# Diesel Pump Tester Resource Manual

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By

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## This Manual was developed with funding provided by Valley CAN

Valley CAN (Valley - Clean Air Now)

Valley CAN is a non-profit advocacy group committed to improving air quality in communities throughout the San Joaquin Valley of California. As a part of its purpose, Valley CAN will:

- Serve as a leader in educating the public in the need to take personal responsibility for the reduction of air pollution.
- Promote voluntary actions to reduce air pollution by individuals, government, agriculture, business and industry.
- Seek to initiate and publicize creative new approaches to reduce air pollution.
- Sponsor pilot programs and educational efforts dedicated to providing solutions to high emissions sources.

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**The Center for Irrigation Technology**

The Center for Irrigation Technology (CIT) is part of the College of Agricultural Sciences and Technology on the campus at California State University, Fresno. CIT performs independent hydraulic testing of various irrigation system components including pumps, sprinklers, drip emitters, backflow preventers, and various types of valves.

CIT also performs applied research in areas such as turf water use, use of electromagnetic inductance techniques for salinity mapping and seepage analysis, and nitrate emissions from dairy waste lagoons.

CIT developed and implemented the Agricultural Peak Load Reduction Program (APLRP) from 2001 – 2003 with funding from the general tax fund under legislation popularly known as SB 5x (passed during the energy crisis). It also developed and implemented the Agricultural Pumping Efficiency Program (APEP) from 2002 – 2008 with funding from the California Public Utilities Commission (see www.pumpefficiency.org).

CIT also developed and maintains a multi-state irrigation scheduling web site, www.wateright.org. Turf, homeowners, and commercial growers can get real time irrigation schedules for their plants and crops. The web site also hosts an extensive water and energy management knowledge base.

In addition to this Manual, CIT implemented two pilot-level programs for diesel-powered pumping efficiency with funding from the US Environmental Protection Agency and Valley CAN.

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## Contents of this Manual

## I. Objective of this Package

The objective of this manual is to promote diesel-powered pump testing in California. This package assembles the latest methodology, procedures, reference materials and software available to successfully and accurately test a diesel-powered pump. This package is not meant to create or redefine any existing or proposed standard for pump testing, under either laboratory or field conditions. Additionally, it assumes that the reader is familiar with standard field test methods for electric-powered pumps. Appendix 4 is included as a reference for these methods.

## II. Importance of Diesel-Powered Irrigation Pumping in California

Diesel-powered pumps (hereafter termed "diesel pumps") compose a significant proportion of large pumps in California agriculture. According to the California Air Resources Board (CARB, 2006), there are an approximately 12,535 diesel irrigation pumps statewide, with an estimated 8,700 well pumps and 3,800 portable booster pumps. The average engine size in the San Joaquin Valley is about 195 nameplate horsepower, and with an estimated 75% load factor, the connected load is about 145 brake horsepower (BHP). In comparison, a 1994 study of electric-powered pumps (hereafter termed "electric pumps") found approximately 22,000 electric pumps in PG&E and SCE that were 50 horsepower (HP) and above (Solomon and Zoldoske, 1994). An assumption is made that electric horsepower sizes of 50 HP and above most closely approximate the diesel engine pump population. A 50 HP electric motor pump would normally require a diesel engine rated at 70 to 80 brake horsepower. Statewide, a rough estimate of the current (2007) inventory for all pumps electric and engine (diesel or natural gas-powered) is that there are 35,000 to 45,000 irrigation pumps of 50 BHP and larger, and that diesel drivers compose approximately 10,000 to 13,000 pumps, or about one third of the population in this size category.

Given the scope of energy usage by diesel irrigation pumps, their importance to agriculture in California, and their impact on air quality, it is reasonable to assume that maintenance of diesel pump efficiency would be a priority to the state and its residents. CIT, with the help of Valley CAN and the United States Environmental Protection Agency (USEPA), has offered a pilot program of testing and retrofit incentives targeting this group. The results of this program have encouraged transition to a second phase effort of developing the test software, methodology, and resource manual that will help expand professional testing services for these pumps.

## III. The Diesel Pumping Efficiency Program

The Diesel Pumping Efficiency Program (DPEP) was developed and implemented by the Center for Irrigation Technology at California State University, Fresno. DPEP is a multi-purpose program in that it addresses four major resource management issues in California today:

- Air Quality
- Energy Conservation
- Water Conservation
- Water Quality

DPEP operated as a pilot-level program in 2005 and 2006 with funding from the USEPA and Valley CAN. The goal of DPEP is to improve the efficiency of diesel-powered pumping plants and their management. An improvement in the pumping plant's efficiency results in a direct decrease in fuel consumption and emissions per gallon of water pumped. Also, all things being equal, if management is improved, the required amount of pumping is minimized.

The DPEP consisted of three basic elements -- pump testing, pump retrofit incentives and education. These elements provided farmers and managers with the information and financial incentives needed to improve and maintain optimum performance of their equipment.

## IV. Current Pump Testing in California

Electric pump testing is a well-established service in California, although since the late 1990's it has not received consistent user supported funding outside of the SCE service area. Tests are performed by one of four groups: electric and natural gas utilities, pump repair companies, private consultants, and public service extension agents.

Significant training is required for a tester to be qualified, although there is not yet a definitive standard for coursework or competence. Traditionally, it has been the electric utilities that developed and implemented training programs for their internal use. Basic training and a written examination have also been offered by Cal Poly San Luis Obispo at their Irrigation Training and Research Center (ITRC- current information can be found at www.itrc.org). In absence of a professional pump tester certification, the Center for Irrigation Technology (CIT) has adopted the following minimum levels for potential testers:

### Minimum Experience Requirements

*"At a minimum, Potential Testers must show that they are either:*

- *A former or current employee of an investor-owned or municipal utility, who is testing (did test) agricultural pumps for efficiency as a matter of normal duties*
- *A former or current employee of a pump repair/installation company that has been in business for at least 5 years, who is testing (did test) agricultural pumps for efficiency as a matter of normal duties*
- *A former or current employee (or owner) of a company whose business was (is) testing agricultural pumps for efficiency and who does (did) so on behalf of this company as a matter of normal duties*
- *On request, the applicant can show that they have tested at least 75 agricultural pumps (40 of which were water wells). Evidence could include submittal of pump test reports."*

## V. Efficiency and Pumping

Efficiency is defined in mathematical terms as the ratio of the equipment's output energy to the equipment's input energy. The output and input must be in the same measurement units (eg, horsepower, or kilowatts, etc.). In pump testing, horsepower is the unit used. Various designations may be used to describe the horsepower measurement, for example:

**V.1 Input Horsepower** (IHP) is a term expressing the energy potential of a fuel source, such as cubic feet of natural gas, gallons of diesel fuel, or kilowatts of electricity. Fuel energy values are described by their BTU (British Thermal Unit is defined as the amount of thermal energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit at sea level) content per volume measurement. For example, a gallon of diesel fuel might have a rating of 138,700 BTU per gallon. The horsepower value is a conversion of the BTU content over time, for example, 1 horsepower = 2547 BTU per hour. Thus, a diesel engine that consumes 5 gallons of fuel with a BTU value of 138,700, has an input horsepower (IHP) of 272 HP:

IHP = 5 gallons per hour x 138,700 BTU per gal / 2547 BTU per hr = 272 IHP

IHP may also be called "Thermal Horsepower" which descriptively avoids some of the confusion. Note the relationship of 1 gph diesel to 54.4 IHP, and the relationship described below in the summary of 1 gph diesel to 20 BHP.

**V.2 Brake Horsepower** (BHP) is the mechanical, rotating energy resulting from the conversion of the fuel source. It may be specified as to its location—for example, BHP developed by the engine or electric motor; or BHP delivered to the pump bowls. It is important to know the exact reference point. Manufacturers specify these numbers in order to rate their equipment. For example, a gear head might be rated for 100 BHP, or a pump end might require 82 BHP at its design rpm and operating conditions. These horsepower ratings or requirements will not be the same BHP required to be delivered from an electric motor or from an engine.

Brake horsepower is used to perform a cost analysis, to estimate new pump loading, and to estimate an OPE for the retrofitted pump. It is also critical information for determining projected load when conversion to an electric motor drive is under consideration.

For an engine, the engine nameplate HP is generally the maximum brake horsepower developed by the engine at the flywheel. The rating may be given as either an intermittent or continuous horsepower rating. The rating will usually be specified at a certain rpm. It may or may not include certain ancillary loads attached to the engine, such as a fan, engine water pump, muffler, or emission catalyst. The exact meaning of the nameplate horsepower may require examination of the engine manufacturer's specification sheet (also called, "cut sheet"). Engine cut sheets for new engines can often be downloaded from the internet. A CD is included with this manual that contains specifications for many of the engines commonly found in the Fresno area.

**V.3 Water Horsepower** (WHP) is the energy transferred to the water from the rotating pump. It is transferred in terms of water flow rate, pressure or total dynamic head (TDH), and velocity head. Velocity head is usually ignored in a field test for pumps, although it can make up a significant portion (~10 %) of the TDH for low lift pumps, and in pumps with a large difference between the suction and discharge sizes (Volk, 1996 pp 54-55). Friction loss components of TDH are also ignored here, due to difficulties in knowing the presence/absence of screens, pump setting depths, and sizes and conditions of column pipe and tubes.

**In summary**, the equations and relationships for OPE, IHP, BHP, and WHP follow:

Overall pumping plant efficiency (OPE) is defined as:

$$OPE = 100 \times WHP / IHP \qquad [1]$$

Where:
OPE = overall pumping plant efficiency as a percent
WHP = water horsepower output from the pumping plant
IHP = power input to the pumping plant as the energy potential of the fuel

And:

$$WHP = Q \times TDH / 3960 \qquad [2]$$

Where:
WHP = water horsepower output from the pumping plant
Q = flow in gallons per minute from the pump
TDH = total measured dynamic head in feet developed by the pumping plant

And:

IHP = gallons per hour fuel flow x BTU value per gallon** / 2547 BTU per HP [3]

Recall that BHP does not enter into the efficiency equations. A rough approximation of BHP is made by using the rule of thumb; 1 gallon of diesel fuel is equal to 20 BHP. Note that this would assume an engine efficiency of approximately 36.8% (20 BHP / 54.4 IHP per gallon = 0.368). An expanded discussion of BHP is found below.

**Standard diesel is 130,000 BTUs per gallon. However, California regulations through 2005 required special low aromatic diesel formulations—most of these formulations used cetane number additives that increased BTU content (Chevron, 1998). With 2007 mandates for ultra-low sulfur diesel formulations in place, one Fresno area petroleum vendor serving the ag diesel market is selling the new diesel formulation with a BTU content of 129,500 (John Bryant, personal communication). When possible, actual BTU contents should be obtained.

**Example problem**:  A diesel irrigation pump consumes 5 gallons of fuel per hour, and produces 1,200 gpm with a total measured head of 200 feet.  The BTU content of the fuel is 129,500.   Find the OPE of the unit.

Step 1:  Determine input horsepower (IHP).  Use equation [3]:

IHP = 5 GPH diesel x 129,500 BTU per gal / 2547 BTU per HP = 254 IHP

Step 2:  Determine the water horsepower (WHP).  Use equation [2]

WHP = 1,200 gpm x 200’ / 3960 = 60.6 WHP.

Step 3: Determine the OPE of the unit.  Use equation [1]

OPE = 100 x WHP / IHP = 60.6 WHP / 254 IHP = 23.9%

## VI. Field Pump Testing, Methods and Equipment

Field pump tests establish the actual operating characteristics of the pump in its environment. Laboratory tests share some similarities with field pump tests, but are different in many ways.

Laboratory tests are conducted in a controlled environment with prescribed hydraulic, mechanical and electrical equipment. The tests are carefully controlled and all test equipment meets prescribed standards. Normally, only the bowl assembly of a turbine type pump is tested for operating characteristics (Hydraulic Institute, 2000). All other conditions such as column losses and motor efficiencies are calculated or calibrated as needed. The results of the test are normally plotted and presented as a head-capacity curve with additional curves for brake horsepower (BHP), pump efficiency, and net positive suction head (NPSH).

Field tests are conducted with the same care but under conditions present in the field. The test technician is faced with the limitations of the installed equipment configuration. This may include the lack of unobstructed flow test sections of the prescribed length, poorly placed pressure measuring ports, cascading water in wells, gasses in the discharge flow, vortexes at the pump inlet, and difficulties in obtaining a suitable location to measure power input. Sometimes a field test can not be made with acceptable accuracy. One common barrier is the lack of a well sounding tube or well entrance which prevents the measurement of standing and pumping water levels.

The limitations of laboratory and field tests must be understood. A laboratory test certifies the performance of the pump bowls as assembled for a specific condition. The efficiency shown is ***pump efficiency*** (also referred to as bowl efficiency or impeller efficiency), which normally excludes the driver and any other influence. Hydraulic Institute Test Procedures specify that a minimum number of seven test points are required, per given electric motor pump speed.

A field test considers the entire pump installation, including the driver (engine or electric) and any equipment upstream of the pressure check point, such as inlet strainers and check valves. The overall plant efficiency will always be lower than pump efficiency. Field tests may not have an option of varying the pump discharge conditions, or operating rotations per minute (RPM). Field tests should be conducted in accordance with H.I. test procedures to the fullest extent possible.

With a diesel pump, we recommend that three different test RPMs be used—standard operating condition and RPM, 1775 RPM pump shaft, and an RPM that is either higher, or lower than, the 1775 RPM test, depending on the standard operating condition. As an example, on a gear head at 1 to 1 ratio, standard engine operating and pump shaft RPM might be 1780. Suggested test speeds could be 1700 RPM, 1780 RPM, and 1850 RPM. However, the pump tester must exercise discretion and caution when changing operating RPMs, as it can be hazardous to people and dangerous to equipment. Accelerating equipment significantly beyond its designed operating condition can be unsafe and unwise.

## VII. Measure Power Input (Fuel Flow)

Fuel consumption by an engine can be quantified using volumetric or weight measurements over time. Flow meters are a safer and more convenient method. In some modern engines with computerized controls, direct readouts can be obtained using a laptop computer or handheld electronic device and appropriate software. This method is not discussed here.

Measuring fuel flow with a meter requires inserting a measurement device between the supply tank and the engine. When fittings or hoses are disconnected, this can introduce air into the fuel system. Diesel engines can experience starting or running problems if air is present in the fuel. Great care must be taken to fully bleed all air introduced into the system during the process. A priming pump should be incorporated into the measuring system.

A diesel engine has a fuel supply line and a fuel return line. The fuel flow rate in the return line is designed by the engine manufacturer to adequately meet cooling requirements for the injectors under all operating conditions. Fuel returned will be warmer than the fuel supply. The manufacturers also provide specifications on how much distance is required before the return fuel can be looped back into the supply line, or whether this fuel must be returned to the fuel tank itself.

Lee (personal communication) developed a fuel flow meter apparatus. This meter measures all fuel coming in from the supply line. Downstream of the meter, a 3-way valve is installed. Actuating this valve allows the return fuel to be routed back to the main tank (normal condition), or mixed in to the fuel going to the engine (test condition) (see Appendix 1). The heart of the system is a Neptune Actaris VLF Flowmeter (mention of this brand does not imply endorsement). Figure 1 is an example of the finished product.

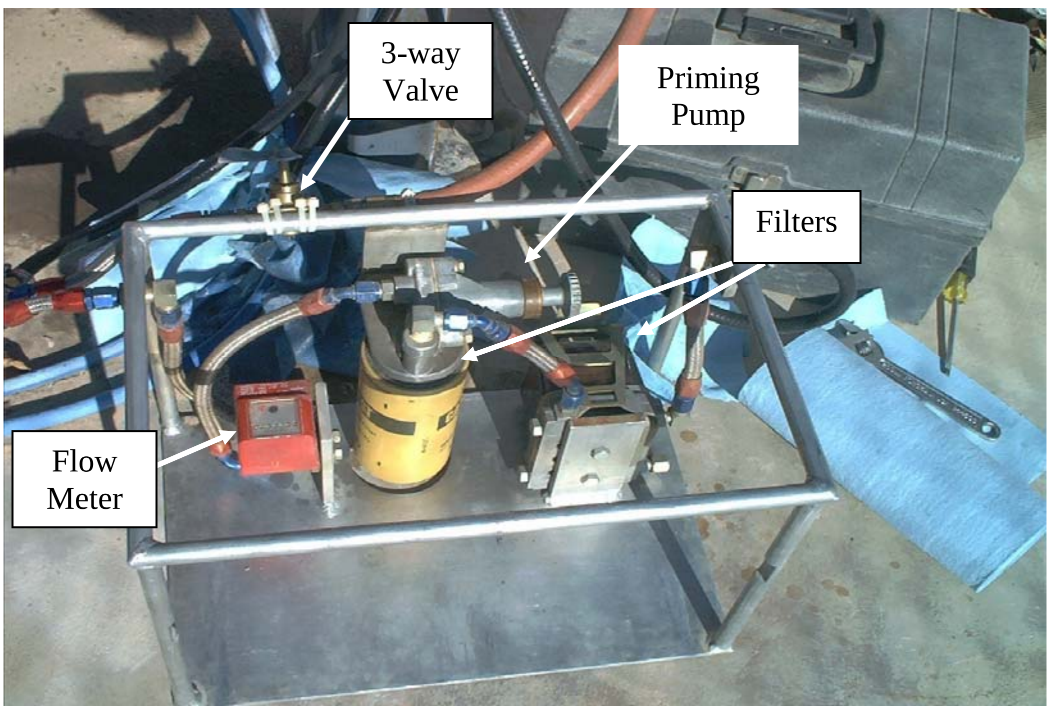


**Figure 1, Pump Check's Fuel Flow Meter**

In addition to the meter itself, the system includes filtration and water separation (to protect the meter, as well as provide additional protection to the engine), a priming pump to aid in air removal, a 3-way valve, and hoses and fittings to accommodate different situations in the field. The assortment of fittings needs to be extensive, as there is not a standard situation in the field. Some installations use simple fuel line and barb fittings, while others use custom hydraulic hose or rigid pipe.

**Figure 2, Hydraulic Fuel Line and Fittings. Note looping of return line at this point.**


**Figure 3, This engine has the return line and supply line looped at the engine. Not recommended by the engine manufacturer as there is not adequate cooling of the fuel before returning to the injectors.**

The Neptune flow meter arrangement is recommended over volumetric or weight measurement methods because of accuracy and safety. The measurement accuracy is within 1% at the 0.01 gallon unit level. It is recommended that 20 complete sweeps (0.20 gallons) be measured. Typically, this represents about 2 to 5 minutes measurement time. During this time, the return flow is recycled downstream of the meter using the 3-way valve and no noticeable temperature rise in the fuel has been observed.

The Neptune meter must be sized adequately to handle both the return flow and consumed flow. Since return flow requirements vary, it is recommended that the VLF8 be selected as it may be possible that the combined flow rate exceeds the 20 gallon per hour rate limit of the smaller VLF4. (Note that 20 gph would be the consumption level for a 400 HP engine—however, with the return flow requirement the test meter on this engine would need to handle more than 20 gph, possibly as much as 40 gph). On the low end, the VLF8 will accurately measure fuel rates to engines with a load of about 20 BHP (about 30 nameplate HP and above).

The Neptune meter, VLF-8 (without pulser) is available in California from the R F MacDonald Company in Hayward, CA. (510) 784-0110. The meter retails for about $600 (2006 pricing, including tax and shipping). Additional equipment (filters, priming pump, 3-way valve, hydraulic hose and fabrication, miscellaneous fittings, and the support frame) total approximately $500 to $1,000 depending on how it is assembled, quality of materials, etc. The total cost runs from $1,000 for self-assembled, to perhaps $2,000 for a custom-ordered unit.

Once fuel flow rate has been measured, it is converted into gallons per hour using the equation:

Gallons per hour = # gallons per revolution x number of revs x 3600 / # of seconds

## VIII. Calculation/Estimate of Brake Horsepower Delivered by the Engine

Brake horsepower estimates are important for several reasons:

- They allow an estimate of current engine load
- They allow the proper load to be determined for a new pump - once proper load is known, it then determines design water flow rate of the new pump
- They allow an estimated electric motor OPE for comparison

As indicated earlier, the brake horsepower output of an engine can be roughly estimated using the 1 gallon per hour for each 20 BHP output. This assumes an engine efficiency of about 36.8% (20 BHP/54.4 IHP per gallon x 100). Actual engine efficiency varies from 25% to 37% (New, 1986). Note the large range of possible efficiencies for engines. Various factors that influence engine efficiency include the engine design, loading, RPM, wear, and maintenance. Other factors that affect horsepower output, but that are not part of the engine's efficiency, are fuel BTU value, ambient temperatures, ancillary equipment, and emissions and noise control systems.

Since there is such a large range in possible engine efficiencies, our approach is to separate out the various factors and then calculate a brake horsepower delivered to the pump shaft at the connection to the gearhead.  The pump shaft point is chosen because it represents the same horsepower that would be delivered by an electric motor at standard shaft speed.  In performing this calculation, some information is generally available, and some needs to be estimated.  The information that is generally available is 1) the visible accounting of various parasitic loads connected to the motor, termed “ancillary equipment”; and 2) the brake specific fuel consumption of the engine at various RPM.

**VIII.1 Engine nameplates and nomenclature basics**.  Brake horsepower is the mechanical energy converted by the engine from a gallon of fuel.  “Ancillary equipment” such as a fan, engine water pump, alternator, and muffler, may or may not be included in the manufacturer’s rating.  Brake horsepower is also the unit of power rated by the manufacturer for the engine.  The rated horsepower is a function of engine RPM, altitude, and ambient temperature.  It may be provided as an “intermittent” maximum horsepower, or as “continuous” maximum horsepower.  In the case of Caterpillar, the distinction between intermittent and continuous horsepower may be designated by a letter code such as an “A” engine, or “B” engine (Caterpillar, 2002).  The engine’s nameplate will typically provide the engine’s brake horsepower, for example from the nameplate below, “96 BHP at 2150 engine RPM”.   If the ratings are not clear on the nameplate, additional information should be sought from the engine vendor or manufacturer.

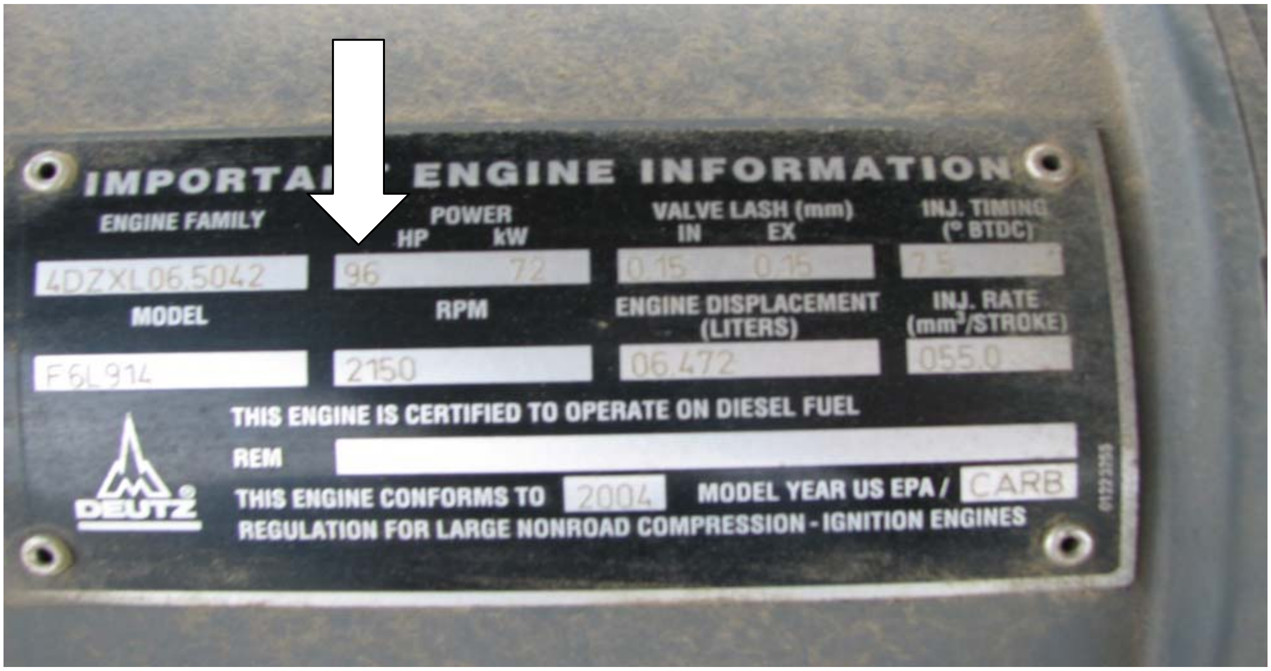


**Figure 4**, **This engine is rated for a “continuous” horsepower of 96 BHP at 2150 RPM at 68 degrees ambient, according to the engine data sheet.  Under hot conditions (90+ degrees F), the maximum load placed on the engine should be about 75% of the engine’s horsepower rating at the desired RPM (Tom Harris, personal communication).  Actual conditions before a pump repair were measured at 80 BHP at 1940 RPM with an 11:10 ratio gearhead.  After the pump repair, the engine was loaded at 73 BHP at 1760 RPM with a 1:1 ratio gearhead.  Holcomb and Sons considered this engine to be “overloaded” and likely to experience a reduced operating life.**

**VIII.2 Concept of Brake Specific Fuel Consumption (BSFC)**. The procedure for determining brake horsepower generated by the engine involves the use of the manufacturer's brake specific fuel consumption curve (BSFC). BSFC can usually be obtained from the manufacturer, and is provided for the engine model in terms of pounds of fuel per BHP-hr, or Grams/KW-hr, across a range of engine RPM. Note that power ratings (both continuous and intermittent) also change with engine RPM. An example of a manufacturer's fuel consumption curve is provided in Appendix 5.

Fuel consumption per brake horsepower is not constant for any given engine RPM with respect to load. This information is generally not provided by the manufacturer and may not be available in any form. As the only available choice, consumption data for a fully loaded engine is used to determine brake horsepower. Lee (2004) cites University of Nebraska findings of increased fuel consumption at 50% load of from 6% to 20%. Since this component can vary depending on the engine, it is recommended to use the manufacturer's full load BSFC values, with the understanding that the actual BHP is some undetermined value lower. More typical loads of about 75% should produce a variance of about half that amount (3% to 10%).

Many manufacturers will use premium diesel fuel when the BSFC curves are developed. Should the actual fuel burned in the field be standard diesel with a BTU content of 130,000, the BHP output by the engine will be overestimated by about 6%. (1- 130,000/138,700) x 100 = 6%. Should the manufacturer not specify BTU content on their cut sheet, a quick check can be made by estimating engine efficiency (see example problem below).

The manufacturer BSFC values may or may not include engine accessories such as cooling systems (air fans, water pumps), alternator, and muffler. The suggested "ancillary equipment" losses, and drive train/gear head losses are reported by Lee (2004):

**Table 1: Power Requirement of Ancillary Equipment (Lee, 2004)**

| | |
|---|---|
| Engine cooling system fan and water pump | 5 % |
| Drive train/gear head | 5 % |
| Muffler | 2.5 % |
| Alternator | 1.0 % |

Note that some of this equipment's affect on power transmission is in "parallel", and some is in "series". The parallel equipment is attached to the engine itself (e.g., cooling system, muffler, alternator). The series equipment is part of the transmission network (e.g., engine drive shaft and gear head). Parallel equipment losses are added together then subtracted from the engine. For example, an engine with a water pump, fan, alternator, and muffler will have a loss of 5% + 2.5% + 1.0% for a total ancillary equipment loss of 8.5% In this case, the ancillary equipment losses are added together, and then multiplied by the brake horsepower to determine the horsepower portion delivered to the driveshaft. Thus, an engine that generates 100 brake horsepower, would supply (1.0-0.085) x 100 BHP = 91.5 BHP to the drive shaft.

Equipment in series has a multiplication affect on efficiency. For example, a series calculation for determining the OPE of the pump would be as follows:

30% engine efficiency x 95% gearhead x 70% pump = 20.0% OPE.

Equipment loss calculations are automatically handled by the software.

**Example Problem**:

**Given**: An engine consumes 10 gallons of diesel per hour at 1620 RPM. The weight of diesel fuel is 7.05 pounds per gallon. The engine is a Cummins water cooled engine model QSC, with a heat exchanger in the pump discharge, a fan for the turbo intercooler, an alternator, and a muffler. The power is transmitted through a right angle gear drive that has a ratio of 10:11. The pump shaft speed is 1780 RPM. The nameplate horsepower is listed as 300 hp. The specific gravity of diesel fuel is 7.05 pounds per gallon. Fuel BTU content is not known.

**Find**: Use the manufacturer's brake specific fuel consumption curve to determine brake horsepower developed by the engine. Then estimate how much brake horsepower is transmitted to the pump line shaft. Determine the load factor of the engine at 1620 RPM.

**Solution:**

Step 1) Look up the manufacturer's brake specific fuel consumption for 1620 RPM, using the curve provided in Appendix 5. No listing is given for 1620 RPM, but at 1600 RPM, the consumption is 0.358 pounds of fuel per horsepower hour. Use this value. Note that the fuel is specified as Diesel Fuel # 2, but no BTU content is given. A quick check of the engine efficiency should be done.

Step 2) Since diesel fuel weighs 7.05 lbs per gallon, the brake horsepower produced by the engine is:

10 gallon per hour / (0.358 lbs/hp-hr) x 7.05 lbs per gallon = 196.8 BHP

Next, do a quick check of this number to decide whether the BTU content is for premium diesel, or standard:

If premium, IHP = 10 GPH x 138,700 BTU per gal / 2547 BTU per hr = 545 IHP

Check the engine efficiency: 196.8 BHP / 545 IHP x 100 = 36%, about right for a new modern engine. If the manufacturer's test fuel was at 130,000 BTU per gallon, the engine would be over 38% efficient (out of range).

**Answer**: The engine develops 196.8 brake horsepower. The brake horsepower must now be adjusted to account for losses at the engine from ancillary equipment such as the air fan, engine water pump, etc.

Step 3) Find how much brake horsepower is transmitted to the pump shaft. Note that the pump shaft location is downstream of the gear head, so the BHP losses due to equipment on the engine, the drive shaft, and gearhead must be estimated and subtracted from the BHP output of the engine.

Look in **Table 1** for losses due to the engine water pump, intercooler fan, alternator and muffler. Since all of the engine components are present, the loss is 5% + 2.5% + 1.0% = 8.5%

Next, subtract this from 1:   1- 0.085 = 0.915.

The BHP delivered to the drive shaft is estimated as 196.8 BHP * 0.915 = 180.0 BHP

Step 4) Determine the brake horsepower transmitted to the pump shaft.  Using a loss of 5%, the horsepower delivered to the pump line shaft is 180.0 x (1-0.05) = 171 BHP. Note that in this case where the pump shaft speed is 1780 RPM, this is also the brake horsepower required from a standard 4 pole electric motor that has a nominal speed of 1780 RPM.

Step 5) Determine the load factor.  Using the manufacturer's curve in Appendix 5, it is noted that the engine's power rating is "intermittent".  In other words, it is not designed for continual usage at maximum load.  In such cases, the engine must be derated, typically at about a 0.7 load factor.

On the engine cut sheet, look up the maximum BHP output at 1600 RPM.  The stated value is 304 BHP.  Derating by 0.70, the continuous load should be no more than 213 BHP.  Since the actual load is 196.8 BHP, this engine is approximately suited for its required condition.   Note that there may be many reasons why an engine is not properly loaded, including pump wear, RPM issues, inappropriate selection of engine size, and differences in perceived loading factors.

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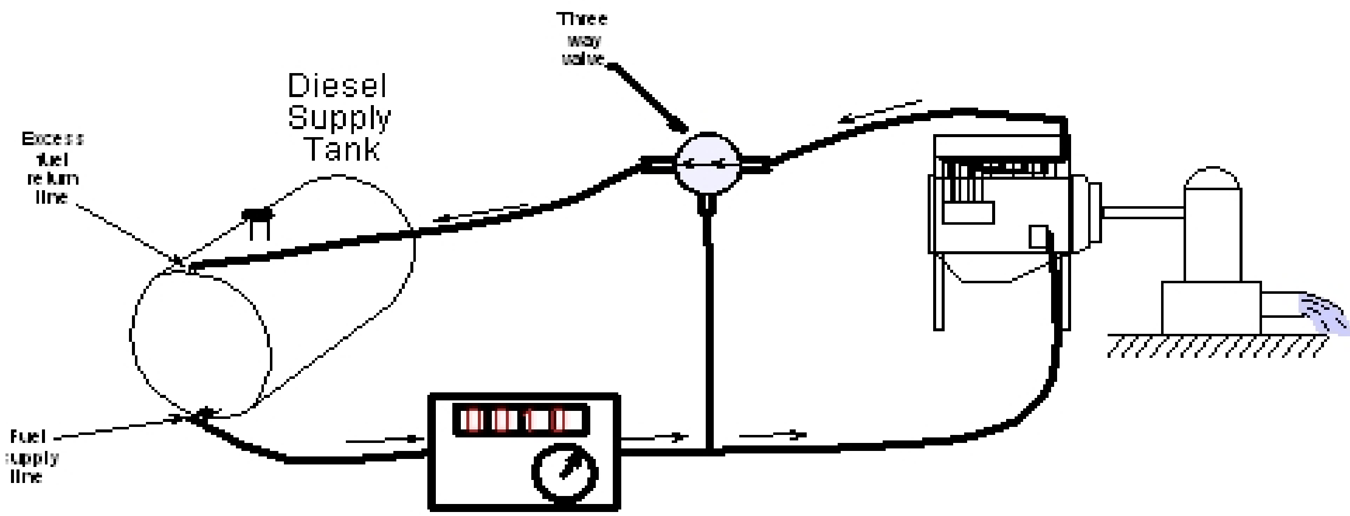
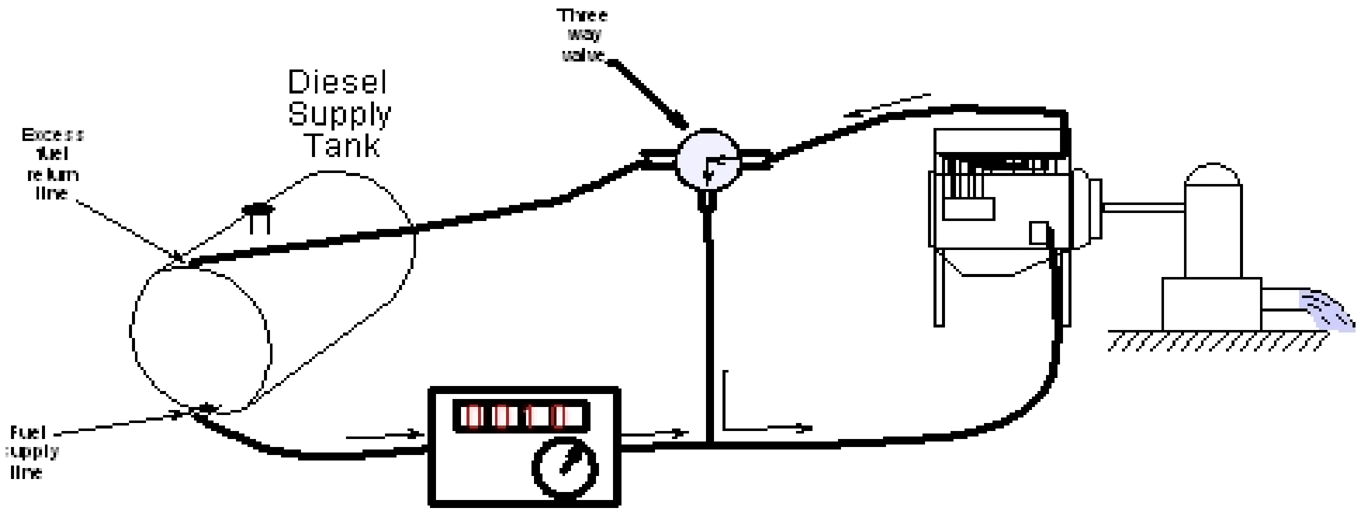
**Appendix 1:** Fuel Meter Connection Schematic




Fuel consumption measuring equipment, (normal mode)




Fuel consumption measuring equipment, (measurement mode)

**Appendix 2:** Fuel Meter Specification Sheet

TS-240
Rev. A
VLF Flowmeters
Size ⅛", ⅜", ¾"

ACTARIS metering systems

# neptune® VLF Flowmeters Models VLF 4 (⅛") VLF 8 (⅜"), VLF 20 (¾")

## SPECIFICATIONS

### DESCRIPTION

Actaris Neptune's VLF (very low flow) flowmeters have been designed to measure the flow of light fuel or diesel oil. They are available in three different sizes: ⅛", ⅜" and ¾" to measure flow rates ranging from 0.25 to 390 gph. The oscillating piston of these flowmeters forms two measuring chambers that are alternately filled and emptied. The passing oil is measured by fractions reflected by the register.

The register unit of the VLF 8 and VLF 20 is housed in a vacuum sealed casing. It is secure from dirt, dust and condensation.

Operation of the flowmeters can be verified at any time by checking the disc rotation in the dial center. This allows accurate monitoring and prompt adjustment of the burner. Flow volume can be determined and quickly compared with the optimal adjustment, allowing full control of oil consumption.

Note: A fine filter is built into the inlet but should the liquid being metered contain foreign matter, a separate screen or removable filter of appropriate size should be fitted on the inlet side. The filter mesh should not be larger than 50 micron for the VLF 4 and VLF 8 meters and 100 micron for the VLF 20.

## SPECIFICATIONS (for light oils and diesels only)

| MODEL | VLF 4 (⅛") | VLF 8 (⅜") | VLF 20 (¾") |
|---|---|---|---|
| Flow Rate | 0.25 to 20 gph (1-80 $dm^3/hr$) | 1 to 50 gph (4-200 $dm^3/hr$) | 9 to 390 gph (30-1500 $dm^3/hr$) |
| Accuracy | ±1% | ±1% | ±1% |
| Repeatability | ±.1% | ±.1% | ±.1% |
| Operating Temperature | 140°F (60°C) | 140°F (60°C)* | 260°F (130°C)* |
| Operating Pressure | 350 psi (25 bar)* | 350 psi (25 bar)* | 225 psi (16 bar)* |
| Dial Registration | 0.001 USG (.01 Litres) | 0.01 USG (.1 Litres) | 0.01 USG (0.1 Litres) |

*Maximum

## **Appendix 2 (continued):** Fuel Meter Specification Sheet

### VLF PULSER SPECIFICATIONS

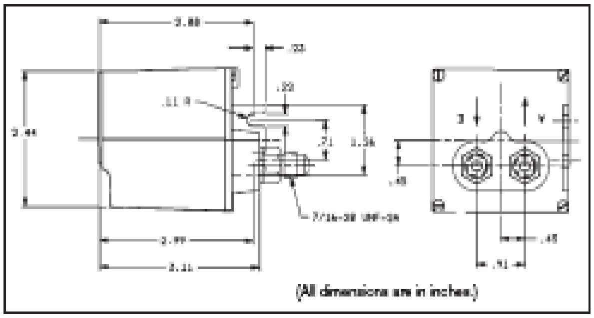
| | |
|---|---|
| Ambient Temperature Limits | -10°C to 60°C (-14°F to 140°F) |
| Switching Element | Reed contact (potential free) |
| Switching Voltage | Max. 48 V DC/AC |
| Switching Current | Max. 50 mA (RI = 47 Ohm)[1] |
| Switching Capacity | Max. 3 watts |
| Static Current | nil |

VLF Pulsers are only available for the VLF 8 and VLF 20 models.
Pulse Values depend on the size of the meter and the units of registration. For metric registration the pulse values are 10 pulses per litre for the VLF 8 and 1 pulse per litre for the VLF 20. For US units of registration the pulse values are 10 pulses per gallon for the VLF 8 and for the VLF 20.

[1]Note: Ri is the resistance of the electronic device that is being driven by the pulser, eg., a counter.

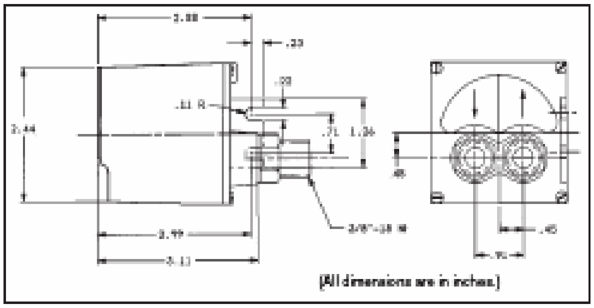
### PHYSICAL DIMENSIONS

#### Model VLF 4



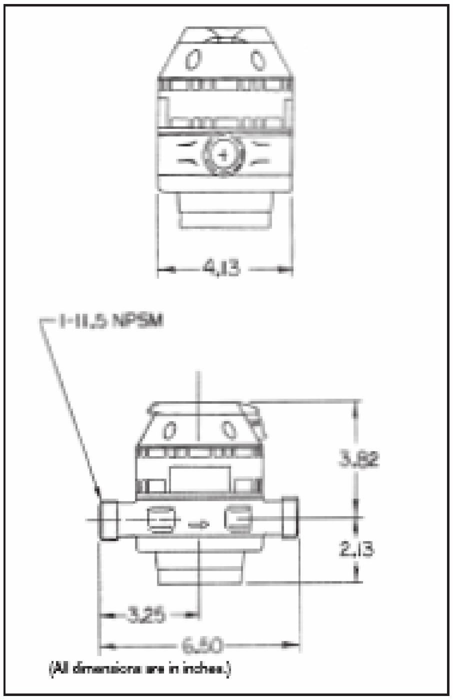

Connections are provided for attaching ¼" 45° female tube fittings.

#### Model VLF 8




Connections are provided for attaching ⅜"-18 NPT female fittings.

#### Model VLF 20




Connections are provided for attaching ¾"-14 NPT female fittings.


U.S.A./International
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ACTARIS metering systems

## **Appendix 3:** Example Diesel Pump Field Data Form

**Diesel Pump Test Field Data Form (v. 1.0, Dec 2006)** **Test Date & Time:** ____________

Tester Company and name: ____________
Company/Client Name: ____________
Mailing Address: ____________
Customer Name: ____________
Customer's Phone #: ____________ Cost per gallon of fuel: ____________
Customer business type: ____________ Crop type: ____________
Acreage farmed: ____________ Annual operating hours: ____________
Pump Name: ____________
Pump Location (physical address): ____________
Pump Location (GPS coordinates): ____________

| **Engine Information** | | **Gearhead Information** | |
|---|---|---|---|
| Engine Make: | | Gear Head Make: | |
| Engine Serial #: | | Gear Head Model: | |
| Engine Model: | | Gearhead indicated ratio: | |
| Displacement: | | Gearhead HP rating: | |
| Engine HP: | | Measured engine rpm: | |
| Model Yr USEPA: | | Measured pump shaft rpm: | |
| Stated N0x (gms/bhp): | | Measured gearhead ratio: | |
| Stated PM (gms/bhp): | | | |
| Continual HP rating @ rpm: | | Hour Reading: | |

Cooling system (description) ____________

| Ancillary Loads: | Fan(air cooled) | Fan(typical) | Water pump | Alternator | Gear Head | Muffler |
|---|---|---|---|---|---|---|
| | 0.95 | 0.975 | 0.975 | 0.99 | 0.95 | 0.98 |

Manufacturer Brake Specific Fuel Consumption (BSFC) at RPM:

| RPM | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 |
|---|---|---|---|---|---|---|---|
| lb/hp-hr | | | | | | | |

| Description of test conditions: | **Run # 1**<br>Shaft RPM<br>at 1775 | **Run # 2**<br>Shaft RPM<br>"Normal" | **Run # 3**<br>Shaft RPM<br>Optional |
|---|---|---|---|
| Engine RPM, measured | | | |
| Pump RPM, measured | | | |
| Static Water Level, feet | | | |
| Pumping Water Level, feet | | | |
| Discharge head, PSI | | | |
| Discharge head, feet | | | |
| Pressure Gauge Height, feet | | | |
| TDH, feet (PWL + Discharge head feet + gauge height feet) | | | |
| Test GPM | | | |
| GPM/ft. drawdown: | | | |
| Water Horsepower (gpm x tdh/ 3960) | | | |
| Fuel meter revolutions, 0.1 gal per revolution | | | |
| # seconds for 2 revolutions | | | |
| GPH ( # revs x 360/#secs) | | | |
| Estimated Input HP (GPH x 55) | | | |
| OPE: (WHP/Thermal HP) | | | |

**Remarks:** ____________

**Appendix 4:** Diesel Pump Test Procedures and Equipment

Diesel Pumping Efficiency Program
Subject: MINIMUM FIELD REQUIREMENTS FOR DIESEL PUMP EFFICIENCY TESTING

Safety devices: The pump tester shall have on hand the following items:

MSDS Sheet: Diesel
Noise Protection: Ear plugs
Eye Protection: Impact resistant eye shield
Hand protection: Appropriate gloves for contact with diesel fuel
Fuel spill cleanup materials: Rags
Fire extinguisher, diesel fuel rated

The following is excerpted from "Pump Efficiency Test Rebate Information Packet – Water Agencies" as seen on **www.itrc.org**. It is to be considered the minimum guidelines for performance of a VALID TEST. Additional comments, in **BOLD**, are taken from the California Association of Pump Test Professionals "Standard Practices" and "Methods and Equipment". Insertions by CIT are made in *ITALICS*.

Minimum requirements include, but are not limited to, the following:

1. Flow rate measurement

   a. If a technique using velocity head is employed (e.g., Collins tube, Cox tube) for a pipe flow rate, the avg. velocity in the test section must be greater than 1 fps.

   b. The test must be conducted using a typical flow rate <u>and</u> pressure.

   c. The flow meters and formulas used must provide a +/- 4% accuracy for the flow rate/velocity ranges that are tested under good testing conditions.

   d. Reasonably accurate flow measurement requires a pipe section without excessive turbulence. Table 1 provides minimum requirements for flow rate test locations to qualify for rebates of the pump efficiency test.

   e. **Pipe inner diameter measurement: A direct inner diameter measurement of the pipe must be performed with the proper tool if any flow measurement device calculates the flow using pipe area**.

   f. Table 1 terminology can be defined as:

      1) "Minimum distance required for any measurement" indicates that flow measurements must be taken further downstream (or upstream, if indicated) than this from the designated valve or fitting. The pipe section throughout this distance must be of a constant diameter, and be free from any in-line fittings. Distances are expressed as "diameters of pipe". For example, a distance of "3 diameters" on a

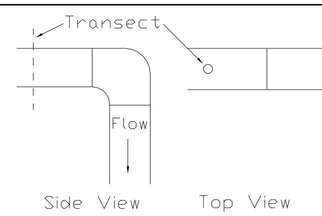
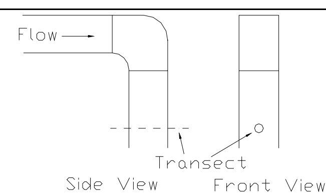
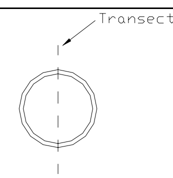
12" diameter pipe indicates a distance of 3 x 12" = 36". Pump tests that rely on a flow rate measurement taken within this distance from the valve/fitting do not qualify for a rebate.

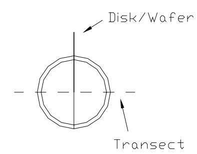
2) "Minimum distance required for a single transect" indicates the distance of clear, unobstructed pipeline downstream (or upstream, if so designated) of a valve/fitting that must be available in order to qualify for a single transect test, or for an ultrasonic test (such as Panameterics®, Controlotron®, or other clamp-on units).

3) A double transect (perpendicular lines of velocity measurements) test must be used if the flow measurement location is between (1) and (2). In general, the double transect should be conducted using 2 segments of velocity measurements taken in planes of 45 degrees from the top of the pipe. However, the pump tester should use discretion as to the best configuration.

4) Ultrasonic measurement devices (e.g., Panameterics®, Controlotron®, or other clamp-on units) must follow the same guidelines as the velocity measurement devices. That is, they require a minimum distance for any acceptable reading, and will require a double transect reading in the same conditions described for Collins/Hall tubes.

**Table 1. Minimum distance and velocity measurement specifications for flow measurement.**

| **Fitting ID for Pump Efficiency Report** | **Valve or Fitting** | **Minimum distance required for any measurement** | **Minimum distance required for a single transect** | **Orientation of a single transect** |
|---|---|---|---|---|
| A | Upstream of an elbow | Within the plane | 1 diameter upstream of the outer limit of the plane |  |
| B | Downstream of an elbow | 0.5 diameters downstream of the outer limit of the plane | 2 diameters downstream of the outer limit of the plane |  |
| C | Swing check valve (the flap on this type of check valve swings completely out of the flow path) | 2 diameters downstream | 4 diameters downstream |  |
| D | Regular check valve | 4 diameters downstream | 8 diameters downstream |  |

| | | | | |
|---|---|---|---|---|
| E | Any partly closed valve, or<br>Pump control valve, or<br>Globe valve | 5 diameters downstream | 9 diameters downstream | |
| F | Open gate valve | 1.5 diameters downstream | 3 diameters downstream | same as “c” |
| G | Open butterfly valve | 1.5 diameters downstream | 3 diameters downstream |  |
| H | Pump discharge | 1.5 diameters downstream | 3 diameters downstream | |
| I | Other | | | Please Define |

f. The plane of an elbow is tangential to the inner radius of the elbow as shown in Figure 1. No measurements will be accepted from the zone within the plane, defined by the outer limits of the plane. An example of the minimum distance required for a flow measurement near an elbow is illustrated in Figure 2.

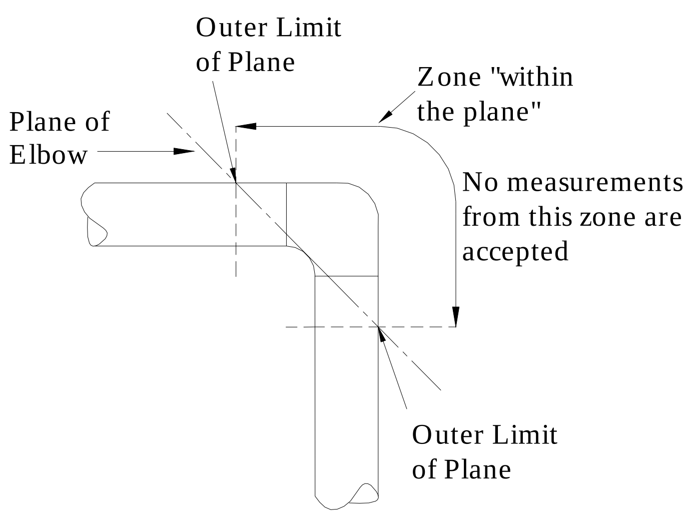



**Figure 1. Definition of a “plane” for an elbow**. The outer limits of the plane are defined by where the plane hits the pipe on either side of the elbow.

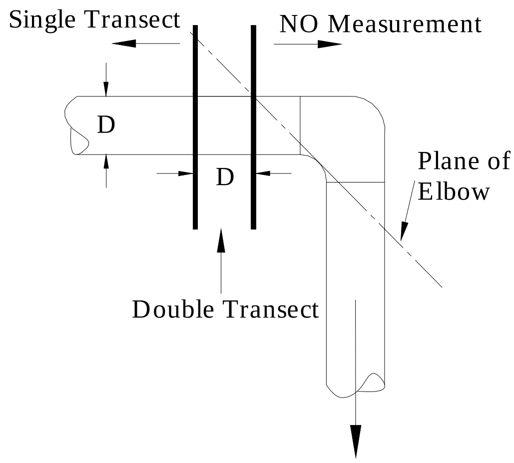



**Figure 2. Example of how to use the information.** In this case, the flow measurement point is located upstream of the elbow (case "a").

g. The flow test method must be defined, according to Table 2 below.

**Table 2. Flow test method identification for Pump Efficiency Report.**

| ID for Pump Efficiency Report | Method Used for Velocity Measurement |
|---|---|
| A | Single Transect Velocity |
| B | Double Transect Velocity |
| C | Propeller Meter |
| D | Ultrasonic Meter |
| E | Other (Please Define) |

h. All transect measurements require multiple velocity points in each transect. With a Collins tube, each transect must contain a minimum of 6 points (3 on each side of the centerline of flow), each of which represents the same cross sectional area of the pipe. A Hall tube qualifies as a "multiple velocity point" meter, and therefore only requires one value.

i. A Hall tube must show a scale balance of less than 1.5 for the pump tester to state that this measurement qualifies for documentation in the pump repair program.

Field data summary sheets for ultrasonic measurement devices must include:

- Signal strength (it must be greater than 50 to obtain an accurate reading.
- Sound speed error. (This is one example of what the pump tester may use as criteria for stating that the test section was inadequate for an accurate measurement).

These are examples of conditions for which a tester will state that the results cannot be guaranteed to be accurate to within +/- 6%.

2. Pressure measurements.
   a. Pressures must be measured with pressure gauges or transducers that have accuracy within +/- 1.5% of full scale.
   b. A pressure gauge should be selected such that the actual pressure reading is in the middle (or higher) of the gauge range.
   c. Pressure gauge accuracy must be verified as often as required to ensure accuracy within +/- 1.5%.

*3. Input fuel measurement.*
   *a. Fuel consumption will be measured using an Actaris Neptune fuel flow meter accurate to +/- 1 % and a stop watch. At least 5 revolutions (0.5 gallons) of the dial will be measured and timed using a stopwatch. The rpm, flow rate, and TDH must be stable when the measurement is taken.*

*4. Engine and pump speed measurement.*
   *a. Engine speed will be measured using an electronic tachometer or strobe light.*
   *b. Pump speed will be measured with an electronic tachometer or strobe light. The speed of the pump shaft must be measured at either the top of the gear head on the adjusting nut, or the shaft itself in the discharge head below the gearhead base.*
   *c. The pump may be tested with multiple runs. However, one condition for the test shall be at a pump shaft speed of 1750-1780 rpm, with normal discharge conditions.*

*5. Statistical data regarding the pump/engine, as available, will be recorded using the data sheet attached.*

6. Total Dynamic Head (TDH) computation for Overall Pumping Plant Efficiency (OPE). The following data must be used to estimate the TDH

   a. <u>For vertical pumps</u>:

      1) Height of the pump discharge pressure measurement point above the ground surface.
      2) Depth from the ground surface to the pumping water level. **Water levels in wells or sumps will be measured with an electric well sounder. The sounder line may be premarked at intervals to facilitate the measurement. A calibrated air line and test pressure gauge in the accuracy class of ½% may also be used for determining the water level in wells or sumps.**
      3) Discharge pressure, immediately at the pump discharge and before any valves.
      4) Estimate of column, inlet screen, and discharge head losses. It is understood that the data required to compute these losses may not be available. However, they are indeed components of the TDH. Therefore, all summary sheets given to the customer <u>must include</u> one of the following statements:
         a). "Disclaimer: The overall pump efficiency is underestimated because computations do not include the pressure loss in the column, screen, foot valve, and discharge head of the pump."
         <u>Or</u>

b). "The total pressure loss in the column, screen, foot valve, and discharge head of the pump could not be directly measured. However, the total loss is estimated to equal a total of __________ft. When accounting for this, the Overall Pumping Plant Efficiency is __________."

b. For horizontal pumps:

1) Inlet pressure.
2) Discharge pressure, immediately at the pump discharge and before any valves
3) Elevation difference between the inlet and discharge pressure measurement points.

c. Verification of Accuracy. For each pump test, the pump tester must clearly state

1. If the gallons per ac-ft is certified (by the pump tester) to be within +/- 6% of the true value, and
2. If the test represents standard operating conditions for the pump.

d. The listed requirements are not all-inclusive and only provide some minimum requirements. The pump tester is responsible for using all necessary safety precautions and equipment, and is responsible for certifying the accuracy of all measurements."

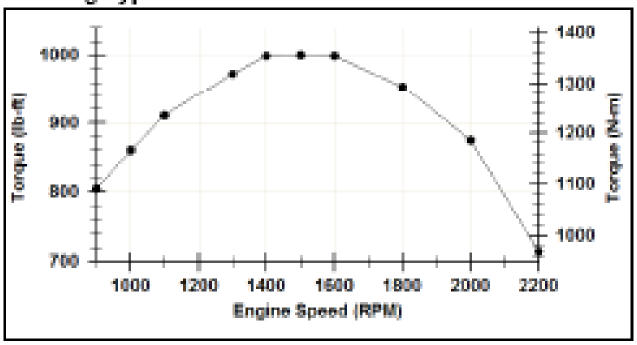
**Appendix 5:** Example Engine Performance Data Sheet

| Engine Performance Data<br>Cummins Inc<br>Columbus, Indiana 47202-3005<br>http://www.cummins.com | Industrial<br>QSC<br>FR91509 | 300 BHP (224 kW) @ 2200 RPM<br>1,000 lb-ft (1,356 N-m) @ 1500 RPM | | |
|---|---|---|---|---|
| | | Configuration<br>D413056CX03 | CPL Code<br>8833 | Revision<br>14-Oct-2006 |

Compression Ratio: 17.6:1
Fuel System: CCR
Emission Certification: U.S. EPA Tier 3, CARB Tier 3, EU Stage IIIA
Displacement: 506 in3 (8.3 L)
Aspiration: Turbocharged and Charge Air Cooled

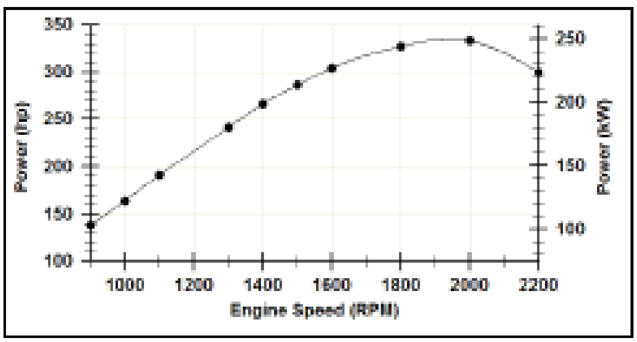
All data is based on the engine operating with fuel system, water pump, and 15 in H2O (3.733 kPa) inlet air restriction with 6 in (152 mm) inner diameter, and with 3 in Hg (10 kPa) exhaust restriction with 4 in (102 mm) inner diameter; not included are alternator, fan, optional equipment and driven components. Coolant flows and heat rejection data based on coolants as 50% ethylene glycol/50% water. All data is subject to change without notice.

Rating Type: Intermittent



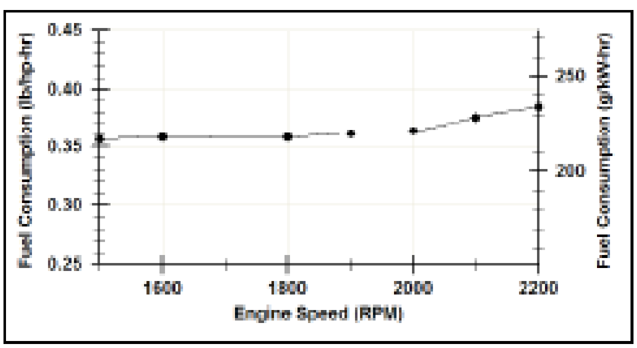

Torque Output

| RPM | lb-ft | N-m |
|---|---|---|
| 900 | 805 | 1,091 |
| 1,000 | 860 | 1,166 |
| 1,100 | 910 | 1,234 |
| 1,300 | 973 | 1,319 |
| 1,400 | 1,000 | 1,355 |
| 1,500 | 1,000 | 1,356 |
| 1,600 | 1,000 | 1,355 |
| 1,800 | 954 | 1,293 |
| 2,000 | 874 | 1,185 |
| 2,200 | 715 | 969 |




Power Output

| RPM | hp | kW |
|---|---|---|
| 900 | 138 | 103 |
| 1,000 | 164 | 122 |
| 1,100 | 191 | 142 |
| 1,300 | 241 | 180 |
| 1,400 | 266 | 198 |
| 1,500 | 286 | 213 |
| 1,600 | 304 | 227 |
| 1,800 | 327 | 244 |
| 2,000 | 333 | 248 |
| 2,200 | 300 | 224 |




Fuel Consumption

| RPM | lb/hp-hr | g/kW-hr |
|---|---|---|
| 1,500 | 0.356 | 217 |
| 1,600 | 0.358 | 218 |
| 1,800 | 0.358 | 218 |
| 1,900 | 0.362 | 220 |
| 2,000 | 0.364 | 221 |
| 2,100 | 0.376 | 229 |
| 2,200 | 0.385 | 234 |

Curves shown above represent gross engine performance capabilities obtained and corrected in accordance with SAE J1995 conditions of 29.61 in Hg (100 kPa) barometric pressure [300ft (91m) altitude] 77 deg F (25 deg C) inlet air temperature, and 0.30 in Hg (1kPa) water vapor pressure with No. 2 diesel fuel. The engine may be operated up to 7,000 ft (2,134 m) altitude before electronic derate is applied.

STATUS FOR CURVES AND DATA: Limited-(measured data)
TOLERANCE: Within +/- 5 %

CHIEF ENGINEER:
Mark A Sublette

Cummins Confidential

## Intake Air System

| | | |
|---|---|---|
| Maximum allowable air temperature rise over ambient at Intake Manifold (Naturally Aspirated Engines) or Turbo Compressor Inlet (Turbo-charged Engines): (This parameter impacts emissions, LAT and/or altitude capability) | 30 delta deg F | 16.7 delta deg C |

## Charge Air Cooling System

| | | |
|---|---|---|
| Maximum intake manifold temperature at 25 deg C (77 F) ambient | 140 deg F | 60 deg C |
| Maximum allowable pressure drop across charge air cooler and OEM CAC piping (IMPD): | 4 in-Hg | 14 kPa |
| Maximum Intake Manifold Temperature Differential (Ambient to IMT) (IMTD): | 63 delta deg F | 35 delta deg C |
| Intake manifold temperature for Fan-ON | 140 deg F | 60 deg C |
| Maximum coolant temperature for engine protection controls | 225 deg F | 107 deg C |
| Maximum coolant operating temperature at engine outlet (max. top tank temp): | 225 deg F | 107 deg C |

## Exhaust System

| | | |
|---|---|---|
| Maximum exhaust back pressure: | 3 in-Hg | 10.1 kPa |
| Recommended exhaust piping size (inner diameter): | 4 in | 101.6 mm |

## Lubrication System

| | | |
|---|---|---|
| Nominal operating oil pressure | | |
| @ minimum low idle | 10 psi | 69 kPa |
| @ maximum rated speed | 55.1 psi | 380 kPa |
| Minimum engine oil pressure for engine protection devices | | |
| @ minimum low idle | 8 psi | 55 kPa |

## Fuel System

| | | |
|---|---|---|
| Fuel cooling requirements (with diesel fuel) | | |
| Maximum heat rejection to return fuel at max. coolant and inlet fuel temperature: | 70 BTU/min | 1.23 kW |
| @ fuel return flow rate of: | 165 lb/hr | 75 kg/hr |
| @ fuel return temperature prior to cooler: | 150 deg F | 66 deg C |
| Maximum supply fuel flow: | 302 lb/hr | 137 kg/hr |
| Maximum return fuel flow: | 165 lb/hr | 75 kg/hr |
| Engine fuel compatibility (consult Service Bulletin #3379001 for appropriate use of other fuels) | DF1, DF2 | |
| Maximum fuel inlet pressure: | 10 psi | 70 kPa |

## Performance Data

| | |
|---|---|
| Maximum low idle speed: | 1,200 RPM |
| Minimum low idle speed: | 600 RPM |
| Minimum engine speed for full load sustained operation: | |

| | Rated Power | | Maximum Power | | Torque Peak | |
|---|---|---|---|---|---|---|
| Engine Speed | 2,200 RPM | | 2,000 RPM | | 1,500 RPM | |
| Output Power | 300 hp | 223 kW | 333 hp | 248 kW | 286 hp | 213 kW |
| Torque | 715 lb-ft | 969 N-m | 874 lb-ft | 1,185 N-m | 1,000 lb-ft | 1,356 N-m |
| Friction Horsepower | 51 hp | 38 kW | 43 hp | 32 kW | 25 hp | 19 kW |
| Intake Manifold Pressure | 51 in-Hg | 172 kPa | 53 in-Hg | 180 kPa | 53 in-Hg | 180 kPa |
| Turbo Comp. Outlet Pressure | 55 in-Hg | 186 kPa | 57 in-Hg | 192 kPa | 56 in-Hg | 188 kPa |
| Turbo Comp. Outlet Temperature | 333 deg F | 167 deg C | 334 deg F | 168 deg C | 334 deg F | 168 deg C |
| Inlet Air Flow | 714 ft3/min | 337 L/s | 667 ft3/min | 315 L/s | 506 ft3/min | 239 L/s |
| Charge Air Flow | 55 lb/min | 25 kg/min | 51 lb/min | 23 kg/min | 39 lb/min | 18 kg/min |
| Exhaust Gas Flow | 1,805 ft3/min | 852 L/s | 1,767 ft3/min | 834 L/s | 1,464 ft3/min | 691 L/s |
| Exhaust Gas Temperature | 995 deg F | 535 deg C | 1,033 deg F | 556 deg C | 1,087 deg F | 586 deg C |
| Maximum Fuel Flow to Pump | 302 lb/hr | 137 kg/hr | | | | |
| Heat Rejection to Coolant | 6,489 BTU/min | 114.1 kW | 6,591 BTU/min | 115.9 kW | 5,414 BTU/min | 95.2 kW |
| Heat Rejection to Fuel | 70 BTU/min | 1.23 kW | | | | |
| Heat Rejection to Ambient | 1,717 BTU/min | 30.2 kW | 1,513 BTU/min | 26.6 kW | 1,985 BTU/min | 34.9 kW |
| Heat Rejection to Exhaust | 12,790 BTU/min | 224.9 kW | 12,659 BTU/min | 222.6 kW | 10,487 BTU/min | 184.4 kW |
| **Steady State Smoke | 0.4 Bosch | | 0.3 Bosch | | 0.8 Bosch | |

**When operating Naturally Aspirated engines above SAE J1995 conditions, it should be noted that smoke levels will increase due to combustion inefficiencies associated with a reduction in the air to fuel mixture.

**Appendix 6:** Material Safety Data Sheet

# Material Safety Data Sheet

## SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

### DIESEL FUEL No. 2

**Product Use:** Fuel
**Product Number(s):** CPS220122 [See Section 16 for Additional Product Numbers]
**Synonyms:** 15 S Diesel Fuel 2, Alternative Low Aromatic Diesel (ALAD), Calco LS Diesel 2, Calco ULS DF2, Calco ULS Diesel 2, Chevron LS Diesel 2, Chevron ULS Diesel 2, Diesel Fuel Oil, Diesel Grade No. 2, Diesel No. 2-D S15, Diesel No. 2-D S500, Diesel No. 2-D S5000, Distillates, straight run, Gas Oil, HS Diesel 2, HS Heating Fuel 2, Light Diesel Oil Grade No. 2-D, LS Diesel 2, LS Heating Fuel 2, Marine Diesel, RR Diesel Fuel, Texaco Diesel, Texaco Diesel No. 2, Ultra Low Sulfur Diesel 2
**Company Identification**
Chevron Products Company
Marketing, MSDS Coordinator
6001 Bollinger Canyon Road
San Ramon, CA 94583
United States of America

**Transportation Emergency Response**
CHEMTREC: (800) 424-9300 or (703) 527-3887
**Health Emergency**
ChevronTexaco Emergency Information Center: Located in the USA. International collect calls accepted. (800) 231-0623 or (510) 231-0623
**Product Information**
MSDS Requests: (800) 689-3998 Technical Information: (510) 242-5357

SPECIAL NOTES: This MSDS covers all Chevron and Calco non-CARB Diesel No. 2 Fuels. The sulfur content is less than 0.5% (mass). Red dye is added to non-taxable fuel. (MSDS 6894)

## SECTION 2 COMPOSITION/ INFORMATION ON INGREDIENTS

| COMPONENTS | CAS NUMBER | AMOUNT |
|---|---|---|
| Diesel Fuel No. 2 | 68476-34-6 | 100 %wt/wt |
| Distillates, hydrodesulfurized, middle | 64742-80-9 | 0 - 100 %wt/wt |
| Distillates, straight run middle (gas oil, light) | 64741-44-2 | 0 - 100 %wt/wt |
| Kerosine | 8008-20-6 | 0 - 25 %wt/wt |
| Kerosine, hydrodesulfurized | 64742-81-0 | 0 - 25 %wt/wt |
| Distillates (petroleum), light catalytic cracked | 64741-59-9 | 0 - 50 %wt/wt |
| Naphthalene | 91-20-3 | 0.02 - 0.2 %wt/wt |
| Total sulfur | None | 0 - 0.5 %wt/wt |

## SECTION 3 HAZARDS IDENTIFICATION

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*EMERGENCY OVERVIEW*

- COMBUSTIBLE LIQUID AND VAPOR
- HARMFUL OR FATAL IF SWALLOWED - MAY CAUSE LUNG DAMAGE IF SWALLOWED
- CAUSES SKIN IRRITATION
- MAY CAUSE CANCER BASED ON ANIMAL DATA
- TOXIC TO AQUATIC ORGANISMS

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**IMMEDIATE HEALTH EFFECTS**

**Eye:** Not expected to cause prolonged or significant eye irritation.

**Skin:** Contact with the skin causes irritation. Skin contact may cause drying or defatting of the skin. Symptoms may include pain, itching, discoloration, swelling, and blistering. Contact with the skin is not expected to cause an allergic skin response. Not expected to be harmful to internal organs if absorbed through the skin.

**Ingestion:** Because of its low viscosity, this material can directly enter the lungs, if swallowed, or if subsequently vomited. Once in the lungs it is very difficult to remove and can cause severe injury or death. May be irritating to mouth, throat, and stomach. Symptoms may include pain, nausea, vomiting, and diarrhea.

**Inhalation:** Mists of this material may cause respiratory irritation. Symptoms of respiratory irritation may include coughing and difficulty breathing. Breathing this material at concentrations above the recommended exposure limits may cause central nervous system effects. Central nervous system effects may include headache, dizziness, nausea, vomiting, weakness, loss of coordination, blurred vision, drowsiness, confusion, or disorientation. At extreme exposures, central nervous system effects may include respiratory depression, tremors or convulsions, loss of consciousness, coma or death.

**DELAYED OR OTHER HEALTH EFFECTS:**

**Cancer:** Prolonged or repeated exposure to this material may cause cancer. Whole diesel engine exhaust has been classified as a Group 2A carcinogen (probably carcinogenic to humans) by the International Agency for Research on Cancer (IARC). Diesel exhaust particulate has been classified as reasonably anticipated to be a human carcinogen in the National Toxicology Program's Ninth Report on Carcinogens. The National Institute of Occupational Safety and Health (NIOSH) has recommended that whole diesel exhaust be regarded as potentially causing cancer. Diesel engine exhaust is known to the State of California to cause cancer. Contains naphthalene, which has been classified as a Group 2B carcinogen (possibly carcinogenic to humans) by the International Agency for Research on Cancer (IARC).

See Section 11 for additional information. Risk depends on duration and level of exposure.

## SECTION 4 FIRST AID MEASURES

**Eye:** No specific first aid measures are required. As a precaution, remove contact lenses, if worn, and flush eyes with water.

**Skin:** Wash skin with water immediately and remove contaminated clothing and shoes. Get medical attention if any symptoms develop. To remove the material from skin, use soap and water. Discard contaminated clothing and shoes or thoroughly clean before reuse.

**Ingestion:** If swallowed, get immediate medical attention. Do not induce vomiting. Never give

anything by mouth to an unconscious person.
**Inhalation:** Move the exposed person to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention if breathing difficulties continue.
**Note to Physicians:** Ingestion of this product or subsequent vomiting may result in aspiration of light hydrocarbon liquid, which may cause pneumonitis.

## SECTION 5 FIRE FIGHTING MEASURES

See Section 7 for proper handling and storage.

**FIRE CLASSIFICATION:**
OSHA Classification (29 CFR 1910.1200): Combustible liquid.

**NFPA RATINGS:** Health: 0 Flammability: 2 Reactivity: 0

**FLAMMABLE PROPERTIES:**
**Flashpoint:** (Pensky-Martens Closed Cup) 52 °C (125 °F) (Min)
**Autoignition:** 257 °C (494 °F)
**Flammability (Explosive) Limits (% by volume in air):** Lower: 0.6 Upper: 4.7

**EXTINGUISHING MEDIA:** Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

**PROTECTION OF FIRE FIGHTERS:**
**Fire Fighting Instructions:** For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus.
**Combustion Products:** Highly dependent on combustion conditions. A complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion.

## SECTION 6 ACCIDENTAL RELEASE MEASURES

**Protective Measures:** Eliminate all sources of ignition in the vicinity of the spill or released vapor. If this material is released into the work area, evacuate the area immediately. Monitor area with combustible gas indicator.
**Spill Management:** Stop the source of the release if you can do it without risk. Contain release to prevent further contamination of soil, surface water or groundwater. Clean up spill as soon as possible, observing precautions in Exposure Controls/Personal Protection. Use appropriate techniques such as applying non-combustible absorbent materials or pumping. All equipment used when handling the product must be grounded. A vapor suppressing foam may be used to reduce vapors. Use clean non-sparking tools to collect absorbed material. Where feasible and appropriate, remove contaminated soil. Place contaminated materials in disposable containers and dispose of in a manner consistent with applicable regulations.
**Reporting:** Report spills to local authorities and/or the U.S. Coast Guard's National Response Center at (800) 424-8802 as appropriate or required.

## SECTION 7 HANDLING AND STORAGE

**Precautionary Measures:** Liquid evaporates and forms vapor (fumes) which can catch fire and burn with explosive force. Invisible vapor spreads easily and can be set on fire by many sources such as pilot lights, welding equipment, and electrical motors and switches. Fire hazard is greater as liquid temperature rises above 29C (85F). Do not get in eyes, on skin, or on clothing. Do not

taste or swallow. Do not breathe vapor or fumes. Do not breathe mist. Wash thoroughly after handling. Keep out of the reach of children.
**Unusual Handling Hazards:** WARNING! Do not use as portable heater or appliance fuel. Toxic fumes may accumulate and cause death.
**General Handling Information:** Avoid contaminating soil or releasing this material into sewage and drainage systems and bodies of water.
**Static Hazard:** Electrostatic charge may accumulate and create a hazardous condition when handling this material. To minimize this hazard, bonding and grounding may be necessary but may not, by themselves, be sufficient. Review all operations which have the potential of generating and accumulating an electrostatic charge and/or a flammable atmosphere (including tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing, agitation, and vacuum truck operations) and use appropriate mitigating procedures. For more information, refer to OSHA Standard 29 CFR 1910.106, 'Flammable and Combustible Liquids', National Fire Protection Association (NFPA 77, 'Recommended Practice on Static Electricity', and/or the American Petroleum Institute (API) Recommended Practice 2003, 'Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents'.
**General Storage Information:** DO NOT USE OR STORE near heat, sparks, flames, or hot surfaces . USE AND STORE ONLY IN WELL VENTILATED AREA. Keep container closed when not in use.
**Container Warnings:** Container is not designed to contain pressure. Do not use pressure to empty container or it may rupture with explosive force. Empty containers retain product residue (solid, liquid, and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition. They may explode and cause injury or death. Empty containers should be completely drained, properly closed, and promptly returned to a drum reconditioner or disposed of properly.

## SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

**GENERAL CONSIDERATIONS:**
Consider the potential hazards of this material (see Section 3), applicable exposure limits, job activities, and other substances in the work place when designing engineering controls and selecting personal protective equipment. If engineering controls or work practices are not adequate to prevent exposure to harmful levels of this material, the personal protective equipment listed below is recommended. The user should read and understand all instructions and limitations supplied with the equipment since protection is usually provided for a limited time or under certain circumstances.

**ENGINEERING CONTROLS:**
Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below the recommended exposure limits.

**PERSONAL PROTECTIVE EQUIPMENT**
**Eye/Face Protection:** No special eye protection is normally required. Where splashing is possible, wear safety glasses with side shields as a good safety practice.
**Skin Protection:** Wear protective clothing to prevent skin contact. Selection of protective clothing may include gloves, apron, boots, and complete facial protection depending on operations conducted. Suggested materials for protective gloves include: Chlorinated Polyethylene (or Chlorosulfonated Polyethylene), Nitrile Rubber, Polyurethane, Viton.
**Respiratory Protection:** Determine if airborne concentrations are below the recommended occupational exposure limits for jurisdiction of use. If airborne concentrations are above the acceptable limits, wear an approved respirator that provides adequate protection from this material, such as: Air-Purifying Respirator for Organic Vapors. When used as a fuel, this material can produce carbon monoxide in the exhaust. Determine if airborne concentrations are below the occupational exposure limit for carbon monoxide. If not, wear an approved positive-pressure air-

supplying respirator. Use a positive pressure air-supplying respirator in circumstances where air-purifying respirators may not provide adequate protection.

**Occupational Exposure Limits:**

| Component | Agency | TWA | STEL | Ceiling | Notation |
|---|---|---|---|---|---|
| Diesel Fuel No. 2 | ACGIH | 100 mg/m3 | -- | -- | Skin A3 total hydrocarbon |
| Diesel Fuel No. 2 | CVX | -- | 1000 mg/m3 | -- | -- |
| Kerosine | ACGIH | 200 mg/m3 | -- | -- | Skin A3 Total hydrocabon vapor |
| Kerosine | CVX | -- | 1000 mg/m3 | -- | -- |
| Kerosine, hydrodesulfurized | ACGIH | 200 mg/m3 | -- | -- | Skin A3 Total hydrocabon vapor |
| Kerosine, hydrodesulfurized | CVX | -- | 1000 mg/m3 | -- | -- |
| Naphthalene | ACGIH | 10 ppm (weight) | 15 ppm (weight) | -- | Skin |
| Naphthalene | OSHA Z-1 | 50 mg/m3 | -- | -- | -- |

## SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Attention: the data below are typical values and do not constitute a specification.

**Color:** Varies depending on specification
**Physical State:** Liquid
**Odor:** Petroleum odor
**pH:** Not Applicable
**Vapor Pressure:** 0.04 kPa (Approximate) @ 40 °C (104 °F)
**Vapor Density (Air = 1):** >1
**Boiling Point:** 175.6°C (348°F) - 370°C (698°F)
**Solubility:** Soluble in hydrocarbons; insoluble in water
**Freezing Point:** Not Applicable
**Melting Point:** Not Applicable
**Specific Gravity:** 0.8 - 0.88 @ 15.6°C (60.1°F) (Typical)
**Viscosity:** 1.9 cSt - 4.1 cSt @ 40°C (104°F)

## SECTION 10 STABILITY AND REACTIVITY

**Chemical Stability:** This material is considered stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.
**Incompatibility With Other Materials:** May react with strong acids or strong oxidizing agents, such as chlorates, nitrates, peroxides, etc.
**Hazardous Decomposition Products:** None known (None expected)
**Hazardous Polymerization:** Hazardous polymerization will not occur.

## SECTION 11 TOXICOLOGICAL INFORMATION

**IMMEDIATE HEALTH EFFECTS**

**Eye Irritation:** The eye irritation hazard is based on evaluation of data for similar materials or product components.

**Skin Irritation:** The skin irritation hazard is based on evaluation of data for similar materials or product components.

**Skin Sensitization:** This material did not cause skin sensitization reactions in a Buehler guinea pig test.

**Acute Dermal Toxicity:** LD50: >5ml/kg (rabbit).

**Acute Oral Toxicity:** LD50: > 5 ml/kg (rat)

**Acute Inhalation Toxicity:** 4 hour(s) LC50: > 5mg/l (rat).

**ADDITIONAL TOXICOLOGY INFORMATION:**

This product contains gas oils.

CONCAWE (product dossier 95/107) has summarized current health, safety and environmental data available for a number of gas oils, typically hydrodesulfurized middle distillates, CAS 64742-80-9, straight-run middle distillates, CAS 64741-44-2, and/or light cat-cracked distillate CAS 64741-59-9. CARCINOGENICITY: All materials tested have caused the development of skin tumors in mice, but all featured severe skin irritation and sometimes a long latency period before tumors developed. Straight-run and cracked gas oil samples were studied to determine the influence of dermal irritation on the carcinogenic activity of middle distillates. At non-irritant doses the straight-run gas oil was not carcinogenic, but at irritant doses, weak activity was demonstrated. Cracked gas oils, when diluted with mineral oil, demonstrated carcinogenic activity irrespective of the occurrence of skin irritation. Gas oils were tested on male mice to study tumor initiating/promoting activity. The results demonstrated that while a straight-run gas oil sample was neither an initiator or promotor, a blend of straight-run and FCC stock was both a tumor initiator and a promoter.

GENOTOXICITY: Hydrotreated & hydrodesulfurized gas oils range in activity from inactive to weakly positive in in-vitro bacterial mutagenicity assays. Mouse lymphoma assays on straight-run gas oils without subsequent hydrodesulphurization gave positive results in the presence of S9 metabolic activation. In-vivo bone marrow cytogenetics and sister chromatic exchange assay exhibited no activity for straight-run components with or without hydrodesulphurization. Thermally or catalytically cracked gas oils tested with in-vitro bacterial mutagenicity assays in the presence of S9 metabolic activation were shown to be mutagenic. In-vitro sister chromatic exchange assays on cracked gas oil gave equivocal results both with and without S9 metabolic activation. In-vivo bone marrow cytogenetics assay was inactive for two cracked gas oil samples. Three hydrocracked gas oils were tested with in-vitro bacterial mutagenicity assays with S9, and one of the three gave positive results. Twelve distillate fuel samples were tested with in-vitro bacterial mutagenicity assays & with S9 metabolic activation and showed negative to weakly positive results. In one series, activity was shown to be related to the PCA content of samples tested. Two in-vivo studies were also conducted. A mouse dominant lethal assay was negative for a sample of diesel fuel. In the other study, 9 samples of No 2 heating oil containing 50% cracked stocks caused a slight increase in the number of chromosomal aberrations in bone marrow cytogenetics assays. DEVELOPMENTAL TOXICITY: Diesel fuel vapor did not cause fetotoxic or teratogenic effects when pregnant rats were exposed on days 6-15 of pregnancy. Gas oils were applied to the skin of pregnant rats daily on days 0-19 of gestation. All but one (coker light gas oil) caused fetotoxicity (increased resorptions, reduced litter weight, reduced litter size) at dose levels that were also maternally toxic.

This product contains naphthalene. GENERAL TOXICITY: Exposure to naphthalene has been reported to cause methemoglobinemia and/or hemolytic anemia, especially in humans deficient in the enzyme glucose-6-phosphate dehydrogenase. Laboratory animals given repeated oral doses of naphthalene have developed cataracts. REPRODUCTIVE TOXICITY AND BIRTH DEFECTS:

Naphthalene did not cause birth defects when administered orally to rabbits, rats, and mice during pregnancy, but slightly reduced litter size in mice at dose levels that were lethal to the pregnant females. Naphthalene has been reported to cross the human placenta. GENETIC TOXICITY: Naphthalene caused chromosome aberrations and sister chromatid exchanges in Chinese hamster ovary cells, but was not a mutagen in several other in-vitro tests. CARCINOGENICITY: In a study conducted by the National Toxicology Program (NTP), mice exposed to 10 or 30 ppm of naphthalene by inhalation daily for two years had chronic inflammation of the nose and lungs and increased incidences of metaplasia in those tissues. The incidence of benign lung tumors (alveolar/bronchiolar adenomas) was significantly increased in the high-dose female group but not in the male groups. In another two-year inhalation study conducted by NTP, exposure of rats to 10, 30, and 60 ppm naphthalene caused increases in the incidences of a variety of nonneoplastic lesions in the nose. Increases in nasal tumors were seen in both sexes, including olfactory neuroblastomas in females at 60 ppm and adenomas of the respiratory epithelium in males at all exposure levels. The relevance of these effects to humans has not been established. No carcinogenic effect was reported in a 2-year feeding study in rats receiving naphthalene at 41 mg/kg/day.

This product may contain significant amounts of Polynuclear Aromatic Hydrocarbons (PAH's) which have been shown to cause skin cancer after prolonged and frequent contact with the skin of test animals. Brief or intermittent skin contact with this product is not expected to have serious effects if it is washed from the skin. While skin cancer is unlikely to occur in human beings following use of this product, skin contact and breathing, of mists, vapors or dusts should be reduced to a minimum.

## SECTION 12 ECOLOGICAL INFORMATION

**ECOTOXICITY**
96 hour(s) LC50: 21-210 mg/l (Salmo gairdneri)
48 hour(s) EC50: 20-210 mg/l (Daphnia magna)
72 hour(s) EC50: 2.6-25 mg/l (Raphidocellus subcapitata)
This material is expected to be toxic to aquatic organisms.

**ENVIRONMENTAL FATE**
On release to the environment the lighter components of diesel fuel will generally evaporate but depending on local environmental conditions (temperature, wind, mixing or wave action, soil type, etc.) the remainder may become dispersed in the water column or absorbed to soil or sediment. Diesel fuel would not be expected to be readily biodegradable. In a modified Strum test (OECD method 301B) approximately 40% biodegradation was recorded over 28 days. However, it has been shown that most hydrocarbon components of diesel fuel are degraded in soil in the presence of oxygen. Under anaerobic conditions, such as in anoxic sediments, rates of biodegradation are negligible.

## SECTION 13 DISPOSAL CONSIDERATIONS

Use material for its intended purpose or recycle if possible. This material, if it must be discarded, may meet the criteria of a hazardous waste as defined by US EPA under RCRA (40 CFR 261) or other State and local regulations. Measurement of certain physical properties and analysis for regulated components may be necessary to make a correct determination. If this material is classified as a hazardous waste, federal law requires disposal at a licensed hazardous waste disposal facility.

## SECTION 14 TRANSPORT INFORMATION

The description shown may not apply to all shipping situations. Consult 49CFR, or appropriate Dangerous Goods Regulations, for additional description requirements (e.g., technical name) and mode-specific or quantity-specific shipping requirements.

**DOT Shipping Description:** GAS OIL, Combustible Liquid, UN1202,III
**IMO/IMDG Shipping Description:** GAS OIL,3,UN1202,III, FLASH POINT SEE SECTION 5
**ICAO/IATA Shipping Description:** GAS OIL,3,UN1202,III,

## SECTION 15 REGULATORY INFORMATION

**EPCRA 311/312 CATEGORIES:**

1. Immediate (Acute) Health Effects: YES 2. Delayed (Chronic) Health Effects: YES
3. Fire Hazard: YES 4. Sudden Release of Pressure Hazard: NO 5. Reactivity Hazard: NO

REGULATORY LISTS SEARCHED:

| | |
|---|---|
| 01-1=IARC Group 1 | 03=EPCRA 313 |
| 01-2A=IARC Group 2A | 04=CA Proposition 65 |
| 01-2B=IARC Group 2B | 05=MA RTK |
| 02=NTP Carcinogen | 06=NJ RTK |
| | 07=PA RTK |

The following components of this material are found on the regulatory lists indicated.

| | |
|---|---|
| Diesel Fuel No. 2 | 07 |
| Distillates, straight run middle (gas oil, light) | 06 |
| Kerosine | 05, 06, 07 |
| Naphthalene | 01-2B, 02, 03, 04, 05, 06, 07 |

**CERCLA REPORTABLE QUANTITIES(RQ)/EPCRA 302 THRESHOLD PLANNING QUANTITIES(TPQ):**

| Component | Component RQ | Component TPQ | Product RQ |
|---|---|---|---|
| Naphthalene | 100 lbs | None | 55556 lbs |

**CHEMICAL INVENTORIES:**
All components comply with the following chemical inventory requirements: AICS (Australia), DSL (Canada), EINECS (European Union), IECSC (China), KECI (Korea), PICCS (Philippines), TSCA (United States).

**NEW JERSEY RTK CLASSIFICATION:**
Refer to components listed in Section 2. Under the New Jersey Right-to-Know Act L. 1983 Chapter 315 N.J.S.A. 34:5A-1 et. seq., the product is to be identified as follows: DIESEL FUEL

**WHMIS CLASSIFICATION:**
Class B, Division 3: Combustible Liquids
Class D, Division 2, Subdivision A: Very Toxic Material - Carcinogenicity
Class D, Division 2, Subdivision B: Toxic Material - Skin or Eye Irritation

## SECTION 16 OTHER INFORMATION

**NFPA RATINGS:** Health: 0 Flammability: 2 Reactivity: 0

(0-Least, 1-Slight, 2-Moderate, 3-High, 4-Extreme, PPE:- Personal Protection Equipment Index recommendation, *- Chronic Effect Indicator). These values are obtained using the guidelines or published evaluations prepared by the National Fire Protection Association (NFPA) or the National Paint and Coating Association (for HMIS ratings).

**Additional Product Number(s):** CPS225114, CPS225115, CPS225150, CPS266176, CPS270005, CPS270094, CPS270095, CPS270096, CPS271006, CPS272093, CPS272102, CPS272126, CPS272152, CPS272185, CPS272190, CPS272195, CPS272593, CPS272601, CPS272693, CPS272793, CPS273003, CPS273030, CPS273053, CPS275000
**REVISION STATEMENT:** This revision updates the following sections of this Material Safety Data Sheet: 1,8
**Revision Date:** 02/14/2006

**ABBREVIATIONS THAT MAY HAVE BEEN USED IN THIS DOCUMENT:**

| | |
|---|---|
| TLV - Threshold Limit Value | TWA - Time Weighted Average |
| STEL - Short-term Exposure Limit | PEL - Permissible Exposure Limit |
| | CAS - Chemical Abstract Service Number |
| ACGIH - American Conference of Government Industrial Hygienists | IMO/IMDG - International Maritime Dangerous Goods Code |
| API - American Petroleum Institute | MSDS - Material Safety Data Sheet |
| CVX - ChevronTexaco | NFPA - National Fire Protection Association (USA) |
| DOT - Department of Transportation (USA) | NTP - National Toxicology Program (USA) |
| IARC - International Agency for Research on Cancer | OSHA - Occupational Safety and Health Administration |

Prepared according to the OSHA Hazard Communication Standard (29 CFR 1910.1200) and the ANSI MSDS Standard (Z400.1) by the Chevron Texaco Energy Research & Technology Company, 100 Chevron Way, Richmond, California 94802.

**The above information is based on the data of which we are aware and is believed to be correct as of the date hereof. Since this information may be applied under conditions beyond our control and with which we may be unfamiliar and since data made available subsequent to the date hereof may suggest modifications of the information, we do not assume any responsibility for the results of its use. This information is furnished upon condition that the person receiving it shall make his own determination of the suitability of the material for his particular purpose.**