February 10, 2020

To: Bradford A. Bruno
Subject: Letter of Transmittal

Dear Mr. Bruno,

This document presents the analysis, evaluation, and final design of the fuel oil transport and heat system. A final design was created with the goal to minimize the total project present worth cost, while trying to maximize the efficiency of the system. The total present worth cost of the final design is $368,600, assuming the system operates 8000 hrs per year for ten years at an interest rate of 8%. The total present worth cost of the system is broken down by the total electricity cost, component cost, material cost, and installation cost. The cost of each is $327,000, $8,200, $11,200 and $22,200, respectively.

Our proposed transport system utilizes 140.2 m of 1 inch stainless steel pipe, fourteen stainless steel flexible bellows, six 90° elbows, a Gorman-Rupp stainless steel rotary gear pump, a 1.5 hp Marathon DC motor, two Apollo stainless steel ball valves, and a GPI turbine flow meter. To handle No. 5 heavy fuel oil's high viscosity at a low pressure, the oil is preheated using the existing electrical heaters at the outlet of the storage tank to 40 °C and at the inlet of the burner to 90 °C. In order to keep the desired temperature, 1.5 inch thick insulation is used throughout the pipe system. The design specifications section of the attached report provides the details of the electric heater, gear pump, valves, flow meter and the overall pipe system.

For further details and in depth analysis of the proposed transport and heat system please reference the attached report. Please contact the team leader at romane@union.edu with any further questions. We look forward to hearing from you after you have reviewed the report.

Sincerely,

Enrique Roman

Enrique Roman – Team Leader of FUDGE Industries
Fuel Under Diligent Guidance of Engineers

Mallory Epstein – Team Economist
Thomas Walker – Fluids Analyst
Roderick Landreth – Heat Transfer Analyst
Adam Perterlein – Legislative Analyst

Project Summary

This report presents a solution to transport heavy fuel oil No. 5 (Bunker B fuel) from a large storage tank to an industrial furnace. The design objective for this project is to create a system that will move 0.4 liters per second of Bunker B fuel and heat the oil to 90 °C before it enters the furnace. Assuming that the system operates 8000 hrs per year for ten years at an interest rate of 8%, we wanted to keep the total project present-worth cost under $500,000. Our final design has an estimated present worth cost of $368,600, which is well below the desired cost. Our proposed oil transportation system flows through 140.2 m of 1 in diameter stainless steel pipe, conforming to the full schematic of the overall design presented in the report. Due to its high viscosity, the oil is preheated using the existing electrical heaters at the outlet of the storage tank to 40 °C and at the inlet of the burner to 90 °C. In order to keep the desired temperature relatively constant, 1.5 inch thick insulation is used throughout the pipe system.

Our system uses a Gorman-Rupp heavy duty stainless steel rotary gear pump with inlet and outlet diameters of 1 in. The rotary gear pump selected is a positive displacement pump that operates at 900 RPM in order to supply the required 0.4 liters per second. To meet the required net inlet pressure of the pump (2 PSIA), a 2 meter drop between the storage tank and the pump was included. The pump is attached to a 1.5 hp Marathon DC motor with variable rpm, capable of altering the flow rate. A GPI turbine flow meter is located just after the pump to measure the flow of the fuel oil in gallons per minute. In addition, an Apollo stainless steel ball valve is placed at the exit of the storage tanks and before the furnace. In order to accommodate thermal expansion in the piping system, stainless steel flexible bellows are added to the system every 10 meters.

Our system was designed to minimize the total present worth cost. Like most other design systems, the 10 year cost is heavily dominated by the electricity needed to power the pump and the heater. The annual heating cost for the pump and heater is about $700 and $48,000, respectively. The following presents the value worth of various costs associated with the proposed pumping system for a ten year period. The total electricity cost is $327,000. The total component cost (which includes the pump, motor, flow meter, and valves) is $8,200. The total material cost which includes the straight pipes, bellows, elbows and insulation is $11,200. The overall installation cost is $22,200. The total present worth cost of our system, $368,600, is not only far below the proposed total present worth cost, $500,000, but it also takes into consideration the maximum fluid and heating losses in the system.

Contents

1 Background and Introduction

Many thick viscous oils are used in a variety of applications and must be pumped from a storage tank to a location where they are burned. Fossil fuels, such as Bunker B, are frequently used in large energy companies for their low cost, despite environmental concerns. Because these companies must run year round to provide energy, it is imperative for the input power supply, as well as energy losses, to be minimized to lower the cost of operation. To accurately and effectively transport fuel, the fluid mechanics and heat transfer aspects of the system must be analyzed. The geometry, pipe diameter, insulation, component efficiency, and other factors must be considered to determine the amount of energy required to run the system, as well as the amount of heat lost. For safety measures, pipe systems include segments called bellows that relieve stress from thermal expansion. Other components, such as valves and flow meters, facilitate in controlling the flow rate of the fuel through the system. Additionally, insulation can be wrapped around the pipes to reduce the amount of heat from the hot fuel lost to the ambient environment, through the process of convection.

The pump must provide energy to increase the fluid's elevation, increasing the fluid's 'head', but the geometry of the system creates losses that effectively increase the required pump head. Many of the required pipe additions and safety measures increase resistance to the flow of the oil, consequently increasing the effective elevation gain the pump must push the fluid through. This is the minor loss within the system, which increases as parts such as pipe elbows, valves and flow meters are added. Flow meters measurements require an instrument to be forced into the flow, adding more resistance within the system. However, the majority of the losses are caused by the roughness of surface of the pipe material that the fluid interacts with. The no-slip condition states that the layer of fluid directly touching the pipe is stationary with respect to the pipe. The rougher the pipe surface, the larger the boundary layer within the pipe that is slowed by this roughness. From a fluid mechanics standpoint, the most efficient system is the one with the least amount of major and minor losses. In other words, the system should have as few bends and be as short as possible. The most efficient system is similar from a heat transfer standpoint as well. The greater the temperature difference between the outside environment and the fluid, the more heat will be lost per length of pipe. A shorter pipe corresponds to less heat that would be lost to the environment. In addition, the resistance to heat loss can be increased with insulation, but only after a critical thickness. If the insulation is too thin, the extra material will aid in conduction, since the thermal resistance it adds scales by the product of the material's thermal resistance and its thickness.

Fossil fuels may be harmful to the environment, but in some instances where employing fossil fuel use is unavoidable, minimizing energy losses not only minimizes cost, but also reduces the carbon footprint created by energy use. Bunker oils are characterized as non-refined oils typically used in large ships or heating, though are fairly toxic and polluting. Thick oils need to be heated before use, for both movement and burning. These oils are classified by their kinematic viscosity into types A, B, and C, categorizing fuel oils No. 1 through 6. Of these, fuel oil No. 6 is the most common, and No. 5 is called the 'Navy Special' [1] for its use in shipping, both used often as furnace fuel. Viscosity is a function of temperature for these oils, increasing greatly at lower temperatures, and greatly impacting the logistics of pumping. Motors drive the pumps which increase pressure to the liquid, and must have enough pressure on the lower pressure side so that the liquid does not vaporize. This leads to the formation of gas bubbles, which often form cause damage to the pump and lowers its lifespan. The type of pump also adds to the safety of the system, choosing between axial and positive displacement can be the difference in being able to shut a valve to stop the flow in an emergency, and shutting the valve to start an emergency due to pressure buildup.

The following report will include a summary of the contract's job requirements, the condensed description of our proposed solution, in depth analysis concerning the solution's benefits and methods, an explanation of the system's constraints and performance, followed by the next recommended steps in completing this contract.

2 Problem Definition

The objective of this report is to propose a piping system to transport heavy fuel oil No. 5 from a storage tank to an industrial furnace. The system must efficiently and safely move 0.4 liters per second of heavy fuel oil No. 5 and heat the oil to 90 °C before it enters the furnace. The desire is to keep the total present worth cost of the system under $500k for a 10 year operating period. A viable design must include a motor, pump, valves, and flow meter to control the flow of heavy fuel oil. The locations of the storage tank and furnace are given and are approximately 150 m apart. The design must have an analysis of pressure drop, the heat transfer along the pipe, and specified fittings and equipment.

A design for the system must analyze multiple elements, including the size and length of stainless steel pipe, and the thickness of insulation. In addition, a pump, valves, and flow meters need to be specified for the decided upon pipe size. The sizes of the piping and components can be optimized to reduce the cost to heat and pump the fluid. The technical fluids and heat transfer specifications for the system are included in table 1. The economic limitations including the lifespan of the system and the estimated interest rate are included below in table 2.

These thermal fluid and economic specifications restrict the possible solutions that can designed. The type and amount of heating can be optimized along with the size and orientation of the piping. In addition a motor, pump, valves, and a flow meter must be specified from manufacturers. Their specification sheets are included in the appendices. The end goal of the design project is to develop a low cost, and efficient fluid transportation system for heavy fuel oil No. 5.

Table 1: A tabulation of provided thermal constraints for the system.

Quantity	Value
Nominal Total Flow Rate	0.4 l/s
Flow Meter	1.0% accuracy
	Measure $\frac{1}{2}$ to 3 times the nominal flow rate
Heavy Fuel Oil No. 5	Initial Temperature, $T_i = 25$ °C
	Final Temperature, $T_f = 90$ °C
Ambient Conditions	Ambient Temperature, $T_\infty = 15$ °C
	Heat Transfer Coefficient, $h = 30$ W/m^{2}K
Bellows	1 per every 10 m
Insulation	$k = 0.08$ W/mK
Furnace Inlet Coordinates	(100, 20, 13) m
Tank Outlet Coordinates	(0, 0, 0) m

Table 2: The total economic specifications. These costs represent a 10 year present worth assuming an interest rate of 8% per year.

Quantity	Value
Duty Cycle	8000 hrs/year
Interest Rate	8%
Electrical Cost	12 cents/kWhr
Installation Cost	2 times material cost

3 Design Description

The oil transportation system that we designed flows through 140.2 m of stainless steel pipe running from the storage tank to the furnace, with a ten year present worth of $368,600. Before the fluid exits the tank it is heated to 40 °C using an electric heater. This is accomplished using an existing electric heater that uses 50.03 kW. After heating, the fluid exits the bottom of the tank where it enters a downward 90° elbow and then flows 2 meters downward until it reaches the Gorman-Rupp heavy duty stainless steel rotary gear pump. The piping used in the system is all 1 inch schedule 40 stainless steel pipe, and is encased in 1.5 in thick insulation. The insulation has a thermal conductivity of 0.08 W/mK. An Apollo stainless steel ball valve is placed at the exit of the storage tank, and before the entrance of the furnace. A GPI turbine flow meter is located just after the pump to measure the flow of the fuel oil in gallons per minute. Since a positive displacement pump is used, the flow of the fuel oil can be controlled using the pump. A 1.5 hp variable speed DC motor is attached to the pump. The rotation speed of the motor correlates directly to the flow rate for the system. The pump is sized to satisfy the total head loss of 88.26 meters. After the pump, the piping runs 140.2 meters, rising 15 meters, to where it attaches to the Eastern face of the furnace. Just prior to entering the furnace, the fuel is heated again to 90 °C using existing electrical heaters. 50.03 kW of electricity are used to heat the fuel to the final temperature. Stainless steel flexible bellows are added to the system every 10 meters to accommodate for thermal expansion in

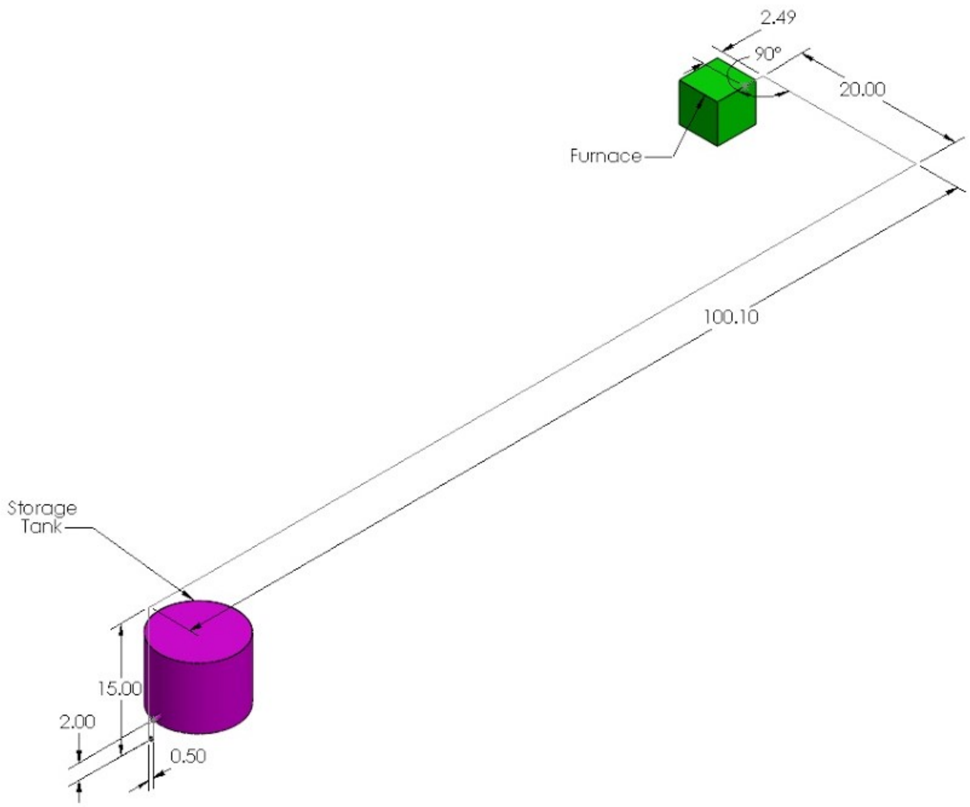

Figure 1: Isometric view of proposed piping system with dimensions. A two meter drop is included before the pump in order to ensure that the requisite pressure at the inlet pump is maintained.

the piping. An isometric drawing of the piping layout is included in figure 1 as a reference for the piping layout, as well as a close up drawing of the pump in figure 2. The location of the components are also shown in figure 3. This does not show the scale of the piping or components, but gives the order and relative locations.

The pump selected for this application is a Gorman-Rupp GHC 1 DE9-B Rotary Gear Pump with an inlet and outlet size of 1 inch. The inlet and outlet are both #150 flanged connections. The rotary gear pump selected is a positive displacement pump, and operates at approximately 900 rpm to supply the required 0.4 liters per second of heavy fuel oil. The pump is attached to a 1.5 hp Marathon DC motor. At our operating conditions, the pump has an efficiency of 0.63, and the motor has an efficiency of 0.85, leading to an overall efficiency of 0.54. In total an estimated 735 W is required by the pump to move the fuel through the pipe. The specification sheets for the pump and motor are attached in Appendix A and B, respectively. The net inlet pressure required for this pump is 2 PSIA, which is accomplished by including a 2 m drop between the storage tank and the pump.

The smaller components including the ball valves, and flow meters were sourced from Apollo and GPI. The ball valves are used purely for shut off purposes and not for metering. The valves are 1 inch stainless steel 87A-200 Series. They have minor losses of approximately 0.006 per valve. The

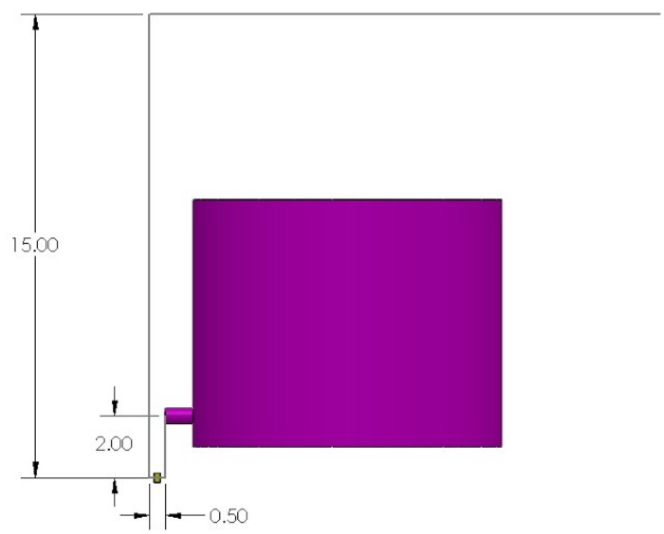

Figure 2: Close-up view of inlet and pump, including the elevation drop in front of the pump to prevent cavitation.

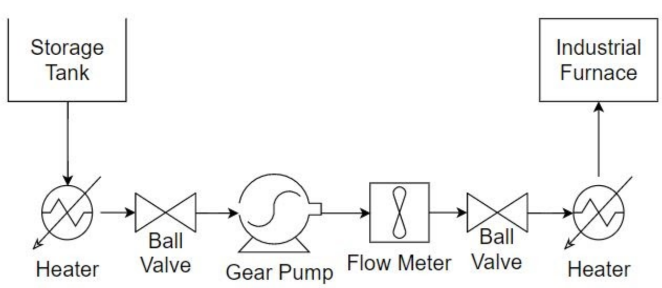

Figure 3: The piping and instrumentation diagram for the proposed system. This includes the storage tank, both heaters, the two safety valves, the pump, the flow meter, and the furnace.

flow meter selected is an internal turbine type and has a minor loss of approximately 5 psi. The complete specifications for these components are given in Appendix C and D. All of the components used in the system are #150 flanged fitting and are stainless steel to match the piping.

The total 10 year present worth value of the pumping system is $368,600. This equates to an annual annuity of $54,900 over 10 years. This includes the initial equipment cost as well as the annual electrical heating and pumping costs. A bill of materials is included in table 3.

Table 3: Bill of material for the proposed system.

Component	Quantity	Size	Unit Cost ($)	Total Cost ($)
Rotary Gear Pump	1	1" inlet/outlet	4500	4500
Motor	1	1.5 hp	368	368
Ball Valve	2		400.57	800
Flow Meter	1			2464
Pipe	140.2m	1"	68.13 per meter	9550
90° Elbow	6	1"	12.86	77.16
Insulation	140.2m	1.5" thickness	6.17 per meter	865
Bellows	14	1"	45.43	636
Electricity – Pump	0.735 kW 8000 hr/year		0.12 per kWhr	710
Electricity – Heat	50.04 kW 8000 hr/year		0.12 per kWhr	48,030
Installation			2 times materials	22,260

4 Analysis

4.1 Fluid Dynamics

The proposed system to transfer heavy fuel oil from the storage tank to the furnace involves selecting a pipe size, pump size, and components. There were quite a few assumptions made to complete the calculations. The heavy fuel oil is assumed to be at steady state, and steady flow. The heat loss and associated change in viscosity was accounted for in the pipe as the oil cooled, but it was assumed that there was uniform temperature change in the fluid. The fuel assumed to be incompressible and fully developed. In addition we assumed a uniform density for the fuel oil, which we know is false, but was assumed to have a negligible effect on the head loss or heat transfer calculations. Based on the Reynolds number we identified that the flow was laminar, and fully developed for the fluids and heat transfer calculations.

In order to get a better estimate of the major loss, the given viscosity plot was digitized and fit to an equation that models viscosity's dependence on temperature, the Walther equation [2]. This equation is given in equation 1.

$$\log(\log(\nu + \lambda)) = A - B \log T \tag{1}$$

Where ν is the kinematic viscosity, λ is a physical constant, A and B are constants based on the fluids, and T is the absolute scale temperature of the fluid. The quality of this fit is shown in figure 4. Two more complex models, the Seeton and Manning models [3], were also considered, but they did not provide a better fit. Combined with the equation for temperature as a function of length along the pipe, x, this equation can be solved analytically for kinematic viscosity as a function of length along the pipe, x, and can then be integrated over the length of the pipe, $x \in [0, L]$, and divided by L to get the average viscosity. This value was then used to calculate average Reynolds number, Re, and average Darcy friction factor, f.

The pipe size was selected based on a balance between the work required to pump the fuel oil, and the heat lost over the length of the pipe. Based on our optimization which will be discussed later, 1" schedule 40 stainless steel pipe was selected for this application. The pump is sized based on the head losses, and the gallons per minute (GPM) required. The head loss was calculated using the modified Bernoulli equation shown as equation 2.

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 + h_{pump} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \left(\sum K + f\frac{L}{D}\right)\frac{V^2}{2g} \tag{2}$$

The pressure components of the equation were eliminated because the inlet and exits are open to the atmosphere. The inlet and outlet mean velocities are also the same, so the velocity components are crossed out. The z component is the vertical height that the fluid has to go up. While we are only required to lift the fluid 13 meters, the total is raised to 15 because we need to lower the pump by 2 meters to ensure we have a positive suction head. The net positive suction head was calculated using equation 3.

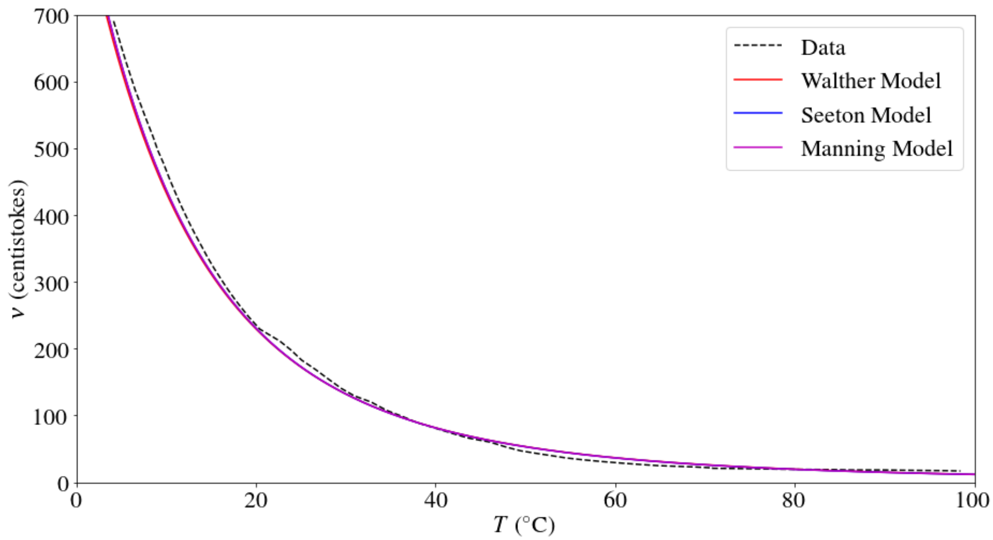

Figure 4: Data from the provided viscosity plot is shown in dashed black, the solid colors represent the models used to quantify the dependence of the viscosity on temperature. The selected model is shown in solid red.

$$NPSH = \frac{P_{total} - P_{vapor}}{\rho g} \tag{3}$$

The vapor pressure for heavy fuel oil at 40 °C is 0.114 psi. It is important to make sure this is positive to prevent cavitation. The other two components to calculate the overall head loss are major and minor losses. From the overall head loss, the work required by the pump can be calculated. The major losses are associated with the interior friction in the pipe. The friction factor is determined using equation 4.

$$f = \frac{64}{Re} \tag{4}$$

The minor losses are a function of the components in the system, elbows, flow meters, valves, and inlets and exits. These each have a K factor which contribute to the minor losses. These values are specific to each component, and are found in their individual specification sheets. These can be found in appendix D. The sum of the minor head loss is 6 m. The work required by the pump is a function of the head loss, density, gravity, and efficiency. This is shown in equation 5.

$$W = \frac{\rho \dot{V} g h_L}{\eta} \tag{5}$$

The overall head loss for the system was calculated to be 107 meters using equation 2, a simplified Bernoulli equation for our particular design. This number was used to select the pump for our design, because the pump must have enough power to overcome the losses associated with the pipe.

The pump was selected to be able to satisfy this overall head loss, and to provide 0.4 liters per second. The pump was selected using the performance curve which specifies the flow rate and the pressure. The performance curve for the selected pump attached in the pump specifications in Appendix A. A Gorman-Rupp positive displacement pump was selected because they are beneficial in high viscosity situations. This pump is stainless steel for durability and was able to handle the relatively low flow rate required. A variable speed motor was selected so the flow rate could be controlled. A 1.5hp Marathon motor was optimum for this design because it's torque and operational RPM's were in the range that is required. The pump requires approximately 900 revolutions per minute to supply 0.4 liter per second. The 1.5 hp motor was picked out for this application because it is slightly larger than required, so increased flow rates can be accounted for. We also chose a DC motor because the speed can be controlled which is important for changing flow rate in a positive displacement pump.

After selecting the pump and motor, specific ball valves were picked out. An Apollo 87A-200 series ball valve was selected because they have a low impact on the minor losses and don't need to be used for flow control. We selected a #150 flanged stainless valve so the material matches the pipe, and so that the material can handle the pressures. Flanged fitting and components were selected for easy installation and for their superior durability and leak resistance compared to threaded fittings. In additon, installation of flanged fittings is easier and more cost efficient for stainless steel systems. Ball valves were selected over gate of globe valves. Since the valves would only be closed for emergencies or maintenance, the drawbacks of wearing out when used for throttling, and fluid being stuck in them when they are closed are not issues. The GPI OM025S513-841R4G flow meter that we specified for this application uses an internal turbine to measure the volumetric flow rate. The meter is accurate to 0.5% and operates within our temperature and pressure ranges. This design gives us the precision that is required based on the project specifications.

In a failure situation, the pump begins slipping at around 1.4 MPa, much lower than the approximately 10 MPa that would be required to begin rupturing pipes and fittings. We are, therefore, confident that in the event the value is completely closed or the system is completely clogged that a pipe rupture, and spill, would not occur.

Other options that were considered included using a different styles of pump, larger or smaller diameters of pipe, higher heating temperatures, and alternative piping routes. Our choice of pump was best for our situation due to its performance at high viscosities and the ability to run a low flow rates. Centrifugal pumps operate at a singular flow rate, and must be throttle using a valve, adding to the losses in the system. While a large piping system could have been used, the heat losses increase with the pipe size, along with the overall costs of the pipe, fittings, and insulation. The initial temperature was selected because it was a point where we had relative confidence in the properties of the fuel oil, but the heat losses over the transport distance were not to large.

4.2 Heat Transfer

The proposed way to transfer the Bunker B fuel oil involves heating the oil as it leaves the holding cell before movement, transferring the liquid, and then heating it to a usable temperature before entering the furnace. Specifically, the oil is heated from 25 to 40 °C, run through 140.2 m of stainless steel pipe with 1.5 in foam insulation, then heated from 37.8 to 90 °C on entrance to the furnace. Material properties of the stainless steel, oil, and insulation are presented in table 4. The most important part of the heat transfer analysis is calculating heat loss, because there is a fixed and unavoidable amount of energy used to heat the oil from 25 to 90 °C.

This system can be simplified by assuming that heat transfer is steady state and does not vary with time and the outside air in contact with the insulation is at a yearly average of 15 °C and exhibits a convective heat transfer coefficient $h = 30\frac{W}{m^2K}$ on the outer surface of the pipe. In addition, the energy generated and stored within the pipe and insulation is assumed to be zero for the system, and the insulation is so fitted to the pipe that there is zero contact resistance, which would block heat transfer because of air gaps between layers. The thermophysical properties of the system are taken to be constant, and the fuel oil is assumed to be laminar, thermally and physically fully developed, and incompressible. Additionally, since there is not readily available documentation about the oil's thermophysical properties, those of its components and oils of similar uses are taken as a weighted average [4] [5]. This yields a thermal conductivity of 0.16 $\frac{W}{mK}$ and a specific heat of 2 $\frac{kJ}{kg}$. The pipe system can be considered one dimensional heat flow because it has radial symmetry, the heat energy moving from the oil through the pipe and insulation into the air, which is constantly the lowest temperature. Figure 5 illustrates the direction of heat transfer.

Using the method of thermal resistance, the heat's transfer from the oil to the pipe, through the pipe, through the insulation, and from the insulation to the air can be modeled as current moving through resistors in series, depicted in figure 5. The resistances in this case compound, but the stainless steel pipe transfers heat so well that it will add a negligible amount to the overall thermal resistance and can be dismissed from analysis. The thermal resistance that will change based on the system is the convection coefficient between the pipe and the oil, affected by the diameter of the pipe changing the rate of the oil's flow. The proposed system uses a pipe with internal diameter 0.87 in (0.0221 m) with 1.5 in of insulation around the pipe. Since the ambient

Table 4: Used system values taken as constant within these temperature ranges

Material	**Temperature (K)**	**Density (kg/m^3)**	**Specific Heat (kJ/kg)**	**Heat Transfer**
Oil	$T_i = 313$	930	1.7 to 2.1	$k = 0.16$ W/m^{2}K
AISI 316 Stainless Steel	300	3238	468	$k = 13.4$ W/m^{2}K
	400		504	$k = 15.2$ W/m^{2}K
Insulation Foam				$k = 0.08$ W/m^{2}K
				$h = 30$ W/mK

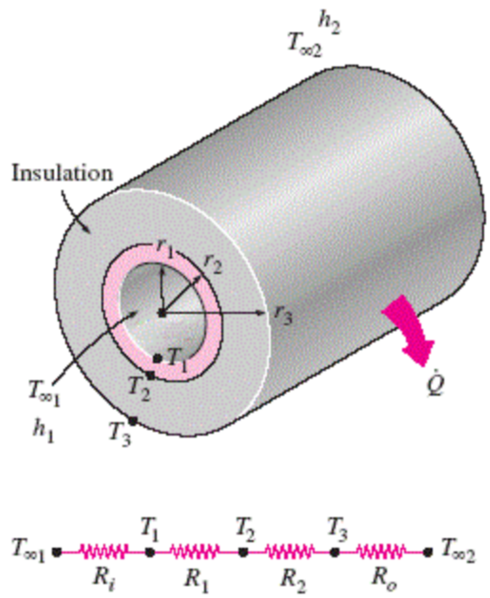

Figure 5: 3-D cutaway view of a radially symmetric pipe compared with its thermal resistance circuit analogy, though R1 was removed assuming the pipe conducts heat readily, adding negligibly to the total thermal resistance [6]

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temperature T_∞ is constant and the flow is laminar, an average Nusselt number ($\bar{N}u_D$) of 3.66 was used. Comparing this to another correlation taking into account the thermal boundary layer [6] yields an average Nusselt number of 3.69 halfway down the pipe, showing the accuracy of the fully developed assumption is acceptable.

$$\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{gen} + \dot{E}_{stored} \tag{6}$$

$$\dot{m}C_p\frac{dT_i}{dx} - UA(T_i - T_o) = 0 \tag{7}$$

The assumptions above reduced the energy balance equation from equation 6 to equation 7, equating the heat escaping through the pipe walls to the change in heat energy within the pipe, as expected. The average convective heat transfer coefficient between the pipe and the oil is around 25 $\frac{W}{m^2K}$ [4, 5], and this corresponds to a total system thermal resistance of U = 1.4 $\frac{K}{W}$. With a heat energy loss of 2-4W per meter of pipe in total drops the temperature from 40 °C to 37.8 °C. The equivalent resistance of the system would have been

The assumption of 15 °C year round is, in most areas of the world, a faulty one. If the ambient environment temperature ranges from 0-30 °C from winter to summer, the temperature drop changes as well. This new temperature range in the winter/summer causes the oil to enter the furnace from 36.4-39.1 °C, causing a maximum change in overall heating in the order of $4,000 if the weather maintained one of the extremes, which fairly small in proportion to the total present value cost.

4.3 Economics

Table 5: Cost of materials used in proposed system including straight pipe, bellows, elbows and insulation.

Pipe Diameter	Component	Quantity	Price
1”	Straight Pipe	140.2 meters	$9,551.83
1”	Bellows	14 units	$636.02
1”	Elbows	6 units	$77.16
1”	1.5” insulation	140.2 meters	$864.53
		Total:	$11,130

There were multiple factors contributing to the total present worth of our proposed system, including capital, installation, and annual costs.

Our system utilizes a motor to power the pump, as well as a flow meter and two valves to control the flow throughout the piping. This total amount is $8,130, as seen in table 6. Using the provided stainless steel piping and insulation data provided, as well as the specified prices of actual components (Appendices A-D), the initial capital cost was calculated to be a total of $17,160. Installation costs are estimated to cost around twice the amount of the material costs, for a total of $22,260.

The annual cost in this proposed system is heavily driven by the amount of electricity used to power both the pump and the electric heater. As previously mentioned in the design description, the motor and pump require 0.735 kW of electricity to run, and the heater requires 50.03 kW of electricity. Assuming that each of these components runs for a total of 8000 hours every year, the amount of kW-hr can be calculated by multiplying these two numbers together. Using the given price of electricity ($0.12 per kW-hr) the annual cost to power the pump and heater was determined to be $705.60 and $48,028.80, respectively, totaling an annual electricity cost of $48,740, as seen in table 7.

Assuming the system runs for ten years at an interest rate of 8%, the estimated total ten year present worth value of our proposed system is about $368,600. This value was calculated using the initial capital costs of $19,262, installation costs of $22,260, and an annual worth to present worth

Component	Quantity	Price
Pump	1	$4,500.00
Motor	1	$368.00
Flow Meter	1	$2464.00
Valves	2	$801.00
	Total:	$8,130

Table 6: Component costs including pump, motor, flow meter, and valves.

	kW needed	Annual Cost
Pump	0.735	\$705.60
Heat	50.03	\$48,028.80
	Total:	\$48,734.40

Table 7: Annual cost of electricity to power the pump and heater.

value for the annual costs of \$48,740, as seen in equation 8. In order to convert the annual cost of electricity over a ten year period at an 8% interest rate, a present value to annuity conversion factor of 6.71 was used.

$$P = \$19,262 + \$22,260 + \$48,740(6.71) = \$368,600 \tag{8}$$

4.4 Optimization

Three free variables were identified within the design space. The diameter of the pipe, D, the temperature the fluid is heated to before pumping, T_i, and the thickness of insulation, t. With a choice for these variables calculations can be performed with the additional constraints that the fluid must be initially heated to at least 40 °C, and that if the temperature of the fluid at the end

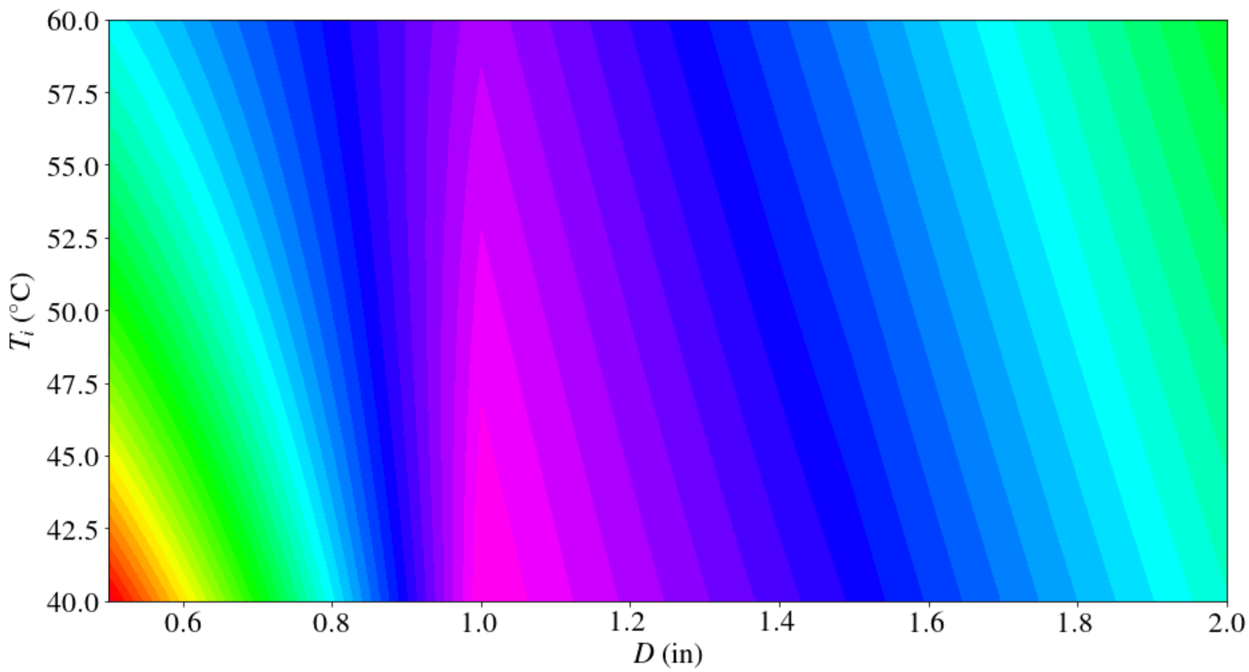

Figure 6: The cost function surface for the investigated values of pipe diameter, D, and initial temperature to which the fluid is heated, T_i, given the insulation. Purple indicates a low cost function, whereas red indicates a high cost function. The cost function is linearly related to total present worth cost.

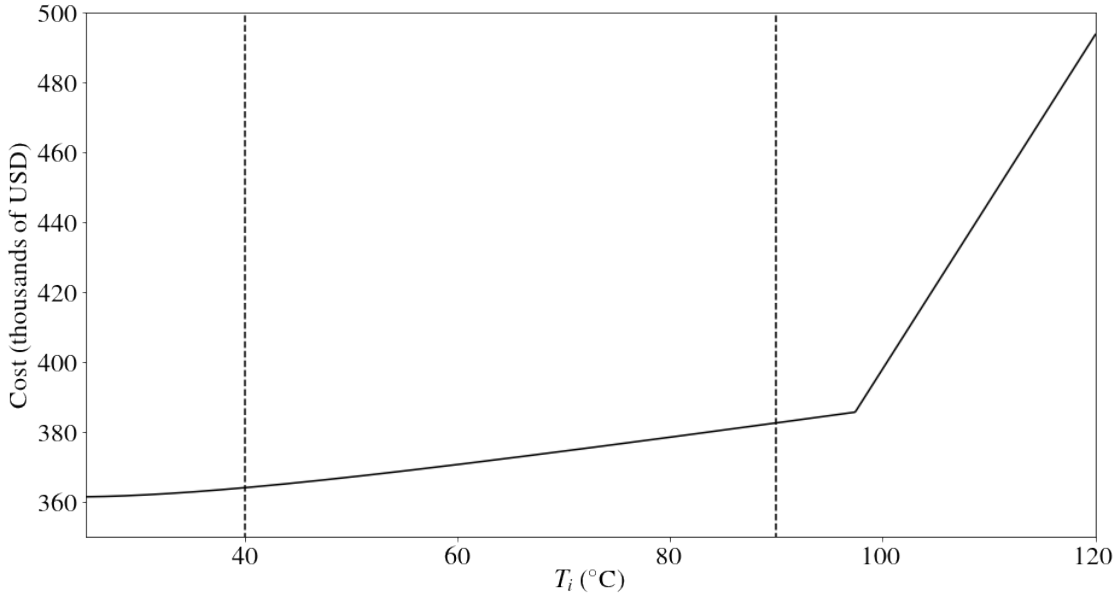

Figure 7: A plot of initial heating temperature, T_i, versus total present worth cost for $D = 1$ in, $t = 1.5$ in.

of the pipe is less than 90 °C, additional heat must be added in the final heater to achieve an outlet temperature of 90 °C. With insulation thickness fixed at one of the three values investigated, $t =$ 0.5, 1.0, 1.5 in, the cost function (which is linearly related to present worth cost) was calculated for all possible combinations of inlet temperature within the reasonable bounds of 40 °C to 200 °C and diameter $D = 0.5, 1.0, 1.5, 2.0$ in. The region was then refined to look at temperatures within 40 °C to 60 °C in steps of 0.2 °C. The generated cost function surface is shown for $t = 1.5$ inches in figure 6 where red is highest cost and purple is lowest cost. The minimum cost was found to be $T_i = 40$ °C, $D = 1$ in, and $t = 1.5$ in. The code with which this optimization was preformed is shown in appendix F.

5 Evaluation of Design and Other Constraints

5.1 Environmental Considerations

At all temperatures present within the system, heavy fuel oil No. 5 is a liquid. As such, there is negligible risk of inhalation or to the atmosphere in the storage and transportation of fuel oil. Emissions from burning heavy fuel oils, however, are major contributors to particulate matter and sulfur dioxide [7]. This puts fuel oil at substantial risk or being banned, taxed, or otherwise phased out by increasingly environmentally conscious governments around the world. Especially in small countries with large ports where emissions from shipping are a major contributor to local pollution. Heavy fuel oil No. 5 floats on water and spills in or around water have been found to cause both fouling of shorelines, and damage to nearby water intakes.

5.2 Political Considerations

Spills of fuel oils must be reported in accordance with local regulations on the subject. In the state of New York, for example, spills must be reported within two hours of their discovery unless all the following are true [8]:

1. The quantity of the spill is known to be less than five gallons
2. The spill is contained and under control
3. The spill has not reached any public land or waterway
4. The spill is cleaned up within two hours of discovery

Furthermore, due to the complexity of regulation involving oil spills, the Department of Environmental Conservation (DEC) recommends that any spills be reported immediately to the spill hotline within your state [8]. Some municipalities provide low interest loans to help clean spills of this nature. Testing of the system for leaks is recommended; however, fuel oils No. 5 and 6 are exempted from Environmental Protection Agency (EPA) regulations regarding regular testing for small leaks within the system, as the viscosity of these oils makes small leaks unlikely. A party found to be responsible for an oil spill (with exemptions for spills involving acts of God and acts of war) may be held liable for [8]:

1. Cleanup costs
2. Damage to natural resources
3. Personal property damage
4. Loss of profits or earning potential

5.3 Health Considerations

Heavy fuel oil No. 5 is generally considered safe to humans. It is a mild skin irritant and has an LD_{50} of between 5 and 15 g/kg giving it a Gosselin, Smith and Hodge toxicity class of 1, "practically non-toxic" [9]. It is considered stable for transport and is not reactive with any common material, including water. Heavy fuel oil No. 5 is flammable and fire prevention measures should be undertaken. Fuel oil fires of this type should be extinguished using dry chemical, foam, or carbon dioxide extinguishers. The NFPA gives fuel oil a 0 for health hazard (blue), 2 for flammability (red), and 0 for instability (yellow). The details of fuel oil safety are shown in appendix E.

6 Conclusions and Recommendations

	PW Value	**% of Total PW**
Materials	\$11,200	3%
Components	\$8,200	2.2%
Electricity	\$327,000	88.8%
Installation	\$22,200	6%
Total	\$368,600	

Table 8: The present value worth of various costs associated with the proposed pumping system. Almost nine tenths of the cost is associated with heating the fluid.

Our proposed system is well below the target cost of \$500,000, with a total present worth cost of \$368,600. However, the system cost could be further reduced if the exit temperature, which is currently 90 °C, is lowered, resulting in less of a difference between the initial and final temperature of the fuel. For instance, if the exit temperature is lowered to 70 °C, while keeping the proposed system unchanged, the total present worth cost would be reduced by approximately \$70,000, a reduction of approximately 20% of total current present worth cost. Out of all the given parameters, relaxing the constraint of the outlet temperature would most effectively reduce the total present worth of the system. Other factors contributing to the further reduction in total cost include increasing the efficiency of the electrical components, decreasing the amount of major and minor head losses caused by friction and geometry, and minimizing the amount of heat lost to the ambient environment by using effective insulation. For these reasons, there are infinite systems that could be employed; however, we believe our choices represent the optimal system within the design space spanned by these parameters. This is what differentiates our system from those of our competitors.

Our design provides an accurate and robust solution for your fluid transportation needs. The selection of a positive displacement gear pump rather than a centrifugal pump, on top of our specified 1.5 hp motor, provide the necessary flexibility to effectively moderate the flow rate. This is imperative in instances such as a sudden change in flow rate or temperature. Our stainless steel rotary gear pump is exceptional at pumping highly viscous fluids, and is durable enough to last our guaranteed lifetime of ten years.

Fuel Under Diligent Guidance of Engineers is more than just our name, it's our mission. Not only can we guarantee one of the most competitive prices on the market, but our diligent work ethic ensures that your system will work the way it's designed. Your safety is another vital concern, and with the inclusion of our ball valve and gear pump assembly, hazardous occurrences within the pipes are minimized. We hope that throughout our proposal we have provided you with the evidence to make the right choice in your fuel transportation needs.

References

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Appendices

A Gorman-Rupp Gear Pump

B Marathon DC Motor

C GPI Flow Meter

D Apollo Ball Valve

E Bunker B Fuel Oil Data Sheet

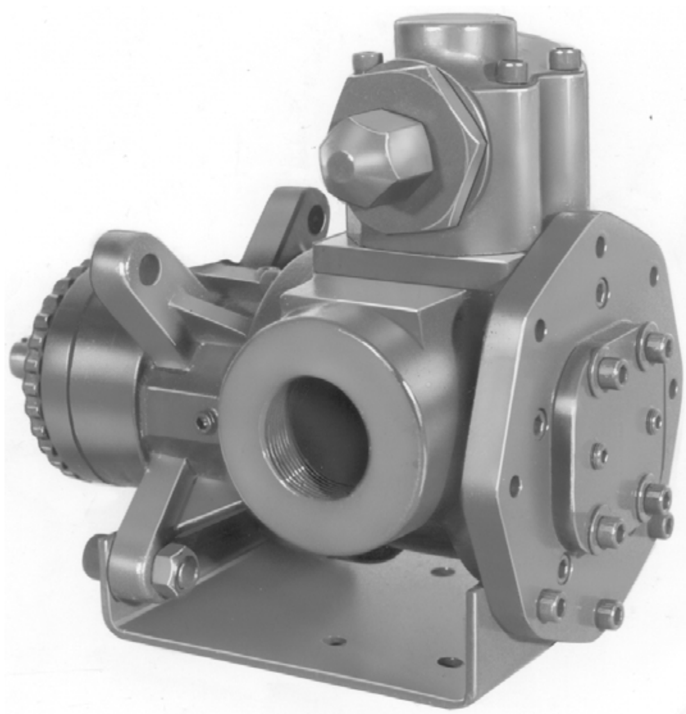
F System Optimization Python Script

GORMAN-RUPP
ROTARY GEAR PUMPS

GHC SERIES
HEAVY DUTY COMPACT
STAINLESS STEEL ROTARY GEAR PUMP

This heavy duty series with internal “wetted” parts of 316 Stainless Steel is ideal for handling corrosive applications. Superior rotor shaft support and an integral maintenance-free radial/thrust bearing, reduce deflection and wear.

Due to the “galling” nature of stainless, extra internal clearance is necessary. A capacity correction table for liquids less than 750 SSU is available in Section 500.



SHOWN W/OPTIONAL THREADED PORTS

The GHC stainless series is designed for applications in the operating ranges noted on the model pages. These units are available with head jackets for temperature control, silicon carbide bushings for wear resistance, and numerous shaft seal options described on the following pages. These units may be foot mounted or, by using a motor adaptor, direct connected to NEMA “C” flange motors.

FEATURES

200 PSI CAPABILITY

BALL BEARING THRUST CONTROL

ROTOR END CLEARANCE EXTERNALLY ADJUSTABLE

EXCEPTIONAL SEAL VERSATILITY WITH INTERNAL SEAL VENT

COMPUTER PROFILED GEARING FOR QUIET OPERATION

MULTIPLE PORT POSITIONS

OPERATING RANGE

CAPACITY	(GPM):		(3 TO 107)
	[LPM] :		[11 TO 405]
PRESSURE	(PSI) :		[0 TO 200)
	[BAR] :		[0 TO 14]
VISCOSITY	(SSU) :		(28 TO 25,000)
	[cSt] :		[1 TO 5417]
TEMPERATURE	(F) :		(-30° TO 350°)
	[C] :		[-34° TO 177°]

APPLICATIONS

USE WITH ANY CLEAN LIQUID COMPATIBLE WITH 316 STAINLESS STEEL

- ★ BOOSTER SERVICE
- ★ CIRCULATING
- ★ FILTERING
- ★ LUBRICATING
- ★ TRANSFERRING

Standard Construction

EXTERIOR	BACKHD	ROTOR & IDLER	HOUSING PORTS	BUSHING	IDLER PIN	SHAFT	SHAFT SEALING: MECH. SEAL ●	SHAFT SEALING: PACKING ■	ROTATION	INTERNAL RELIEF VALVE: MATERIAL	INTERNAL RELIEF VALVE: SETTING
316 STAIN. STEEL	CAST IRON	316 STAIN. STEEL	GHC 180°FLG. GHS 90°NPT	CARBON GRAPHITE	COATED 316 SST	STAIN. STEEL	CARBON, SiC, TEFLON ENC.	CARBON FIBER	C.W.	316 STAINLESS STEEL	75 PSI [5 BAR]

Standard Models

G	H	C	1	DC	9	– B
G	H	S	1	DC	9	– B
GEAR	DUTY	DESIGN	PORT SIZE	HYD. SIZE	SEAL	STYLE

MODEL NUMBER: GHC	MODEL NUMBER: GHS	NOM. CAPACITY - SPEED: MAXIMUM GPM [LPM]	MAXIMUM RPM 60 Hz [50 HZ]	ALTERNATIVE GPM [LPM]	ALTERNATIVE RPM 60 Hz [50 Hz]	MAXIMUM DIFF. PRESSURE - PSI [BAR]: BELOW 38 SSU [4 cSt]	38 TO 100 SSU [21 cSt]	100 TO 250,000 SSU [55,000 cSt]	MAXIMUM TEMP. °F [°C]	SHIPPING DATA: Wt. LBS [KG]	Vol. CU. FT.
GHC 1 DC9–B ① ● ⁋	**GHS 1 DC9–B** ① ● **GHS 1 DC10–B** ① ■	9 [28]	1750 [1460]	6 [19]	1150 [960]	75 [5]	100 [7]	200 [14]	GHC ● 350 [177] GHS ● 400 [204] ■ 500 [260]	32 [14,5]	2.9
GHC 1 DE9–B ① ● ⁋	**GHS 1 DE9–B** ① ● **GHS 1 DE10–B** ① ■	11 [35]		7 [22]						32 [14,5]	2.9
GHC 1-1/2 GC9–B ● ⁋	**GHS 1-1/2 GC9–B** ● **GHS 1-1/2 GC10–B** ■	16 [50]		10 [32]						63 [28,6]	2.9
	GHS 2 GC9–B ● GHS 2 GC10–B ■									63 [28,6]	2.9
GHC 1-1/2 GF9–B ● ⁋	**GHS 1-1/2 GF9–B** ● **GHS 1-1/2 GF10–B** ■	23 [73]		15 [47]						63 [28,6]	2.9
	GHS 2 GF9–B ● GHS 2 GF10–B ■									63 [28,6]	2.9
GHC 1–1/2 GH9–B ● ⁋	**GHS 1–1/2 GH9–B** ● **GHS 1–1/2 GH10–B** ■	31 [98]		20 [63]						63 [28,6]	2.9
	GHS 2 GH9–B ● GHS 2 GH10–B ■									63 [28,6]	2.9
GHC 1-1/2 GJ9–B ● ⁋	GHS 1-1/2 GJ9–B ● GHS 1-1/2 GJ10–B ■	38 [120]		25 [79]						63 [28,6]	2.9
	GHS 2 GJ9–B ● **GHS 2 GJ10–B** ■									63 [28,6]	2.9
	GHS 2 JG9–B ● **GHS 2 JG10–B** ■	40 [126]	1150 [960]	30 [95]	870 [725]					161 [73,2]	5.3
GHC 3 JG9–B ● ⁋	GHS 3 JG9–B ● GHS 3 JG10–B ■									161 [73,2]	5.3
	GHS 2 JJ9–B ● GHS 2 JJ10–B ■	56 [177]		42 [133]						161 [73,2]	5.3
GHC 3 JJ9–B ● ⁋	**GHS 3 JJ9–B** ● **GHS 3 JJ10–B** ■									161 [73,2]	5.3

STANDARD MODELS CONTINUED

① 3450 [2875] RPM PERMISSIBLE TO 1,000 SSU [220 cSt.] AND 100 PSI [7 BAR]

● MECHANICAL SEAL

■ PACKING/LIP SEAL

⁋ PORTS ARE COMPATIBLE WITH 150# ANSI FLANGES. ALL OTHER PORTS ARE TAPPED NPT FOR ANSI PIPE. OPTIONAL [DIN] FLANGES OR TAPPED [BSP] PORTS ARE AVAILABLE FOR EXPORT MARKET.

NOTE: RECOMMENDED PORT SIZES ARE SHOWN IN **BOLDFACE**. EXAMPLE: **GHC 1 DC9–B, GHS 1 DC9–B**

Standard Models (Continued)

MODEL NUMBER		NOM. CAPACITY – SPEED				MAXIMUM				SHIPPING DATA	
		MAXIMUM		ALTERNATIVE		DIFF. PRESSURE – PSI [BAR]			TEMP.	Wt.	Vol.
GHC	GHS	GPM [LPM]	RPM 60 Hz [50 HZ]	GPM [LPM]	RPM 60 Hz [50 Hz]	BELOW 38 SSU [4 cSt]	38 TO 100 SSU [21 cSt]	100 TO 250,000 SSU [55,000 cSt]	°F [°C]	LBS [KG]	CU. FT.
	GHS 2 JL9-B ● GHS 2 JL10-B ■	77 [243]	1150 [960]	58 [133]	870 [725]	75 [5]	100 [7]	200 [14]		161 [73,2]	5.3
GHC 3 JL9-B ● ⊧	**GHS 3 JL9-B** ● **GHS 3 JL10-B** ■									161 [73,2]	5.3
	GHS 2 JP9-B ● GHS 2 JP10-B ■	107 [338]		81 [256]						161 [73,2]	5.3
GHC 3 JP9-B ● ⊧	**GHS 3 JP9-B** ● **GHS 3 JP10-B** ■									161 [73,2]	5.3
	GHS 2 NK9-B ● GHS 2 NK10-B ■	99 [375]	960 [960]	60 [189]	580 [480]				GHC ● 400 [204] GHS ● 400 [204] ■ 500 [260]	180 [81,8]	5.3
	GHS 2-1/2 NK9-B ● GHS 2-1/2 NK10-B ■									180 [81,8]	5.3
	GHS 3 NK9-B ● **GHS 3 NK10-B** ■									180 [81,8]	5.3
	GHS 2 NM9-B ● GHS 2 NM10-B ■	132 [500]		80 [252]						180 [81,8]	5.3
	GHS 2-1/2 NM9-B ● GHS 2-1/2 NM10-B ■									180 [81,8]	5.3
	GHS 3 NM9-B ● **GHS 3 NM10-B** ■									180 [81,8]	5.3
	GHS 2-1/2 NP9-B ● GHS 2-1/2 NP10-B ■	165 [624]		99 [312]						180 [81,8]	5.3
	GHS 3 NP9-B ● **GHS 3 NP10-B** ■									180 [81,8]	5.3
	GHS 2 RM9-B ● GHS 2 RM10-B ■	172 [542]	720 [600]	115 [362]	480 [400]					357 [162]	10.7
	GHS 2-1/2 RM9-B ● ⊧ GHS 2-1/2 RM10-B ■ ⊧									357 [162]	10.7
	GHS 3 RM9-B ● ⊧ **GHS 3 RM10-B** ■ ⊧									357 [162]	10.7
	GHS 4 RM9-B ● ⊧ GHS 4 RM10-B ■ ⊧									357 [162]	10.7
	GHS 3 RP9-B ● ⊧ **GHS 3 RP10-B** ■ ⊧	215 [678]		143 [451]						357 [162]	10.7
	GHS 4 RP9-B ● ⊧ GHS 4 RP10-B ■ ⊧									357 [162]	10.7

STANDARD MODELS CONTINUED

● MECHANICAL SEAL
■ PACKING/LIP SEAL

⊧ PORTS ARE COMPATIBLE WITH 150# ANSI FLANGES. ALL OTHER PORTS ARE TAPPED NPT FOR ANSI PIPE. OPTIONAL [DIN] FLANGES OR TAPPED [BSP] PORTS ARE AVAILABLE FOR EXPORT MARKET.

NOTE: RECOMMENDED PORT SIZES ARE SHOWN IN **BOLDFACE**. EXAMPLE: **GHC 1 DC9–B, GHS 1 DC9–B**

Standard Models (Continued)

MODEL NUMBER		NOM. CAPACITY - SPEED				MAXIMUM				SHIPPING DATA	
		MAXIMUM		ALTERNATIVE		DIFF. PRESSURE - PSI [BAR]			TEMP.	Wt.	Vol.
GHC	GHS	GPM [LPM]	RPM 60 Hz [50 HZ]	GPM [LPM]	RPM 60 Hz [50 Hz]	BELOW 38 SSU [4 cSt]	38 TO 100 SSU [21 cSt]	100 TO 250,000 SSU [55,000 cSt]	°F [°C]	LBS [KG]	CU. FT.
	GHS 3 RR9-B ● ⊩ GHS 3 RR10-B ■ ⊩	255 [804]	720 [600]	170 [536]	480 [400]	75 [5]	100 [7]	200 [14]	GHS ● 400 [204] ■ 500 [260]	357 [162]	10.7
	GHS 4 RR9-B ● ⊩ **GHS 4 RR10-B** ■ ⊩									357 [162]	10.7
	GHS 4 RS9-B ● ⊩ **GHS 4 RS10-B** ■ ⊩	295 [930]		196 [618]						357 [162]	10.7

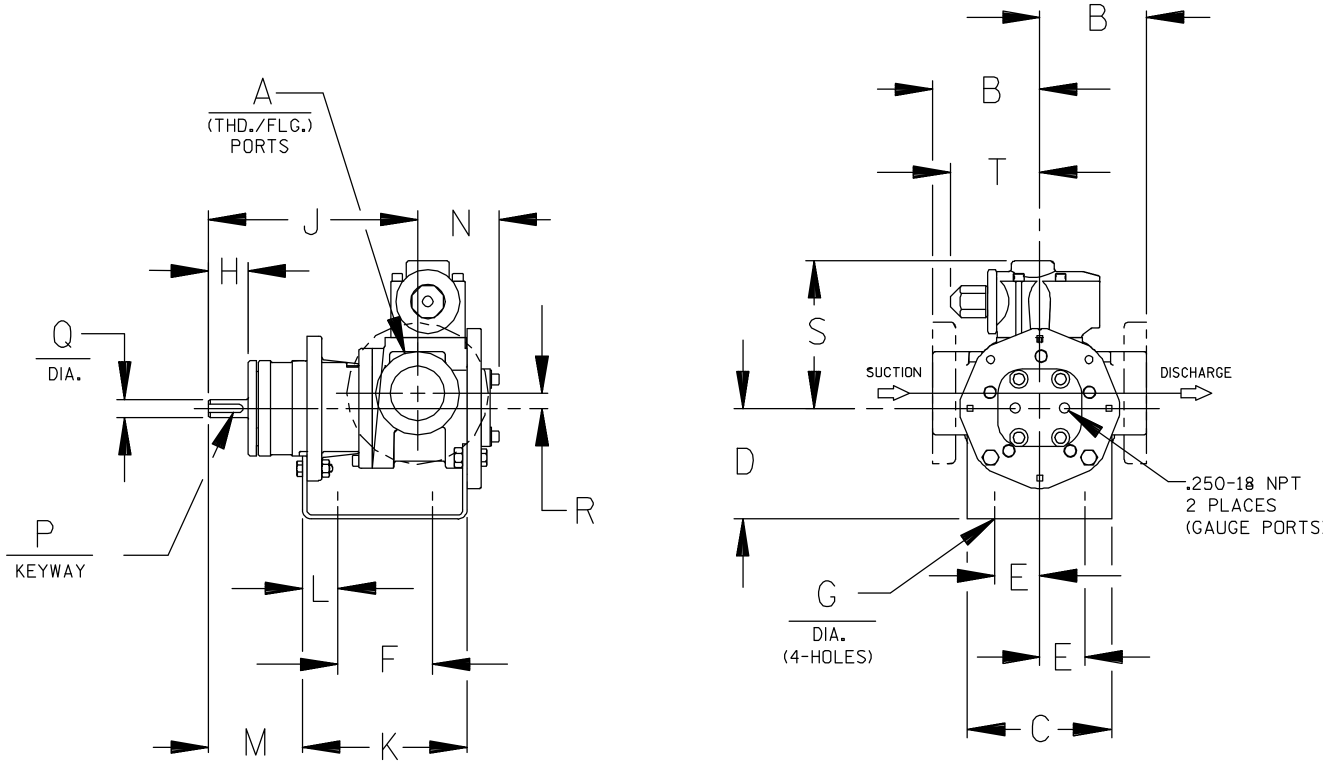
⊩ PORTS ARE COMPATIBLE WITH 150# ANSI STAINLESS STEEL FLANGES. ALL OTHER PORTS ARE TAPPED NPT FOR ANSI PIPE.OPTIONAL [DIN] FLANGES OR TAPPED [BSP] PORTS AVAILABLE FOR EXPORT MARKET.

NOTE: RECOMMENDED PORT SIZES ARE SHOWN IN BOLDFACE. EXAMPLE: **GHC 1 DC9–B, GHS 1 DC9–B**

APPLICATION RECOMMENDATIONS:

APPLICATION	**OPTIONS REQUIRED (Select One From Each Row)**	**OPERATING LIMITATIONS**
GHS ONLY HIGH TEMPERATURE	25U, 25V, OR 25W 35J – 35M (AS REQ'D) 40R, 70K 61H OR 65Q	TEMPERATURE: 675°F MAX. PRESSURE: 200 PSI MAX.
GHS ONLY JACKETED	40K, 40W, 41U, 41W	LIMIT JACKET PRESSURE TO 150 PSI

NOTE: PROPER PUMP APPLICATION REQUIRES CONSIDERATION OF ADDITIONAL FACTORS. PLEASE REVIEW APPLICATION GUIDE IN SECTION 500 OR CONSULT THE FACTORY.



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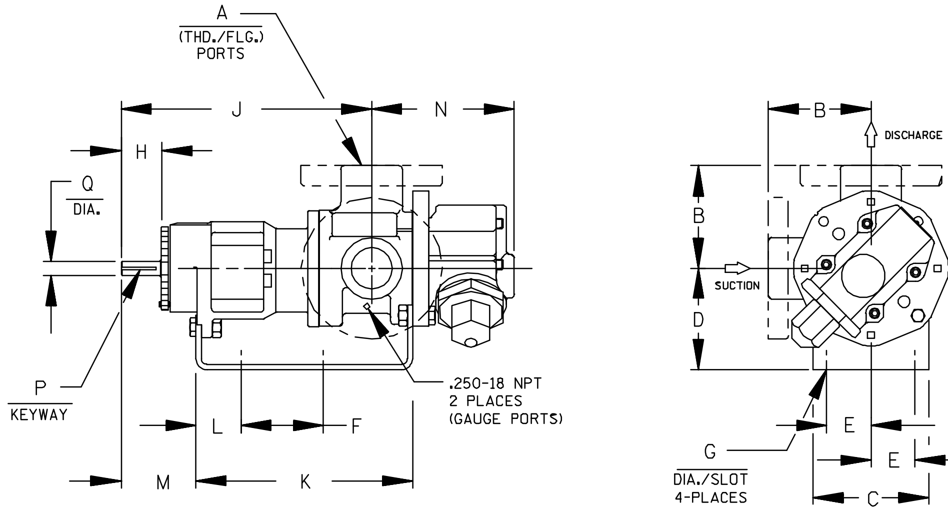
MODEL NUMBERS	PUMP DIMENSIONS - INCHES [MILLIMETERS]																	
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T
GHC D	1"	2.50 [64] † 4.00✳ [102] ⊢	4.00 [102]	3.50✳ [89] 4.50 [114] 5.25 [133]	1.62 [41]	3.12 [79]	.41 [10]	1.16 [30]	6.19 [157]	5.04 [128]	.76 [19]	2.62 [66]	2.74 [70]	.12 [3] × .75 [19]	.50 [13]	.62 [16]	5.19 [132]	3.58 [91]
GHC G	1-1/2"	3.50 [89] † 4.00✳ [102] ⊢	5.88 [149]	3.50✳ [89] 4.50 [114] 5.25 [133] 6.25 [159]	1.62 [41]	4.00 [102]	.41 [10]	1.62 [41]	8.50 [216]	6.71 [170]	1.06 [27]	3.82 [97]	3.35 [85]	.19 [5] × 1.25 [32]	.75 [19]	.62 [16]	6.00 [152]	3.62 [92]
GHC J	3"	4.50 [114] † 6.00✳ [152] ⊢	6.88 [175]	4.50 [114] 5.25✳ [133] 6.25 [159] 7.00 [178] 8.00 [203]	2.88 [73]	4.25 [108]	.44 [11]	2.50 [64]	12.12 [308]	9.75 [248]	1.75 [44]	5.50 [140]	4.66 [118]	.25 [6] × 2.00 [51]	1.00 [25]	1.12 [28]	9.06 [230]	6.75 [171]

✳ STANDARD DIMENSION

⊢ PORTS ARE COMPATIBLE WITH 125# OR 250# ANSI CAST IRON FLANGES. ALL OTHER PORTS ARE TAPPED NPT FOR ANSI PIPE. OPTIONAL (DIN) FLANGES OR TAPPED (BSP) PORTS AVAILABLE FOR EXPORT MARKET.

† 90° HOUSING



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MODEL NUMBERS	PUMP DIMENSIONS - INCHES [MILLIMETERS]															
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
GHS D	1"	2.50 ✳ [64] 4.00 ⊢ [102] †	4.00 [102]	3.50 ✳ [89] 4.50 [114] 5.25 [133]	1.62 [41]	5.50 [140]	.41 [10]	1.16 [30]	8.43 [214]	7.54 [192]	1.09 [28]	2.29 [58]	4.98 [127]	.12 [3] × .75 [19]	.50 [13]
GHS G	1-1/2" 2"	3.50 ✳ [89] 4.00 ⊢ [102] †	4.88 [124]	3.50 ✳ [89] 4.50 [114] 5.25 [133] 6.25 [159]	1.62 [41]	8.00 [203]	.41 [10]	1.62 [41]	12.06 [306]	10.72 [272]	1.52 [39]	3.35 [85]	5.70 [145]	.19 [5] × 1.25 [32]	.75 [19]
GHS J	2" 3"	4.50 ✳ [114] 6.00 ⊢ [152] †	6.88 [175]	5.25 ✳ [133] 6.25 [159] 7.00 [178] 8.00 [203]	2.88 [73]	10.00 [254]	.44 [11]	2.50 [64]	15.68 [398]	14.31 [363]	2.77 [70]	4.48 [114]	8.50 [216]	.25 [6] × 2.00 [51]	1.00 [25]
GHS N	2" 3"	5.12 [130]	8.00 [203]	4.50 [114] 5.25 ✳ [133] 6.25 [159] 7.00 [178] 8.00 [203]	2.88 [73]	10.00 [254]	.44 [11]	2.58 [66]	16.37 [416] ✳	15.14 [385]	2.69 [68]	4.56 [116]	8.72 [221] ✳	.25 [6] × 2.00 [51]	1.12 [32]
GHS R	2" 2-1/2" 3" 4"	6.50 [165] 7.19 ⊢ [183]	10.50 [267]	7.00 [178]	3.75 [95]	13.75 [349]	.52 [13]	2.25 [57]	17.87 [454]	17.36 [441]	1.86 [47]	4.70 [119]	11.31 [287]	.38 [10] × 1.88 [48]	1.44 [37]

✳ STANDARD DIMENSION
⊢ PORTS ARE COMPATIBLE WITH 150# OR 300# ANSI STAINLESS STEEL FLANGES. ALL OTHER PORTS ARE TAPPED NPT FOR ANSI PIPE. OPTIONAL (DIN) FLANGES OR TAPPED (BSP) PORTS AVAILABLE FOR EXPORT MARKET.
† 180° HOUSING

SUPERSEDES ALL PREVIOUS ISSUES

GHC/GHS

FOR GHC DRIVE OPTIONS

AND DIMENSIONS

SEE SECTION 540

FOR GHS DRIVE OPTIONS

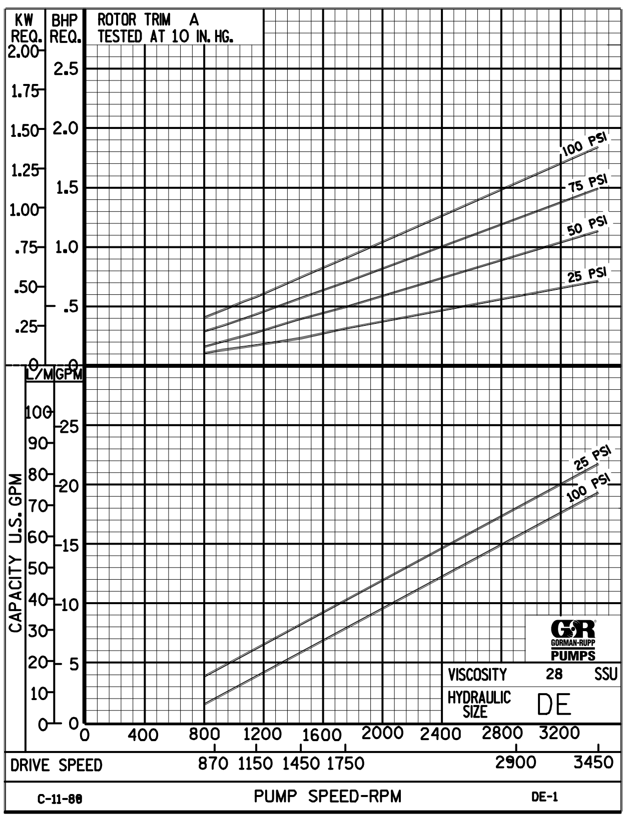
AND DIMENSIONS

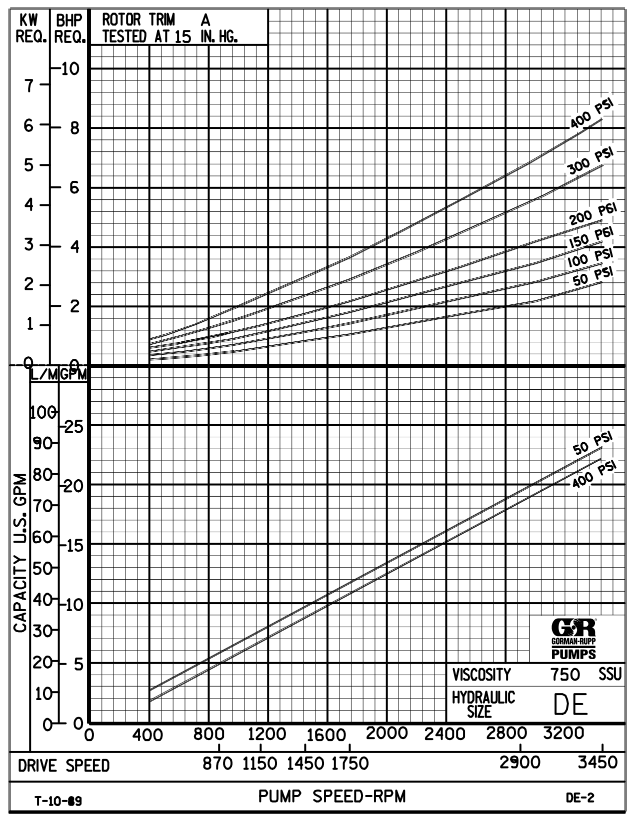
SEE SECTION 545

PERFORMANCE CURVES

SPEED VS. CAPACITY/HORSEPOWER

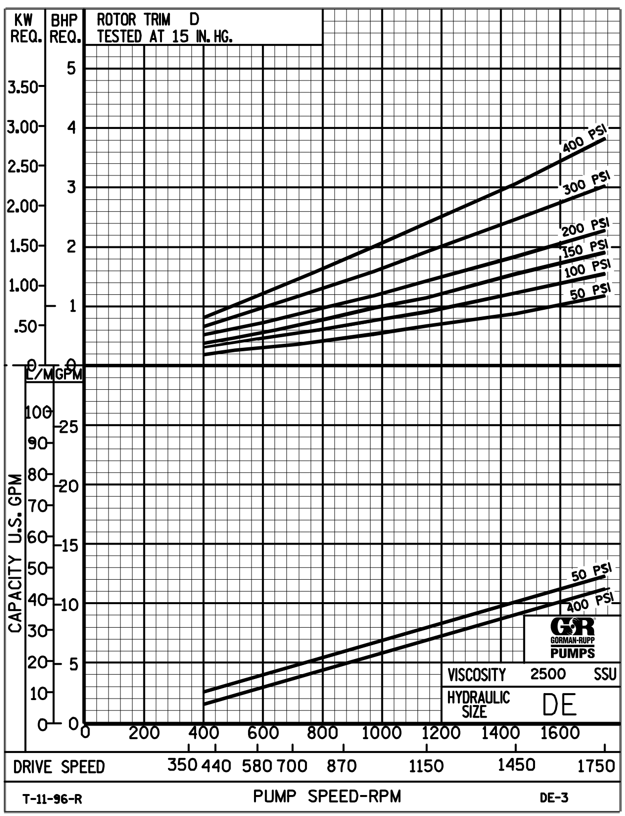
DE Hydraulic Size

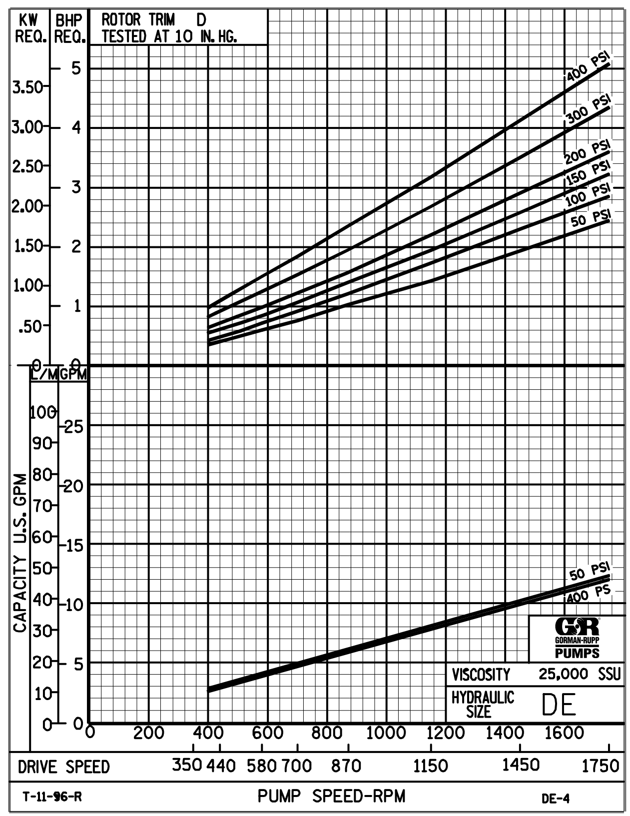




PERFORMANCE CURVES DE Hydraulic Size

SPEED VS. CAPACITY/HORSEPOWER





GORMAN-RUPP®
ROTARY GEAR PUMPS

DE

PUMP HYDRAULIC SIZE CHART

**22 GPM
3450 RPM**

NOMINAL		ROTOR TRIM	VISCOSITY	N.I.P.R.	FRICTION PIPE LOSS (PSI/FT) (Based on Sch 40 Steel Pipe)					FULL BYPASS RELIEF VALVE PRESSURE (PSI)					CAPACITY (GPM) / H.P. REQUIRED							
					PIPE DIAMETER					CRACKING PRESS. (PSI)					DIFFERENTIAL PRESSURE (PSI)							
										LOW PRES R/V			HI PRES R/V		MEDIUM DUTY AND HEAVY DUTY						HEAVY DUTY ONLY	
CAP. GPM	SPEED RPM		(SSU)	(PSIA)	¾”	1”	1¼”	1½”	2”	50	75	100	150	200	25	50	75	100	150	200	300	400
22	3450	STD	28	12.3	.01	.01	.01	.01	.01	74	99	127			21.0	21.0	20.0	19.0				
			32		.33	.11	.03	.02	.01						.85	1.2	1.6	1.9				
			38	12.3	.43	.14	.04	.02	.01	74	99	129	178		22.0	21.0	21.0	20.0	20.0			
			50		.51	.16	.05	.02	.01						1.2	1.5	1.9	2.2	3.0			
			70	12.3	.59	.18	.05	.03	.01	74	100	131	179	232	22.0	22.0	22.0	21.0	21.0	20.0		
			100		.68	.22	.06	.03	.01						1.6	1.9	2.3	2.7	3.4	4.2		
			150	12.3	.75	.24	.07	.04	.01	74	101	134	180	234	23.0	22.0	22.0	22.0	21.0	21.0	20.0	20.0
			200		.80	.27	.09	.05	.02						2.1	2.4	2.7	3.0	3.8	4.6	6.1	7.6
			300	12.3	.85	.33	.11	.06	.02	75	103	137	181	236	23.0	23.0	22.0	22.0	22.0	21.0	21.0	20.0
			500		1.41	.54	.18	.10	.04						2.4	2.7	3.0	3.3	4.0	4.8	6.3	7.8
			750	12.3	2.11	.80	.27	.15	.06	76	105	140	183	238	23.0	23.0	23.0	23.0	23.0	22.0	22.0	22.0
			1,000		2.81	1.07	.36	.19	.07						2.6	2.9	3.2	3.6	4.3	5.0	6.5	7.9
		“D”	2,000																			
			3,500																			
			5,000																			
			7,500																			
			10,000																			
			15,000																			
			20,000																			
			25,000																			
			50,000																			
			75,000																			
			100,000																			
			150,000																			
			200,000																			
			250,000																			

(NOTE) For speeds not shown on the pump hydraulic charts, consult factory.

GORMAN-RUPP
ROTARY GEAR PUMPS

DE

PUMP HYDRAULIC SIZE CHART

11 GPM
1750 RPM

NOMINAL CAP. GPM	NOMINAL SPEED RPM	ROTOR TRIM	VISCOSITY (SSU)	N.I.P.R. (PSIA)	FRICTION PIPE LOSS (PSI/FT) (Based on Sch 40 Steel Pipe) PIPE DIAMETER ¾"	1"	1¼"	1½"	2"	FULL BYPASS RELIEF VALVE PRESSURE (PSI) CRACKING PRESS. (PSI) LOW PRES R/V 50	LOW PRES R/V 75	LOW PRES R/V 100	HI PRES R/V 150	HI PRES R/V 200	CAPACITY (GPM) / H.P. REQUIRED — DIFFERENTIAL PRESSURE (PSI) — MEDIUM DUTY AND HEAVY DUTY 25	50	75	100	150	200	HEAVY DUTY ONLY 300	400
11	1750	STD	28	3.2	.01	.01	.01	.01	.01	60	86	114			10.0	9.5	8.5	8.0				
			32		.10	.03	.01	.01	.01						.39	.57	.76	.95				
			38	3.2	.13	.04	.01	.01	.01	60	86	115	163		10.0	9.5	8.5	8.5	7.5			
			50		.05	.02	.01	.01	.52						.52	.70	.89	1.1	1.5			
			70	3.2	.17	.06	.02	.01	.01	60	87	116	163	215	10.0	10.0	9.5	9.0	8.5	7.5		
			100		.21	.06	.02	.01	.01						.65	.84	1.0	1.2	1.6	2.1		
			150	3.2	.28	.09	.03	.01	.01	60	87	117	164	216	11.0	10.0	10.0	10.0	9.5	9.5	9.0	8.5
			200		.36	.14	.05	.03	.01						.79	.97	1.2	1.4	1.7	2.1	2.9	3.6
			300	3.2	.43	.16	.06	.03	.01	61	88	118	164	216	11.0	11.0	11.0	10.0	10.0	10.0	10.0	9.5
			500		.70	.27	.09	.05	.02						.84	1.0	1.2	1.4	1.8	2.1	2.9	3.7
			750	3.2	1.05	.40	.14	.07	.03	61	89	120	165	217	11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.0
			1,000		1.41	.54	.18	.10	.04						.88	1.1	1.3	1.5	1.8	2.2	2.9	3.7
		"D"	2,000	5.0	2.81	1.07	.36	.19	.07	62	90	121	166	218	12.0	12.0	12.0	12.0	12.0	12.0	11.0	11.0
			3,500		4.91	1.87	.63	.34	.13						1.1	1.3	1.5	1.6	2.0	2.4	3.1	3.9
			5,000	6.3	7.02	2.67	.89	.48	.18	65	92	121	167	219	12.0	12.0	12.0	12.0	12.0	12.0	11.0	11.0
			7,500		10.5	4.01	1.34	.72	.27						1.3	1.5	1.7	1.9	2.2	2.6	3.4	4.2
			10,000	7.7	14.0	5.34	1.79	.96	.36	68	94	122	168	220	12.0	12.0	12.0	12.0	12.0	12.0	12.0	11.0
			15,000		21.0	8.01	2.68	1.45	.53						1.7	1.9	2.1	2.3	2.6	3.0	3.8	4.6
			20,000	9.0	28.0	10.7	3.57	1.93	.71	71	96	122	169	221	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
			25,000		35.0	13.4	4.46	2.41	.89						2.2	2.4	2.6	2.9	3.2	3.6	4.2	5.1
			50,000																			
			75,000																			
			100,000																			
			150,000																			
			200,000																			
			250,000																			

(NOTE) For speeds not shown on the pump hydraulic charts, consult factory.

GORMAN-RUPP
ROTARY GEAR PUMPS

DE

PUMP HYDRAULIC SIZE CHART

7 GPM
1150 RPM

NOMINAL CAP. GPM	NOMINAL SPEED RPM	ROTOR TRIM	VISCOSITY (SSU)	N.I.P.R. (PSIA)	FRICTION PIPE LOSS (PSI/FT) (Based on Sch 40 Steel Pipe) PIPE DIAMETER ¾"	1"	1¼"	1½"	2"	FULL BYPASS RELIEF VALVE PRESSURE (PSI) CRACKING PRESS. (PSI) LOW PRES R/V 50	75	100	HI PRES R/V 150	200	CAPACITY (GPM) / H.P. REQUIRED DIFFERENTIAL PRESSURE (PSI) MEDIUM DUTY AND HEAVY DUTY 25	50	75	100	150	200	HEAVY DUTY ONLY 300	400
7	1150	STD	28	2.0	.01	.01	.01	.01	.01	56	81	108			6.0	5.0	4.5	3.5				
			32		.04	.02	.01	.01	.01						.17	.30	.44	.59				
			38	2.0	.06	.02	.01	.01	.01	56	81	109	161		6.5	6.0	5.0	4.5	3.5			
			50		.07	.02	.01	.01	.01						.30	.42	.54	.67	.93			
			70	2.0	.08	.03	.01	.01	.01	56	82	110	161	212	7.0	6.5	6.0	5.5	5.0	4.0		
			100		.09	.03	.01	.01	.01						.41	52	.64	.76	1.0	1.3		
			150	2.0	.11	.04	.02	.01	.01	57	83	111	161	213	7.0	7.0	6.5	6.5	6.0	5.5	5.0	4.5
			200		.23	.09	.03	.02	.01						.50	.60	.71	.82	1.1	1.4	1.9	2.3
			300	2.0	.27	.11	.04	.02	.01	57	84	112	162	213	7.5	7.0	7.0	7.0	6.5	6.5	6.0	5.5
			500		.45	.17	.06	.03	.01						.52	.63	.74	.86	1.1	1.4	1.9	2.4
			750	2.0	.67	.26	.09	.05	.02	57	85	113	162	213	7.5	7.5	7.5	7.5	7.5	7.0	7.0	7.0
			1,000		.89	.34	.11	.06	.02						.54	.64	.75	.87	1.1	1.4	1.9	2.4
		"D"	2,000	3.5	1.79	.68	.23	.12	.05	58	86	113	163	213	8.0	8.0	7.5	7.5	7.5	7.5	7.0	7.0
			3,500		3.13	1.19	.40	.22	.08						.56	.72	.88	1.1	1.3	1.5	2.0	2.5
			5,000	4.5	4.46	1.70	.57	.31	.11	60	87	113	163	213	8.0	8.0	8.0	7.5	7.5	7.5	7.5	7.0
			7,500		6.70	2.55	.85	.46	.17						.77	.92	1.1	1.2	1.5	1.7	2.2	2.7
			10,000	5.5	8.93	3.40	1.14	.61	.23	62	88	114	164	214	8.0	8.0	8.0	8.0	7.5	7.5	7.5	7.5
			15,000		13.4	5.10	1.70	.92	.34						1.1	1.2	1.3	1.5	1.7	2.0	2.4	2.9
			20,000	6.4	17.9	6.80	2.27	1.23	.45	63	88	114	164	214	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.5
			25,000		22.3	8.50	2.84	1.53	.57						1.3	1.4	1.6	1.7	2.0	2.2	2.7	3.2
			50,000	9.9	44.6	17.0	5.68	3.06	1.13	65	91	117	167	218	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.5
			75,000		-	-	-	-	-						1.7	1.8	1.9	2.0	2.3	2.5	3.1	3.5
			100,000																			
			150,000																			
			200,000																			
			250,000																			

(NOTE) For speeds not shown on the pump hydraulic charts, consult factory.

GORMAN-RUPP
ROTARY GEAR PUMPS

DE

PUMP HYDRAULIC SIZE CHART

5.5 GPM
870 RPM

NOMINAL		ROTOR TRIM	VISCOSITY	N.I.P.R.	FRICTION PIPE LOSS (PSI/FT) (Based on Sch 40 Steel Pipe)					FULL BYPASS RELIEF VALVE PRESSURE (PSI)					CAPACITY (GPM) / H.P. REQUIRED							
					PIPE DIAMETER					CRACKING PRESS. (PSI)					DIFFERENTIAL PRESSURE (PSI)							
										LOW PRES R/V			HI PRES R/V		MEDIUM DUTY AND HEAVY DUTY						HEAVY DUTY ONLY	
CAP. GPM	SPEED RPM		(SSU)	(PSIA)	¾”	1”	1¼”	1½”	2”	50	75	100	150	200	25	50	75	100	150	200	300	400
5.5	870	STD	28	1.5	.01	.01	.01	.01	.01	54	80	106			4.5	4.0	3.5	3.0				
			32		.03	.01	.01	.01	.01						.11	.20	.32	.45				
			38	1.5	.04	.01	.01	.01	.01	54	80	106	158		4.5	4.5	3.5	3.5	3.0			
			50		.05	.02	.01	.01	.01						.15	.26	.38	.50	.75			
			70	1.5	.06	.02	.01	.01	.01	54	80	107	158	208	5.0	4.5	4.5	4.0	3.5	3.0		
			100		.07	.03	.01	.01	.01						.21	.32	.43	.55	.78	1.0		
			150	1.5	.09	.04	.01	.01	.01	55	81	107	158	209	5.5	5.0	5.0	4.5	4.5	4.0	3.5	3.0
			200		.19	.07	.02	.01	.01						.27	.38	.49	.60	.80	1.0	1.4	1.7
			300	1.5	.23	.09	.03	.02	.01	55	81	108	159	209	5.5	5.5	5.0	5.0	5.0	4.5	4.5	4.0
			500		.38	.15	.05	.03	.01						.32	.42	.52	.62	.81	1.0	1.4	1.7
			750	1.5	.57	.22	.07	.03	.01	55	81	108	159	209	5.5	5.5	5.5	5.5	5.5	5.5	5.0	5.0
			1,000		.76	.29	.10	.05	.02						.35	.44	.54	.64	.83	1.0	1.4	1.7
		“D”	2,000	2.8	1.53	.58	.19	.10	.04	56	82	108	159	209	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.0
			3,500		2.67	1.02	.34	.18	.07						.39	.50	.61	.72	.91	1.1	1.5	1.8
			5,000	3.6	3.82	1.46	.49	.26	.10	57	83	109	160	210	6.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5
			7,500		5.74	2.19	.73	.39	.15						.53	.64	.75	.86	1.1	1.3	1.6	2.0
			10,000	4.5	7.65	2.91	.97	.53	.19	59	85	110	160	210	6.0	6.0	6.0	6.0	6.0	5.5	5.5	5.5
			15,000		11.5	4.37	1.46	.79	.29						.72	.85	.94	1.0	1.2	1.4	1.8	2.1
			20,000	5.2	15.3	5.83	1.95	1.05	.39	61	86	111	161	211	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
			25,000		19.1	7.28	2.43	1.31	.48						.93	1.0	1.1	1.2	1.4	1.6	2.0	2.4
			50,000	9.3	38.3	14.6	4.86	2.63	.97	62	87	112	162	212	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
			75,000		-	-	-	-	-						1.2	1.3	1.4	1.5	1.7	1.8	2.2	2.6
			100,000																			
			150,000																			
			200,000																			
			250,000																			

(NOTE) For speeds not shown on the pump hydraulic charts, consult factory.

GORMAN-RUPP
ROTARY GEAR PUMPS

DE

PUMP HYDRAULIC SIZE CHART

3.5 GPM
580 RPM

NOMINAL CAP. GPM	NOMINAL SPEED RPM	ROTOR TRIM	VISCOSITY (SSU)	N.I.P.R. (PSIA)	FRICTION PIPE LOSS (PSI/FT) (Based on Sch 40 Steel Pipe) PIPE DIAMETER ¾"	1"	1¼"	1½"	2"	FULL BYPASS RELIEF VALVE PRESSURE (PSI) CRACKING PRESS. (PSI) LOW PRES R/V 50	75	100	HI PRES R/V 150	200	CAPACITY (GPM) / H.P. REQUIRED DIFFERENTIAL PRESSURE (PSI) MEDIUM DUTY AND HEAVY DUTY 25	50	75	100	150	200	HEAVY DUTY ONLY 300	400
3.5	580	STD	28	1.1	.01	.01	.01	.01	.01	53	78	104			3.0	2.5	2.0	2.0				
			32		.02	.01	.01	.01	.01						.06	.11	.21	.31				
			38	1.1	.03	.01	.01	.01	.01	53	78	104	154		3.0	3.0	2.5	2.0	2.0			
			50		.04	.01	.01	.01	.01						.07	.13	.23	.32	.50			
			70	1.1	.04	.01	.01	.01	.01	53	78	104	154	204	3.5	3.0	3.0	2.5	2.5	2.0		
			100		.06	.02	.01	.01	.01						.09	.16	.26	.37	.59	.75		
			150	1.1	.07	.03	.01	.01	.01	53	78	104	155	205	3.5	3.5	3.0	3.0	3.0	2.5	2.5	2.0
			200		.15	.06	.01	.01	.01						.12	.20	.30	.41	.59	.75	1.0	1.2
			300	1.1	.17	.07	.02	.01	.01	53	79	104	155	205	3.5	3.5	3.5	3.5	3.0	3.0	3.0	2.5
			500		.29	.11	.04	.02	.01						.15	.23	.33	.44	.59	.75	1.1	1.3
			750	1.1	.43	.17	.06	.03	.01	53	79	104	155	205	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.0
			1,000		.58	.22	.07	.04	.02						.17	.26	.36	.46	.60	.75	1.1	1.4
		"D"	2,000	2.3	1.15	.44	.15	.08	.03	54	79	105	155	205	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5
			3,500		2.00	.77	.26	.14	.05						.20	.28	.37	.49	.64	.77	1.1	1.4
			5,000	3.0	2.87	1.09	.37	.20	.07	54	80	105	156	206	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5
			7,500		4.31	1.64	.55	.30	.11						.31	.39	.46	.54	.67	.81	1.1	1.4
			10,000	3.8	5.74	2.19	.73	.40	.15	55	80	106	156	206	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5
			15,000		8.61	3.28	1.09	.59	.22						.42	.49	.56	.63	.76	.89	1.2	1.5
			20,000	4.5	11.5	4.37	1.46	.79	.29	56	81	106	156	206	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5
			25,000		14.4	5.46	1.83	.99	.36						.52	.59	.66	.73	.85	.97	1.3	1.6
			50,000	7.9	28.7	10.9	3.65	1.97	.73	56	81	106	156	206	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.5
			75,000		43.0	16.4	5.47	2.95	1.09						.85	.90	.96	1.0	1.1	1.3	1.5	1.8
			100,000																			
			150,000																			
			200,000																			
			250,000																			

(NOTE) For speeds not shown on the pump hydraulic charts, consult factory.

PRODUCT INFORMATION PACKET

Model No: 182TTDB6092
Catalog No: GT0505
1 1/2,1200,DP,182JM,3/60/575
JM

Product Information Packet: Model No: 182TTDB6092, Catalog No:GT0505 1 1/2,1200,DP,182JM,3/60/575

Nameplate Specifications

Output HP	**1.50 Hp**	Output KW	**1.1 kW**
Frequency	**60 Hz**	Voltage	**575 V**
Current	**1.8 A**	Speed	**1180 rpm**
Service Factor	**1.15**	Phase	**3**
Efficiency	**86.5 %**	Duty	**Continous**
Insulation Class	**F**	Design Code	**B**
KVA Code	**J**	Frame	**182JMV**
Enclosure	**Drip Proof**	Overload Protector	**No**
Ambient Temperature	**40 °C**	Drive End Bearing Size	**6206**
Opp Drive End Bearing Size	**6203**	UL	**Recognized**
CSA	**Y**	CE	**Y**
IP Code	**22**		

Technical Specifications

Electrical Type	**Squirrel Cage Inverter Rated**	Starting Method	**Line Or Inverter**
Poles	**6**	Rotation	**Reversible**
Mounting	**Rigid base**	Motor Orientation	**Horizontal Or Shaft Down**
Drive End Bearing	**Ball**	Opp Drive End Bearing	**Ball**
Frame Material	**Rolled Steel**	Shaft Type	**JM**
Overall Length	**16.34 in**	Shaft Diameter	**0.875 in**
Shaft Extension	**4.26 in**	Assembly/Box Mounting	**F1 Only**
Outline Drawing	**SS620311**	Connection Diagram	**EE7300**

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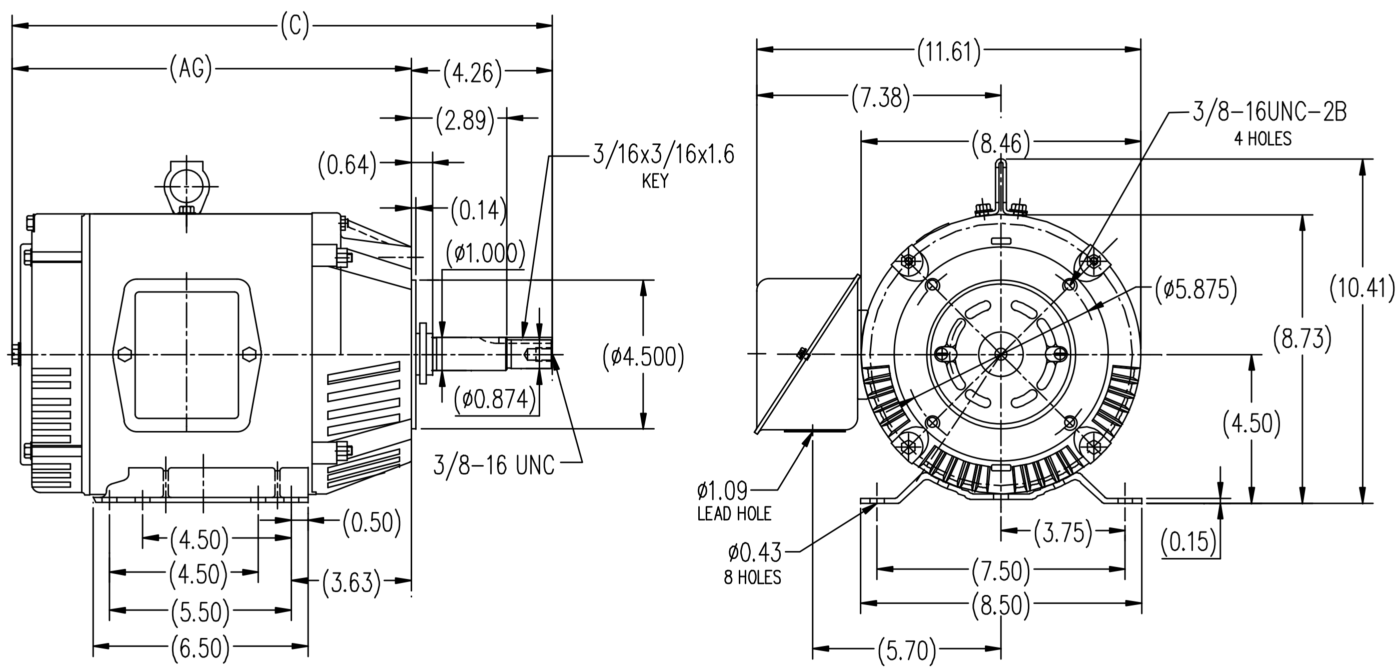
SS620311



FRAME	AG	C
182T	12.09	16.34
184T	13.11	17.37

NO.	REVISION	BY & DATE	CHK
1	CORRECT THE ID FOR AG & C DIM WAS B1 & B	MO01-09-2012	

TOLERANCES UNLESS SPECIFIED	
DEC.	INCHES
.X	±.1
.XX	±.03
.XXX	±.005
.XXXX	±.0005
ANG	±1/2-

REGAL-BELOIT CORPORATION

TITLE: OUTLINE 182/184T FR–JM–ROLLED STEEL

MAT'L.

FINISH

CAD FILE SS620311

RFP

DIST

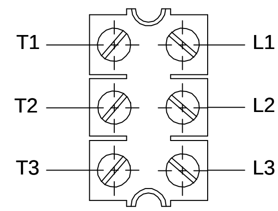
DRAWN ZYH 6-9-2010
CHK HZJ 6-9-2010
APPD CL 6-9-2010
SCALE 1=4
REF
FMF HWADA
PREV

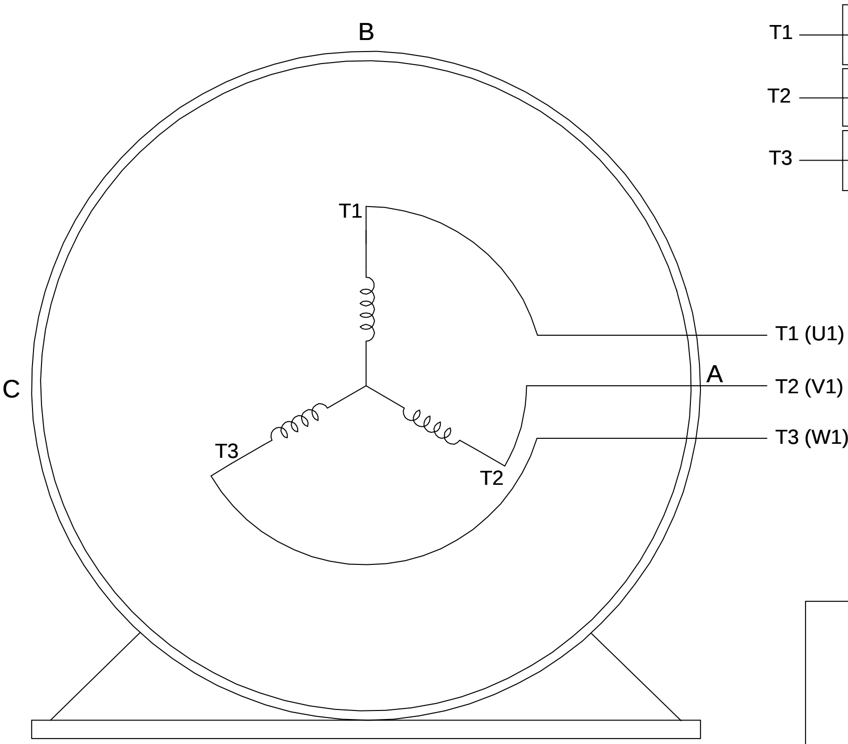
SIZE B | DRAWING NO. SS620311 | REV. 1

THREE PHASE - SINGLE VOLTAGE
MOTOR - CONDUIT BOX @ 'A'

TO REVERSE ROTATION:
INTERCHANGE ANY TWO
LINE LEAD CONNECTIONS.

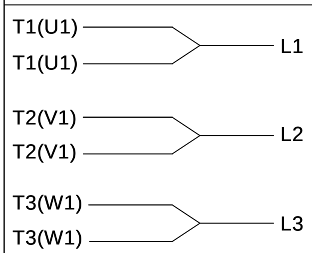
TERMINAL BLOCK WHEN SPECIFIED





VIEW OF TERMINAL END

IF MOTOR HAS
6 LEADS



A-9806 DECAL

OPTIONAL CORD CONNECTION

L1 WHITE
L2 RED
L3 BLACK

DRAWING REVISION	REVISION BY	DATE
AB	JJB	06-27-2017
ECO	APPROVED BY	DATE
ECO-0125361	TB	06-27-2017

ECO DESCRIPTION
UPDATED TO CURRENT STANDARDS

DRAWN BY: DA
DATE: 03-26-1993
APPROVED BY: TB
DATE: 03-26-1993
REFERENCE
THIRD ANGLE PROJECTION

REGAL™ Regal Beloit America, Inc.

DESCRIPTION
CONNECTION DIAGRAM
EXTERNAL - SINGLE VOLTAGE - 3Ø MOTOR

MATERIAL | PROCESS/FINISH

SIZE	DRAWING NUMBER	SHEET
A	EE7300	1 OF 1

CERTIFICATION DATA SHEET

Model#:	182TTDB6092 AA	**WINDING#:**	CHT18260008 NONE 3
CONN. DIAGRAM:	EE7300	**ASSEMBLY:**	F1/F2 CAPABLE
OUTLINE:	SS620311		

TYPICAL MOTOR PERFORMANCE DATA

HP	KW	SYNC. RPM	F.L. RPM	FRAME	ENCLOSURE	KVA CODE	DESIGN
1 1/2	1.12	1200	1180	182JMV	DP	J	B

PH	Hz	VOLTS	FL AMPS	START TYPE	DUTY	INSL	S.F	AMB°C	ELEVATION
3	60	575	1.75	LINE OR INVERTER	CONTINUOUS	F7	1.15	40	3300

FULL LOAD EFF: 86.5	3/4 LOAD EFF: 86.5	1/2 LOAD EFF: 86.5	GTD. EFF	ELEC. TYPE	NO LOAD AMPS
FULL LOAD PF: 69	3/4 LOAD PF: 63	1/2 LOAD PF: 51	85.5	SQ CAGE INV RATED	1

F.L. TORQUE	LOCKED ROTOR AMPS	L.R. TORQUE	B.D. TORQUE	F.L. RISE°C
6.7 LB-FT	12	11.2 LB-FT 167	20 LB-FT 298	25

SOUND PRESSURE @ 3 FT.	SOUND POWER	ROTOR WK^2	MAX. WK^2	SAFE STALL TIME	STARTS /HOUR	APPROX. MOTOR WGT
54 dBA	64 dBA	0.38 LB-FT^2	32 LB-FT^2	25 SEC.	2	70 LBS.

*** SUPPLEMENTAL INFORMATION ***

DE BRACKET TYPE	ODE BRACKET TYPE	MOUNT TYPE	ORIENTATION	SEVERE DUTY	HAZARDOUS LOCATION	DRIP COVER	SCREENS	PAINT
C-FACE	STANDARD	RIGID	HORIZONTAL OR SHAFT DOWN	FALSE	NONE	FALSE	NONE	BLUE (ENAMEL)

BEARINGS		GREASE	SHAFT TYPE	SPECIAL DE	SPECIAL ODE	SHAFT MATERIAL	FRAME MATERIAL
DE	OPE						
BALL	BALL	POLYREX EM	JM	NONE	NONE	1045 HOT ROLLED (C-204)	ROLLED STEEL
6206	6203						

THERMO-PROTECTORS				THERMISTORS	CONTROL	SPACE /n HEATERS
THERMOSTATS	PROTECTORS	WDG RTDs	BRG RTDs			
NONE	NOT	NONE	NONE	NONE	FALSE	NONE VOLTS

If Inverter equals NONE, contact factory for further information

NOTES

INVERTER TORQUE: VARIABLE 10:1
INV. HP SPEED RANGE: NONE

ENCODER: NONE
NONE NONE
NONE NONE PPR

BRAKE: NONE NONE
NONE P/N NONE
NONE NONE
NONE FT-LB NONE V NONE Hz

DATE: 06/27/2017 01:34:16 AM
FORM 3531 REV.3 02/07/99
** Subject to change without notice.

Uncontrolled Copy

Data Sheet

Date: 29-06-2017
Customer:
Attention:
Submitted by: FAREEDA DUDEKULA

182TTDB6092

Submittal

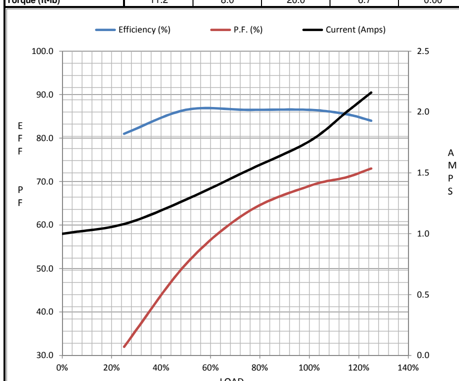
Data @ 575 V

Motor Load Data

Load	0%	25%	50%	75%	100%	115%	125%	LR	
Current (Amps)	1.00	1.08	1.28	1.52	1.76	2.00	2.16	12.0	
Torque (ft-lb)	0.00	1.65	3.3	5.0	6.7	7.7	8.4	11.2	
RPM	1200	1195	1190	1185	1180	1,178	1175	0	
Efficiency (%)		81.0	86.5	86.5	86.5	85.5	84.0		
P.F. (%)	6.0	32.0	51.0	63.0	69.0	71.0	73.0	37.0	

Motor Speed Data

	LR	Pull-Up	BD	Rated	Idle
Speed (RPM)	0	600	1050	1180	1200
Current (Amps)	12.0	10.4	7.2	1.76	1.00
Torque (ft-lb)	11.2	8.0	20.0	6.7	0.00



Information Block

HP	1.5	
Sync. RPM	1200	
Frame	182	
Enclosure	DP	
Construction	TDB	
Voltage	575	V
Frequency	60	Hz
Design	B	
LR Code letter	J	
Service Factor	1.15	
Temp Rise @ FL	25	° C
Duty	CONT	
Ambient	40	° C
Elevation	1,000	feet
Rotor/Shaft wk²	0.38	Lb-Ft²
Ref Wdg	CHT18260008	NONE
Sound Pressure @ 1M	54	dBA
VFD Rating	VARIABLE 10:1	
Outline Dwg	SS620311	
Conn. Diag	EE7300	

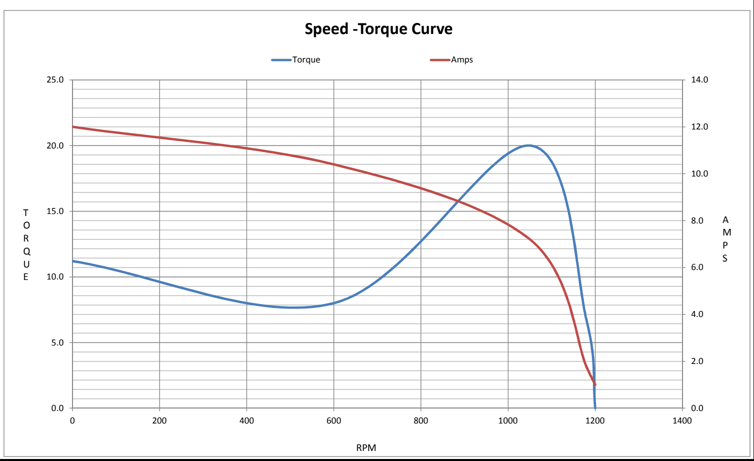
Additional Specifications:

0

365THFS8036

EQUIV CKT (OHMS / PHASE)

R1	R2	X1	X2	Xm
7.0880	3.5440	21.2630	28.0550	339.6090



6 of 6

FLOMEC®

PRODUCT CONFIGURATION

OM SERIES MEDIUM CAPACITY (OVAL GEAR METERS)

The **FLOMEC® OM Medium Capacity Meters** are great for medium flow ranges and have the ability to handle a wide range of fluid viscosities.

FEATURES / BENEFITS

- High accuracy and repeatability, direct volumetric reading
- Measures high and low viscosity liquids
- Quadrature pulse output option and bi-directional flow
- Optional Exd I/IIB approval (ATEX, IECEx)
- No requirement for flow conditioning (straight pipe runs)
- Only two moving parts

PRODUCT IDENTIFIER 1

OM = Oval Gear Meter

METER SIZE 2

015 = 1/2" (15 mm), 0.26-10.6 GPM (1-40 L/min)
025 = 1" (25 mm), 2.6-40 GPM (10-150 L/min)
040 = 1-1/2" (40 mm), 4-66 GPM (15-250 L/min)
050 = 2" (50 mm), 8-118 GPM (30-450 L/min) with SS Rotors
050 = 2" (50 mm), 8-130 GPM (30-500 L/min) with PPS Rotors

BODY MATERIAL 3

A = Aluminum
M = Intermediate pressure aluminum meter (2000 psi [138 bar] max.) (OM025 only)
S = 316L Stainless Steel
N = Intermediate Pressure 316L SS (OM015-OM025N = 1450 psi [100 bar]) (OM040N-OM050N = 725 psi / 50 bar)

ROTOR MATERIAL / BEARING TYPE 4

00 = PPS (not available for 300º F [150º C] meters) / No bearing
10 = Keishi cut PPS (for high viscosity liquids) (not available for 300º F [150º C] meters) / No bearing
51 = Stainless Steel / Carbon Ceramic
71 = Keishi cut Stainless Steel (for high viscosity liquids) / Carbon Ceramic

O-RING MATERIAL 5

1 = FKM (Viton™) (standard for Alum.) -5º F minimum (-15º C)
3 = PTFE encapsulated FKM (Viton™)
4 = Buna-N (Nitrile), -40º F minimum (-40º C)

MAXIMUM TEMPERATURE LIMIT 6

-2 = 250º F (120º C) max.
-3 = 300º F (150º C) max. (Hall Effect) (Includes Stainless Steel terminal cover)
-5 = 250º F (120º C) max. (includes integral cooling fin)
-8 = 176º F (80º C) max. (meters with integral instruments)

PROCESS CONNECTIONS 7

0 = No fittings (Not available on 015 size)
1 = BSPP (G) female threaded (ISO 228)
2 = NPT female threaded
3 = Sanitary Fittings (are 1/2" (13 mm) larger than meter size)
4 = ANSI-150 RF Flanged
5 = ANSI-300 RF Flanged
6 = PN16 DIN Flanged

CABLE ENTRIES 8

1 = M20 x 1.5 mm (M16 x 1.5 mm for R4 option)
2 = 1/2 in. NPT
6 = 3 x 16 mm drilled holes (for F instruments only)

INTEGRAL OPTIONS 9

___ = Combination Reed Switch and Hall Effect Sensor
SS = Stainless Steel terminal cover
RS = Reed Switch only - to suit Intrinsically safe installations
E1 = Explosion proof Exd IIB T3...T6 (Aluminum & Stainless meters) [IECEx & ATEX approved]
E2 = Explosion proof Exd I/IIB T3...T6 (stainless meters only) [IECEx & ATEX mines approved]
QP = Quadrature pulse (2 NPN phased outputs)
QPN = Quadrature pulse (2 NPN phased outputs) with Australian NZNMI approval for trade sale
Q1 = Explosion proof Exd (with quadrature pulse) [IECEx & ATEX approved]
Q1N = Explosion proof Exd (IECEx & ATEX) with Quadrature pulse with Australian NMI & NZ approval for trade sale (Not available on 015 size)
R3 = Intrinsically safe RT12 with all outputs (GRN housing) [IECEx & ATEX approved]*#
R3G = RT12 Intrinsically Safe rate totalizer with all outputs (GRN Housing) [IECEx & ATEX approved] (with gallons calibration)*#
R4 = RT40 rate totalizer with backlit large digit LCD [scalable pulse output, backlight]*#
R4G = RT40 rate totalizer with backlit large digit LCD (Alloy housings with facia) (with gallons calibration)*#
R5 = RT14 backlit rate totalizer with all outputs (GRN Housing)*#
R5G = RT14 backlit rate totalizer with all outputs (GRN Housing) (with gallons calibration)*#
E0 = EB10 batch controller [2 stage DC batcher & totalizer] (GRN Housing)*#
E0G = EB10 batch controller [2 stage DC batcher & totalizer] (with gallons calibration) (GRN Housing)*#
E18 = E018 backlit rate/tot, pulse, 4-20mA, 10 point linearization, HART, aluminium body [IECEx & ATEX approved] (Not available with 015 size)#
E19 = E018 backlit rate/tot, pulse, 4-20mA, 10 point linearization, HART, stainless steel body [IECEx & ATEX approved] (Not available with 015 size)#
F18 = F018 backlit rate/tot, pulse, 4-20mA, 10 point linearization, HART#
F19 = F018 backlit rate/tot, pulse, 4-20mA, 10 point linearization, HART, Intrinsically safe [IECEx & ATEX approved]#
F31 = Intrinsically safe F130 2 stage batch controller [IECEx & ATEX approved]#

	1	2	3	4	5	6	7	8	9
--->>>>	OM	025	A	51	2	-5	2	1	R4

Temp code 5 required for integral instruments between 176ºF (80ºC) & 250ºF (120ºC)
#Temp code 8 required for integral instruments below 176ºF (80ºC) by 20%

SPECIFICATIONS

	OM015	OM025	OM040	OM050
Nominal Size:	1/2" (13 mm)	1" (25 mm)	1 1/2" (38 mm)	2" (51 mm)
*Flow Range:	0.26-10.6 GPM (1-40 L/min)	2.6-40 GPM (10-150 L/min)	4-66 GPM (15-250 L/ min)	8-118 GPM (30-450 L/ min) (SS) 8-130 GPM (30-500 L/ min) (PPS)
Accuracy @3cp:	± 0.5% of reading (accuracy is ± 0.2% of reading with optional RT14 with non-linearity correction)			
Repeatability:	Typically ± 0.03% of reading			
Temperature Range:	-40° F to +300° F (-40° C to +150° C) refer to factory for lower temperature			
Pressure Rating (Threaded Meter):				
Aluminum	990 psi (68 bar)	990 psi (68 bar)	435 psi (30 bar)	285 psi (20 bar)
Intermediate Pressure Aluminum		2000 psi (138 bar)		
316 Stainless Steel	990 psi (68 bar)	990 psi (68 bar)	435 psi (30 bar)	550 psi (38 bar)
Intermediate Pressure SS	1450 psi (100 bar)	1450 psi (100 bar)	725 psi (50 bar)	725 psi (50 bar)

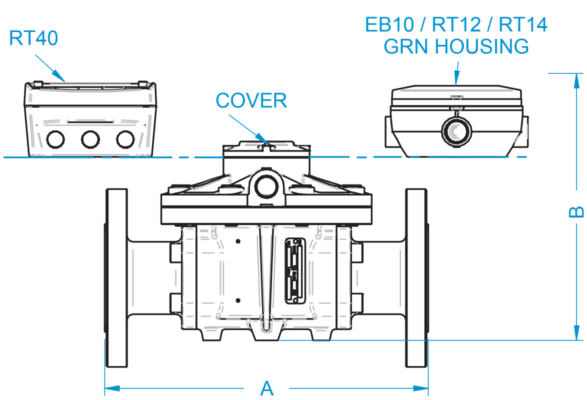
	OM015	OM025	OM040	OM050
Pressure Rating (Mechanical Meter):				
Aluminum	580 psi (40 bar)	580 psi (40 bar)	435 psi (30 bar)	285 psi (20 bar)
316 Stainless Steel	580 psi (40 bar)	580 psi (40 bar)	435 psi (30 bar)	285 psi (20 bar)
Recom-mended Filtration	100 mesh (150 µm)			
Electrical:				
Output Pulse Resolution:	Pulses / gallon (Pulses / L) - Nominal			
Reed Switch	318 (84)	120 (27)	53 (14)	25 (6.5)
Hall Effect	636 (168)	405 (107)	212 (56)	99 (26)
QP - Quadrature Hall Option	636 (168)	204 (54)	106 (28)	49 (13)
Reed Switch Output	30V (dc) x 200mA max. [maximum thermal shock 18° F (10° C) / minute]			
Hall Effect Output (NPN)	3 wire open collector, 5-24V (dc) max., 20mA max.			
Optional Outputs	4-20mA, scaled pulse, quadrature pulse, flow alarms or two stage batch control			

**Maximum flow is to be reduced as viscosity increases, see flow de-rating guide. Max recommended pressure drop is 14.5 psi (1 bar).*

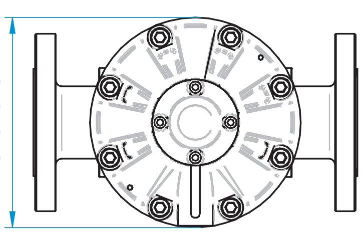
DIMENSIONS *All dimensions are ± .079 (±2 mm)*

Modular Fitting	A					
	OM015	OM025A	OM025S/N	OM040	OM050	OM050E
A.N.S.I.150 DIN16	7.4” (189 mm)	7.8” (198 mm)	9.3” (237 mm)	9.9” (252 mm)	10.9” (277 mm)	10.9” (277 mm)
B.S.P N.P.T.	4.3” (110 mm)	5.4” (137 mm)	6.9” (176 mm)	7.4” (188 mm)	8.3” (212 mm)	8.3” (212 mm)

Configuration	B							
	OM015A	OM015S/N	OM025A	OM025S/N	OM040A	OM040S/N	OM050	OM050E
EB10 / RT12 / RT14 GRN Housing	6.0” (154 mm)	5.8” (148 mm)	6.6” (168 mm)	6.5” (165 mm)	7.9” (203 mm)	7.6” (194 mm)	8.6” (218 mm)	10.5” (268 mm)
RT40 Alloy Housing	6.2” (157 mm)	5.9” (151 mm)	6.7” (171 mm)	6.6” (168 mm)	8.1” (206 mm)	7.8” (197 mm)	8.7” (221 mm)	10.7” (271 mm)
Cover	4.2” (106 mm)	3.9” (100 mm)	4.7” (123 mm)	4.6” (117 mm)	6.1” (155 mm)	5.7” (146 mm)	6.7” (170 mm)	8.6” (220 mm)



OM040: Ø6.3” (160 mm)
OM050: Ø7.1” (180 mm)
OM015: Ø4.3” (110 mm)
OM025: Ø4.7” (120 mm)



APPLICATIONS

- Oils
- Fuel
- Diesel
- Truck Metering
- Bunker C Fuel Oil
- Chemical Additive Injection
- Batching
- Molasses
- Clean Fluids
- Oil-Based Paints
- Industrial Fluids
- Chemical Feed Lines

APPROVALS

ATEX

NEMA 4X

IP66/67

"Apollo" Valves | INDUSTRIAL PRODUCTS

87A-200 SERIES

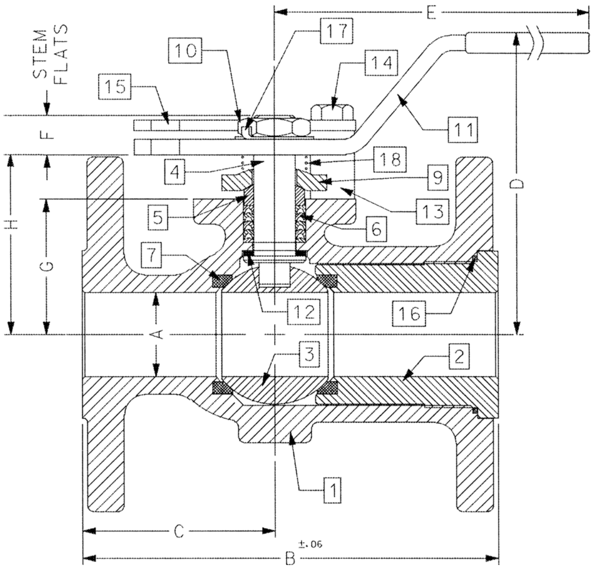
STAINLESS STEEL ASME CLASS 150 FLANGED FULL PORT BALL VALVE
1/2" THRU 1"

5 YEAR WARRANTY MADE IN USA

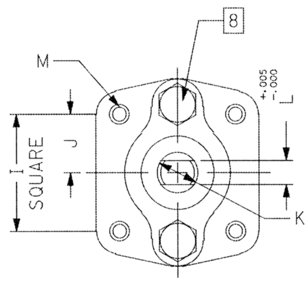
FOR STANDARDS COMPLIANCE AND STANDARD FEATURES REFER TO PAGE D-3.

STANDARD MATERIAL LIST

	PART	MATERIAL
1	Body	ASTM A351 CF8M
2	Retainer	ASTM A276 Type 316
3	Ball	ASTM A276 Type 316
4	Stem	ASTM A276 Type 316
5	Packing Gland	ASTM A276 Type 316
6	Stem Seals	PTFE
7	Seats	TFM 1700
8	Gland Screws	ASTM A193 B8 Class 1
9	Gland Plate	302 or 304 Stainless Steel
10	Stem Nut	316 Stainless Steel
11	Lever	302 or 304 with Vinyl Grip
12	Stem Bearing	RPTFE
13	Stop	ASTM A276 Type 316
14	Stop Screw	18-8 Stainless Steel
15	Lock Plate	302 or 304 Stainless Steel
16	Body Seal	RPTFE
17	Lockwasher	302 or 304 Stainless Steel
18	Grounding Spring	Stainless Steel



ACTUATOR MOUNTING



VARIATIONS AVAILABLE

- 87H - Hastelloy
- 87M - Monel
- 87N - Nickel
- 87S - 304L Stainless Steel

OPTIONS AVAILABLE

(MORE INFORMATION IN SECTION J)

- Minimum quantities apply.
- To specify an option, replace the "01" standard suffix with the suffix of the option.
- To specify multiple options, replace the "01" suffix with the desired suffixes in the numerical order shown below. NOTE: Not all suffixes can be combined together.

(SUFFIX)	OPTION
-01	Standard Configuration
-04-	2-1/4" Stem Extension (Carbon Steel, Zinc Plated)
-14-	Side Vented Ball (Uni-Directional)
-15-	Wheel Handle, Steel
-21-	UHMWPE Seats
-24-	Graphite Packing, Spiral Wound Graphite Body Seal, RPTFE Bearing (API 607, 6th Edition, ISO 10497:2010)
-35-	PTFE Seats and Seals
-38-	PEEK Seats and Graphite Packing
-49-	No Lubrication. Assembled Dry
-57-	Oxygen Cleaned
-65-	MPTFE Seats and Graphite Packing (Fire Safe)
-69-	Drilled and Tapped Purge Port with Plugs
-70-	4" Extended Bonnet
-73-	316 Stainless Steel Spiral Wound Gaskets with PTFE Filler
-76-	Live Loaded (Lever)
-77-	Live Loaded (Gear, Actuator)
-80-	TFM 1600 Seats, PTFE Chevron Packing, Spiral Wound PTFE Body Seal, PEEK Bearing
-82-	Flat Face Flanges
-90-	Double Packed 4" Extended Bonnet
-9P-	Double Packed 4" Extended Bonnet with Monitoring Port
-CE-	CE Marking. See Page D-3 "Product Approvals" for Availability
-EF-	Graphite Packing (API 641 Compliant) (Not Available on 1/2" Size)
-EP-	Garlock EVSP Stem Packing with Spiral Wound Graphite Gasket (Fire Safe by Design)
-KF-	PCTFE Stem Bearing
-MP-	Positive Material Identification
-TC-	With Test Certificate
-TD-	Tested to API Spec 6D
-UA-	AIS (American Iron & Steel) Compliant
-UL-	UL & CSA Listed (with Markings)
-ZP1-	Fugitive Emissions Packing (Viton)
-ZP2-	Fugitive Emissions Packing (Buna-N)
-ZP3-	Fugitive Emissions Packing (Kalrez)

Pressure/Temperature Ratings - Page M-9, Graph No. 2

DIMENSIONS

PART NO.	SIZE	A	B	C	D	E	F	G	H	I	J	K	L	M	WT.
87A-203-01A	1/2"	0.50	4.25	2.06	2.74	5.12	0.24	1.09	1.44	1.00	0.500	0.375	0.245	10-24	5
87A-204-01A	3/4"	0.75	4.62	2.18	3.43	5.54	0.22	1.65	2.13	1.392	0.696	0.500	0.312	1/4-20	6
87A-205-01	1"	1.00	5.00	2.32	4.62	6.53	0.47	1.62	2.15	1.392	0.696	0.500	0.287	1/4-20	7

REV. 10SEP19

87A-200 SERIES

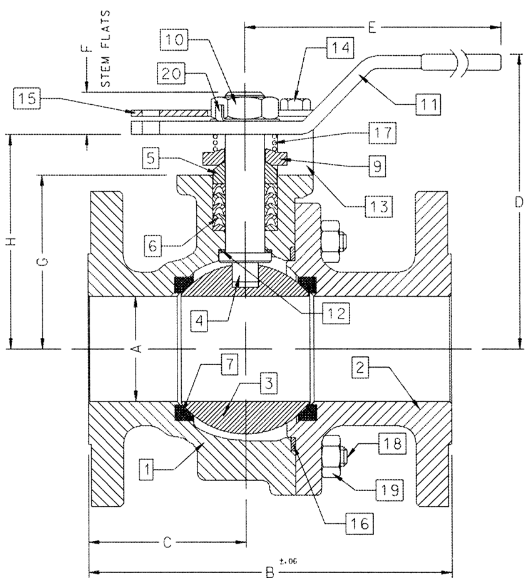
STAINLESS STEEL ASME CLASS 150 FLANGED FULL PORT BALL VALVE
1-1/2" THRU 2-1/2"

5 YEAR WARRANTY MADE IN USA

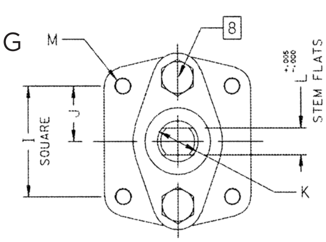
FOR STANDARDS COMPLIANCE AND STANDARD FEATURES REFER TO PAGE D-3.

STANDARD MATERIAL LIST

	PART	MATERIAL
1	Body	ASTM A351 CF8M
2	Retainer	ASTM A351 CF8M
3	Ball	ASTM A276 Type 316 or A351 CF8M
4	Stem	ASTM A276 Type 316
5	Packing Gland	ASTM A276 Type 316
6	Stem Seals	PTFE
7	Seats	TFM 1700
8	Gland Screws	ASTM A193 B8 Class 1
9	Gland Plate	316 Stainless Steel
10	Adapter Screw	18-8 Stainless Steel
11	Lever	316 Stainless Steel
12	Stem Bearing	RPTFE
13	Stop	ASTM A276 Type 316
14	Stop Screw	316 Stainless Steel
15	Lock Plate	302 or 304 Stainless Steel
16	Body Seal	RPTFE
17	Grounding Spring	Stainless Steel
18	Body Joint Stud	ASTM A193 Grade B8M
19	Body Joint Nut	ASTM A194 Grade 8
20	Lockwasher	302 or 304 Stainless Steel



ACTUATOR MOUNTING



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(SUFFIX)	OPTION
-01	Standard Configuration
-04-	2-1/4" Stem Extension (Carbon Steel, Zinc Plated) (up to 2-1/2")
-14-	Side Vented Ball (Uni-Directional)
-21-	UHMWPE Seats
-24-	Graphite Packing, Spiral Wound Graphite Body Seal, RPTFE Bearing (API 607, 6th Edition, ISO 10497:2010)
-35-	PTFE Seats and Seals
-38-	PEEK Seats and Graphite Packing
-49-	No Lubrication. Assembled Dry
-57-	Oxygen Cleaned
-65-	MPTFE Seats and Graphite Packing (Fire Safe)
-69-	Drilled and Tapped Purge Ports with Plugs
-70-	4" Extended Bonnet
-73-	316 Stainless Steel Spiral Wound Gaskets with PTFE Filler
-76-	Live Loaded (Lever)
-77-	Live Loaded (Gear, Actuator)
-80-	TFM 1600 Seats, PTFE Chevron Packing, Spiral Wound PTFE Body Seal, PEEK Bearing
-82-	Flat Face Flanges
-MG-	Gear Operator with Standard Handwheel
-90-	Double Packed 4" Extended Bonnet
-9P-	Double Packed 4" Extended Bonnet with Monitoring Port
-CE-	CE Marking. See Page D-3 "Product Approvals" for Availability
-EF-	Graphite Packing (API 641 Compliant)
-EP-	Garlock EVSP Stem Packing with Spiral Wound Graphite Gasket (Fire Safe by Design)
-KF-	PCTFE Stem Bearing
-MH-	Gear Operator with Standard Handwheel & Locking Device
-MJ-	Gear Operator with Oversize Handwheel
-MK-	Gear Operator with Oversize Handwheel & Locking Device
-MP-	Positive Material Identification
-TC-	With Test Certificate
-TD-	Tested to API Spec 6D
-UA-	AIS (American Iron & Steel) Compliant
-UL-	UL & CSA Listed (with Markings)
-ZP1-	Fugitive Emissions Packing (Viton)
-ZP2-	Fugitive Emissions Packing (Buna-N)
-ZP3-	Fugitive Emissions Packing (Kalrez)

Pressure/Temperature Ratings - Page M-9, Graph No. 2

DIMENSIONS

PART NO.	SIZE	A	B	C	D	E	F	G	H	I	J	K	L	M	WT.
87A-207-01	1-1/2"	1.50	6.50	3.00	4.62	6.65	0.72	2.41	3.09	1.949	0.974	0.625	0.412	5/16-18	14
87A-208-01	2"	2.00	7.00	3.04	5.61	8.41	0.80	3.31	4.08	1.949	0.974	0.750	0.477	5/16-18	25
87A-209-01	2-1/2"	2.50	7.50	3.34	6.24	8.41	0.80	3.94	4.71	1.949	0.974	0.750	0.477	5/16-18	30

REV. 18JUL19

87A-200 SERIES

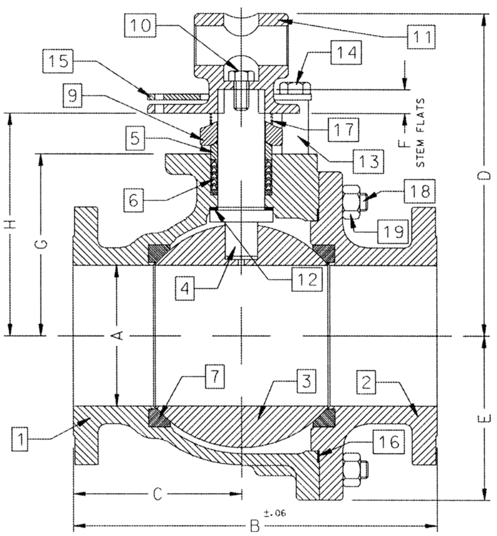
STAINLESS STEEL ASME CLASS 150 FLANGED FULL PORT BALL VALVE
3" THRU 6"

5 YEAR WARRANTY MADE IN USA

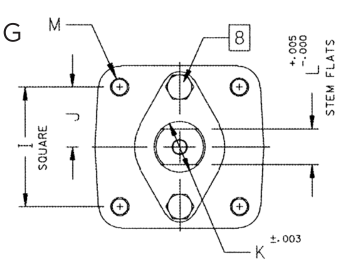
FOR STANDARDS COMPLIANCE AND STANDARD FEATURES REFER TO PAGE D-3.

STANDARD MATERIAL LIST

	PART	MATERIAL
1	Body	ASTM A351 CF8M
2	Retainer	ASTM A351 CF8M
3	Ball	ASTM A276 Type 316 or A351 CF8M
4	Stem	ASTM A276 Type 316
5	Packing Gland	ASTM A276 Type 316
6	Stem Seals	PTFE
7	Seats	TFM 1700
8	Gland Screws	ASTM A193 B8 Class 1
9	Gland Plate	316 Stainless Steel
10	Adapter Screw	18-8 Stainless Steel
11	Handle Adapter	316 with Vinyl Grip
12	Stem Bearing	RPTFE
13	Stop	ASTM A276 Type 316
14	Stop Screw	316 Stainless Steel
15	Lock Plate	302 or 304 Stainless Steel
16	Body Seal	RPTFE
17	Grounding Spring	Stainless Steel
18	Body Joint Stud	ASTM A193 Grade B8M
19	Body Joint Nut	ASTM A194 Grade 8
20	Pipe Handle	Galvanized Steel (not shown)



ACTUATOR MOUNTING



VARIATIONS AVAILABLE

- 87H - Hastelloy
- 87N - Nickel
- 87S - 304L Stainless Steel

OPTIONS AVAILABLE

(MORE INFORMATION IN SECTION J)

- Minimum quantities apply.
- To specify an option, replace the "01" standard suffix with the suffix of the option
- To specify multiple options, replace the "01" suffix with the desired suffixes in the numerical order shown below. NOTE: Not all suffixes can be combined together.

(SUFFIX)	OPTION
-01	Standard Configuration
-14-	Side Vented Ball (Uni-Directional)
-21-	UHMWPE Seats
-24-	Graphite Packing, Spiral Wound Graphite Body Seal, RPTFE Bearing (API 607, 6th Edition, ISO 10497:2010)
-35-	PTFE Seats and Seals
-38-	PEEK Seatsand Graphite Packing
-49-	No Lubrication. Assembled Dry
-57-	Oxygen Cleaned
-65-	MPTFESeats and Graphite Packing (Fire Safe)
-69-	Drilled and Tapped Purge Ports with Plugs
-70-	4" Extended Bonnet
-73-	316Stainless Steel Spiral Wound Gaskets with PTFE Filler
-76-	Live Loaded (Lever)
-77-	Live Loaded (Gear,Actuator)
-80-	TFM 1600 Seats, PTFE Chevron Packing, Spiral Wound PTFE Body Seal, PEEK Bearing
-82-	Flat Face Flanges
-90-	Double Packed 4" Extended Bonnet
-9P-	Double Packed 4" Extended Bonnet with Monitoring Port
-CE-	CE Marking. See Page D-3 "Product Approvals" for Availability
-EF-	Graphite Packing (API 641 Compliant)
-EP-	Garlock EVSP Stem Packing with Spiral Wound Graphite Gasket (Fire Safe by Design)
-KF-	PCTFE Stem Bearing
-MG-	Gear Operator with Standard Handwheel
-MH-	Gear Operator with Standard Handwheel& Locking Device
-MJ-	Gear Operator with Oversize Handwheel
-MK-	Gear Operator with Oversize Handwheel & LockingDevice
-MP-	Positive Material Identification
-TC-	With Test Certificate
-TD-	Tested to API Spec 6D
-UA-	AIS (American Iron & Steel) Compliant
-UL-	UL & CSA Listed (with Markings)
-ZP1-	Fugitive Emissions Packing (Viton)
-ZP2-	Fugitive Emissions Packing (Buna-N)
-ZP3-	Fugitive Emissions Packing (Kalrez)

Pressure/Temperature Ratings - Page M-9, Graph No. 2

DIMENSIONS

PART NO.	SIZE	A	B	C	D	E	F	G	H	I	J	K	L	M	WT.
87A-200-01	3"	3.00	8.00	3.68	8.80	3.88	0.50	4.75	5.95	2.840	1.420	1.250	0.725	3/8-16	60
87A-20A-01	4"	4.00	9.00	3.94	9.99	5.13	0.50	5.94	7.13	2.840	1.420	1.250	0.725	3/8-16	91
87A-20C-01	6"	6.00	15.50	7.19	13.73	7.00	1.00	7.75	9.48	4.596	2.298	2.000	1.375	3/4-10	248

REV. 18JUL19

87A-200 SERIES

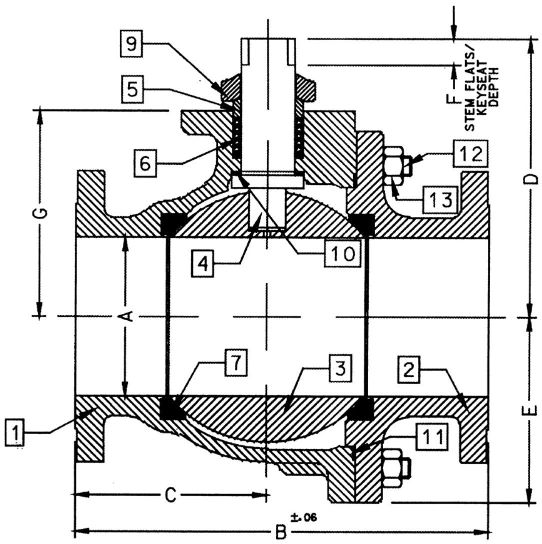
STAINLESS STEEL ASME CLASS 150 FLANGED FULL PORT BALL VALVE
8" THRU 12"

5 YEAR WARRANTY MADE IN USA

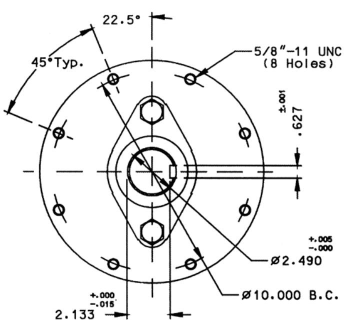
FOR STANDARDS COMPLIANCE AND STANDARD FEATURES REFER TO PAGE D-3.

STANDARD MATERIAL LIST

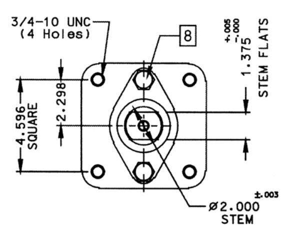
	PART	MATERIAL
1	Body	ASTM A351 CF8M
2	Retainer	ASTM A351 CF8M
3	Ball	ASTM A276 Type 316 or A351 CF8M
4	Stem	ASTM A276 Type 316
5	Packing Gland	ASTM A276 Type 316
6	Stem Seals	PTFE
7	Seats	TFM 1700
8	Gland Screws	ASTM A193 B8 Class 1
9	Gland Plate	316 Stainless Steel
10	Stem Bearing	RPTFE
11	Body Seal	RPTFE
12	Body Joint Stud	ASTM A193 Grade B8M
13	Body Joint Nut	ASTM A194 Grade 8



ACTUATOR MOUNTING



10" & 12"



8"

VARIATIONS AVAILABLE

- 87H - Hastelloy
- 87N - Nickel
- 87S - 304L Stainless Steel

OPTIONS AVAILABLE

(MORE INFORMATION IN SECTION J)

- Minimum quantities apply.
- To specify an option, replace the "01" standard suffix with the suffix of the option.
- To specify multiple options, replace the "01" suffix with the desired suffixes in the numerical order shown below. NOTE: Not all suffixes can be combined together.

(SUFFIX)	OPTION
-01	Standard Configuration
-14-	Side Vented Ball (Uni-Directional)
-21-	UHMWPE Seats
-24-	Graphite Packing, Spiral Wound Graphite Body Seal, RPTFE Bearing (API 607, 6th Edition, ISO 10497:2010)
-35-	PTFE Seats and Seals
-49-	No Lubrication. Assembled Dry
-57-	Oxygen Cleaned
-65-	MPTFE Seats and Graphite Packing (Fire Safe)
-69-	Drilled and Tapped Purge Ports with Plugs
-70-	4" Extended Bonnet (8" Only)
-77-	Live Loaded (Gear, Actuator)
-80-	TFM 1600 Seats, PTFE Chevron Packing, Spiral Wound PTFE Body Seal, PEEK Bearing
-82-	Flat Face Flanges
-90-	Double Packed 4" Extended Bonnet
-9P-	Double Packed 4" Extended Bonnet with Monitoring Port
-CE-	CE Marking. See Page D-3 "Product Approvals" for Availability
-EF-	Graphite Packing (API 641 Compliant)
-EP-	Garlock EVSP Stem Packing with Spiral Wound Graphite Gasket (Fire Safe by Design)
-KF-	PCTFE Stem Bearing
-MG-	Gear Operator with Standard Handwheel
-MH-	Gear Operator with Standard Handwheel & Locking Device
-MJ-	Gear Operator with Oversize Handwheel
-MK-	Gear Operator with Oversize Handwheel & Locking Device
-MP-	Positive Material Identification
-TC-	With Test Certificate
-TD-	Tested to API Spec 6D
-UA-	AIS (American Iron & Steel) Compliant
-UL-	UL & CSA Listed (with Markings)
-ZP1-	Fugitive Emissions Packing (Viton)
-ZP2-	Fugitive Emissions Packing (Buna-N)
-ZP3-	Fugitive Emissions Packing (Kalrez)

Pressure/Temperature Ratings - Page M-9, Graph No. 2

DIMENSIONS

PART NO.	SIZE	A	B	C	D	E	F	G
87A-20E-01	8"	8.00	18.00	8.88	12.83	9.18	1.00	10.22
87A-20G-01	10"	10.00	21.00	10.26	18.57	11.33	2.31	12.80
87A-20H-01	12"	12.00	24.00	12.09	20.31	13.40	2.31	14.92

REV. 18JUL19

FLOW DATA

FLOW DATA

The listed C_v "factors" are derived from actual flow testing, at Apollo's Pageland, South Carolina factory. These tests were completed using standard "off the shelf" valves with no special preparation and utilizing standard schedule 40 pipe. It should be understood that these factors are for the valve only and also include the connection configuration. The flow testing is done utilizing water as a fluid media and is a direct statement of the gallons of water flowed per minute with a 1 psig pressure differential across the valve/connection unit. Line pressure is not a factor. Because the C_v is a factor, the formula can be used to estimate flow of most media for valve sizing.

FLOW OF LIQUID

$$Q = C_V \sqrt{\frac{\Delta P}{SpGr}}$$

$$\text{or } \Delta P = \frac{(Q)^2\,(SpGr)}{(C_v)^2}$$

WHERE:

- Q = Flow in US gpm
- ΔP = Pressure drop (psig)
- SpGr = Specific gravity at flowing temperature
- C_v = Valve constant

FLOW OF GAS

$$Q = 1360\, C_V \sqrt{\frac{(\Delta P)\,(P_2)}{(SpGr)\,(T)}}$$

$$\text{or } \Delta P = \frac{5.4 \times 10^{-7}\,(SpGr)\,(T)\,(Q)^2}{(Cv)^2\,(P_2)}$$

WHERE:

- Q = Flow in SCFH
- ΔP = Pressure drop (psig)
- SpGr = Specific gravity (based on air = 1.0)
- P2 = Outlet pressure–psia (psig + 14.7)
- T = (temp. °F + 460)
- C_v = Valve constant

CAUTION: The gas equation shown, is valid at very low pressure drop ratios. The gas equation is NOT valid when the ratio of pressure drop (ΔP) to inlet pressure (P1) exceeds 0.02.

NOTE: Only use the gas equation shown if (P1-P2)/P1 is less than 0.02.

CV FACTORS FOR APOLLO VALVES (CONTINUED ON M-4)

VALVE	SIZE (IN.)													
	1/4	3/8	1/2	3/4	1	1.25	1.5	2	2.5	3	4	6	8	10	12
70B-140 Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
70-100/200 Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	---
70-300/400 Series	--	--	15	30	43	48	84	108	--	--	--	--	--	--	--
70-600 Series	2.3	4.5	5.4	12	14	21	34	47	--	--	--	--	--	--	--
70-800 Series	8.4	7.2	15	30	43	48	84	--	--	--	--	--	--	--	--
71-AR Series	--	--	--	30	43	48	84	108	190	370	--	--	--	--	--
71-100/200 Series	--	--	--	30	43	48	84	108	190	370	--	--	--	--	--
72-100/900 Series	--	--	26	48	65	125	170	216	--	--	--	--	--	--	--
72-1xx-A/72-9xx-A Series	--	--	26	48	65	125	170	245	--	--	--	--	--	--	--
73A-100 Series	8.4	7.2	15	30	43	48	84	108	--	--	--	--	--	--	--
73-300/400 Series	--	--	26	48	65	125	170	216	--	--	--	--	--	--	--
74-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
75-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
76-AR Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
76F-100 Series	8.1	15	15	51	68	125	177	389	--	--	--	--	--	--	--
76FJ-100 Series	8.1	15	15	51	68	125	177	389	--	--	--	--	--	--	--
76FK-100 Series	8.1	15	15	51	68	125	177	389	--	--	--	--	--	--	--
76-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
76-300/400 Series	--	--	26	48	65	125	170	216	--	--	--	--	--	--	--
76-600 Series	2.3	4.5	5.4	12	14	21	34	47	--	--	--	--	--	--	--
76J-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
76J-AR Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
76K-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
76K-AR Series	8.4	7.2	15	30	43	48	84	108	190	370	670	--	--	--	--
7K-100 Series	--	--	15	51	68	125	177	389	503	--	--	--	--	--	--
77-AR Series	8.1	15	15	51	68	--	177	389	--	--	--	--	--	--	--

REV. 21APR17

FLOW DATA
FOR APOLLO BALL VALVES

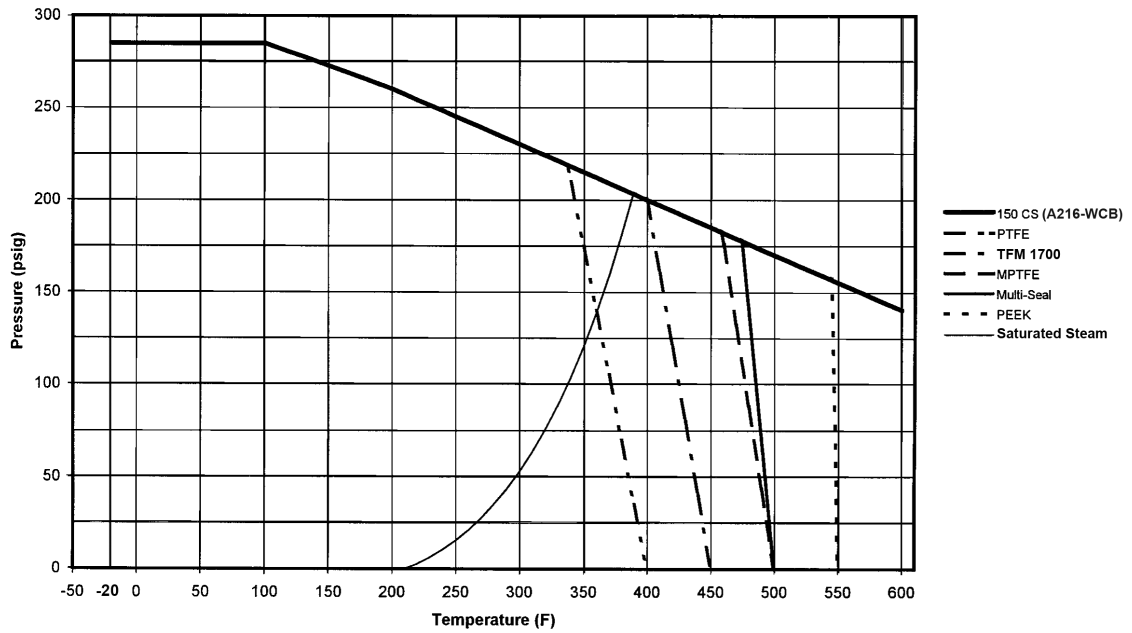
CV FACTORS FOR APOLLO VALVES (CONTINUED FROM M-3)

VALVE	SIZE (IN.)														
	1/4	3/8	1/2	3/4	1	1.25	1.5	2	2.5	3	4	6	8	10	12
77C-100/200 Series	4.5	7.2	16	36	68	125	177	389	503	--	--	--	--	--	--
77D-140 Series	4.5	7.2	16	36	68	125	177	389	--	--	--	--	--	--	--
77D-640 Series	--	--	--	11	24	35	--	--	--	--	--	--	--	--	--
77G-UL Series	4.5	7.2	16	36	68	125	177	389	503	--	--	--	--	--	--
77W Series	--	--	16	36	68	125	177	389	--	--	--	--	--	--	--
77-100/200 Series	8.1	15	15	51	68	125	177	389	503	--	--	--	--	--	--
79 Series	8.5	8.5	9.8	32	44	66	148	218	440	390	--	--	--	--	--
80 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
82-100/200 Series	8.1	14	26	51	68	120	170	376	510	996	1893	--	--	--	--
83A/83B Series	8.1	14	26	51	68	120	170	376	--	--	--	--	--	--	--
83R-100/200 Series	--	--	--	--	--	--	170	376	--	996	1893	--	--	--	--
86A/86B Series	8.1	14	26	51	68	120	170	376	--	--	--	--	--	--	--
86R-100/200 Series	--	--	--	--	--	--	170	376	--	996	1893	--	--	--	--
87A-100 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87A-200 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
87A-700 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87A-900 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
87A-F00 Series	--	--	--	--	75	--	195	410	545	1021	2016	4837	--	--	--
87B-100 Series	--	--	--	--	--	--	--	--	--	375	673	1099	1902	3890	--
87J-100 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87J-200 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
87J-700 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87J-900 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
87K-100 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87K-200 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
87K-700 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
87K-900 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
88A-100 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
88A-200 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
88A-700 Series	--	--	--	--	--	--	86	104	234	375	673	1099	1902	3890	--
88A-900 Series	--	--	15	19	75	--	195	410	545	1021	2016	4837	9250	15170	22390
88A-F00 Series	--	--	--	--	75	--	195	410	545	1021	2016	4837	--	--	--
88B-100 Series	--	--	--	--	--	--	--	--	--	375	673	1099	1902	3890	--
89-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
9A-100 Series	8.3	6.7	5.7	10	16	25	40	62	--	--	--	--	--	--	--
90-100 Series	8.3	6.7	5.7	10	16	25	40	62	--	--	--	--	--	--	--
92-100 Series	8.3	6.7	5.7	10	16	25	40	62	--	--	--	--	--	--	--
93-100 Series	8.3	6.7	5.7	10	16	25	40	62	--	--	--	--	--	--	--
94A-100/200 Series	6	7	19	34	50	104	268	309	629	1018	1622	--	--	--	--
96-100 Series	8.3	6.7	5.7	10	16	25	40	62	--	--	--	--	--	--	--
399-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--
489-100 Series	8.4	7.2	15	30	43	48	84	108	190	370	--	--	--	--	--

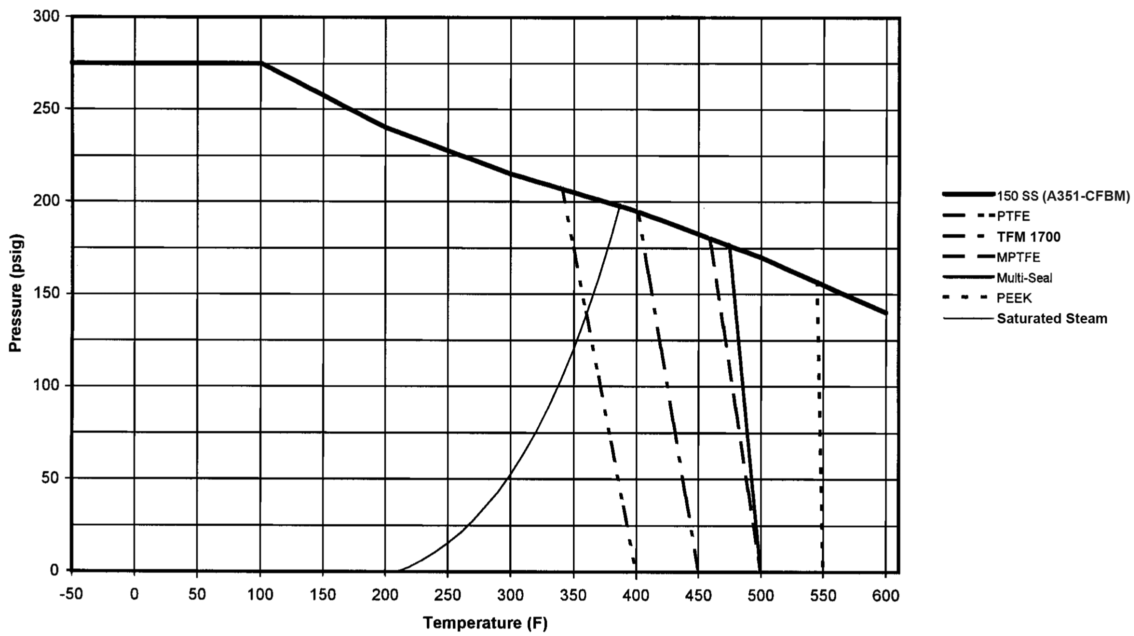
PRESSURE/TEMPERATURE RATINGS

ENGINEERING DATA

CLASS 150 (CS) ASTM A216-WCB GRAPH 1



CLASS 150 (SS) ASTM A351-CF8M GRAPH 2



OILS, FUEL: 5

OFV

CAUTIONARY RESPONSE INFORMATION

Common Synonyms			
No. 5 Residual fuel oil	Oily liquid	Dark	Strong lube oil odor
	Usually floats on water.		

Keep people away. Avoid contact with liquid.
Call fire department.
Notify local health and pollution control agencies.
Protect water intakes.

Fire	Combustible. Extinguish with dry chemical, foam or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.
Exposure	CALL FOR MEDICAL AID. LIQUID Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
Water Pollution	Effect of low concentrations on aquatic life is unknown. Fouling to shoreline. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.

1. CORRECTIVE RESPONSE ACTIONS

Stop discharge
Contain
Collection Systems: Skim
Chemical and Physical Treatment: Burn; Absorb
Clean shore line
Salvage waterfowl

2. CHEMICAL DESIGNATIONS

2.1 CG Compatibility Group: 33; Miscellaneous Hydrocarbon Mixtures
2.2 Formula: Not applicable
2.3 IMO/UN Designation: 3.3/1223
2.4 DOT ID No.: 1993
2.5 CAS Registry No.: Currently not available
2.6 NAERG Guide No.: 128
2.7 Standard Industrial Trade Classification: 33440

3. HEALTH HAZARDS

3.1 Personal Protective Equipment: Protective gloves; goggles or face shield.
3.2 Symptoms Following Exposure: INGESTION: gastrointestinal irritation. ASPIRATION: treatment probably not required; delayed development of pulmonary irritation can be detected by serial chest x-rays; consider prophylactic antibiotic regime if condition warrants. EYES: wash with copious quantity of water. SKIN: wipe off and wash with soap and water.
3.3 Treatment of Exposure: Currently not available
3.4 TLV-TWA: Notice of intended change: Not listed.
3.5 TLV-STEL: Not listed.
3.6 TLV-Ceiling: Not listed.
3.7 Toxicity by Ingestion: Grade 1; LD_{50} = 5 to 15 g/kg
3.8 Toxicity by Inhalation: Currently not available.
3.9 Chronic Toxicity: Currently not available
3.10 Vapor (Gas) Irritant Characteristics: None
3.11 Liquid or Solid Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
3.12 Odor Threshold: Currently not available
3.13 IDLH Value: Not listed.
3.14 OSHA PEL-TWA: Not listed.
3.15 OSHA PEL-STEL: Not listed.
3.16 OSHA PEL-Ceiling: Not listed.
3.17 EPA AEGL: Not listed

4. FIRE HAZARDS

4.1 Flash Point: >130°F C.C.
4.2 Flammable Limits in Air: 1%-5%
4.3 Fire Extinguishing Agents: Dry chemical, foam, or carbon dioxide
4.4 Fire Extinguishing Agents Not to Be Used: Water may be ineffective.
4.5 Special Hazards of Combustion Products: Not pertinent
4.6 Behavior in Fire: Not pertinent
4.7 Auto Ignition Temperature: Currently not available
4.8 Electrical Hazards: Not pertinent
4.9 Burning Rate: 4 mm/min.
4.10 Adiabatic Flame Temperature: Currently not available
4.11 Stoichometric Air to Fuel Ratio: Not pertinent.
4.12 Flame Temperature: Currently not available
4.13 Combustion Molar Ratio (Reactant to Product): Not pertinent.
4.14 Minimum Oxygen Concentration for Combustion (MOCC): Not listed

5. CHEMICAL REACTIVITY

5.1 Reactivity with Water: No reaction
5.2 Reactivity with Common Materials: No reaction
5.3 Stability During Transport: Stable
5.4 Neutralizing Agents for Acids and Caustics: Not pertinent
5.5 Polymerization: Not pertinent
5.6 Inhibitor of Polymerization: Not pertinent

6. WATER POLLUTION

6.1 Aquatic Toxicity: Currently not available
6.2 Waterfowl Toxicity: Currently not available
6.3 Biological Oxygen Demand (BOD): Currently not available
6.4 Food Chain Concentration Potential: None
6.5 GESAMP Hazard Profile: Not listed

7. SHIPPING INFORMATION

7.1 Grades of Purity: Fuel oil No. 5 (heavy); Fuel oil No. 5 (light)
7.2 Storage Temperature: Ambient
7.3 Inert Atmosphere: No requirement
7.4 Venting: Open (flame arrester)
7.5 IMO Pollution Category: Currently not available
7.6 Ship Type: Currently not available
7.7 Barge Hull Type: Currently not available

8. HAZARD CLASSIFICATIONS

8.1 49 CFR Category: Flammable liquid
8.2 49 CFR Class: 3
8.3 49 CFR Package Group: III
8.4 Marine Pollutant: No
8.5 NFPA Hazard Classification:

Category	Classification
Health Hazard (Blue)..........	0
Flammability (Red)............	2
Instability (Yellow)............	0

8.6 EPA Reportable Quantity: Not listed.
8.7 EPA Pollution Category: Not listed.
8.8 RCRA Waste Number: Not listed
8.9 EPA FWPCA List: Not listed

9. PHYSICAL & CHEMICAL PROPERTIES

9.1 Physical State at 15° C and 1 atm: Liquid
9.2 Molecular Weight: Not pertinent
9.3 Boiling Point at 1 atm: 426–>1062°F = 218–>570°C = 491–>843°K
9.4 Freezing Point: 0°F = –18°C = 255°K
9.5 Critical Temperature: Not pertinent
9.6 Critical Pressure: Not pertinent
9.7 Specific Gravity: 0.936 at 16°C (liquid)
9.8 Liquid Surface Tension: Currently not available
9.9 Liquid Water Interfacial Tension: Currently not available
9.10 Vapor (Gas) Specific Gravity: Not pertinent
9.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent
9.12 Latent Heat of Vaporization: Not pertinent
9.13 Heat of Combustion: –18,000 Btu/lb = –10,000 cal/g = -418.68×10^5 J/kg
9.14 Heat of Decomposition: Not pertinent
9.15 Heat of Solution: Not pertinent
9.16 Heat of Polymerization: Not pertinent
9.17 Heat of Fusion: Currently not available
9.18 Limiting Value: Currently not available
9.19 Reid Vapor Pressure: Currently not available

NOTES

9.20 SATURATED LIQUID DENSITY		9.21 LIQUID HEAT CAPACITY		9.22 LIQUID THERMAL CONDUCTIVITY		9.23 LIQUID VISCOSITY	
Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F	Temperature (degrees F)	British thermal unit inch per hour-square foot-F	Temperature (degrees F)	Centipoise
50	58.360	50	0.460	40	0.873	100	43.500
52	58.360	52	0.461	45	0.873		
54	58.360	54	0.462	50	0.873		
56	58.360	56	0.463	55	0.873		
58	58.360	58	0.464	60	0.873		
60	58.360	60	0.465	65	0.873		
62	58.360	62	0.466	70	0.873		
64	58.360	64	0.467	75	0.873		
66	58.360	66	0.468	80	0.873		
68	58.360	68	0.469	85	0.873		
70	58.360	70	0.470	90	0.873		
72	58.360	72	0.471	95	0.873		
74	58.360	74	0.472	100	0.873		
76	58.360	76	0.473	105	0.873		
78	58.360	78	0.474				
80	58.360	80	0.475				
82	58.360	82	0.476				
84	58.360	84	0.477				
		86	0.478				
		88	0.479				
		90	0.480				
		92	0.481				
		94	0.482				
		96	0.483				
		98	0.484				
		100	0.485				

9.24 SOLUBILITY IN WATER		9.25 SATURATED VAPOR PRESSURE		9.26 SATURATED VAPOR DENSITY		9.27 IDEAL GAS HEAT CAPACITY	
Temperature (degrees F)	Pounds per 100 pounds of water	Temperature (degrees F)	Pounds per square inch	Temperature (degrees F)	Pounds per cubic foot	Temperature (degrees F)	British thermal unit per pound-F
	INSOLUBLE	70	0.042		NOT PERTINENT		NOT PERTINENT
		75	0.049				
		80	0.057				
		85	0.065				
		90	0.076				
		95	0.087				
		100	0.100				
		105	0.114				
		110	0.131				
		115	0.149				
		120	0.170				
		125	0.193				
		130	0.218				
		135	0.247				
		140	0.279				
		145	0.314				
		150	0.352				
		155	0.395				
		160	0.443				
		165	0.495				
		170	0.552				
		175	0.615				
		180	0.683				
		185	0.758				
		190	0.841				
		195	0.930				

F: System Optimization Python Script

```
import math
import numpy as np
import time
import matplotlib
import matplotlib.pyplot as plt
import random
import pdb
import scipy.optimize as optimize
import scipy.integrate as integrate

# Set the font and font size to look nicer
matplotlib.rc('font', **{'family': 'serif', 'serif':['Times'], 'size':22})

# Allow the use of latex in plots
matplotlib.rc('text', usetex=True)

def cost(T_i_i, D_int_i, D_ext_i, t_ins_i, p_cost_i, i_cost_i, verbose=False):
    # Global constants
    g = 9.81 # m/s^2
    in_to_m = 0.0254 # m/in
    ft_to_m = 0.3048 # m/ft
    C_to_K = 273.15
    hr_to_sec = 60 * 60 # s/hr
    w_to_hp = 0.001341 # hp/W
    cp_to_m_s = 1e-6 # m^2/s/cp

    # Oil properties
    k_fluid = 0.16 # W/m K
    c_p = 2000 # J/kg K
    rho = 930 # kg/m^3

    # Oil viscosity coefficients
    A = 8.214
    B = 3.178
    lam = 0.7

    # System geometry
    D_int = D_int_i * in_to_m # m
```

```
D_ext = D_ext_i * in_to_m # m
t_ins = t_ins_i * in_to_m # m
L = 150 # m
dz = 13 # m

# System efficiencies
eta_p = 0.6

# Flow properties
V_dot = 4e-4 # m^3/s
m_dot = V_dot * rho
V = V_dot / (math.pi/4 * D_int**2)

# Known temperatures
T_inf = 15 + C_to_K # K
T_i = T_i_i + C_to_K # K
T_f = 70 + C_to_K # K
T_oil = 25 + C_to_K # K

# Thermal properties
k_ins = 0.08 # W/m K
h_ext = 30 # W/m^2 K
NuD = 3.66
h_int = k_fluid / D_int * NuD
if t_ins > 0:
    h_ins = k_ins / t_ins
    U = 1/(1/h_ext + (D_ext+2*t_ins)/(h_int*D_int) + 1/h_ins)
else:
    U = 1/(1/h_ext + (D_ext+2*t_ins)/(h_int*D_int))

# Quantities that vary along x
x = np.linspace(0, L, L*1000)
T = (lambda x: np.exp(-math.pi*(D_ext+t_ins*2)*x*U/(m_dot*c_p)) \
    * (T_i - T_inf) + T_inf)(x)
nu = (lambda T: np.power(10, np.power(10, A) \
    * np.power(T, -B)) - lam)(T) * cp_to_m_s
Re = V*D_int/nu
f = 64/Re
```

```
# Calculated heat transfer
w_heat_i = (T_i - T_oil) * m_dot * c_p
w_heat_f = 0
if T[-1] < T_f:
    w_heat_f = (T_f - T[-1]) * m_dot * c_p

# Integrated quantities
h_L = V**2/(2*g*D_int) * integrate.simps(f, x)
h_m = V**2/(2*g) * (6 * 0.425 + 0.5 + 1.0)
h_V = (2 * 46 + 34474) / (rho * g)
h_P = h_L + dz + h_m + h_V
w_pump = h_P * m_dot * g

# Econ constants
pipe_cost = p_cost_i / ft_to_m # usd/m
ins_cost = i_cost_i / ft_to_m # usd/m
operation = 8000 * hr_to_sec # s/yr
elec_cost = 0.12 / 1000 / hr_to_sec # usd/J
interest = 0.08 # annually
lifetime = 10 # years
A_to_P = ((1 + interest)**lifetime - 1) / (interest * (1 + interest)**lifetime)

# Costs
material = (pipe_cost + ins_cost) * L
install = material * 2
pump_cost = 9500*np.power(w_pump * w_to_hp / 100, 0.58)
electric = (w_pump / eta_p + w_heat_i + w_heat_f) * operation * elec_cost
e_PV = A_to_P * electric

if verbose:
    print("Pipe cost is $%.2f" % (pipe_cost * L))
    print("Insulation cost is $%.2f" % (ins_cost * L))
    print("Material cost is $%.2f" % material)
    print("Installation cost is $%.2f" % install)
    print("Pump cost is $%.2f" % pump_cost)
    print("Pump electricity cost is $%.2f per year" % (w_pump / eta_p \
        * operation * elec_cost))
    print("Heating electricity cost is $%.2f per year" % ((w_heat_i + w_heat_f) \
        * operation * elec_cost))
```

```
        print("Electricity cost is $%.2f per year" % electric)
        print("Electricity present value is $%.2f" % e_PV)
        pdb.set_trace()

    return material + install + pump_cost + e_PV

def approx_from_OD(T, OD, ins, verbose=False):
    t = 1/8 if OD < 3 else 3/16
    ID = OD - t
    p_cost = 100 * (OD**2 - ID**2)
    i_cost = .25 * ((OD + ins)**2 - OD**2)
    i_cost = 1.6 if i_cost < 1.6 else i_cost
    return cost(T, ID, OD, ins, p_cost, i_cost, verbose)

T = np.linspace(40, 60, 1e2)
D = np.array([.5, 1, 1.5, 2])
s = np.array(np.meshgrid(T, D)).T.reshape(-1,2)

start = time.time()
c = np.vectorize(lambda t, d: approx_from_OD(t, d, 1.0))(*s.T)
i = c.argmin()

# Output
print("Calcaulted in %.0f seconds" % (time.time()-start))
print("Minimum cost is $%.0f" % c[i])
print("For T_i = %.4f C, D = %.1f in" % (s[i,0], s[i,1]))

# Make a new figure
plt.figure(figsize=(15,8))

# Plot colors
plt.contourf(D, T, c.reshape(len(T), len(D)), 50, cmap="gist_rainbow_r", \
    antialiased=False)

# Axis labels
plt.xlabel(r"$D$ (in)")
plt.ylabel(r"$T_i$ ($^\circ$C)")

# Axis limits
```

```
plt.axis([.5, 2, 40, 60])

# Show plot
plt.show()

T = np.linspace(40, 60, 1e2)
D = np.array([.5, 1, 1.5, 2])
s = np.array(np.meshgrid(T, D)).T.reshape(-1,2)

start = time.time()
c = np.vectorize(lambda t, d: approx_from_OD(t, d, 1.5))(*s.T)
i = c.argmin()

# Output
print("Calcaulted in %.0f seconds" % (time.time()-start))
print("Minimum cost is $%.0f" % c[i])
print("For T_i = %.4f C, D = %.1f in" % (s[i,0], s[i,1]))

# Make a new figure
plt.figure(figsize=(15,8))

# Plot colors
plt.contourf(D, T, c.reshape(len(T), len(D)), 50, cmap="gist_rainbow_r",
    antialiased=False)

# Axis labels
plt.xlabel(r"$D$ (in)")
plt.ylabel(r"$T_i$ ($^\circ$C)")

# Axis limits
plt.axis([.5, 2, 40, 60])

# Show plot
plt.show()

T = np.linspace(40, 60, 1e2)
D = np.array([.5, 1, 1.5, 2])
s = np.array(np.meshgrid(T, D)).T.reshape(-1,2)
```

```
start = time.time()
c = np.vectorize(lambda t, d: approx_from_OD(t, d, 2.0))(*s.T)
i = c.argmin()

# Output
print("Calcaulted in %.0f seconds" % (time.time()-start))
print("Minimum cost is $%.0f" % c[i])
print("For T_i = %.4f C, D = %.1f in" % (s[i,0], s[i,1]))

# Make a new figure
plt.figure(figsize=(15,8))

# Plot colors
plt.contourf(D, T, c.reshape(len(T), len(D)), 50, cmap="gist_rainbow_r", \
    antialiased=False)

# Axis labels
plt.xlabel(r"$D$ (in)")
plt.ylabel(r"$T_i$ ($^\circ$C)")

# Axis limits
plt.axis([.5, 2, 40, 60])

# Show plot
plt.show()

print("Total cost is %.2f" % approx_from_OD(40, 1, 1.5, True))

T = np.linspace(25, 120, 1e3)
D = 1

start = time.time()
c = np.vectorize(lambda t: approx_from_OD(t, D, 1.5))(T)
print("Calcaulted in %.0f seconds" % (time.time()-start))

# Make a new figure
plt.figure(figsize=(15,8))

# Plot colors
```

```python
plt.plot(T, c/1000, "k")
plt.plot((40, 40), (1e2, 1e3), "--k")
plt.plot((90, 90), (1e2, 1e3), "--k")

# Axis labels
plt.xlabel(r"$T_i$ ($^\circ$C)")
plt.ylabel(r"Cost (thousands of USD)")

# Axis limits
plt.axis([25, 120, 350, 500])

# Show plot
plt.show()
```