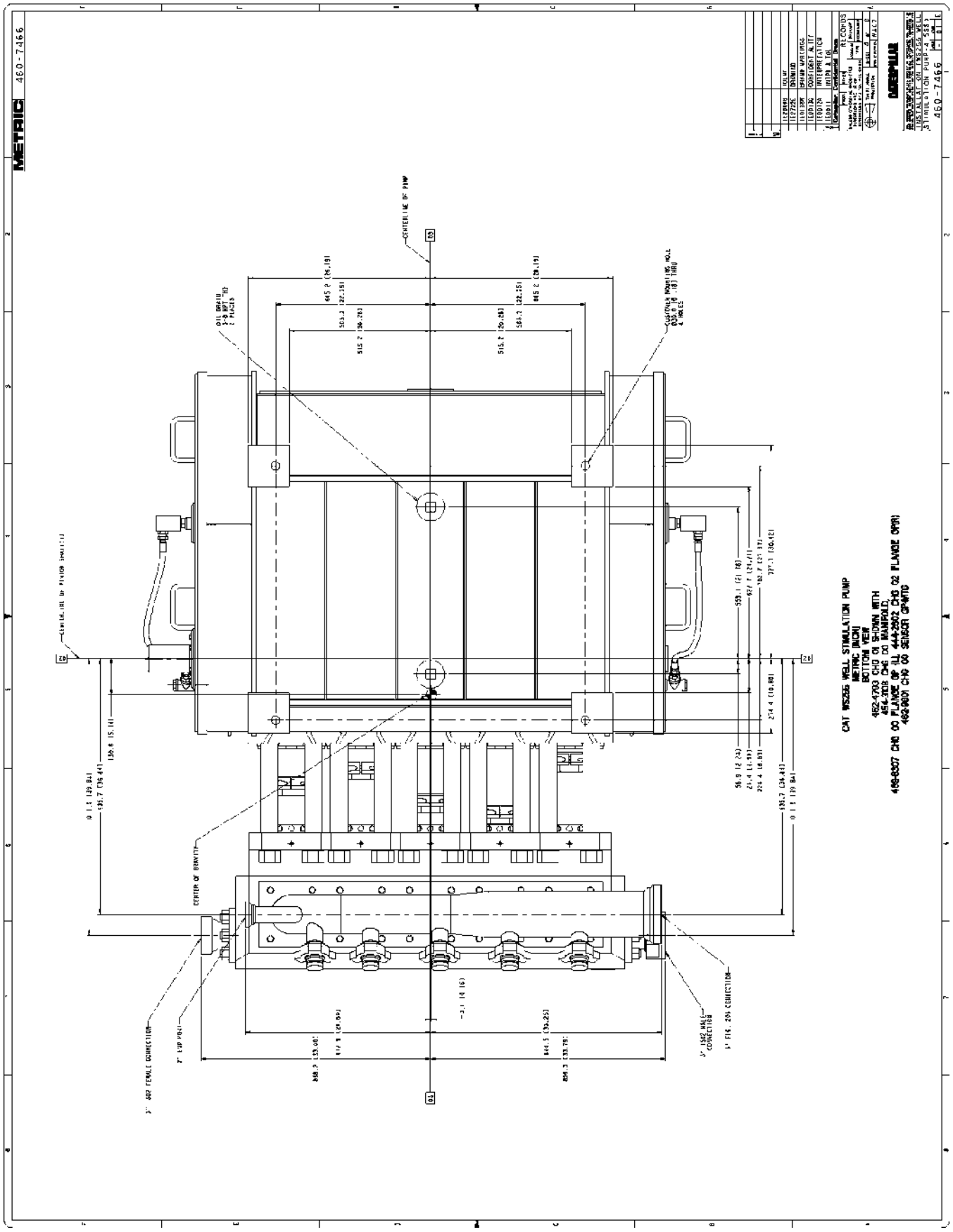

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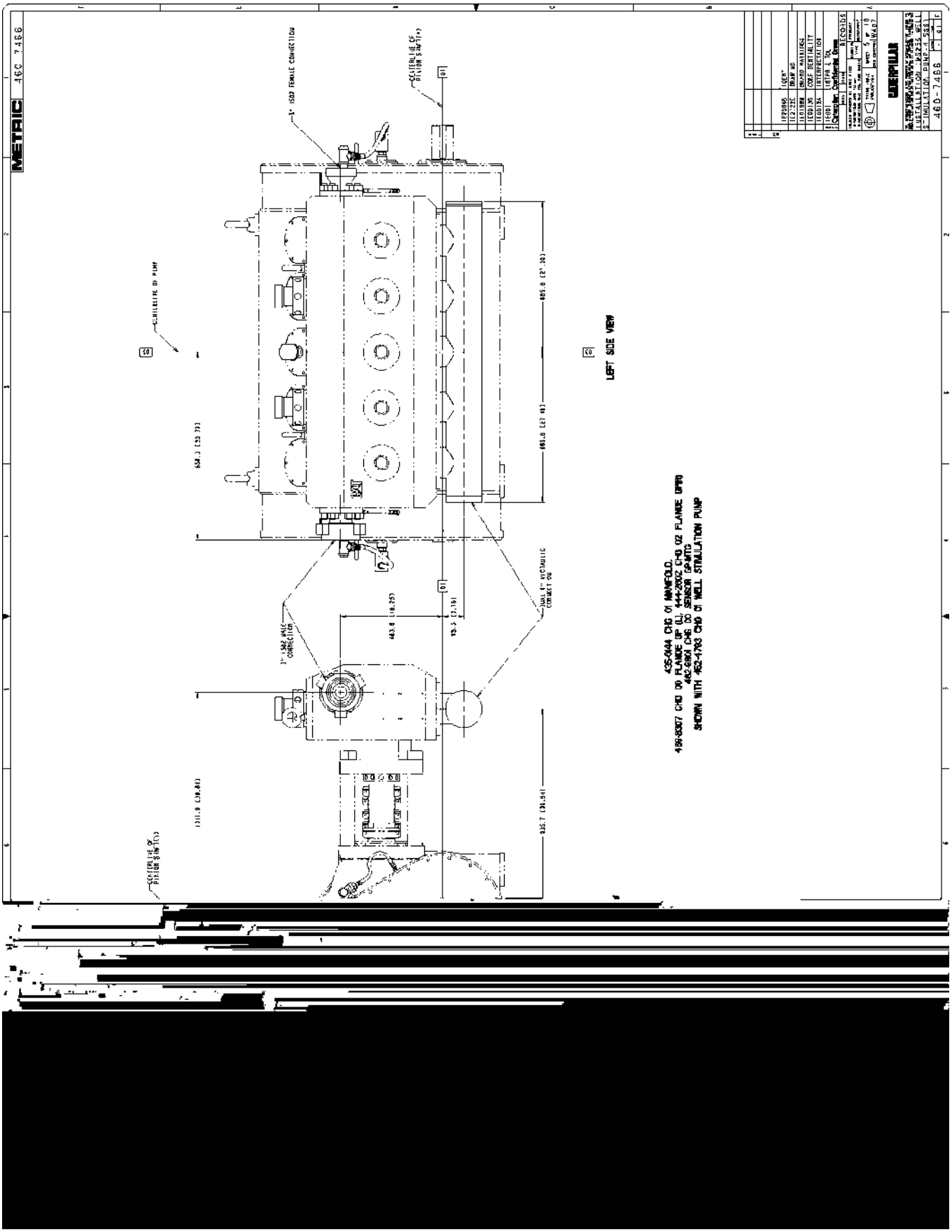

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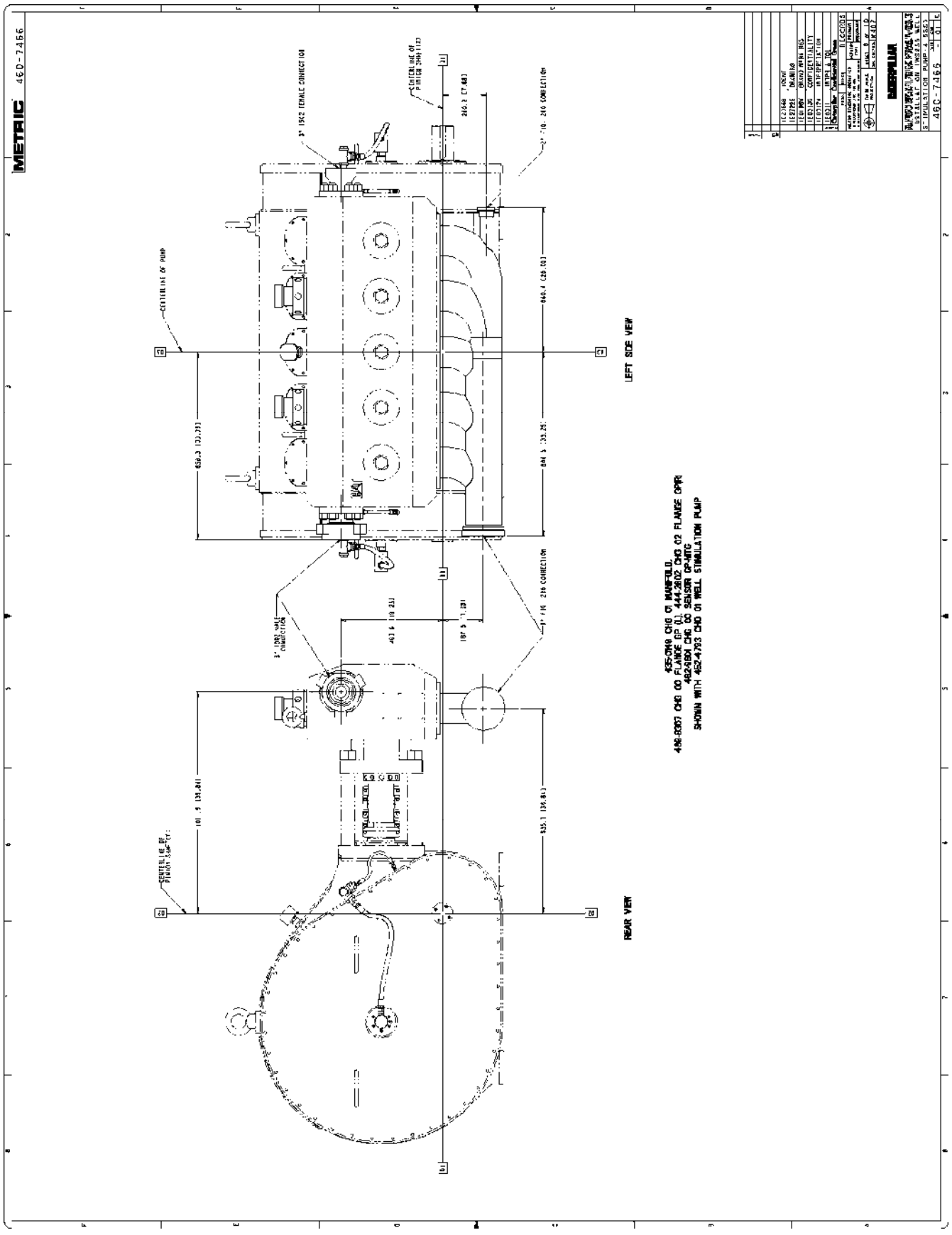

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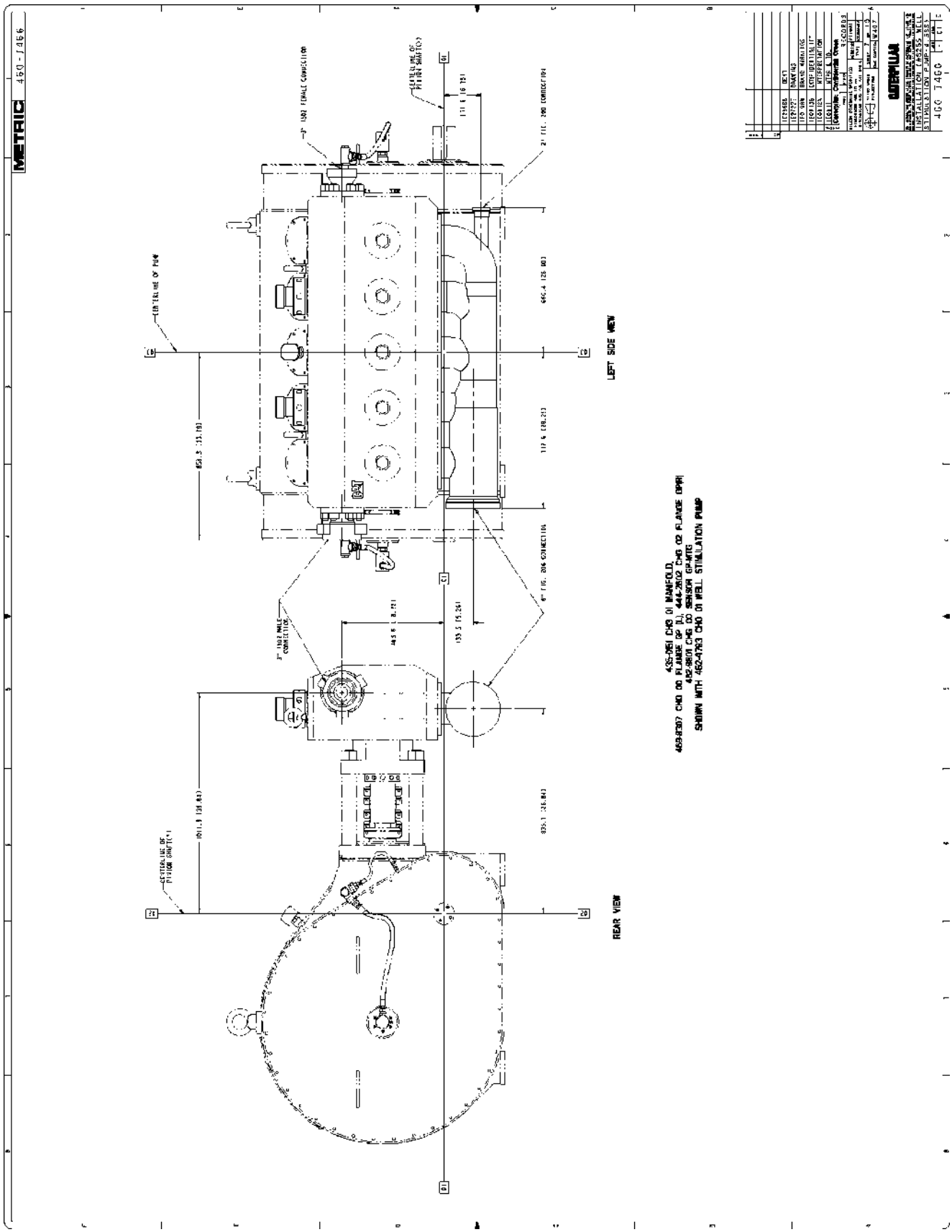

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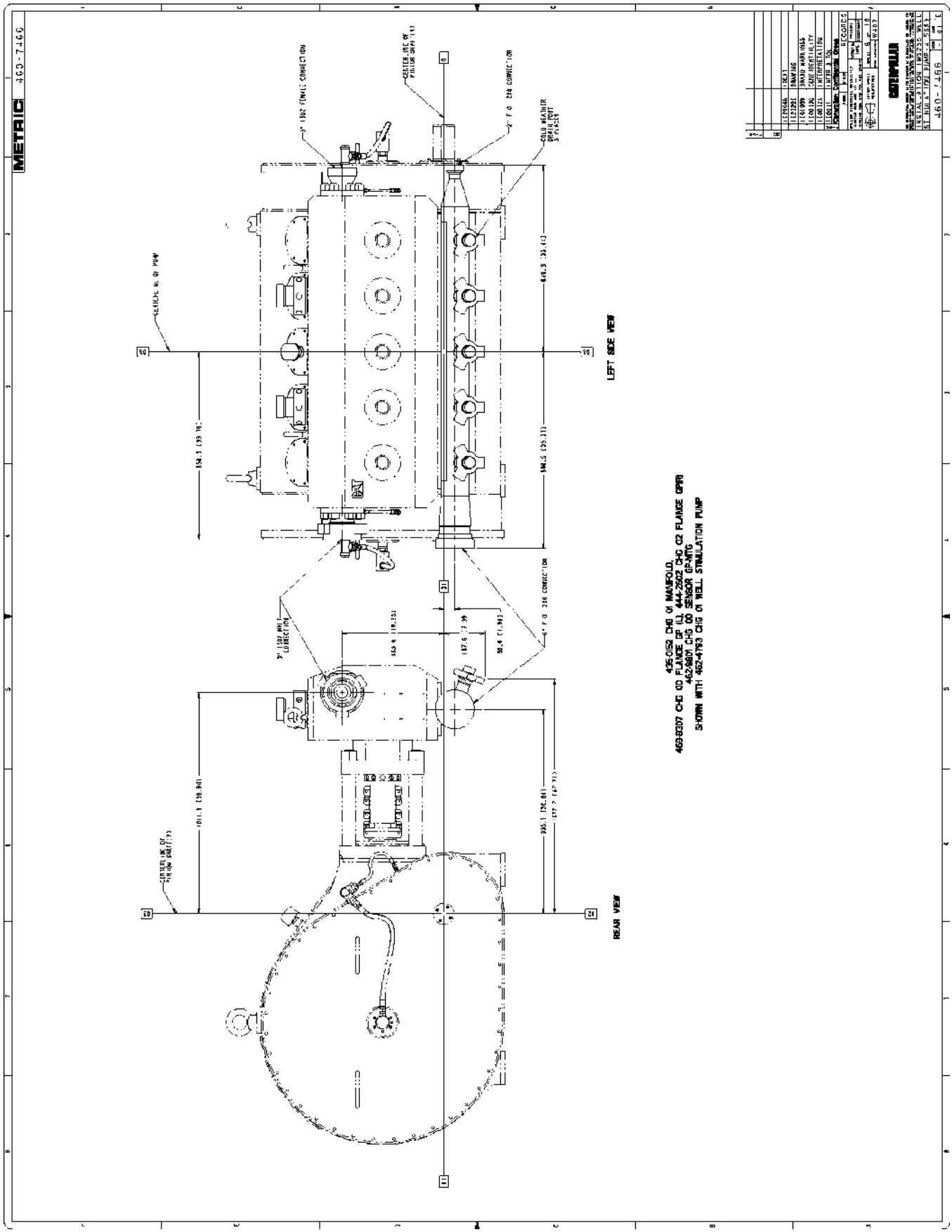

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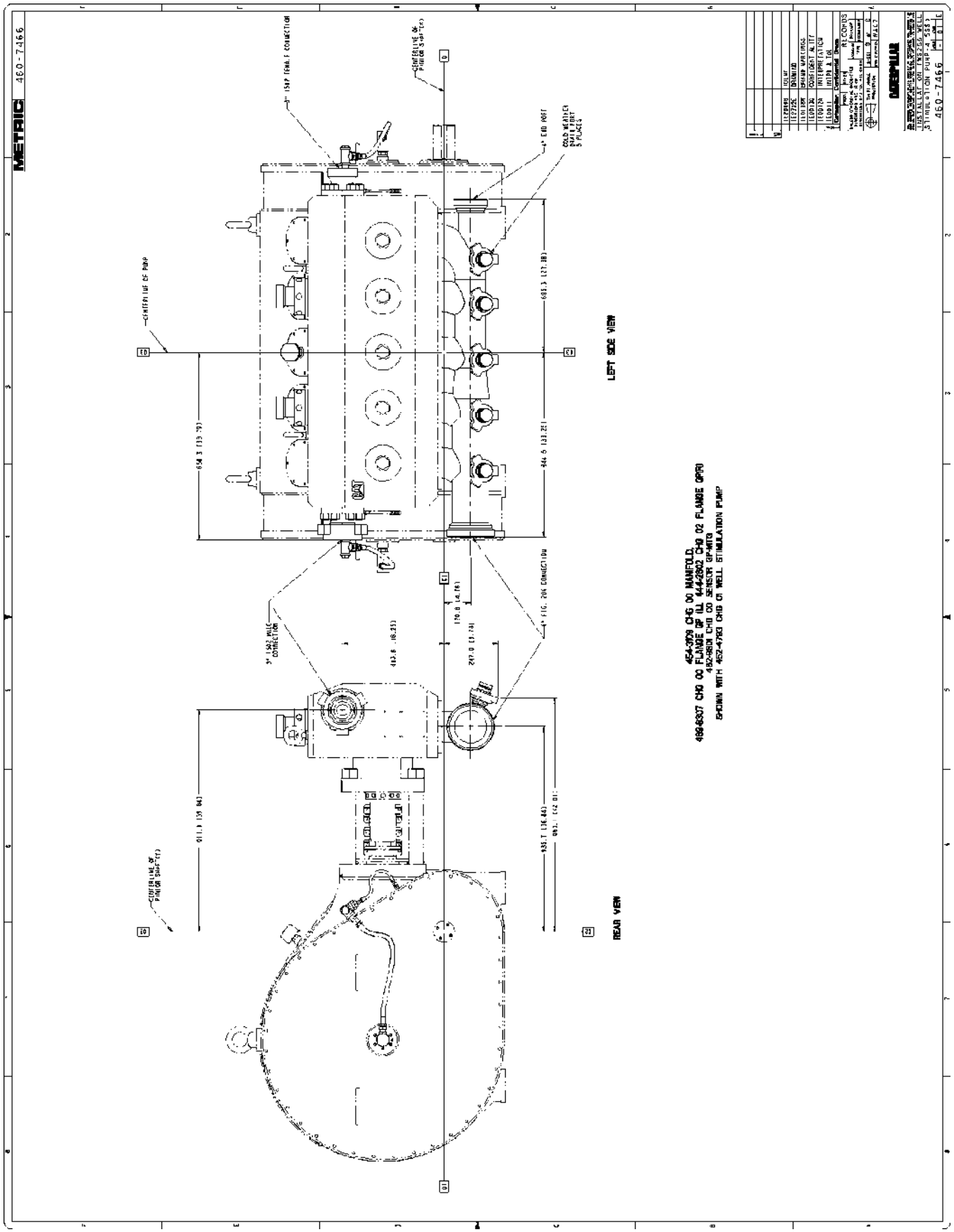

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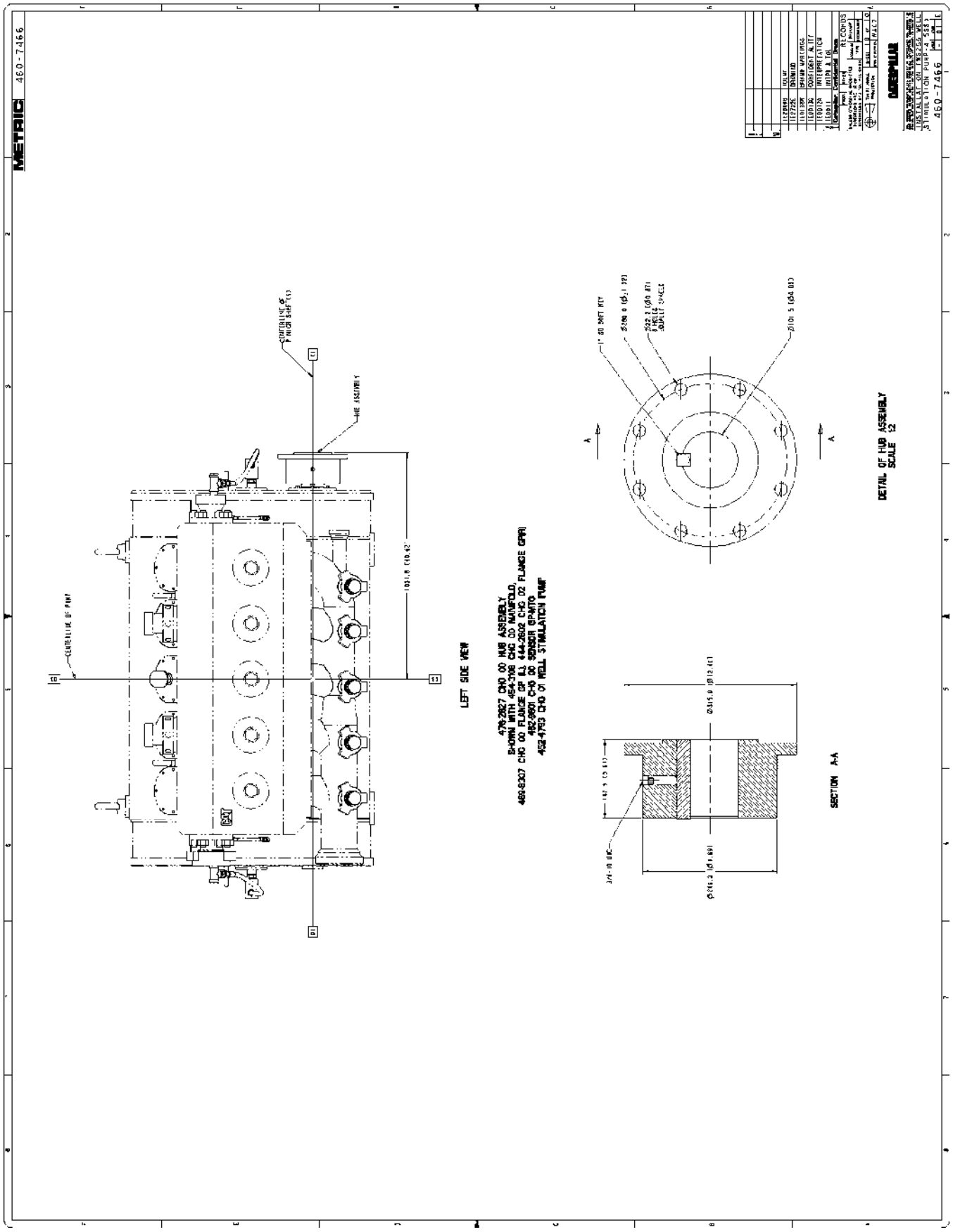
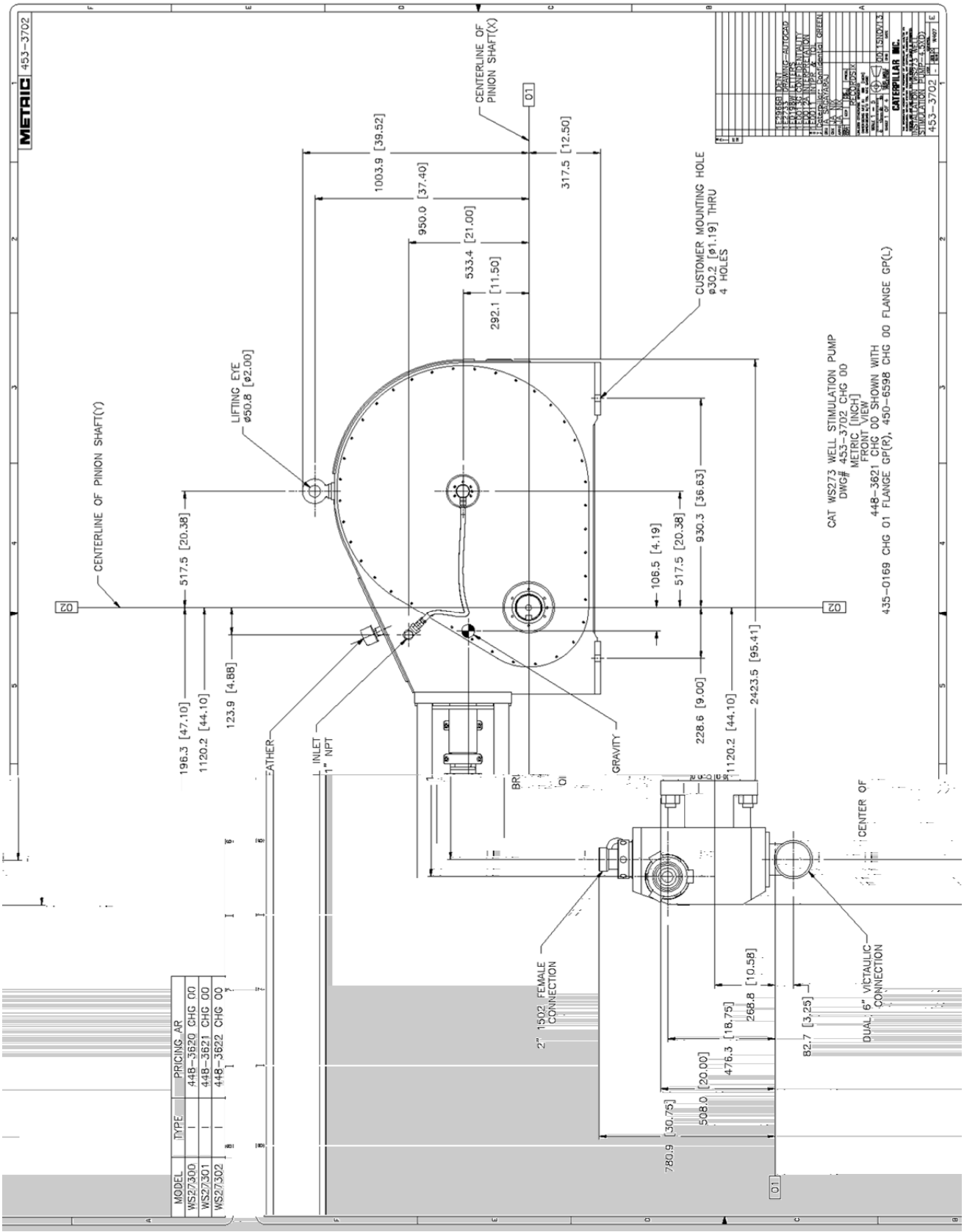
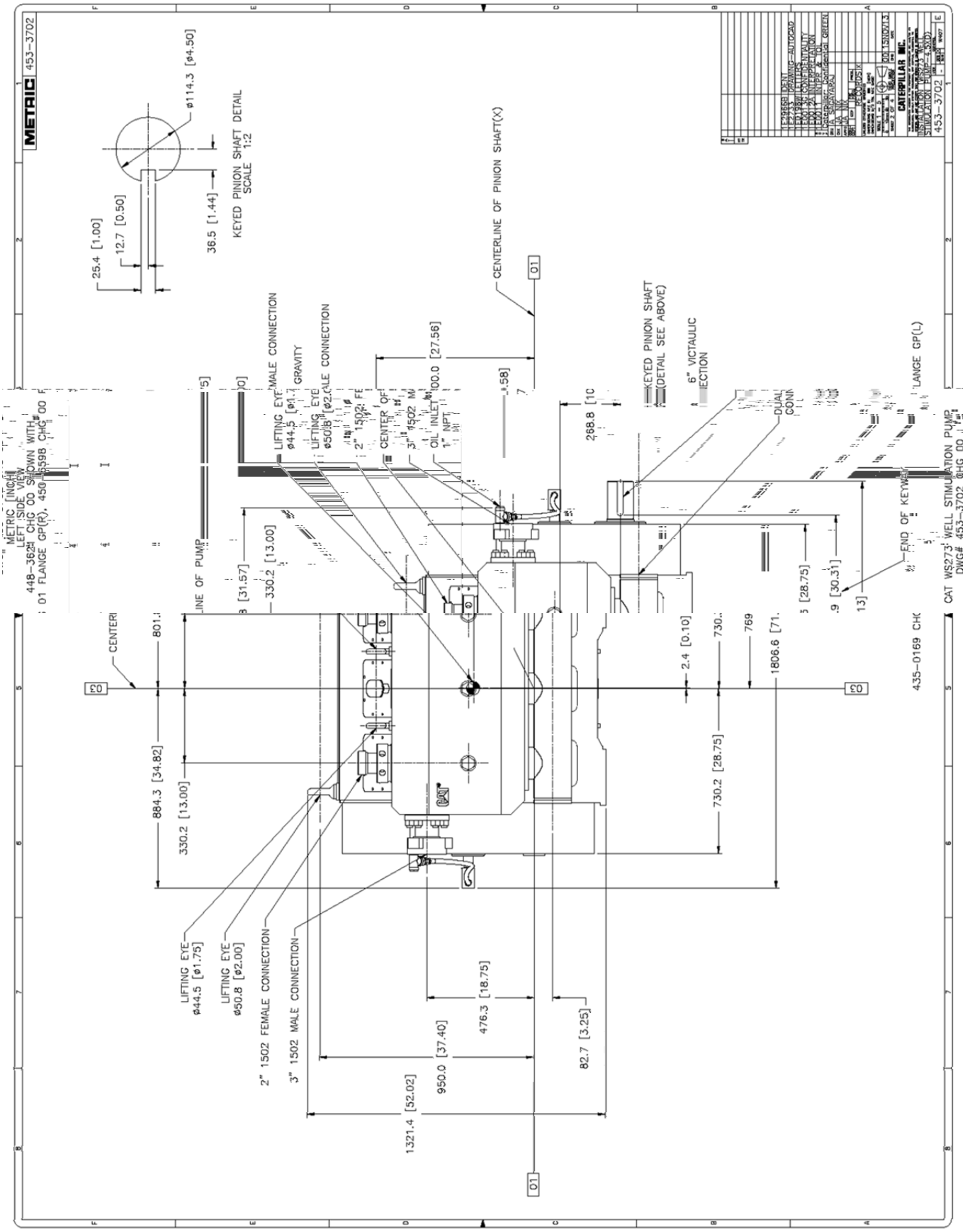


WS273XD Drawings – 453-3702

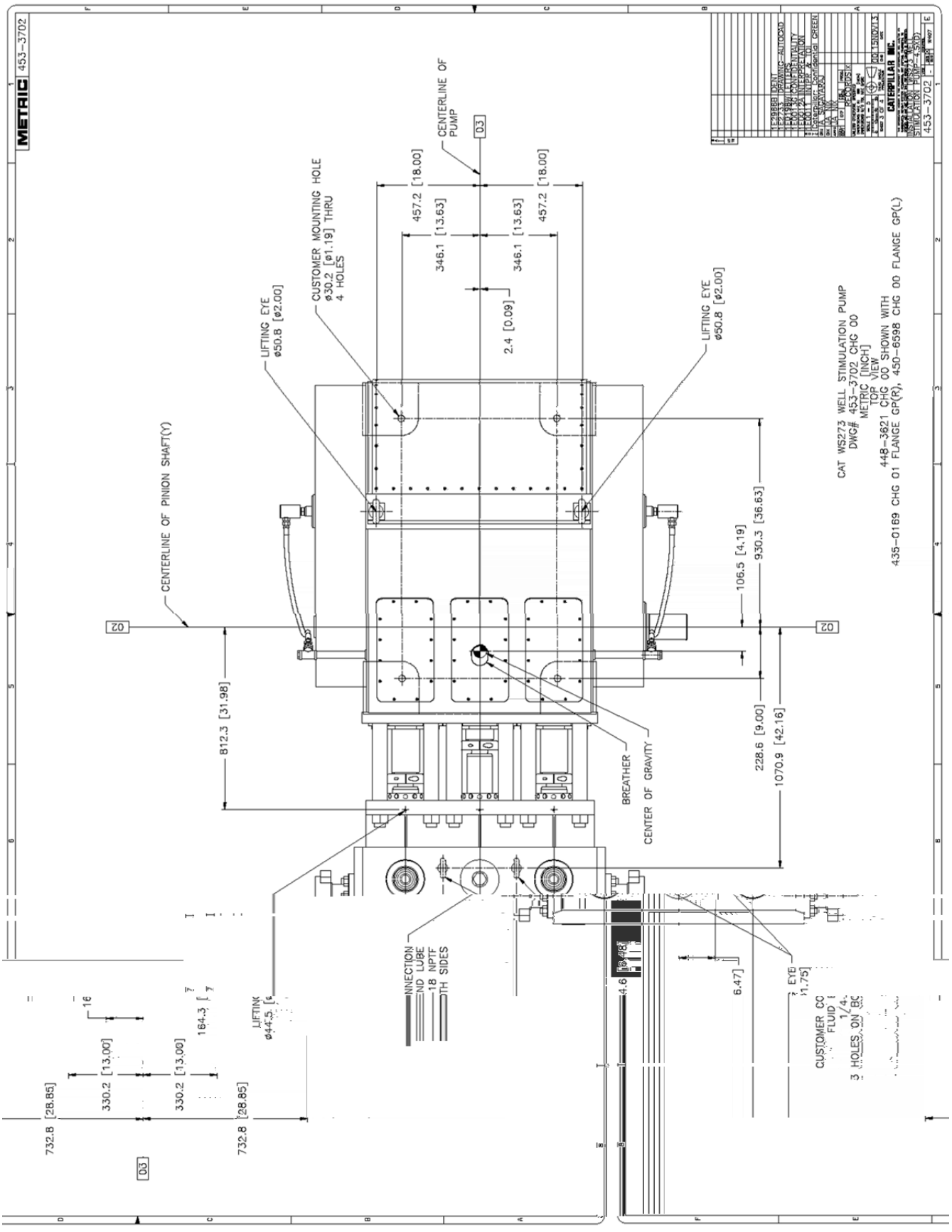
WS273XD Front View



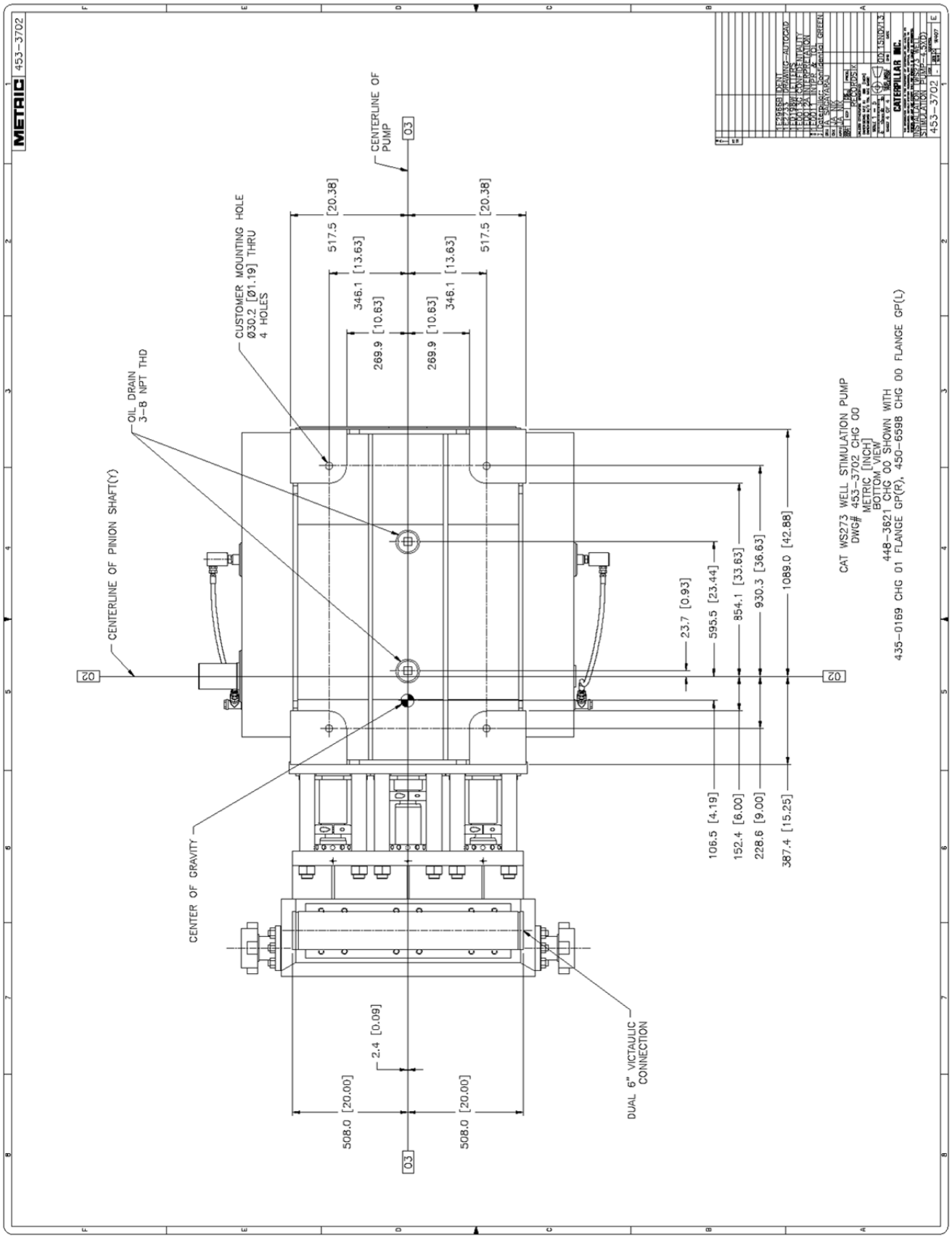
WS273XD Left Side View



WS273XD Top View

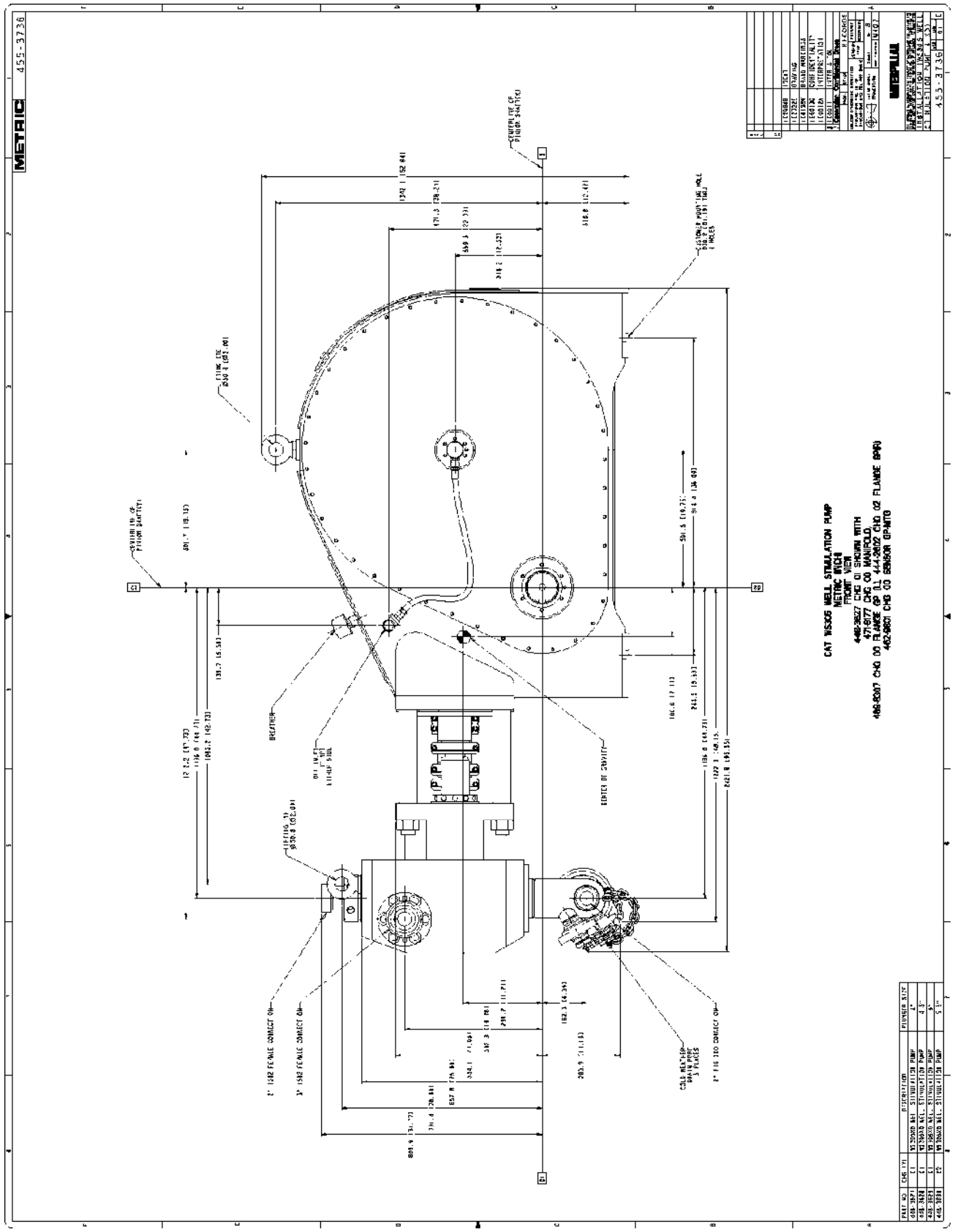


WS273XD Bottom View

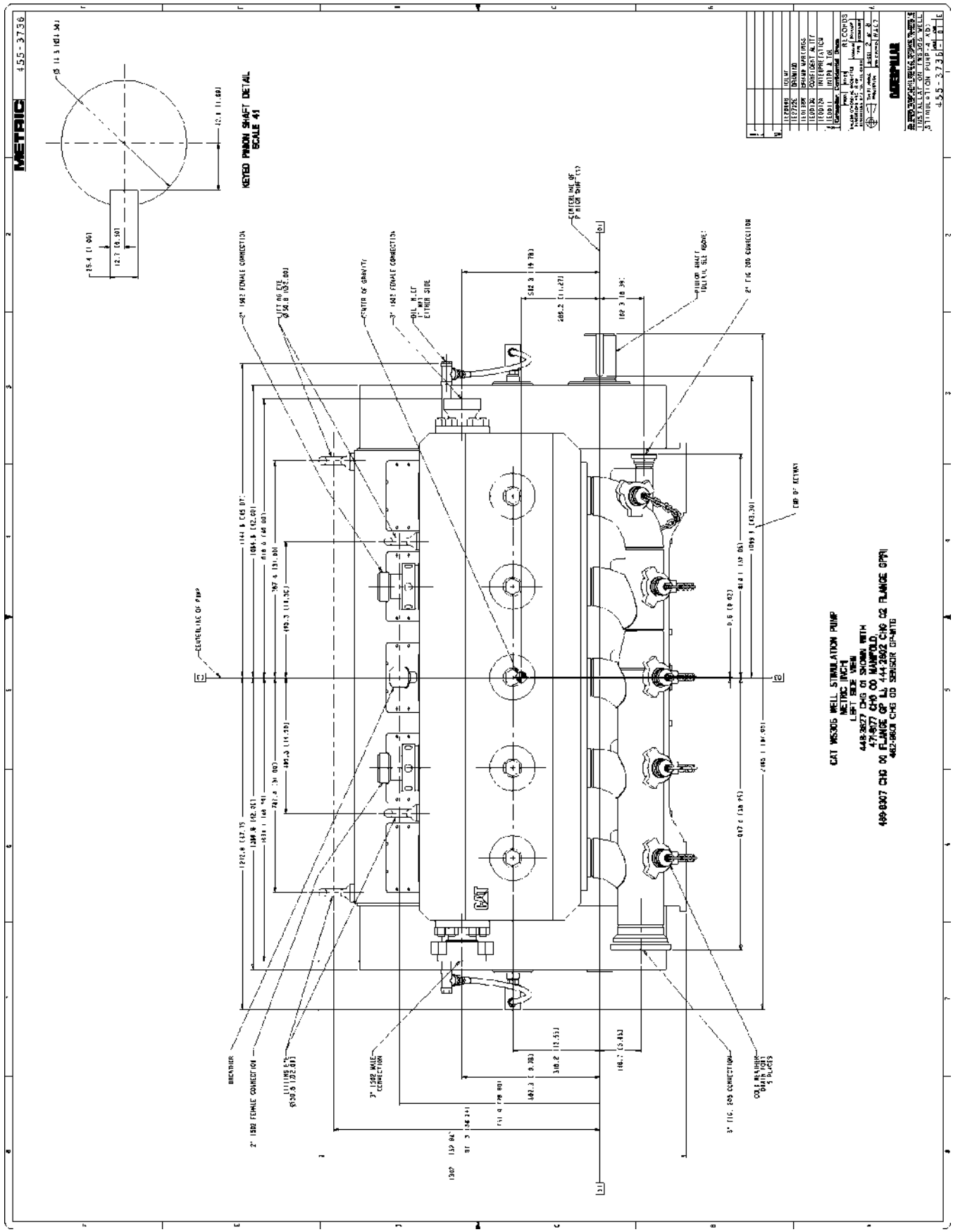


WS305XD Drawings – 455-3736

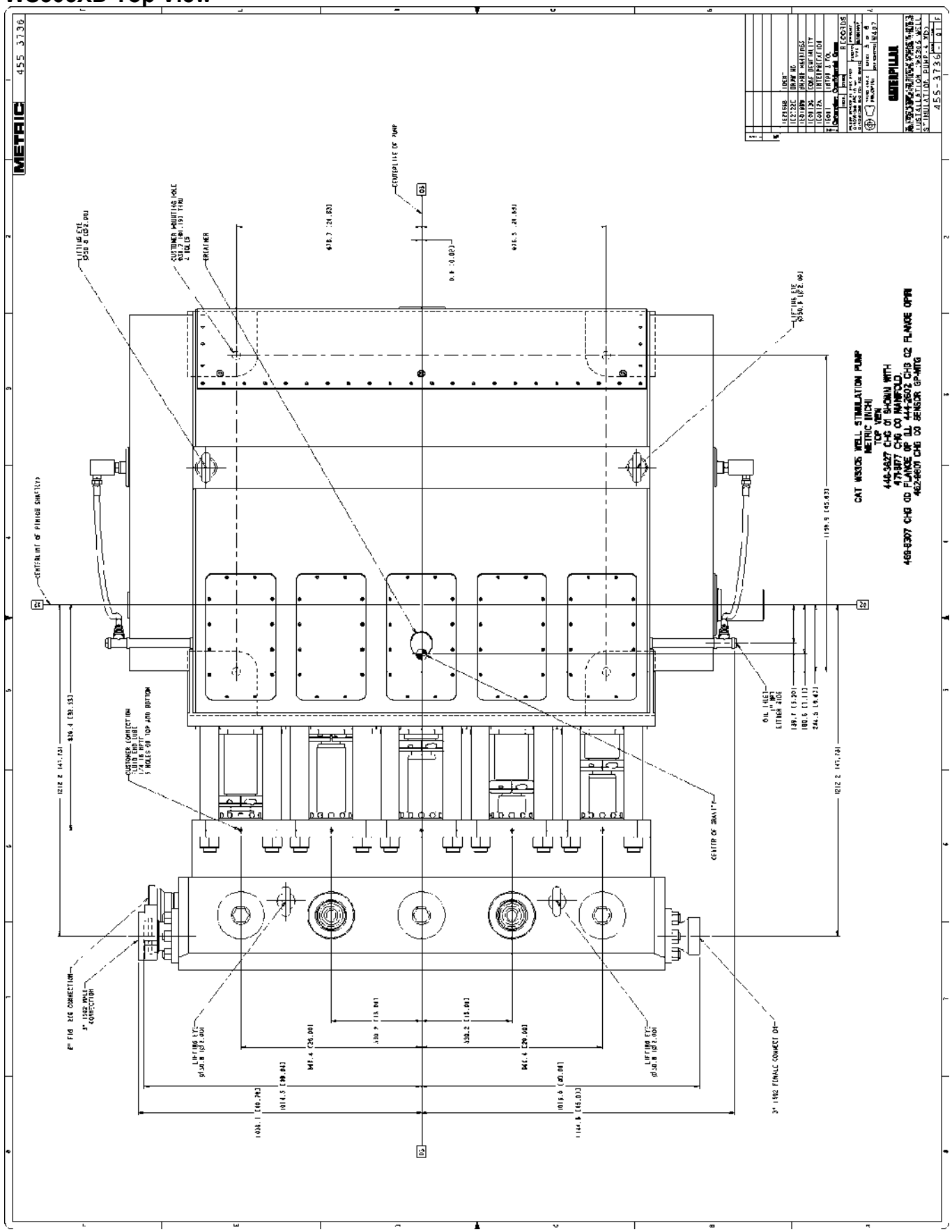
WS305XD Front View



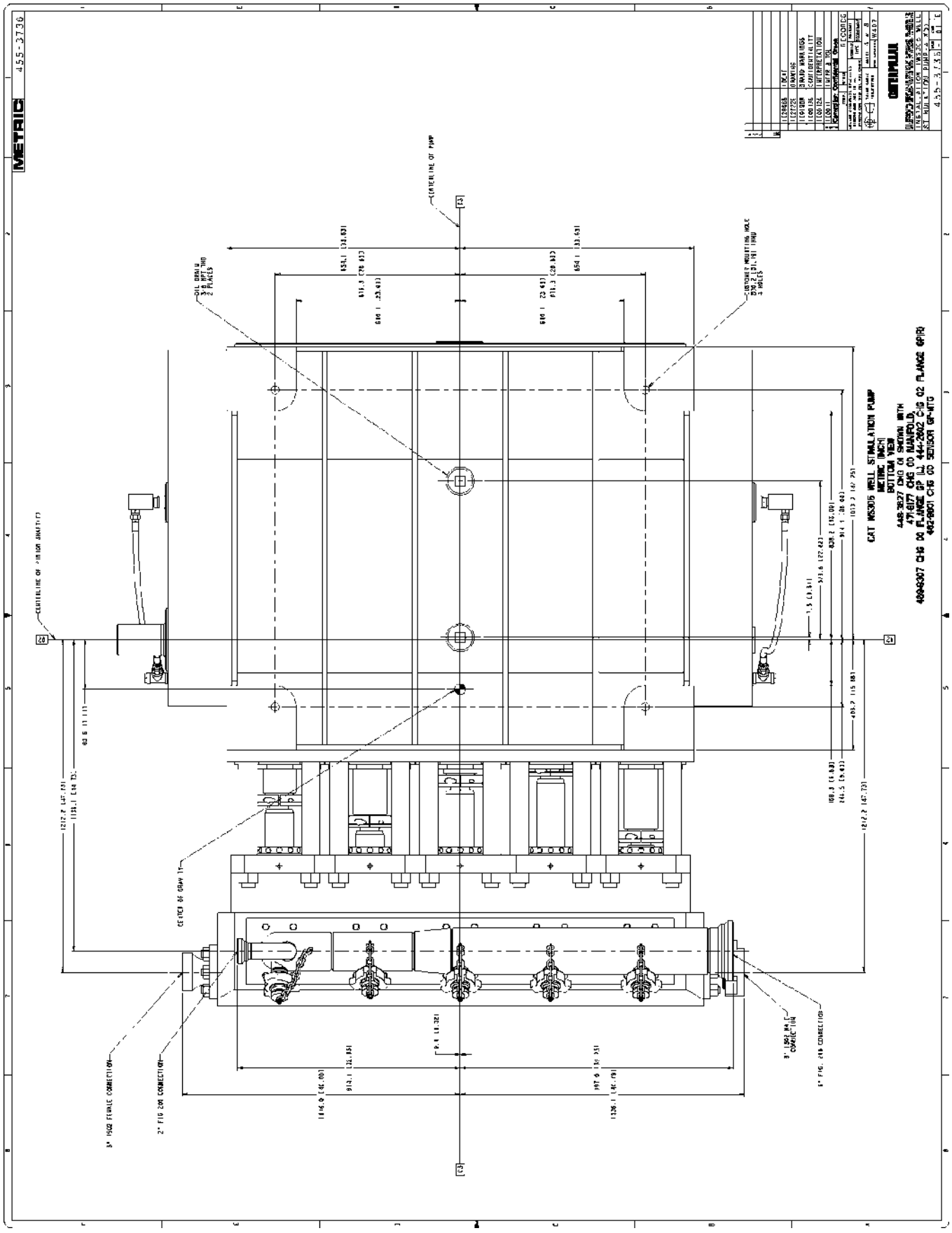
WS305XD Left Side View



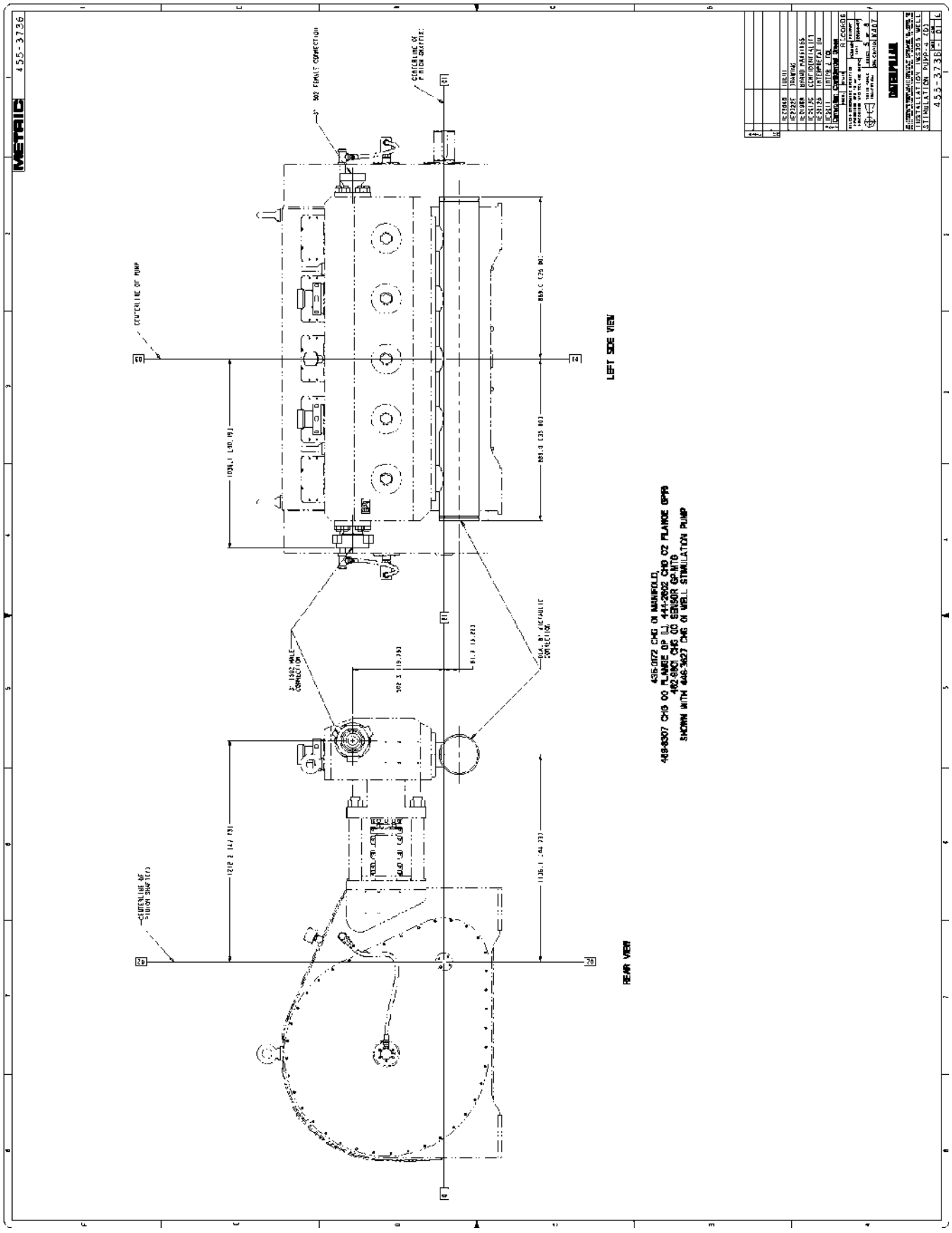
WS305XD Top View



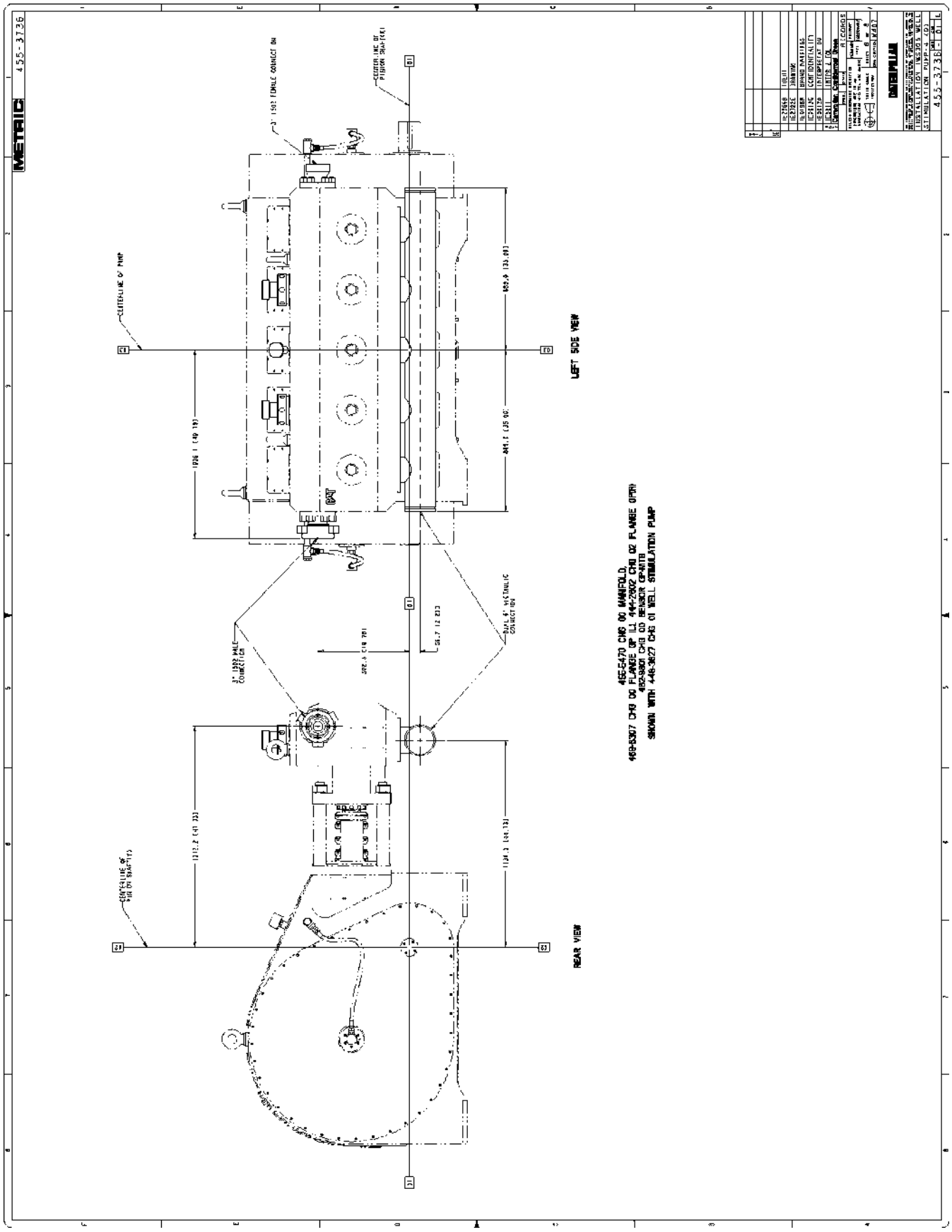
WS305XD Bottom View



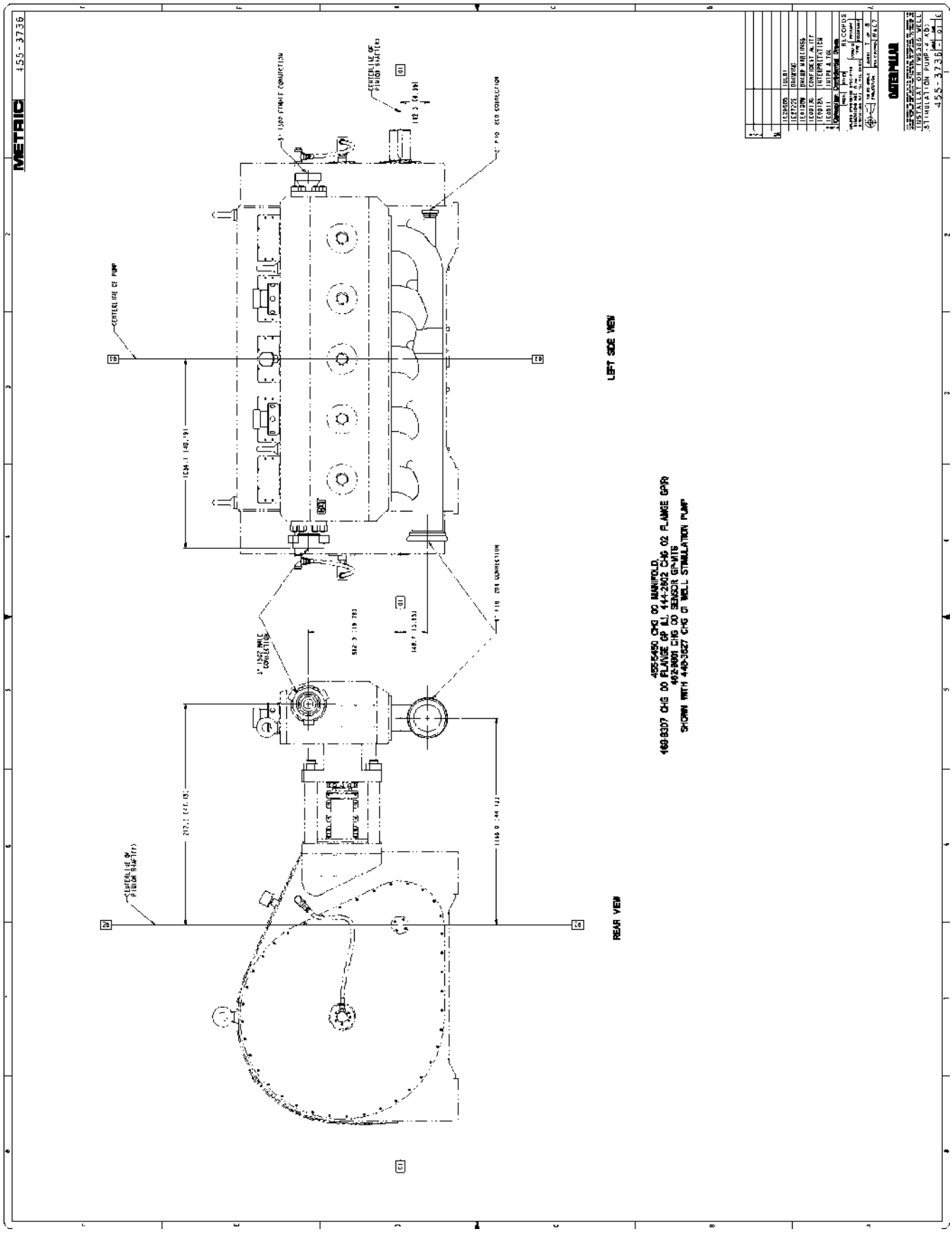
WS305XD Optional Attachments 1



WS305XD Optional Attachments 2



WS305XD Optional Attachments 3



WS305XD Optional Attachments 4