DESIGN AND FIELD EVALUATION OF A FUEL FILTRATION/ADDITIVE UNIT (FAU)

INTERIM REPORT
BFLRF No. 288

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Under Contract to
U.S. Army Belvoir Research, Development and Engineering Center
Logistics Equipment Directorate
Fort Belvoir, Virginia

Contract No. DAAK70-92-C-0059

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June 1993
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A Fuel Filtration/Additive Unit (FAU) was designed, fabricated, and field tested. The FAU is capable of removing water and particulate debris from vehicle fuel cells and returning the clean fuel to the fuel cell. In addition, the FAU is capable of on-line addition of additives to convert Jet A to JP-8 or treating microbiological growth with a biocide.
EXECUTIVE SUMMARY

Problems and Objectives: Historically, the military stores vehicles and equipment with full fuel cells for long periods of time. Also, during maneuvers, vehicles such as the M1A1 combat tank do not use all the fuel or only "top off" the rear fuel cells, since the front fuel cells are difficult to reach. Under these circumstances, the fuel deteriorates and absorbs moisture. Under these conditions, degradation products are formed, free water is accumulated, and microbiological growth may begin. These products will quickly plug the fuel filters, disabling the vehicle. These fuel-related problems have affected many units to such an extent that they are well below combat-ready status. During Operation Desert Shield/Storm (ODS), fuel cells in entire battalions required cleaning before they could be transported to the battle area.

The objective of this program was to design, build, and demonstrate the concept of a mobile piece of equipment capable of cleaning contaminated fuel and dispensing the fuel additives for microbiological growth control and fuel stability.

Importance of Project: A mobile Fuel Filtration/Additive Unit (FAU) could remove contaminated fuel from the vehicle, filter particulate and water, inject required additives, and return the clean fuel into the vehicle. This FAU would allow for the military units to remain combat ready and to reduce maintenance, cleanup, and fuel filter replacement costs. An additional capability of the FAU is that it can convert Jet A-1 into JP-8 for the Army's "Single Fuel on the Battlefield Concept."

Technical Approach: A mobile Fuel Filtration/Additive Unit was designed. The unit has the capability of filtering dirty or contaminated fuel, injecting additives into the clean fuel, and returning the fuel into the vehicle.

Accomplishments: The FAU has been fabricated, qualified, and field tested. The field testing included an emergency contamination problem in which up to 80 percent of a battalion was having fuel-related problems. The FAU was able to clean the fuel cells and return the unit to combat-ready status in a short period of time.

Military Impact: The development of the FAU allows for a simple and rapid means for the military to clean and additize fuel containing gross quantities of particulate and water. The additive system is also capable of converting Jet A-1 to JP-8.
FOREWORD/ACKNOWLEDGMENTS

This work was performed by the Belvoir Fuels and Lubricants Research Facility (BFLRF) at Southwest Research Institute (SwRI), San Antonio, TX, under Contract Nos. DAAK70-87-C-0043 and DAAK70-92-C-0059 during the period 01 March 1991 to 31 March 1993. Work was funded by the U.S. Army Belvoir Research, Development and Engineering Center (Belvoir RDE Center), Ft. Belvoir, VA. Mr. T.C. Bowen, SATBE-FL, served as contracting officer's representative, and Mr. M.E. LePera, SATBE-FL, served as technical monitor. Field testing was performed at Ft. Stewart, GA, with Major Bryan L. Wiles as coordinator.

Special acknowledgments are given to Messrs. Howard Chesneau, Fuel Quality Services, Inc.; Sim Christie, Jr., Industrial Diesel Systems, Inc.; and Al Hayden, Gate City Equipment Co., Inc., for their design and fabrication of the Fuel Filtration/Additive Unit. BFLRF technician G.L. Phillips' efforts in evaluating and operating the FAU are gratefully acknowledged. Special efforts of Mr. J.W. Pryor and Ms. L.A. Pierce of the BFLRF documents processing group are also appreciated.
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I. INTRODUCTION AND BACKGROUND

The military has encountered fuel stability-related problems for over 30 years. These problems have occurred as far away as Diego Garcia in the Indian Ocean and coast-to-coast in the continental United States. When vehicles use this contaminated fuel, they frequently encounter massive fuel-filter plugging. The constituents in the fuel that plug the filters include: 1) inorganic compounds, i.e., sand, dust, and dirt; 2) fuel-container surfaces, i.e., resins, fiberglass, polyurethane foams, and elastomers; 3) fuel filter media; 4) microbiological products, i.e., fungus, yeast, and bacteria; and 5) organic products, i.e., fuel-derived sediment and gum. In addition to these contaminants, the fuel cells breathe due to temperature changes. This process brings moisture into the fuel cells. The excess moisture then accumulates and settles to the bottom of the fuel cell. Besides the water itself being a problem, free water is an ideal media for the growth of microbiological products. The design of fuel cells on armored vehicles is furthering complicating this difficult problem. Generally, the fuel cells have unconventional designs, containing many hidden traps for water and debris. Even if a drain plug exists, not all the water and debris will drain. Heavily armor these areas and you have fuel cells that have poor access and which are very difficult to properly clean.

Historically, the military has not been able to maintain these problem vehicles without great expense and time. Many times, the only method for cleaning the fuel cells involved completely removing the power pack. Even this power-pack removal did not completely solve the problems.

During Operation Desert Shield/Storm, at Ft. Hood, TX, whole battalions had to have their fuel cells cleaned before the M1A1 battle tanks could be driven to the railcars for shipment to Saudi Arabia.

Even in Saudi Arabia, other fuel problems surfaced. The military had decided to use JP-8 as the "single fuel on the battlefield." This concept had been successfully demonstrated in a JP-8 Fuel Demonstration Program conducted at Ft. Bliss, TX. However, most vehicles in Operation

* Underscored numbers in parentheses refer to the list of references at the end of this report.
Desert Storm had to operate on Jet A-1 fuel. This use of different fuels created further fuel filter plugging problems.

The military preferred to operate its vehicles and equipment on JP-8, which contains a corrosion inhibitor, fuel system icing inhibitor, and a static dissipator required by the military for aviation-type fuels. However, only limited sources for converting the Jet A-1 to JP-8 were available, and the Air Force controlled those.

II. OBJECTIVES

The objectives of this program were to design, fabricate, and demonstrate the feasibility of a piece of equipment that could clean fuel contaminated with gross quantities of particulate and water and could dispense additives into the fuel. These additives could either convert Jet A-1 to JP-8 or control microbiological growth, thus increasing fuel stability.

III. APPROACH

The approach was to design and assemble a mobile system capable of pumping fuel from the vehicles and small storage tanks, filtering any particulates and water, injecting additives, and returning the fuel to the fuel cell. The system had to be flexible in operation, yet be user friendly.

When designing this system, as many of these features as possible were incorporated, without making the FAU unduly cumbersome to transport and operate.

IV. DESIGNING THE FUEL FILTRATION/ADDITIVE UNIT (FAU)

In designing the Fuel Filtration/Additive Unit (FAU), certain operation parameters had to be fulfilled. Some of these constraints were: 1) the FAU was to be trailer mounted for field
operations; 2) the pumps were to be either centrifugal or positive displacement pumps capable of transferring fuel at a rate of 227 liters per minute (60 gallons/minute (gpm)) with a 10-foot total head, using a test fuel with a maximum viscosity of 4.1 cSt at 40°C; 3) the FAU had to be capable of supplying its own power, with gasoline-powered engines not being allowed; 4) all fuel-wetted components were to be explosion proof; 5) an additive injection system capable of metering three separate additives into the clean fuel was to be installed (this capability allows for the conversion of Jet A-1 to JP-8); and 6) after processing the fuel, the clean fuel shall contain not more than 2.0 milligrams per liter (mg/L) of solid particulate and less than 25 parts per million free (ppm) water. All design requirements are listed in Appendix A.

These requirements were distributed to seven companies and a bid package requested. Of these companies, three returned "no bids" and four transmitted completed bid packages to BFLRF. Of these four bid packages, the low bid failed to meet the requirements specified in the package, and the high bid was too expensive. The contract to fabricate the FAU was awarded to one of the mid range companies due to its creative and flexible design.

V. FUEL FILTRATION/ADDITIVE UNIT (FAU)

The FAU, shown in Fig. 1, consists of four major components: 1) power and pump system, 2) control system, 3) additive injection system, and 4) filtration system. Each system is discussed in detail in the following sections, and a complete parts lists is shown in Appendix B.

A. Power and Pump System

A self-regulated 240-V, 3-phase, 1800-rpm generator is powered by a 10-kW air-cooled engine mounted on a steel base with an integrated fuel tank. In event of on-board failure, the unit may be switched to an external power source. A control panel is dedicated to the engine and power system. The controls include: 1) main circuit breaker, 2) AC voltage, current and frequency gauges, 3) DC engine gauges with safety shutdown in case of low oil pressure or high temperature, and 4) emergency stop and emergency power switch.
The pump system uses a positive displacement pump with 5.1-cm (2-in.) fittings. The pump is capable of pumping in excess of 230 liters per minute. A rotary-vane positive displacement pump was chosen for its durability and ease of repair. A 40-mesh wire screen is installed upstream of the pump to protect it from large debris being withdrawn from the fuel cells. The pump is coupled to an hydraulic driver to allow the operator maximum flexibility in controlling the flow rates. This flexibility in flow rates is critical, since the fuel cell openings vary in size. The hydraulic unit has a 150-liter tank powered by a 3.73-kW (5-hp) electric motor. This configuration controls any cavitation that may occur because of the various size hoses required to perform these operations.
A small air compressor activates the pneumatic valves and the additive injection system, and a bypass connection has been included to use air from an auxiliary source if the compressor fails. The system is designed with 5.1-cm (2-in.) plumbing to allow the unit to utilize the maximum flow capacity of the pump. This flexibility will add to the unit's mission capability and allow for much smaller inlet and exit hoses.

B. **Control System**

All controls are mounted on a control panel conveniently accessible to the operator. From two side-by-side panels, the operator can control the 1) flow rate, 2) various flow loop configurations, and 3) the additive injection system. The operator can also monitor 1) the differential pressure across each filter housing, 2) fuel pressure, 3) warning lights for low fluid and high temperature in the hydraulic system, high water in the fuel/water filter separator housing, and low level in the storage tank, and 4) air pressure.

C. **Additive Injection System**

The additive injection system is designed to inject up to three separate additives into the fuel with or without prior filtration of the contaminated fuel. An injector, Fig. 2, installed on each additive tank is calibrated for various injection rates ranging from 0 to 3,500; 0 to 5,000; and 1 to 10,000 parts per million (ppm).

The injector uses the on-board air supply to shift a piston inside a cylinder, forcing additive into the fuel stream. The injector is paced using an in-line flowmeter with a multiple head transmitter mounted to the meter. Two pulsers are attached to the transmitter. The first pulser is pneumatic and is used to pace the injection system. The second pulser is digital and provides the electronic output to record the flow rate through the meter and the fuel being additized. The additive selector system is also designed to permit each injector to be used independently, according to the additive requirements of the fuel.
An air-logic system, using a minimum of 483 kPa (70 psi) air pressure, was specifically designed to operate the control valves using a sequenced step-through procedure. As a result, the five logic buttons must be activated in numerical sequence. This numerical sequence requirement prevents accidental engagement of incorrect valves during the system operation. A separate
single-button system permits the operator to quickly additize the fuel by bypassing the filtration system and the normal numerical sequence. This feature is useful when treating fuel containing microbiological contamination or for on-line conversion of Jet A-1 to JP-8 fuel.

D. Flow-Loop Configurations

The FAU is designed for flexibility. The flow loop/additive injection control panel allows the operator to select from five possible configurations, depending upon the desired function. The flow loop in each configuration is determined by controlling six air-actuated valves. The functions addressed by the FAU include:

- **Initial Additive Injection** — This configuration permits treatment of the fuel with MIL-S-5021 (biocide and fuel stability additives) or other approved additives before the filtration process begins or for converting Jet A to JP-8 fuel.

- **Open Flow Loop** — This configuration, which is the first loop in the numerical sequence, pumps the dirty fuel from the fuel cell, through the filtration system, and returns clean fuel into the fuel cell. The return fuel agitates settled debris in the fuel cell, thereby permitting as much debris and water as possible to be pumped through the filtration system.

- **Extraction of Fuel into the Holding Tank** — The second loop in the numerical sequence permits the operator to pump the fuel from the fuel cell(s) into a 2300-liter storage tank. Thus, all fuel is removed from the vehicle in preparation for the next operation.

- **Closed Filtration Loop** — The third loop in the numerical sequence allows the operator to recirculate the fuel in the storage tank through the filtration system until the desired degree of cleanliness is obtained.
• Additive Injection and Replacement of the Fuel Into the Fuel Cells — The fourth and final loop of the numerical sequence allows the injection of one to three additives (MIL-S-53021 or other approved additives) into the filtered fuel and to return the additive-treated clean fuel to the fuel cells.

E. Filtration System

The filtration system is the heart of the FAU and consists of three separate housings that can use either conventional or threaded base elements. Each filter housing has its own function, depending upon the severity of the fuel contamination.

Water is the most prevalent contaminant in the military fuel systems. Thus, the first housing contains the fuel-water separator, which consists of two water coalescers and one separator filter. The pickup line is generally placed near or on the bottom of the fuel cell so as to remove as much debris and water as possible from the fuel cell and to agitate any loose debris to allow it to be filtered. The fuel-water separator is the first in-line filter to remove most of this free water and to protect downstream filters from excessive water.

The second housing may contain one of a variety of fuel filters, depending upon the filtration requirements. If additives are to be extracted from the fuel, an activated clay filter should be used. The fuel-water separator will protect the clay filter from being quickly depleted by excessive water. If large quantities of water are encountered or additional water protection is required, a polymeric-type water-absorbing element should be used to absorb and trap the free water. Increasing differential pressure will indicate when the filter is saturated with water. If heavy particulates and light water are encountered, a pleated paper element of the preferred micrometer rating should be used.

The third and final housing can utilize a variety of particulate filters. This filter should extract at least the smallest particle that is potentially damaging to the hardware. At the present time, a rated 0.5-micrometer element is used. However, if extra protection is desired, elements as low
a 0.1 micrometer may be installed. This filtration configuration provides the flexibility to handle most fuel contamination problems that occur in the field.

VI. OPERATIONAL VERIFICATION OF THE FAU

The FAU operation was verified at the manufacturer's facility and was witnessed by BFLRF and Belvoir RDE Center personnel. The FAU was tested using approximately 1700 liters of locally purchased diesel fuel. The FAU was first tested using clean fuel to determine if all components operated properly. The test fuel was then contaminated with AC Fine Test Dust, a sludge/water slurry, and clean water and recirculated in the holding tank with a transfer pump to ensure that the contaminants were thoroughly mixed. Samples of the test fuel were taken before entering and after leaving the FAU and analyzed for particulate and water concentrations.

The affluent (upstream) samples contained 39.0 milligrams per liter (mg/L) of particulates and 2030 parts per million (ppm) of water. The effluent (downstream) samples contained 1.0 mg/L particulates and 150 ppm water. Both analyses were performed according to ASTM procedures.(5)

VII. FIELD EVALUATION

A. 24th Infantry Division (Mechanized), Ft. Stewart, GA

The FAU had an immediate mission at the 24th Infantry Division (M) at Ft. Stewart, GA. The 24th Infantry Division was experiencing numerous problems due to dirty fuel plugging fuel filters. Ft. Stewart supplied BFLRF with three fuel samples, a plugged filter, and a small amount of material that had been removed from the side of a tank on an HEMTT refueler to be analyzed. Two of the samples were from the Ft. Stewart main storage tank, Evans tank farm (a middle sample and a bottom sample). The third sample was obtained from the rear fuel cells on an M1A1 battle tank. All three samples contained visible particulate and the bottom sample from the bulk supply also contained some undissolved water. Only the bottom sample from the bulk
supply had a particulate contamination level (12.4 mg/L) in excess of the specification limit 10 mg/L. The results from these analyses showed that the fuel was not contaminated with residual fuel or used lubricating oil; in general, these samples were clean and stable.

Infrared (IR) spectra analysis was performed on the debris removed from the plugged fuel filter and HEMTT samples. The spectra contained no indication of microbiological debris, but were consistent with the presence of fuel degradation products, while the spectra for the HEMTT sample had a small adsorption consistent with the presence of microbiological contamination.

BFLRF personnel visited Ft. Stewart to investigate these reported problems. Examination of the fuel in the M1A1 battle tanks in the field revealed few problems. These were the vehicles that had experienced the initial problems. During maneuvers, these vehicles had "worked" their way through the problems by consuming the contaminated fuel and multiple fuel filter changes. Examination of vehicles preparing for maneuvers revealed the problems experienced previously. The first sample was black in color and very highly contaminated with particulates. The second sample contained much free water and particulates, but no indication of microbiological activity. Tank crews indicated that, in some cases, the fuel in the front fuel cells had remained untouched for more than a year. Note: Ft. Stewart uses a biocide at its fuel farm to control microbiological contamination. The FAU was air-shipped to Ft. Stewart for immediate decontamination of M1A1 battle tanks, M113 personnel carriers, and an assortment of other vehicles.

Military personnel from the 24th Infantry Division (M) were trained in the use of the FAU for approximately 1 week and supervised during operation for an additional week, Fig. 3.

As shown in Fig. 4, the fuel was heavily contaminated with both water and particulate. The water contamination is generally created by the fuel cells "breathing." In geographical areas with high humidity, the air contains large quantities of moisture, which condenses when ambient temperatures decrease. The heavy, black particulate debris is fuel degradation products,
a. 24th ID (M) soldier operating FAU

b. 24th ID (M) soldier sampling inlet fuel to determine cleanliness

Figure 3. Photographs of military personnel being trained in the use of the FAU

which is common in the military environment.(7) Fuel stability is not infinite. Therefore, with time, the fuel will begin to break down, forming particulates and gum [toluene-acetone-methanol
Before FAU

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Some of the black debris may be residual microbiological growth, which has been killed with the biocide portion of MIL-S-53021 that Ft. Stewart uses. Also, Fig. 4 illustrates that the FAU is capable of removing these contaminants and returning "clean and bright" fuel to the fuel cell. Additional contaminants were removed from the 40-mesh wire screen that protects the pump (Fig. 5). The main component that plugged this screen was a tarry asphalt-like material. This tarry material contained other contaminants such as: 1) fiberglass shavings, 2) check valves, 3) paper, and 4) elastomer materials (Fig. 6). Fig. 7 illustrates the large quantity of toluene/acetone/methanol (TAM)-insoluble material present. This material is an indication of inorganic or high molecular weight resinous materials that help plug the fuel filters. Fig. 7 also illustrates the presence of metallic flakes in this composite. In general, a fuel filter will not encounter all these materials, but, obviously, many were encountered during these operations.

An interesting observation concerning the M1A1 filtration system was that the primary filter was the only filter plugged when the maintenance personnel needed to change filters. The final
Figure 5. Debris from an M1A1's front fuel cell collected in a 40-mesh wire screen

Check Valves

Fiberglass Shavings

Paper

Rubber/Elastomeric Materials

Figure 6. Photograph containing check valves, fiberglass shavings, paper, and rubber/elastomeric materials
Toluene/Acetone/Methanol (TAM) Insolubles

Metallic Plating

Figure 7. Photograph illustrating toluene/acetone/methanol (TAM) insolubles and metallic plating

(secondary) and coalescer filters were relatively clean (Fig. 8). When military personnel order replacement filters, a complete set of four filters is received. In instances such as these, three of the filters do not require replacement. Replacing the three still usable filters each time the primary filter is replaced results in additional costs and maintenance time and increased filter disposal problems.

During this exercise, 323 vehicles were inspected to determine fuel quality. Of these vehicles, 243 had the fuel processed through the FAU. Since this operation frequently encountered excessive water, the polymeric-type water-absorbing filter element was used in the second housing. An after-action memorandum from the 24th ID DISCOM reported satisfaction with the FAU and a continuing need for its deployment, Appendix C.(8)
Use of the FAU was requested by the U.S. Marine Corps, 1st Reconnaissance Battalion, Light Armored Vehicles (LAVs), at Camp Pendleton, CA. The FAU was transported via truck to Camp Pendleton. The LAVs were experiencing filter plugging problems similar to those found at Ft. Stewart, GA, Fig. 4, due to fuel degradation products and water contamination. However, it was found that due to the use of FOA-15, the Fuel Oil Additive portion of MIL-S-53021, the fuel degradation products were smaller. This particulate tended to plug the final, 0.5 micrometer, filter on the FAU, instead of the middle, 5 micrometer, filter.

A gunnery sergeant was trained to operate the FAU and successfully cleaned the fuel cells on 93 LAVs. Once this operation was completed, Twentynine Palms requested that the FAU be transported there to clean contaminated fuel from M1A1 battle tanks that was drained into an underground storage tank. Once Twentynine Palms personnel realized the potential of the FAU, select vehicles were also processed.
An after-action letter (point paper) from Camp Pendleton, 1st Reconnaissance Battalion reported satisfaction with the operation and capabilities of the FAU, Appendix D.(10)

C. **FAU Modifications**

After completion of the field evaluations, several modifications were determined that would make the FAU more user friendly and allow for longer operability. These modifications included:

- Replace starter switch with on-switch and starter button,
- Redesign the hydraulic system to allow for operation at lower flow rates. This modification also included installing a fluid/water separator on the hydraulic system, heat exchanger, and new flow control on the control panel.

**VIII. CONCLUSIONS**

A mobile fuel filtration and additive system was needed in the field for cleanup and additization operations on U.S. Army vehicles and equipment. The FAU, designed and fabricated to solve these two problems, is capable of cleaning extremely dirty fuel containing large quantities of free water. This capability saves the Army time and money in maintenance and in the cost of replacement filters. The FAU has already demonstrated its benefits in the field and ease of use to the Army in its recent cleanup effort at Ft. Stewart, GA, and with U.S. Marine Corps units at Camp Pendleton and Twentynine Palms, CA. Upon completion of the Ft. Stewart and Camp Pendleton operations, Camp JeJeune, NC, Ft. Carson, CO, and Ft. Knox, KY, expressed interest in using the FAU. However, at the time, these bases were unable to obtain the necessary funding needed to transport the FAU, provide the needed training, and monitor the overall operations.

The design and results of the field demonstrations were presented to the 1993 Society of Automotive Engineers (SAE) International Congress and Exposition, held in Detroit, MI, 01–05 March 1993.(11)
IX. RECOMMENDATIONS

The current FAU model was designed to prove the concept that a trailer-mounted filtration/additive system was feasible and valuable to military logistic and maintenance communities. This design now needs to be militarized to be functional in the military environment. A proposal has been submitted to U.S. Army Belvoir Research, Development and Engineering Center to militarize the FAU and improve the operation using suggestions generated by the soldiers in the field.

Currently, U.S. Army Belvoir Research, Development and Engineering Center is attempting to expedite the production of the FAU by actively pursuing an Operational Need Statement (ONS) with the assistance of Ft. Stewart, Camp Pendleton, and endorsement of the memorandum from Ft. Stewart for "Support for Procurement of Fuel Filtration/Additive Unit (FAU)" directed to the Deputy Chief of Staff Operations and Plans, United States Army, Washington, DC.(12)

X. LIST OF REFERENCES


APPENDIX A

Design Requirements of Filtration/Additive Unit (FAU)
General Description of Proposed Fuel Filtration/Additive Unit (FAU)

Intended Use: The Fuel Filtration Additive Unit (FAU) is intended primarily to aid in the cleanup of fuel in ground vehicle fuel cells. The FAU will provide a simple and rapid means to remove particulate and water contamination from fuel in Army ground vehicles and equipment. The FAU has three additive injection pumps for addition of additives to the clean fuel. These additive injectors can be used to convert Jet A-1 to JP-8 fuel through the addition of icing inhibitor, corrosion inhibitor, and static dissipator additives. The FAU is to be designed to clean and additive-treat diesel in fuel volumes between 100 and 1200 gallons. The designed pump rate is 60 gallons per minute (minimum) using diesel fuel at its maximum viscosity (4.1 cSt) at 40°C. For larger fuel volumes, other means should be used to keep operating time throughput at a convenient level.

FAU Minimum Requirements

Trailer

1. The FAU will be trailer mounted.

2. The trailer shall not be more than seven (7) feet wide at its maximum width.

3. The tongue of the trailer will consist of an eyelet trailer hitch for use with military vehicles.


5. The total empty weight of the trailer and all components shall be less than 8000 pounds.
6. The trailer chassis shall be provided with grounding capability using a grounding cable or rod. Grounding shall be provided for the incoming and outgoing fuel connections. In addition, all major components shall be grounded (bonded) to the chassis.

**Filter/Coalescer**

1. Unless otherwise specified, the filter/coalescer shall be designed to meet the performance criteria of specification MIL-F-8901. The procedure will be modified to use only AC Fine Test Dust and water. (Note: No red iron oxide will be used for this test.) The test fuel used for this test will be Caterpillar 1H2 test fuel.*

2. The fuel filter shall be capable of withstanding a flow rate of 60 gallons per minute (GPM) using a fuel with a viscosity of 4.1 cSt at 40°C.

3. The effluent from the coalescer, or water separator, shall contain less than 10 parts per million (ppm) free water.

**Housings/Storage Tank/Piping**

1. All filter/coalescer/water separator housings shall be constructed of any material that meets ASME Code, Section VIII construction standards for pressure vessels and is compatible with hydrocarbon-type fluids.

2. A 200-gallon temporary working fuel storage tank shall be provided to allow collection of clean fuel when necessary.

3. The fuel flow scheme shall allow for fuel to be pumped into the 200-gallon storage tank and recirculated through the system for addition of fuel additives.

*Caterpillar 1H2 is a Reference No. 2 diesel fuel, and its specification requirements are set forth in Section 5.2, Methods 354 and 355 of Federal Test Method Standard (FTMS) 791C, and described in Appendix F of the ASTM STP 509A, Part I and II.
4. All piping shall be 2 inches in diameter.

Additive Injection System

1. The additive injection system installed shall be capable of metering three separate additives into the cleaned fuel.

2. The pumps shall be capable of metering the additives into the fuel at a rate of 1 to 1500 milligrams per liter ± 2 vol% of setpoint. (Note: Any additive that is specified as weight percent will be converted to volume percent.)

Power Supplies

1. Diesel engines shall be used to drive the pump(s) and/or generator for producing electrical power. Note: No gasoline-powered engines or pumps will be allowed.

2. All pumps or solenoid valves and other components that make intimate contact with the fuel shall be explosion proof.

3. The FAU shall not require any external power supply.

4. The FAU shall have the capability of running on external or auxiliary power in case of failure of the on-board generator.

Pumps

1. Pumps may be centrifugal or positive displacement.

2. The fuel transfer pump shall be capable of pumping at a rate of 60 GPM with a 10-foot total head using a test fuel with a viscosity of 4.1 cSt at 40°C.
Extra Equipment and Parameters

1. The FAU shall have one filtration system that is sufficiently monitored to determine when the filters are plugging.

2. The FAU shall have a control panel with all switches and readouts (preferably digital) of flow rates, pressures, etc.

3. Automatic air eliminators shall be installed on all housings.

4. If positive displacement pumps are used, a pressure relief system is required.

5. Sight glasses shall be installed in all housings placed near the top of the housing.

6. Differential pressure gauges shall be installed on each filter or filter/separator housing.

7. Pressure relief valves shall be installed on each housing.

8. Sampling valves shall be installed at the inlets and outlets of each housing and before and after the additive injection system.

9. A removable stainless steel wire mesh screen shall be installed at the pump inlet according to manufacturer specifications.

10. A flow totalizer meter shall be installed in the fuel flow system and for each of the additive units with, preferably, digital readouts.

11. An emergency, master cutoff switch shall be installed.

12. Elastomeric materials used in seals and hoses shall be of the highest quality and fully compatible with the fluids they contact.
13. Manual/automatic water drains shall be mounted on all filter and/or coalescer/water separators.

14. If diesel driven, the engine fuel storage tank shall be sized to allow a minimum of 4 hours continuous operation without refueling, but shall not exceed 118 gallons.

15. A commercially available tool box with the approximate dimensions, 24 inches high x 36 inches wide x 12 inches deep, shall be mounted to the trailer.

16. A 4 inch diameter x 6 foot long PVC tube shall be installed on the trailer for housing any hoses.

17. The FAU will be completed within 180 days of awarding the contract.

18. Materials that are disallowed are copper and copper bearing alloys when in continuous contact with the fluids.

19. All materials shall be compatible with hydrocarbon fluids and fuel additives (Kaython, FOA-15, Anti-Static Additive, and Fuel System Icing Inhibitor).

20. All equipment must be capable of withstanding double the maximum expected operating pressures without failure.

21. The FAU shall be designed to operate at temperatures from 0°C (32°F) to 50°C (122°F) and outdoors without shelter.

22. Clean fuel will be defined as fuel containing not more than 2.0 mg/L of solids contamination and less than 25 ppm free water.

23. The contractor will furnish engineering drawings to BFLRF (SwRI) prior to fabrication.
24. Testing of the system will be required with BFLRF (SwRI) personnel present.

25. The FAU shall meet all necessary safety requirements to ensure personnel safety.

26. The use of systems/components already in the Army inventory or commercially available is encouraged to minimize special designs and costs.
APPENDIX B

Parts List
-FAU-
Filtration
Additive Injection
Unit

Developed by:
Fuel Quality Services, Inc.
Industrial Diesel Systems, Inc.
Gate City Equipment Co., Inc.
Filterdyne Filtration Systems
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A.———Operations and Sequence
B.———Engine
C.———Generator
D.———Control Panel / Eng.-Gen. / Motor Starter
E.———Pneumatic Actuators
F.———Transmitter, Multiple Head
G.———Liquid Level Switch
H.———Inspection Manhole
I.———Ball Valves
J.———Tank Air Vent
K.———Hydraulic Pump and Motor
L.———Hydraulic Reservoir Level & Temperature Switch
M.———Blackmere Fuel Pump
N.———Additive Injection System
O.———Air Compressor
P.———Flanged Fittings
Q.———Pressure Differential Guages
R.———Electronic Counter (LCD)
S.———Air Eliminators
T.———Water Level Switch
U.———Filtration System
OPERATIONAL SEQUENCE
FILTRATION ADDITIVE UNIT OPERATIONAL SEQUENCE

STEP 1: Open Filtration Loop (Optional)

Operator powers up F.A.U. and turns control switch to position #1. In this step, the necessary control valves are actuated to allow fuel to be pumped from the vehicle, through particulate filters and returned to the vehicle's fuel tank. This step is repeated until all contaminants are flushed from the vehicle's fuel tank.

STEP 2: Extraction of Fuel into Holding Tank

Operator turns control switch to position #2. In this step, the necessary control valves are actuated to allow the fuel to be pumped from the vehicle and into a storage tank aboard the F.A.U.

STEP 3: Closed Filtration Loop

Operator turns control switch to position #3. In this step, the necessary control valves are actuated to allow the fuel to be pumped from the storage tank, through particulate filters and returned to the storage tank. This step is repeated for a duration required to remove all contaminants from the fuel.

STEP 4: Additive Injection

Operator turns control switch to position #4. In this step the necessary control valves are actuated to allow the filtered fuel to be pumped from the storage tank and through a flow meter. After the fuel passes through the meter, the required additives are injected into the fuel and it is pumped back into the vehicle's fuel tank.

* NOTE: Please refer to the schematic diagram when reviewing the operational sequence.
EMERGENCY ADDITIVE LOOP

THE OPERATOR PUSHES THE EMERGENCY ADDITIVE BUTTON AND PRE-SELECTED VALVES OPEN TO ALLOW THE QUICK ADDITIZATION OF THE FUEL IN THE VEHICLE. THIS LOOP BY-PASSES THE FILTERS AND METERS ONE OR ALL THE ADDITIVES INTO THE FUEL.
EMERGENCY ADDITIVE LOOP

© 1992 Gate City Equipment Co., Inc.
ENGINE
## ENGINE

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
<th>S.N./PT. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Air Cooled</td>
<td>Deutz</td>
<td>8222822</td>
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<tr>
<td>Model F3L1011</td>
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<td></td>
</tr>
<tr>
<td>Manifold Muffler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 Volt Alternator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Cleaner / Dry Type</td>
<td></td>
<td>438 - 4102</td>
</tr>
<tr>
<td>Fuel Filter</td>
<td></td>
<td>117 - 4696</td>
</tr>
<tr>
<td>Oil Filter</td>
<td></td>
<td>117 - 4417</td>
</tr>
</tbody>
</table>
**Engine Design Description**

**Working Principle**
4-stroke diesel featuring the new BRZD direct injection system

**Stroke/Strokes**
81/105 (mm)

**Swept Volume**
2049 (ccm)

**Compression Ratio**
18.5

**Number of Cylinders**
3

**Cylinder Arrangement**
Vertical in line

**Cooling System**
Integrated water-air cooling system cylinders oil-cooled, cylinder heads air-cooled with integrated cooling fan

**Crankcase Design**
Black-type crankcases with integrated liners

**Crankcase Breathing System**
Closed water-cooled control breathing system with diaphragm valve rod return connection to the inlet port, the oil seal being utilized for valve seat lubrication

**Cylinder Heads**
Black-type cylinder head grey cast iron

**Valve Arrangement/Timing**
Overhead valves in the cylinder head, one inlet and one exhaust valve per cylinder, controlled via tappets, pushrods and rocker arms. Timing by internal caged belt

**Plates**
Three-ring pistons with two compression rings and one oil scraper ring

**Piston Cooling**
By water jackets with cooling oil

**Connecting Rod**
Steel drop forged with straight joint

**Main and Big End Bearings**
Ready-made hardened bearings with aluminum overlay. Four main bearings, one shared fitted with thrust plate (Hertz bearing)

**Crankshaft**
Nodular cast iron with cast-on counterweights

**Camshaft**
Steel shaft with driving cams for fuel injectors and transfer pumps, seated in the crankcase in binary bearing sleeves

**Lubrication System**
Forced-feed system with return oil pump with internal impellers feeding simultaneously the lubricating and oil heating circuits (if oil heating is provided)

**Engine Oil Cooler**
Engine-integrated light metal cooler

**Thermostat-controlled Oil Cooler**
Engine with oil heating facility have a thermostat-controlled cooling oil circuit

**Lube Oil Filtration**
Paper-type screen filter with replaceable cartridge, in full oil flow

**Fuel Injection Pump/Governor**
Individual withdrawable element-type calibrated pumps/Speed governor integrated in front cover

**Fuel Transfer Pump**
Diaphragm pump

**Injector Bleeders**
4-hole maxi

**Fuel Filters**
Replaceable-cartridge type

**Alternator**
Integrated in fan hub, 14 volts, 55 amps (standard)

**Starting Motor**
2.2 kW, 12 volts (standard)

**CAB Heating System**
Connection facility on engine for oil heating circuit

---

**Version Options**
- Intake manifold connections
- Exhaus pipes
- Fan guard
- Compressor
- Hydraulic pump
- Engine mounting, rigid or resilient
- Oil pan
- Oil dipstick
- SAE J1835 adapter housing
- Alternator, 12 or 24 V

---

40
### Maximum Torque

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<tr>
<th></th>
<th>M (Nm)</th>
<th>n (RPM)</th>
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<tr>
<td>I Automotive power</td>
<td>113</td>
<td>1800</td>
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<tr>
<td>II Highly intermittent operation</td>
<td>113</td>
<td>1800</td>
</tr>
<tr>
<td>III Intermitten operation</td>
<td>110</td>
<td>1800</td>
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### Minimum no-load speed

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<tr>
<th></th>
<th>RPM</th>
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<tr>
<td>Brake specific fuel consumption</td>
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<table>
<thead>
<tr>
<th></th>
<th>kg</th>
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<tbody>
<tr>
<td>Engine weight incl. starter motor incl. alternator incl. integrated cooling fans</td>
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**Power ratings for automotive and equipment engines**

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<tr>
<th>Rating category</th>
<th>P (kW)</th>
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<tr>
<td>I Automotive power ratings</td>
<td>2000</td>
</tr>
<tr>
<td>to NEES 65/126/EC</td>
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<tr>
<td>or ISO 1585</td>
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</tr>
<tr>
<td>II ISO net brake fuel step power</td>
<td>22.0</td>
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<td>(SFR) to DIN 8271</td>
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<td>for highly intermittent operation</td>
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<tr>
<td>III ISO net brake fuel step power</td>
<td>21.0</td>
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<tr>
<td>(SFR) to DIN 8271</td>
<td></td>
</tr>
<tr>
<td>for intermittent operation</td>
<td></td>
</tr>
<tr>
<td>IV ISO standard fuel step power</td>
<td>21.0</td>
</tr>
<tr>
<td>(SFR) to DIN 8271</td>
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</tr>
<tr>
<td>for continuous operation</td>
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**Power ratings for power generating sets**

<table>
<thead>
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<th>Rating category</th>
<th>P (kW)</th>
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<tr>
<td>ISO standard power available by 10% for one hour, with or without interruption.</td>
<td>27.0</td>
</tr>
<tr>
<td>ISO net brake fuel step power (SFR) to DIN 8271, for highly intermittent operation, plus for standby generator</td>
<td>30.0</td>
</tr>
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</table>

*Contact head office.*

Subject to engineering change without prior notice.

Conversions:

- **ft/min = m/s x 1.0885**
- **PSI = bar x 14.5**
- **lb/ft = Nm x 0.737**
- **lb = kg x 2.2**

Represented by:

Klicker-Humboldt-Deutz AG
D-5000 Klin 80
Deutz Mietherer-Str. 111
WP 2 21/0 22.1
Teld. 88 12-8
Telefax: - 218 22-35 25
AM-M: 05/86
Best-Nr: 0031 1404

KHD DEUTZ MEN AND ENGINES
New Engine.

The DEUTZ FL1011 engine family offers future-oriented user-friendly and flexible “all-around” driving packages covering the power range between 10 and 53 kW.

Future-oriented – as they are engines based on technical and social standards which will safely carry us into the future.

User-friendly – as their low vibrations, low noise level, easy operation and excellent cab heating performance are the criteria which define a comfortable working environment.

Flexible – as their great number of optional components makes them a ready match for any given application – a feature inherent to all DEUTZ engines.

Various different power take-off locations render the engine installation low-cost and simple.

New Technology.

In addition to the characteristic KHD DEUTZ quality standards, i.e. high reliability, indifference to extreme ambient conditions, modular construction concept engineered for minimum maintenance and service effort, etc. this engine offers some important innovative features, such as integrated two-media cooling using air and oil, a new DEUTZ direct injection system and an individual injection pump for each cylinder.

New Values

The new FL ten-elevens are bound to be winners thanks to their high fuel economy, reduced pollutant emissions in the exhaust and reduced noise level.

They are outstanding performers in their power class, also in respect of economy and environmental compatibility.
GENERATOR
# GENERATOR

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
<th>S.N./PT. No.</th>
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<tr>
<td>Single</td>
<td>Lima</td>
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<tr>
<td>Self Regulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>240 Volts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1800 RPM's</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Phase</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 120 V on single phase, one line of 3 phase is high voltage
TYPE MAC Brushless AC Synchronous, Internally Regulated Alternator Frame 280
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- Circuit Diagram .................................................. 4
- Performance Data ................................................ 4

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- Rotor Damage Repair Procedures ............................... 5
- Generator Windings (Drying) ..................................... 5
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PRINCIPLE OF OPERATION
The MAC generator is a self-regulated, rotating field synchronous unit with the rotor having a salient pole construction with amortisseur windings. The generator stator and exciter stator are combined in a common housing. The generator field, exciter rotor and rotating rectifier assembly are mounted on a common shaft. The output of the exciter rotor is applied to the generator field winding through a rotating, full wave bridge, silicon rectifier unit.

The exciter pole pieces contain residual magnetism, setting up lines of force across the air gap to the exciter armature. When the exciter armature begins to rotate, a voltage is induced and current flow is initiated in the exciter armature AC windings. This voltage is fed to the rotating rectifier assembly, rectified and fed to the alternator field coils. This DC voltage is sufficient to magnetize the laminated alternator field which will set up lines of force across the air gap to the alternator stator. As the generator rotor rotates a voltage will be induced and current will flow in the alternator stator windings and to the output circuit.

All connections between the exciter stator windings and the generator stator windings are internally connected within the stator housing. Only the output power leads of the generator unit are brought out to the generator terminal box.

CIRCUIT DIAGRAM
Figure 2 shows the internal schematic diagram of the generator, exciter and rectifier unit. The generator is a three phase unit and the exciter stator and exciter rotor also have three phase windings. A portion of the exciter stator windings is connected across a tap on the generator stator windings. Another portion of the exciter stator windings is connected in series with the output of the generator and provides a compounding excitation characteristic.

The rotor is, in effect, the secondary of a rotating current transformer induction frequency converter. The exciter rotor output voltage is applied to the generator field windings by a three phase full wave rotating silicon rectifier unit. The response time of the excitation system is very fast since the exciter stator carries an alternating current corresponding to the load current which appears immediately on the exciter primary. An increase in load current will cause an immediate increase in the exciter secondary output voltage which is rectified and applied to the generator field windings. The inherent compounding characteristics of the excitation system provide excellent voltage regulation even under heavy overload conditions.

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PERFORMANCE DATA

The excitation characteristics of fast exciter response with maximum exciter output makes this generator ideal for motor starting loads that require a very high current at low power factor during the motor starting and acceleration periods. At the same time it offers the rugged, reliable, maintenance-free operation inherent in the brushless type generator. No external controls are needed with a Lima MAC generator. The performance of a 10 kW Lima MAC synchronous generator is indicated in Figure 3.

SECTION I
INSTALLATION AND OPERATION

UNPACKING:
When unpacking, check for damage in shipping. Report any damage at once to delivering carrier. Read instruction tags shipped with generator.

INSTALLATION:
The generator must be properly aligned and located in a well-ventilated place where the air temperature will not exceed 40°C or 104°F, and should be accessible for cleaning. An open type generator should not be located where there are abrasive or conductive dusts, corrosive gases or fumes, or where excessive moisture may be encountered. A totally fan-cooled generator should be used where these conditions exist. Air openings of the generator should be cleaned frequently to remove accumulated dust and dirt, which may cause overheating and burn out.

WIRING CONNECTIONS:
Electrical characteristics are shown on the nameplate. Refer to connection diagrams on pages 10 and 11 for proper electrical connections.

OPERATION:
After the generator has been properly connected to the driving unit and the load lines connected to the generator's leads according to the wiring diagram, the unit is ready for operation. To connect the coupling discs of a single bearing generator to the driving engine's flywheel it may be necessary to slide the rotor forward a few inches out of the stator. Taking care not to slide it so far as to cause the rotor to come out of the bearing entirely and down upon the stator windings, causing damage to the windings.

Ordinarily, a chain hoist is needed to jockey the generator rotor into position.

STANDBY UNITS:
Generators used as an auxiliary power source in case of commercial power failure must be isolated from the commercial line before being placed in operation.

CAUTION: MAKE SURE UNIT IS COMPLETELY SHUT DOWN AND FREE OF ANY POWER SOURCE BEFORE ATTEMPTING ANY REPAIR OR MAINTENANCE ON THE UNIT.

PARALLEL OPERATION:
For parallel operation, both units must be of the same voltage, frequency, and phase. Phase voltages of paralleled units must be synchronized. This generator set utilizes the "dark lamp" method of paralleling.

ROTATION:
The generator can be operated in either direction of rotation.

OVERLOAD:
The load on the generator should be checked with an AC ammeter to see that the ampere rating stamped on the nameplate is not exceeded. Prolonged overload on the generator may cause it to overheat and possibly burn out.

LUBRICATION:
Ball bearings on Lima generators are pre-lubricated and require no further lubrication for the life of the bearing.
**SECTION II**

**SERVICE AND MAINTENANCE**

**PREVENTATIVE MAINTENANCE AND OPERATING PERCAUTIONS:**

Costly repairs and down time can usually be prevented by operating electrical equipment under conditions which are compatible with those at which the equipment was designed to operate. Follow the instructions as outlined to insure maximum efficient utilization of the electrical equipment.

**COOLING:**

Keep all cooling parts clean and make certain sufficient room is left on all sides for a plentiful supply of fresh coolant air flow. DO NOT EXCEED AIR TEMPERATURE RISE AS SHOWN FOR 50°C ABOVE A 40°C AMBIENT. This insures that the insulation NEMA Class "F" will not be damaged. DO NOT EXCEED RATED LOAD, except as specified for the equipment. OPERATE AT RATED SPEED. Failure to operate generators at rated load or speed will cause overheating and possibly damage to windings due to over voltage or current.

**BEARING REPLACEMENT:**

Factor lubricated shielded bearings will normally provide several years of trouble free service when operated under normal conditions. Excessive bearing load and adverse environment conditions will greatly shorten bearing life. Should bearing failure occur, bearings can be replaced. ALWAYS REPLACE WITH THE SAME TYPE BEARING AS INSTALLED AT THE FACTORY. CHECK PARTS LIST FOR PART NUMBER. Include generator serial number when ordering bearings.

**ROTATING DIODE BRIDGE:**

The rotating diode bridge can be removed and replaced. Excessive overcurrent, overvoltage, overspeed, or reverse currents can cause damage to the assembly or any of the component parts.

**ROTOR DAMAGE:**

The damper bars of the generator prevent excessive hunting when AC generators are operated in parallel. Damper bars, because they must have low electrical resistance and are subjected to extreme centrifugal forces, must be mechanically secure and permanent. Consequently, they are welded to end plates completely covering the field.

All rotors are static and dynamically balanced to a high degree on precision machines to assure minimum vibration. They will, therefore, remain dynamically stable at speed well beyond the synchronous speed of the generator. The rotors on generators are, however, subjected to extreme centrifugal forces which can increase beyond safe operating limits at excessive overspeed. Therefore, the prime mover should be adequately governed to prevent overspeed.

Damage to the rotor can also occur due to overheating which can be caused by the air flow being restricted from dust or other foreign objects collecting in the air passage.

If a rotor becomes defective, it should be returned to the factory with full nameplate data, because the rotor coils are enclosed in welded squirrel cage winding. To repair a rotor the special tooling and technique of the factory is necessary and essential. The Lima Electric Company, incorporated, facilities can perform a complete rebuild, or rewind job with greater skill and craftsmanship than can be found in the average motor rewind shop. Should a failure occur, the factory should be notified immediately and steps will be taken to get the generator back into service with the least expense; and more important, to determine the cause of the failure and take steps to prevent a recurrence.

**PRECAUTIONS:**

**GENERATOR WINDINGS (DRYING):**

Generators that have been in transit or storage for long periods may be subjected to extreme temperature and moisture changes. This can cause excessive condensation, and the generator windings should be thoroughly dried out before bringing the generator up to full nameplate voltage. If this precaution is not taken, serious damage to the generator can result. The following steps should be taken to effectively dry the generator windings:

A. (1) Place generator in drying oven or hot room.
   (2) Dry with warm air blower directed through windings.

B. (1) If the generator has been operated and then put into storage for any period of time, a P.D. George #11127 type air-dry fungus resistant varnish should be reapplied.

Experience has shown that it is necessary to take these precautions in locations such as seaboard installations and other highly humid areas. Some installations will be in atmospheres that are much more corrosive than others. A little precaution along the lines outlined here could eliminate an unnecessary repair job.
Each generator was subjected to a standard NEMA insulation test, which means 1000 volts plus twice the highest voltage for which the generator is rated was impressed between the winding and frame. All machines are insulated with a high safety factor for the class of insulation used. The latest and newest in insulation and baking techniques are used.

The finest insulation job can be very quickly broken down carelessly applying high voltage to windings in a moisture saturated condition. Mishandling in this respect can easily cause a breakdown, making it necessary to return the generator to the factory for repair, and consequent expense and loss of time.

**WARNING:** HIGH VOLTAGE (DIELECTRIC) TESTING MUST NOT BE PERFORMED TO THE MACHINE WITHOUT FIRST OBSERVING NEMA RULES. THE INSULATION OF THIS GENERATOR WINDING MAY BE SAFELY CHECKED BY USING A MEGGER. A HIGH MEGGER READING INDICATES LOW INSULATION LEAKAGE.

**RESTORING RESIDUAL MAGNETISM:**
The current necessary to magnetize the alternator field is obtained from the exciter. Initially, upon starting the generator, current flow and voltage are induced into the exciter armature by the magnetic lines of force set up by the residual magnetism of the exciter field poles.

Residual magnetism of the exciter field poles may be lost or weakened by a strong neutralizing magnetic field from any source, or if the generator is not operated for a long period of time.

Should the generator fail to build up voltage after being disassembled for any reason, a momentary short-circuit of any two generator leads should be sufficient to correct this condition. If not, an alternate method may be used. Apply either an alternating current or a direct current voltage of approximately 20 volts to any to generator leads. Do not make a positive connection but rather touch the leads together until the generator voltage begins to rise and then remove. It is suggested that a 30 ampere fuse be inserted in the circuit to prevent any damage in case the build-up voltage is not removed quickly enough.

Start generator and observe generator build-up. Reflash field if generator output voltage does not build up.

**TESTING DIODES WITH AN OHMMETER:**
Isolate the rectifier assembly by disconnecting the two leads from the main rotor and three leads from the exciter rotor. Do not unsolder diodes. Test each diode by applying the probes of an ohmmeter to the anode and cathode.

A good diode will produce a meter reading of only a few ohms when the probes are applied in one direction, and a reading of near infinity when the probes are reversed. If both readings are high, or both are low, the diode is defective and must be replaced.

Diode failure after a 25 hour "run-in" period is generally traceable to external causes such as lightning strike, overheating or a reverse current fed into the alternator. To save excessive service time and call-backs, it is a generally accepted practice to replace the entire rectifier assembly where failure can be traced to external causes AFTER THE CAUSE OF DIODE FAILURE IS IDENTIFIED AND CORRECTED.

**RECTIFIER REMOVAL PROCEDURE:**
Rectifiers may be removed through the bearing cap on the rear of the generator. (See Figure 6, Item B.) First, remove the bearing cap by removing the four bolts shown in Figure 6 as Item A. You can now see both the bearing (Item C) and rectifier assembly (Item D). Use a bearing puller to remove the bearing from the main shaft being careful to locate the puller on the inner race of the bearing to avoid bearing damage. Once the bearing is free it is then necessary to disconnect leads A, B, C, and D as shown in Figure 5 assembly drawing. Then remove the three hold-down cap screws which secure the rectifier assembly to its adaptor. Once this procedure is complete the rectifier assembly is free for removal.

Follow the testing procedures outlined in testing diodes and Figure 5.
After the rectifier assembly has been repaired or replaced, reverse the procedure as stated above, being careful that all lead connections are tight and that set screws are locked with a Lock-Tite compound.

TRoubleshooting Procedures

AC Brushless Generator

As with any machine, trouble may develop in electrical generators. It may be due to long service or neglect of regular maintenance, servicing, and checking. Should trouble develop, the following instructions will be helpful in tracing the cause and making repairs.

Speed Deviations:
The generator speed should be maintained at rated nameplate speed. The frequency and voltage of the generator output depends on speed. If the generator runs slower than rated speed, the voltage will drop off.

No Voltage:

CAUSE
Loss of residual magnetism in exciter field poles
Open in stator windings.
* Open or short in rotating rectifiers.
Short circuited.
* Open in alternator field.
* Shorted exciter armature.
* Shorted leads between exciter armature and generator field.

CHECK AND REMEDY
Flash field, see page 5 "Restoring Residual Magnetism".
Check for continuity in windings. Return to factory for repair if open.
Check rectifiers per previous instructions, replace if faulty.
Clear lead to restore voltage build-up.
Check for continuity and return rotor to factory for repair if field coils are open.
Check for short and replace if faulty. Use a "Kelvin" type bridge to measure this resistance.

NOTE: *Designate rotating parts. Generator must be open to test.

Low Voltage:

CAUSE
Excessive load.
Low speed.
Line loss.
High resistance connections — connection will be warm or hot.
Shorted field.
Low power factor.

CHECK AND REMEDY
Reduce load. With 3 phase generators, the load on each leg should be as evenly balanced as possible and should not exceed the rated current on any leg.
Check engine for malfunction or system for overload.
Increase size of line lead wire.
Test field coils for possible short by checking resistance with an ohmmeter or resistance bridge. Return rotor assembly to factory for repair if alternator field coils are shorted.
Reduce inductive (motor) load. Some AC motors draw approximately the same current regardless of load. Do not use motors of larger horsepower rating than is necessary to carry the mechanical load.
FLUCTUATING VOLTAGE:

(May be indicated by flickering lights)

CAUSE
Irregular speed of engine.
Fluctuating speed.
Loose terminal or load connections.
Defective bearing causing uneven air gap.

CHECK AND REMEDY
Check engine for malfunction or load for fluctuation.
Stabilize load. The addition of a lamp load (resistance load) may compensate partially for load changes caused by intermittent motor operation. Do not overload.
Make better connection mechanically and electrically.
Replace worn bearing.

HIGH VOLTAGE:

CAUSE
Excessive speed.

CHECK AND REMEDY
Check engine for malfunction.

OVERHEATING:

CAUSE
Generator overloaded.
Clogging ventilation screens.
High room temperature
Insufficient circulation.
Low power factor.
Unbalanced load.
Dry bearing.

CHECK AND REMEDY
Reduce load. (Check with ammeter and compare with nameplate rating.)
Clean air passages.
Provide cross-ventilation.
Reduce inductive loads or install power factor improvement capacitors.
The load on each leg should be as evenly balanced as possible and should not exceed the rated current on any leg.
Replace bearing.

MECHANICAL NOISE:

CAUSE
Defective bearing
Rotor scrubbing on stator.
Loose laminations.
Loose or misaligned coupling.

CHECK AND REMEDY
Replace bearing.
Sad bearing, replace. Bent shaft, return to factory.
Loose endbell, tighten; loose drive discs, tighten.
Return to factory for repair.
Tighten or align.

GENERATOR FRAME PRODUCES SHOCK WHEN TOUCHED:

CAUSE
Static charge.
Grounded armature or field coil.

CHECK AND REMEDY
Ground generator frame.
Return to factory for repair.
ELECTRICAL WIRING PROCEDURES  --  WIRING DIAGRAMS

CAUTION

Wiring of the alternator should be done in accordance with good electrical practices. Follow government, association and industry standards. In some wiring arrangements, groups of terminals are connected together with no further termination. These terminals must be properly insulated to avoid a hazard to personnel and potential equipment damage.

WIRING REFERENCE CHART

<table>
<thead>
<tr>
<th>Configuration</th>
<th>MAC Type Specific Voltage (60 Hz)</th>
<th>Ref. Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-Lead Unit, 4-Wire 240 Volt Delta Connected</td>
<td>240V</td>
<td>A</td>
</tr>
<tr>
<td>12-Lead Unit, High Voltage Wye Connected</td>
<td>416V</td>
<td>B</td>
</tr>
<tr>
<td>12-Lead Unit, Low Voltage Wye Connected</td>
<td>208V</td>
<td>C</td>
</tr>
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<td>10-Lead Unit, High Voltage Wye Connected</td>
<td>460V</td>
<td>D</td>
</tr>
<tr>
<td>10-Lead Unit, Low Voltage Wye Connected</td>
<td>240V</td>
<td>E</td>
</tr>
<tr>
<td>12-Lead Unit, Low Voltage Delta</td>
<td>120V</td>
<td>F</td>
</tr>
<tr>
<td>12-Lead Unit, 240 Volt Zigzag</td>
<td>240V</td>
<td>G</td>
</tr>
</tbody>
</table>

DIAGRAM A
12-Lead Unit, 240 Volt, Delta Connected, 3 Phase
Connect together the following six sets of terminations:
T1 and T12 to form L1
T2 and T11 to form L2
T3 and T10 to form L3

T6 and T9

OUTPUTS: 120V, 120V, 240V, 30V
L1 to L0 L1 to L2 L2 to L0 L2 to L3 L3 to L1

CAUTION: Properly insulate all unused terminations.

DIAGRAM B
12-Lead Unit, High Voltage, Wye Connected, 2 Phase
Connect together the following four sets of terminations:
T4 and T7, T5 and T9
T6 and T8
T10, T11 and T12 to form L0

T1 to T0 T2 to T0 T3 to T3

OUTPUTS: 240V, 416V, 30V
L1 to L0 L1 to L2 L2 to L0 L3 to L3 L3 to L0 L1 to L3

CAUTION: Properly insulate all unused terminations.
12-Lead Unit, Low Voltage, 240 Volt, Zigzag, 1 Phase
Connect together the following four sets of terminations:
T1 and T7 to form L1
T2 and T8 to form L2
T3 and T9 to form L3
T4, T5, T6, T10, T11 and T12 to form L0

OUTPUTS: 120V, 10
240V, 10
L1 to L0
L1 to L2
L2 to L0
L2 to L3
L3 to L0
L3 to L1

CAUTION: Properly insulate all unused terminations.

12-Lead Unit, High Voltage, Wye Connected, 3 Phase
Connect together the following four sets of terminations:
T4 and T7
T5 and T8
T6 and T9
T1 is L1
T2 is L2
T3 is L3

OUTPUTS: 377V, 10
240V, 30
L1 to L0
L1 to L2
L2 to L0
L2 to L3
L3 to L0
L3 to L1

CAUTION: Properly insulate all unused terminations.

12-Lead Unit, Low Voltage, Y-Wye Connected, 3 Phase
Connect together the following four sets of terminations:
T1 and T7 to form L1
T2 and T8 to form L2
T3 and T9 to form L3
T4, T5, T6 and T10 to form L0

OUTPUTS: 120V, 10
240V, 30
L1 to L0
L1 to L2
L2 to L0
L2 to L3
L3 to L0
L3 to L1

CAUTION: Properly insulate all unused terminations.
### DRIPPROOF GENERATOR PARTS LIST
#### 280 FRAME
#### TWO BEARING

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<tr>
<th>Part No.</th>
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<td>Bearing, Cap</td>
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<td>5</td>
<td>Rectifier Assembly</td>
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<td>Exciter Rotor</td>
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<td>7</td>
<td>Exciter Stator</td>
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<tr>
<td>8</td>
<td>Generator Rotor</td>
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### DRIPPROOF GENERATOR PARTS LIST
#### 230 FRAME
#### SINGLE BEARING

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<td>Bearing, Cap</td>
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<td>Rectifier Assembly</td>
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<td>Screen</td>
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<td>Generator Frame</td>
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<td>21</td>
<td>O-Ring</td>
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Generator Application Considerations for Electric Center Pivot and Lateral Move Irrigation Systems

INTRODUCTION

Most center pivot and lateral move irrigation systems are installed in applications where 3 phase utility power is not available or economical. In these applications, electric generators are used to power the 3 phase electric motor that drives the wheels at each irrigation tower.

The primary generator application considerations are:

1. Electric motor starting capacity of the generator
2. Electric motor operating characteristics
3. Ambient temperatures
4. Environmental conditions
5. Maintenance requirements
6. Generator sizing

This paper will address each of these considerations. The observations presented here are supported by the successful performance of the Lima MAC generators on over 30,000 irrigation systems around the world.
1. ELECTRIC MOTOR STARTING CAPABILITY

Typical irrigation systems have from 7 to 20 support towers. There is usually a 3 phase, 480 volt, 60 hertz or 3 phase, 400 volt, 50 hertz electric drive motor at each tower. The electrical control systems continuously turn these motors on and off as required to keep the system in alignment. Thus, the ability of the generator to accommodate the high inrush starting current of the motors is a critical application consideration. The generator design characteristic is usually expressed in motor HP/generator KW electric motor starting capabilities. Thus, a generator with a 1 HP/1 KW characteristic has twice the motor starting capability as another design with a .5 HP/1KW capability.

Most general purpose type generators which utilize external automatic voltage regulators have motor starting capability of approximately .5 HP/1KW.

Special purpose generators such as the patented Lima MAC (Motor Application Characteristic) have a 1 HP/1KW motor starting capability, and are better suited for irrigation system applications. The MAC output voltage dips less than 35% when a 1HP/1KW motor load is applied across the line, and smoothly recovers to full voltage in less than one second.

2. ELECTRIC MOTOR OPERATING CHARACTERISTICS

Most irrigation systems use electric drive motors rated 1 HP, 3 phase, 480 volts, 60 hertz, 1800 RPM or 400 volts, 50 hertz, 1500 RPM. The drive motor is connected to a gear reduction system to obtain the proper wheel speed. The drive motors are designed for the extremely high torque starting requirements of the system. The starting amperage requirement of an individual motor is commonly 10-15 times its running amperage. The total irrigation system operates at a low power factor of .5 to .6 because of the inherently low P.F. of each motor running and extremely low P.F. of individual motors when starting. The conservative 80 degree C temperature rise rating of the Lima MAC generator provides extra KVA capacity to handle the low power factor irrigation system loads.

The generator is also rated 3 phase, 480 volts, 60 hertz, 1800 RPM, or 400 volts, 50 hertz, 1500 RPM. The output voltage is controlled by the generator voltage regulation system, but the output frequency is entirely controlled by the speed of the engine driving the generator. If the generator speed varies from rated RPM, the output frequency will go above or below rated frequency. Irrigation applications many times use the pumping engine to pump water plus drive the generator. Thus, engine speed and generator frequency control is not as precise as normal generator applications.

The electric drive motor has a volts/hertz design characteristic. The volts/hertz design characteristic allows the drive motor to be operated under and over rated frequency as long as the voltage changes in direct relation to the change in frequency. To avoid drive motor overheating, the generator output voltage should also have this volts/hertz characteristic.

Most general purpose type generators with an external voltage regulator have constant output voltage regardless of variations in engine speeds. Some voltage regulators have “underfrequency protection” and will reduce the voltage at speeds below rated frequency, but will not increase the voltage at speeds above rated frequency.

The Lima MAC Generator has an inherent volts/hertz characteristic both below and above rated speed and this design feature is especially suited for irrigation systems, avoiding damage to the drive motors.
3. AMBIENT TEMPERATURES

Most modern generators, including the Lima MAC, use Class F insulation materials rated 145 degree C total temperature. The temperature rise of the generator is determined as follows:

145 degree C Total Temperature
- 40 degree C Ambient Temperature
  = 105 degree C Maximum Temperature Rise

This means that in a 40 degree C ambient, the generator cannot exceed 105 degree C rise during operation without experiencing insulation system deterioration. Also, if ambient temperatures above 40 degree C are expected, a generator with less than 105 degree C temperature rise must be selected. For example, if 50 degree C ambients are expected, the generator temperature rise should be limited to a maximum 95 degree C temperature rise.

Most generators designed to British standards are rated 100 degree C rise. Most continuous duty generators designed to NEMA standards have 105 degree C rise ratings.

The Lima MAC Irrigation Generators are rated at a conservative 80 degree C rise and are well suited for irrigation system applications in areas where 50 degree C ambients are experienced.

Generator designs which utilize brushes and slip rings should be avoided. Generators which have complicated electronic voltage regulators, fragile printed circuit boards, contactors, sliding resistors, and complicated wiring of external current transformers are prone to numerous maintenance problems and poor reliability.

The Lima MAC has an extremely simple rotating current transformer exciter, is brushless, self-regulated, and does not utilize an external automatic voltage regulator. The weather protected Type I construction, double sealed bearings, and moisture resistant electrical insulation system provides long life on irrigation system applications.

5. MAINTENANCE REQUIREMENTS

As in any sophisticated system, minimum maintenance is a key design objective. More often, less complicated designs result in minimum maintenance because of their simplicity, fewer parts, etc.

Following is a comparison of the Lima MAC and other general purpose generator designs from a maintenance viewpoint:

<table>
<thead>
<tr>
<th>Bearings</th>
<th>Lima MAC Generator</th>
<th>Typical General Purpose Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overlaid -</td>
<td>Full Wave 3 Phase,</td>
<td>Penn. Lubed or Greaseable</td>
</tr>
<tr>
<td>Permanent Lubed</td>
<td>Rotating Rectifier Assy.</td>
<td>Complicated Induction</td>
</tr>
<tr>
<td>Simple Outboard Location</td>
<td>Slip Rings, Brushes</td>
<td>Design</td>
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<tr>
<td></td>
<td>External Volt. Regulator</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Switches, Knobs, Resistors</td>
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</tr>
<tr>
<td></td>
<td>For Output Control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>Some only half wave</td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>None</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The simplicity of the Lima MAC design has proven to be the minimum maintenance design for irrigation systems.

4. ENVIRONMENTAL CONDITIONS

Most irrigation system generators are installed outdoors in unprotected areas. Thus, they are subject to blowing sand and dirt, water, and agriculture chemicals. For maximum generator life with minimum maintenance, a simple, reliable, basic design is desired.
6. GENERATOR SIZING

Because of the 1 HP/1 KW motor starting capability of the MAC, sizing the generator to the irrigation system is simple.

a. STANDARD IRRIGATION SYSTEM:
   Number of irrigation system towers \leq KW rating of Lima MAC Generator

b. IRRIGATION SYSTEM WITH ELECTRIC BOOSTER PUMP:
   Number of irrigation system towers + HP rating of booster motor \leq KW rating of Lima MAC generator.

<table>
<thead>
<tr>
<th>Number of Towers</th>
<th>Booster Motor HP</th>
<th>Lima MAC Generator Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0 HP</td>
<td>7 1/4 KW</td>
</tr>
<tr>
<td>7</td>
<td>3 HP</td>
<td>10 KW</td>
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<tr>
<td>10</td>
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</tr>
<tr>
<td>12</td>
<td>5 HP</td>
<td>20 KW</td>
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</table>

If a larger than required (oversized) Lima MAC Generator is used to power the irrigation system, the power demanded by the irrigation system does not change. The Lima MAC Generator only supplies the power demanded by the electrical load.

"Oversized" Lima MAC Generators operate cooler than normal, increasing overall life expectancy. Also, an oversized alternator may allow for the addition of an electric booster pump at a later date, incorporating the original generator.

The decision of using "oversized" Lima MAC Generators is typically made based on an evaluation of first cost, interchangeability of generators between irrigation systems, inventory costs, and future electrical requirements (increasing system length/addition of booster pump).

In summary, the Lima MAC Generator is the SIMPLIST, most RELIABLE, and most ECONOMICAL generator available for pivot and lateral move irrigation system.

SPECIFY LIMA MAC...YOUR PRODUCTIVITY DEPENDS ON IT!!

Patented Recovery Circuit

This oscillograph shows the recovery capability of the MAC's patented voltage control circuitry. With a 1 HP per KW motor load applied across the line, voltage dip is under 35%, followed by a smooth recovery to full voltage in less than one second.

LIMA Lima Energy Products

The Lima Electric Co., Inc.
P.O. Box 918
Lima, Ohio 45802
(419) 227-7327
TELEX 242433

Making Energy Work For You

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<td>16.12</td>
<td>1.50</td>
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<td>+6</td>
<td>1/2</td>
<td>.41</td>
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<td>1/2</td>
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<td>10.371</td>
<td>9.62</td>
<td>2.44</td>
<td>1.80</td>
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</tbody>
</table>

**Diagram Details:**
- **Adapter #161:**
- **Drive Disc Equally Spaced:**
- **Holes Designated:**
- **Legend:**
  - **\( \Phi 80 \)**
  - **\( \Phi 7.00 \)**
  - **\( \Phi 7.00 - 7.05 \)**

**Master Copy:**
- **Title:**
- **Date:**
- **Revision:**
- **Scale:**
- **Drawing Number:**
- **Approval:**
- **Sheet:**

**Additional Notes:**
- **Air Space - This Area Must be Free of Any Obstructions**
- **Not to Scale**

**Legend:**
- **X:**
- **Y:**
- **Z:**
- **M:**
- **E:**
- **B:**
- **H:**
- **G:**
- **J:**
- **C:**
- **D:**
- **Label:**
CONTROL PANEL
S SERIES CHANGE — Series B only applies to the Type S Starter Form B (3 ambient compensated overloads). All parts of Form B Series A and B starters are interchangeable, only the overload relay block differs. If the overload relay block of a Form B Series B starter is replaced with the Series B block, the overload relay thermal unit must be selected from the Series B thermal unit selection tables for proper motor protection.

ACCESSORIES — Auxiliary contacts, power pole kits and other field selectable kits are available. Refer to the Square D Digest Class 1999 section for selection and application information.

OVERLOAD RELAYS — Melting alloy overload relay blocks are supplied as standard with provisions for 1, 2 or 3 thermal units. The 3 thermal unit melting alloy overload block can be converted to a 3 thermal unit block by removing the center strap and installing a thermal unit in its place. The contact unit (item 6) of the melting alloy overload block can be supplied with a N.O. or N.C. delayed alarm circuit contact in addition to the standard N.C. contact. The alarm circuit contact unit can be installed in the field. See Parts List.

Bimetallic overload relays are available as an optional feature. Starters with Form B1 (provisions for 2 thermal units) and Form B2 (provisions for 3 thermal units) units are supplied with a bimetallic compensated overload relay block. A SPDT contact is supplied as standard on all Type S bimetallic overload relays. The N.C. contact can be used in an alarm circuit and must be wired on the same polarity as the N.C. contact. Contacts are not replaceable. In order to directly replace a bimetallic overload relay, the appropriate part number listed on the Parts List should be used.

TERRITORIES — Power and control terminals on standard devices are suitable for use with switch wire seally.

CONTACTS — Are not harmed by decoloration and slight pitting. DO NOT FILE THEM as dressing wastes contact material. Replacement is necessary only when the contact has worn thin.

CONTACT INSPECTION — It is unnecessary to remove any wiring to inspect contacts. Merely loosen the two captive screws (item C) which hold the contact actuator to the contact block. Lift the contact actuator to expose contacts.

DANGER: Hazard of electrical shock or burn. Be sure to turn off power supplying this equipment before working on it.

MECHANICALLY INTERLOCKED UNITS — Refer to Service Bulletin 9095-286 for mechanical interlock.

REPLACEMENT CONTACTS — Replacement power contacts and springs for starters or contacts are available as kits. Order from Parts List.

MANUAL OPERATION — Manual operation of contactors and starters may be accomplished by pushing the contact down with a screwdriver. A slot is provided in the contactor cover for this use. DANGER — Do not manually operate unless starter is isolated from the line.

COIL REPLACEMENT — To replace the coil loosen the two captive cover screws (item A) and remove the cover. Disconnect wires from coil terminals. Remove the coil and magnet assembly. Separate the coil from the magnet assembly. Reassemble is a reversal of the above. Manually operate (See Manual Operation above) the device when reassembled to ensure all parts are functioning properly. Follow recommended tightening torques when reassembling device.

ASSEMBLY INSTRUCTIONS — Factory recommended torques for mechanical, electrical and pressure wire connections are listed in the Recommended Tightening Torque Table and Instruction Sheet. These must be followed to ensure proper functioning of the device.

SHORT CIRCUIT PROTECTION — Branch-circuit overcurrent protection must be provided for each contactor or starter. Starters, refer to instructions furnished with the thermal unit selection table. For contactors (Class 8502 or 8702), provide branch-circuit overcurrent protection in accordance with the National Electrical Code, except do not exceed the maximum protective device rating listed below.

<table>
<thead>
<tr>
<th>NEVIA Value</th>
<th>Maximum Voltage</th>
<th>Trip Delay</th>
<th>Fuse Ampere</th>
<th>Hold Time</th>
<th>Delay Fuse</th>
<th>Circuit Breaker (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>250</td>
<td>30</td>
<td>80</td>
<td>80</td>
<td>40</td>
<td>60</td>
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</table>

8502/36-278

Classes 8502 and 8536 Sizes 1 and 1P — AC Magnetic Contactors and Starters

Type SC, Series A or Series B
DISTANT CONTROL OF CONTACTORS & STARTERS

To assure proper contactor operation, series impedance and shunt capacitance of the control circuit must be considered. Depending upon the voltage, wire size, and the number of control wires used, the limiting factor for figuring the maximum distance of the wire run may be series impedance or shunt capacitance. If distances to start or stop stations are longer than those listed, the wire run configuration and materials must be analyzed. For further information contact your local Square D field office and ask for Product Data Bulletin M379.

ORDERING INSTRUCTIONS — Specify quantity, part number and description of part, giving complete nameplate data of the device. For example, one Armature and Magnet Kit 31041-805-50 for Class 8536 Type 8C-3, Series A starter.

PARTS LIST

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Part Number</th>
<th>1 Pole</th>
<th>2 Pole</th>
<th>3 Pole</th>
<th>4 Pole</th>
<th>6 Pole</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Armature and Magnet Kit</td>
<td>21041-805-50</td>
<td>Y4</td>
<td>Y4</td>
<td>Y4</td>
<td>Y4</td>
<td>Y4</td>
</tr>
<tr>
<td>2</td>
<td>Contact Holding Contact</td>
<td>8536-805-50</td>
<td>Y4</td>
<td>Y4</td>
<td>Y4</td>
<td>Y4</td>
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<tr>
<td>3</td>
<td>Normal Open</td>
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<td>Y4</td>
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<td>Normal Close</td>
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<td>5</td>
<td>Contact Holding Circuit</td>
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<td>Control Kit</td>
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FACTORY RECOMMENDED TIGHTENING TORQUES

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Torque (lb-in)</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Close Screws (2 per series)</td>
<td>10-21</td>
</tr>
<tr>
<td>B</td>
<td>Close Terminal Ring Connectors (2 per series)</td>
<td>3-17</td>
</tr>
<tr>
<td>C</td>
<td>Tighten Ring Connectors (2 per series)</td>
<td>3-17</td>
</tr>
<tr>
<td>D</td>
<td>Tighten Contact Leads (2 per series)</td>
<td>0-8</td>
</tr>
<tr>
<td>E</td>
<td>Tighten Control Contact Leads (per series)</td>
<td>0-8</td>
</tr>
<tr>
<td>F</td>
<td>Wires Inside the Cabinet (2 per series)</td>
<td>10-21</td>
</tr>
<tr>
<td>G</td>
<td>Drop-in Ball Bearing Screws</td>
<td>3-17</td>
</tr>
<tr>
<td>H</td>
<td>Close Terminal Ring Connectors (2 per series)</td>
<td>17-21</td>
</tr>
<tr>
<td>I</td>
<td>Close Terminal Ring Connectors (2 per series)</td>
<td>17-21</td>
</tr>
<tr>
<td>J</td>
<td>Close Terminal Ring Connectors (2 per series)</td>
<td>17-21</td>
</tr>
<tr>
<td>K</td>
<td>Wires Inside the Cabinet (2 per series)</td>
<td>17-21</td>
</tr>
<tr>
<td>L</td>
<td>Wires Inside the Cabinet (2 per series)</td>
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MAGNET COILS

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<th>208 V</th>
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<th>415 V</th>
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</table>

SQUARE D

Superstore 27888 dated April, 1985

PAGE 2

P.O. Box 3744
Eakins Point, N.C. 27811
(919) 720-3671
June, 1988
30 Ampere Disconnect Switches with Flange Mounted Operating Mechanism

Used in Classes 8538 and 8738 —
Type SB Series C Size 0 and Type SC Series C Size 1
3-Pole AC Combination Starters

WARNING: Be sure to open the back-up disconnect device before inspecting or servicing the disconnect switch. Do not operate starter or disconnect switch with arc chamber cover or arc suppressor removed.

TABLE 1 PARTS LIST

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Part Number</th>
<th>Quantity Required</th>
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<tbody>
<tr>
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<td>Complete Disconnect Switch Assembly with operating mechanism — include item 2-5.</td>
<td>31301-014-52</td>
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<tr>
<td>2</td>
<td>Link Assembly</td>
<td>31301-012-00</td>
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<tr>
<td>3</td>
<td>Washer</td>
<td>31301-008-01</td>
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<td>4</td>
<td>E-Ring</td>
<td>24807-018-10</td>
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</tr>
<tr>
<td>5</td>
<td>Spring</td>
<td>31301-010-01</td>
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<tr>
<td>6</td>
<td>Lug</td>
<td>25056-09660</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Flange Assembly</td>
<td>31055-229-71</td>
<td>1</td>
</tr>
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<td>8</td>
<td>For NEMA Type 1 or 12 enclosures</td>
<td>31055-229-52</td>
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<td>9</td>
<td>Return Spring</td>
<td>32017-142-01</td>
<td>1</td>
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<td>10</td>
<td>Bolt, Spring Holder</td>
<td>31055-248-01</td>
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<td>11</td>
<td>Cotter Pin</td>
<td>24301-08400</td>
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<td>12</td>
<td>Hex Head Cap Screw</td>
<td>21401-22000</td>
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<td>13</td>
<td>Lock Washer</td>
<td>23701-22000</td>
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<td>14</td>
<td>Fuse Block</td>
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Squares D COMPANY

MARCH, 1993  Page 1
TABLE 2 FUSE CLIP KITS

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</table>

INTERCHANGEABLE

Non-INTERCHANGEABLE

1. Each kit includes six fuse clips, mounting hardware, and instruction label.
2. Class codes may be removed, once installed.

ELECTRICAL INTERLOCK

A one or two-pole electrical interlock kit may be added to the switch operating mechanism. The snap switch in the interlock kit may be replaced on existing installations. See table 3.

ORDERING INSTRUCTIONS

Specify quantity, part number and description of part.

SQUARE D COMPANY

PAGE 2

MAR. 1, 1982

65
PNEUMATIC ACTUATORS
RPB-Series Pneumatic Actuators
Design and Construction

Models RPB250-RPB2250

Mechanical Components

The Bettis RPB-Series pneumatic rack & pinion actuators are specifically designed for "quarter-turn" rotating mechanisms and are ideally suited for operation of plug, butterfly, or ball valves. These quality constructed and uncomplicated actuators provide a dependable, reliable and economic method of opening and closing a valve.

Double-acting models, requiring pressure to rotate in both directions, are available with output torques to 16,500 lb-in. Spring-return models, requiring pressure to rotate in one direction, are available with spring ending output torques up to 5150 lb-in. Standard operating pressures are 40 to 120 PSIG. Operating media for both double-acting and spring-return models may be dry or lubricated non-corrosive gas. Standard operating temperatures are from -40° to +200° Fahrenheit. Optional, high temperature trim is available for 0° to +350° Fahrenheit. All models are factory lubricated for the optimum cycle life of the actuator. All actuators are constructed for indoor or outdoor installation.
Models: RPB5000-RPB11000

Features

1. Bottom loaded, one piece blow-out-proof output shaft, is retained by a safety redundant internal retaining ring.
2. Self-contained space saving spring modules allow safe and simple conversion from double-acting to spring-return or to a different spring configuration.
3. Integral position stops allow up to ±5 degrees field adjustment at the 90 degree position.
4. The highly visible position indicator may be indexed 90 degrees as appropriate for optional mounting configurations.
5. An exposed square male drive suitable for manual override or accessory drive purposes may be removed along with the position indicator to expose the low profile slot-type accessory drive.
6. All fasteners are stainless steel.
7. All fasteners are stainless steel.
8. All fasteners are stainless steel.
9. All fasteners are stainless steel.
10. All fasteners are stainless steel.

Materials of Construction

A. Body: Precision-extruded aluminum alloy, hard anodized and fluoropolymer impregnated.
B. Piston: Cast aluminum alloy, dichromate dipped.
C. Output Shaft/Plan: Carbon steel, fluoropolymer coated.
D. End Caps: Cast aluminum alloy, fluoropolymer coated.
E. Fasteners: All stainless steel.
F. Seals: Nitrile standard.
G. Spring: Carbon steel, phosphate coated, oil dipped.
H. Heel Bearing: PEEK Alloy.
J. Piston Bearing: Fluoroplastic.
Operation

For counterclockwise output rotation, apply pressure to Port 1, which will force the pistons apart. The linear travel of the pistons is converted to a rotation of the drive shaft by the rack to pinion connection. The volume outside each piston is exhausted at Port 2.

For clockwise output rotation, apply pressure to Port 2, which will force the pistons together. The volume between the pistons is exhausted at Port 1.

Reverse Rotation

When required, the pistons can be inverted in the housing resulting in a clockwise rotation when pressure is applied to Port 1.

Travel Stop Adjustment

Drive shaft rotation is limited to 90° plus or minus 5° by the stop screws located in each end cap which limit the pistons outward travel.

Standard Assembly

Adjustment of the counterclockwise rotation limit is accomplished by rotating the stop screws to reduce or increase output rotation.

Reverse Assembly

When required, the pistons can be inverted in the housing allowing travel stop adjustment of the clockwise output rotation.
Typical Specifications

The following information may be used as a guide to compile specifications for rack and pinion pneumatic actuators. GH-Bettis RPB-Series actuators meet, or exceed all the specifications stated below.

1.0 Bettis RPB-Series
Pneumatic Rack & Pinion Actuators

1.1 The pneumatic actuator shall be quarter-turn, opposed piston rack and pinion type of a totally enclosed design with no external moving linkages.

1.2 The actuator shall be capable of 95° rotation and shall include external travel stops with a minimum of 10° adjustment.

1.3 The actuator shall be rated for continuous operation using dry or lubricated non-corrosive gas and suitable for mounting in any position.

1.4 Ambient temperature range shall be from -40°F to +200°F. For high temperature service, the actuator shall be rated from 0°F to +250°F.

2.0 Construction

2.1 Actuator housing shall be precision extruded aluminum, hard anodized with external and internal UV resistant fluoropolymer impregnation.

2.2 Actuator shall be supplied with all stainless steel fasteners.

2.3 The drive shaft and pinion shall be one piece steel, bottom loaded blowout-proof with a fluoropolymer coating and secured by non-exposed, redundant stainless steel retaining rings for safety.

2.4 End caps shall be cast aluminum UV resistant fluoropolymer coated.

2.5 Actuator shall incorporate internal porting to permit use of either direct mount or remote controls with a minimum of external tubing.

2.6 Actuator shall be provided with a mechanical indexable visual position indicator. An optional slot for direct, low profile of shaft driven accessories utilizing uni-drive hardware shall be provided.

3.0. Design

3.1 Double-acting and spring-return models shall be offered and field convertible by only the replacement of end caps or spring module assemblies.

3.2 All spring module assemblies must be of self contained field service safe design.

3.3 Spring design shall allow safe conversion of spring modules to fit application requirements.

3.4 Special tools shall not be required to adjust or accomplish field conversions.

3.5 There shall be no bearing area outboard of the pressure containing or weather seals.

3.6 Use of self-threading or thread forming fasteners shall be strictly prohibited.

3.7 Actuator must not incorporate any metal-to-metal pressure seals.

3.8 All springs must be shot peened and corrosion protected to ensure maximum cycle life.

3.9 Actuator shall be field reversible to provide ±5° travel adjustment at outboard end of travel and non-adjustable ½° nominal over travel in opposite direction.

3.10 Full tooth engagement, at the pitch line, shall be maintained throughout full range of travel minimizing potential tooth failure.

Materials of Construction

A. Body: Precision-extruded aluminum alloy, hard anodized and fluoropolymer impregnated.

B. Pistons: Cast aluminum alloy, dichromate dipped.

C. Output Shaft/ Pinion: Carbon steel, fluoropolymer coated.

D. End Caps: Cast aluminum alloy, fluoropolymer coated.

E. Fasteners: All stainless steel.

F. Seals: Nitrile standard.

G. Piston Bearing: Viton, optional.

H. Spring: Carbon steel, phosphate coated, oil dipped.

J. Piston Bearing: Fluoroplastic.
Sizing Information

The following information is designed to aid in correctly selecting GH-Bettis Rack and Pinion Actuators. Accurate valve torques must be determined at extreme and intermediate valve positions. Valve size and type are determined by application requirements, such as differential pressure, media, temperature and valve manufacturers' suggested safety factor, that affect required torque at specific valve positions and direction of travel.

For Double-Acting

Using the minimum operating pressure available at the actuator's installed location, select a column from the Torque Rating Chart of less than or equal pressure. Look down the column until an output torque is selected which is greater than the valve's maximum operating requirement. Determine the correct actuator model number which appears on the same line as the selected output torque.

For Spring-Return

The valve's maximum torque requirement at specific locations and direction of travel must be exceeded by the actuator's spring start, end, air start, and end as appropriate.

On-Off Fail-Closed Applications

1. Select appropriate actuator spring end and air start torque for maximum valve seating and break torque requirements respectively.
2. Select spring start and air end torque for maximum valve torque requirement at full open position.
3. Compare spring start torque to maximum valve stem allowable torque.

On-Off Fail-Open Applications

1. Select appropriate actuator spring start and air and torque for maximum valve break and seating torque requirement respectively.
2. Select spring end and air start torque for maximum valve torque requirement at full open position.
3. Compare air start torque to maximum stem allowable torque. For modulating and other severe service applications, a minimum actuator torque of 25% greater than the valve torque requirement at all positions of travel is recommended.

Torque Ratings (Pound/Inches)

<table>
<thead>
<tr>
<th>Double-Acting Actuators</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPS</td>
</tr>
<tr>
<td>250</td>
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<tr>
<td>450</td>
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<td>600</td>
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<tr>
<td>750</td>
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<tr>
<td>1000</td>
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<tr>
<td>1500</td>
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### Torque Ratings (Pound/Inches)

**Spring Return Actuators**

#### RPB-Series (Pneumatic)

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Spring Torque Output</th>
<th>Air Torque Output at Operating Pressure—PSIG</th>
</tr>
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<tr>
<td><strong>RPM</strong></td>
<td><strong>Start</strong></td>
<td><strong>End</strong></td>
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**RPQ-Series (Pneumatic)**

<table>
<thead>
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<th>Spring Torque Output</th>
<th>Air Torque Output at Operating Pressure—PSIG</th>
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</thead>
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<tr>
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<td><strong>Start</strong></td>
<td><strong>End</strong></td>
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</tr>
<tr>
<td>3.0</td>
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</table>

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Performance Data

Operating Pressure Range: 40 to 120 PSIG.

Maximum Allowable Working Pressure: 150 PSIG.
Maximum Operating Pressure: 120 PSIG.
Operating Media: Dry or lubricated non-corrosive gas.

Operating Temperature:
- Standard: -40°F to +200°F
- Optional: 0°F to +350°F

Double Acting Actuators

<table>
<thead>
<tr>
<th>Actuator Model</th>
<th>Volume Co. In.**</th>
<th>Max. Oper. Pressure (OSP)</th>
<th>Max. Allow. Wg. Pressure (MAP)</th>
<th>Weight (lbs.)</th>
<th>Open Time* (Seconds)</th>
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<td></td>
<td>CW</td>
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*For one 90° operation with Ben/Sealed—no load (NEMA 4)
**Displacement plus carry

Spring Return Actuators

<table>
<thead>
<tr>
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<th></th>
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<td>CDW</td>
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RPQB-Series

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<th>Displacement In.**</th>
<th>Max. Oper. Pressure (OSP)</th>
<th>Max. Allow. Wg. Pressure (MAP)</th>
<th>Weight (lbs.)</th>
<th>Open Time* (Seconds)</th>
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</thead>
<tbody>
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<td></td>
<td>BR 1.0 BR 1.5 BR 2.0 BR 2.5 BR 3.0</td>
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<td>RPQB1000-150</td>
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<td>95</td>
<td>105</td>
<td>120</td>
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</tbody>
</table>

*For one 90° operation with Ben/Sealed—no load
**Displacement plus carry
***Maximum pressure allowed on the actuator under operating conditions at the stop position

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BettiSolenoid

BettiSolenoids are custom designed for use with the RPB-Series pneumatic actuator product line offering a direct mount feature which eliminates interconnecting tubing and fittings.

General Description
1. 4-Way, 5 port, 2 position, single coil with manual override.
2. 3-Way: 2 position, normally closed, single coil with manual override.

Operation:
The valve operates when the coil is electrically energized and returns when the coil is de-energized.

Media: dry or lubricated non-corrosive gas.

Pressure:
Minimum operating differential: 35psi (2.4 bar).
Maximum operating differential: 150psi (10.3 bar).

Orientation:
Valve may be mounted in any attitude/position.

Coil Enclosure:
1. NEMA 4, Watertight and dust tight—indoor and outdoor. Intended for use indoors or outdoors to protect against splashing water, seepage of water, falling or hose directed water and severe external condensation. All coils are UL and CSA listed.
2. NEMA 4-7-9, combination watertight and explosion proof—indoor and outdoor. Offers the same protection as NEMA 4 listed above plus hazardous location ratings 7C, 7D, 9E, 9F and 9G (Class I & II, Groups C, D, E, F and G) Division I and II. Enclosure is UL and CSA listed.

Coil Connection—NEMA 4:
1. ½ NPT Terminal type plug-in, standard.
2. Strain Relief, no cord, terminal type plug-in.
3. Strain Relief with 6 ft. (1.8m) cord, plug-in.
4. Strain Relief with 120VAC-60Hz light, no cord.
5. Strain Relief with 24VDC light, no cord, terminal type, plug-in.

Coil Connection—NEMA 4-7-9:
½ NPT, potted, 24" leads
Temperature:
Media: -40°F to +200°F.
Ambient: NEMA 4, -40°F to +100°F.
NEMA 4-7-9, -40°F to +125°F.

Coil Rating:
1. NEMA 4: Continuous duty molded Class H insulation.
2. NEMA 4-7-9: Continuous duty molded Class B insulation.

Coil Voltage:
1. 120VAC-60Hz/110VAC-50 Hz.
2. 240VAC-60Hz/220VAC-50Hz/230VDC.
3. 48VAC-60Hz/44VAC-50Hz/24VDC.
4. 24VAC-60Hz/22VAC-50Hz/12VDC.

Coil Voltage Variation: ± 10% of Nominal.

Power Consumption: 6 Watts

Materials:
Valve Body = Aluminum, anodized.
Seals/O-Rings = Nitrile.
Fasteners = Stainless Steel assembly and attachment.

Dimensions
MULTIPLE HEAD TRANSMITTER
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<td>Parts Listing Right Angle Drive</td>
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</tr>
<tr>
<td>Parts Listing Shafts and Couplings</td>
<td>21</td>
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</tbody>
</table>
MULTIPLE HEAD TRANSMITTER

The Multiple Head Transmitter is a compact and durable transmitter designed and developed by Gate City to provide from one to four outputs in a single housing with future modifications in mind. Where space limitations make stacking of several transmitters difficult, the Multiple Head Transmitter becomes the ideal alternative using only 4-5/8" of height in the meter stack.

The Multiple Head Transmitter can be used with any metering system that uses Veeder-Root accessories with a variety of adaptors and couplings to fit your meters needs. For proper transmitter application, our engineering staff will need to know what type of meter, the model number, and the volume per output shaft revolution. Our custom gear plate designs allow any volume of measurement to be used.

The Multiple Head Transmitter is currently available with two types of electrical outputs, both of which are enclosed in explosion-proof housings which, depending on the electrical code requirements, the approval authority can be U.L., C.S.A., BASEEFA of Ex. Most European countries will soon standardize on CENELAC which will combine BASEEFA & Ex. When a low resolution is required a Single Pole Single Throw (SPST) pulser is used, this would include such applications as 1 pulse per gallon, 1 pulse per dekaliter, or similar output. This type of pulser is normally used to signal a data system or similar device. A similar transmitter modified with a contact protection network would be used with inductive devices such as a Gate-Pak™ additive injector. For applications that require a high-resolution pulse output a Veeder-Root solid state pulser is used to supply outputs such as 100 pulses per gallon, 10 pulses per liter, etc. This type of pulser is normally used in applications such as product blending or electronic presets where a high degree of accuracy is required.

The Multiple Head Transmitter is also available with a Right Angle Drive output that can be used to drive various mechanical and electrical devices normally associated with electronic meter proving or rate of flow indicators. The Right Angle Drive can be set up to provide one output revolution per 5 gallons, 10 gallons, 1 barrel, 1 dekaliter, etc.

When the Multiple Head Transmitter is used and only one pulser is required at the present time, but future requirements are known, Gate City can provide your Multiple Head Transmitter with the appropriate gearing so that the correct pulser may be added in the future. The future pulser can be added merely by removing a blind plate cover, and bolting the new pulser into position.

For further information contact the Gate City distributor in your area, or contact Gate City direct and let us solve your liquid measurement problems.
MULTIPLE HEAD TRANSMITTER APPLICATIONS

- Optical Gating Contactor
- Digital Shaft Encoder
- Right Angle Drive for Attachment of Portable Electronic Meter Proving Equipment
- Contact Pulse Transmitter for Terminal Automation and Data Processing 1 Pulse per Gallon Output
- Master Meter Prover Counter MMC-7
- Contact Pulse Transmitter for Additive Injection Systems - Pulse Rate per System Requirements
- Gate-Pak Injector Additive Systems
- Transmitter Housing, and Input/Output Couplings are Adaptable to Various Meter Applications. Some Adaptors May be Required.
- Solid State Pulse Transmitter for Digital Valve Control Equipment with Optional Parity Check Feature.
- Electronic Presets, Blenders, and Other Electronic Controls
DIMENSIONS

TOP VIEW

SIDE VIEW
APPLICATION

SMITH METER

TYPICAL SMITH PRESET
VEEDER-ROOT
LNC/PRINTER

(2) - MOUNTING BOLTS
REFER TO SMITH
PRESET MOUNTING
INSTRUCTIONS

SMITH TO VEEDER-ROOT
ADAPTOR (4649-1)
(2) - ADAPTOR SCREWS
3/8-16X3/4 SLOT

BLIND COVER PLATE
WITH GASKET
(4) - MOUNTING BOLTS
1/4-28X1-1/8 HEX
(4) - NUTS 1/4-28 HEX

TYPICAL VEEDER-ROOT
PRESET
LNC/PRINTER

MULTIPLE HEAD
TRANSMITTER WITH
SMITH/VEEDER-ROOT
INPUT/OUTPUT
COUPLINGS

(4) - MULTIPLE HEAD TRANSMITTER
MOUNTING BOLTS
1/4-28X7/8 HEX

TYPICAL COUPLINGS

SMITH METER
(F4-S1 SHOWN)
APPLICATION

SMITH METER

OUTPUT COUPLING APPLICATION

INVERTED: FOR SMITH 342 A&B SERIES PRESET AND OTHER SMITH EQUIPMENT. SEE INVERTED DETAIL. DIMENSION MUST BE AS SHOWN.

PROCEDURE - LOOSEN SET SCREW AND INVERT COUPLING. ADJUST TO PROPER HEIGHT AND TIGHTEN SET SCREW.

STANDARD: FOR VEEDE-R-ROOT 340C (7866) SERIES PRESET AND COUNTER PRINTERS. SEE STANDARD DETAIL.
APPLICATION

BROOKS BRODIE METER

BRODIMATIC COUNTER

COUNTER BASE

SPACER SHAFT

ADAPTOR PLATE (P/N 3650300000)

BLIND COVER PLATE WITH GASKET

(4) MOUNTING BOLTS 1/4-28X1-1/8 HEX

(4) NUTS 1/4-28 HEX

ADAPTOR MOUNTING

(4) BOLTS - 1/4-28X7/8 HEX

(4) NUTS - 1/4-28 HEX

TRANSMITTER MOUNTING

(4) BOLTS - 1/4-28X1-1/8 HEX

(4) NUTS - 1/4-28 HEX

*ADJUSTER

*NOTE TO MOUNT THE MULTIPLE HEAD AS SHOWN THE HOLES PATTERN ON THE ADAPTOR MUST BE MODIFIED. SEE THE ADAPTOR DRAWING.

MULTIPLE HEAD TRANSMITTER WITH BRODIE/BRODIE (BROOKS) INPUT/OUTPUT COUPLINGS

(4) MULTIPLE HEAD TRANSMITTER MOUNTING BOLTS 1/4-28X7/8 HEX

*NOTICE TO MOUNT THE MULTIPLE HEAD AS SHOWN THE HOLES PATTERN ON THE ADAPTOR MUST BE MODIFIED. SEE THE ADAPTOR DRAWING.

TYPICAL VEEDER-ROOT PRESET LNC/PRINTER

(4) MOUNTING BOLTS 1/4-28X1-1/8 HEX

ADAPTOR MOUNTING (4) BOLTS - 1/4-28X7/8 HEX

(4) NUTS - 1/4-28 HEX

ADAPTOR MOUNTING

(4) BOLTS - 1/4-28X7/8 HEX

(4) NUTS - 1/4-28 HEX

TRANSMITTER MOUNTING

(4) BOLTS - 1/4-28X1-1/8 HEX

(4) NUTS - 1/4-28 HEX

SPACER SHAFT

TYPICAL COUPLING

BROOKS BRODIE METER
APPLICATION

BROOKS TO VEEKER-ROOT ADAPTOR

HOLE PATTERN MODIFICATION:
LOCATE THE 4 DRILL GUIDES
BETWEEN EXISTING HOLES
AND DRILL NEW HOLES 3/16"
DIAMETER. USE ANY 4 HOLE
PATTERN FOR REQUIRED
TRANSMITTER MOUNTING.
APPLICATION

LIQUID CONTROLS METER

BLIND COVER PLATE WITH GASKET
(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX
(4) - NUTS 1/4-28 HEX

TYPICAL
VEEDER-ROOT
PRESET
LN/PRINTER

(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX

MULTIPLE HEAD TRANSMITTER WITH LIQUID CONTROLS INPUT/OUTPUT COUPLINGS

(4) - MULTIPLE HEAD TRANSMITTER MOUNTING BOLTS 1/4-28X7/8 HEX

TYPICAL COUPLINGS

LIQUID CONTROLS METER
APPLICATION

NEPTUNE METER

BLIND COVER PLATE WITH GASKET
(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX
(4) - NUTS 1/4-28 HEX

TYPICAL VEEDER-ROOT PRESET LNC/PRINTER

(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX

MULTIPLE HEAD TRANSMITTER WITH NEPTUNE INPUT/OUTPUT COUPLINGS PER APPLICATION

NEPTUNE TO VEEDER-ROOT ADAPTOR

NEPTUNE GEAR CALIBRATOR

TYPICAL COUPLINGS

NEPTUNE METER
APPLICATION

TOKHEIM METER

BLIND COVER PLATE WITH GASKET
(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX
(4) - NUTS 1/4-28 HEX

TYPICAL VEEDE-ROOT PRESET LNC/PRINTER
(4) - MOUNTING BOLTS 1/4-28X1-1/8 HEX

MULTIPLE HEAD TRANSMITTER WITH TOKHEIM INPUT/OUTPUT COUPLINGS
(4) - MULTIPLE HEAD TRANSMITTER MOUNTING BOLTS 1/4-28X7/8 HEX

TOKHEIM METER

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GATE CITY MULTIPLE HEAD TRANSMITTER HOUSING DESIGNED FOR VARIOUS METER APPLICATIONS

OPTIONAL TOP COVER PLATE WITH GASKET

OUTPUT COUPLINGS FOR VARIOUS METER APPLICATIONS

BLIND COVER PLATES (FUTURE APPLICATIONS)

PULSE TRANSMITTERS *DRY CONTACT *DRY CONTACT WITH CONTACT PROTECTION *SOLID STATE ELECTRONIC *SOLID STATE ELECTRONIC WITH PARITY CHECK

RIGHT ANGLE DRIVE (RAD) WITH DUST CAP

GEAR PLATE (OUTPUTS PER APPLICATION) WITH INPUT COUPLINGS FOR VARIOUS METER APPLICATIONS
Series 1871
Pulse Transmitters

Applications
The series 1871 pulse transmitter has been designed for use with gasoline pump computers and miscellaneous electrical counters in remote indicating and data systems. It provides fast, accurate pulsing for counters, printers, and stepping motors used with remote indicating, totalizing, and data systems. UL listed, CSA certified.

Description
The pulse transmitter chops a fixed level input voltage to form a square wave pulse with minimum contact bounce for use with transistorized circuits.

The Series 1871 pulser consists of a rugged die cast explosion proof housing with a screw type cover for easy access to the pulsing mechanism. The transmitter utilizes a dry reed switch, magnet, and gear train, synchronized to provide 2 pulses per revolution or 10 pulses per revolution, as required.

Specifications
Contact rating..........................Maximum 50 VA resistive
Not to exceed 250V or 3 amperes

Type switch...............................Single Pole Single Throw

Contact Resistance.....................500 milliohms

Actuating Time..........................1 millisecond average

Contact bounce..........................1 millisecond average

Speed.................................0-3000 pulses per minute, 600 RPM maximum

Pulse Timing............................40 to 50% on, the balance off

Temperature...............................Compensated for -40°F to + 160°F

Housing..................................UL/CSA, explosion-proof Class 1, Groups C & D
Cover holes provided for wire seal

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These solid state pulse transmitters provide fast and accurate signaling for remote indication, totaling, and data monitoring systems. They are UL listed for gasoline pump computers and in applications that require monitoring of output shaft rotation in hazardous locations.

The output can be either dual channel with 50 pulses per revolution per channel or single channel with 100 pulses per revolution. The dual channel pulse trains can be staggered or overlapping. A staggered output allows errors to be detected on either channel or concurrently (power loss to pulse). An overlapping output permits the detection of direction of rotation and errors on either channel, but not both concurrently. The single channel devices are used when greater pulse density is desired and error detection is not required.

**Specifications**

**Recommended Operating Conditions**

- **Supply voltage**: 10-15v DC; 75 ma max a \( \leq \) 15v DC
- **Output Switching times**:
  - Rise time: 2 microseconds maximum
  - Fall time: 4 microseconds maximum
- **Input shaft speed**: 600 RPM
- **Operating Environment**: -40°F to 180°F (-40°C to 32°C)
- **Housing**: Explosion-proof. For use in Hazardous locations Class 1, Group D
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<th>Description</th>
<th>Part Number</th>
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<td>Bushing</td>
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<td>3</td>
<td>Gear plate (Standard 16:1)</td>
<td>02-00075*</td>
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<td>4</td>
<td>Gear plate screws (2 req)</td>
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<td>Blind plate</td>
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<td>6</td>
<td>Blind plate bolt</td>
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<td>Add-on Pulser</td>
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<tr>
<td></td>
<td>2 pulses per revolution</td>
<td>02-00100**</td>
</tr>
<tr>
<td></td>
<td>10 pulses per revolution</td>
<td>02-00200**</td>
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<tr>
<td></td>
<td>100 pulses per revolution</td>
<td>02-00300**</td>
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<td>Pulser mounting plate bolt</td>
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<td>Right angle drive adaptor</td>
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<td>Blind cover gasket</td>
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<td>Blind cover</td>
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</table>

* To insure the correct replacement gear plate will require the original Multiple Head Transmitter serial number

** To insure the correct replacement or add-on pulser will require the original Multiple Head Transmitter serial number
PARTS LIST

PULSE TRANSMITTERS

DRY CONTACT PULSER PARTS

-16-
## PARTS LISTING

### PULSE TRANSMITTERS

<table>
<thead>
<tr>
<th>ID #</th>
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<th>Part Number</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td></td>
<td>2 PPR* (187180-051)</td>
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<td>10 PPR(187180-052)</td>
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<td>100 PPR (767181-325)</td>
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<td>100 PPR with parity check (767181-325P)</td>
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<td>3</td>
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<td>7</td>
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<td>36 Tooth pulser drive gear</td>
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<tr>
<td>9</td>
<td>18 Tooth pulser drive gear</td>
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<tr>
<td>10</td>
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<tr>
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<td>02-00115</td>
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* Pulses per revolution
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<td>Cable</td>
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<td>Cap</td>
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<td>8</td>
<td>Mounting bolt</td>
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<td>02-00002</td>
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<tr>
<td>10</td>
<td>36 Tooth pulser drive gear</td>
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<tr>
<td>13</td>
<td>Set Screw, drive gear</td>
<td>02-00115</td>
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PARTS LIST

SHAFTS AND COUPLINGS

LIQUID CONTROLS

VEEDER-ROOT

TOKHEIM

ROCKWELL

VEEDER-ROOT

BRODIE

NEPTUNE

LIQUID CONTROLS

VEEDER-ROOT/VEEDER-ROOT

BRODIE/VEEDER-ROOT

BRODIE/BRODIE

NEPTUNE

LIQUID CONTROLS

SMITH

TOKHEIM

ROCKWELL

BRODIE SQUARE DRIVE

NEPTUNE

-20-
<table>
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<td>Liquid Controls shaft</td>
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<td>Liquid Controls Input coupling</td>
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<td>Veeder-Root (Smith) Output coupling</td>
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<tr>
<td>Veeder-Root to Veeder-Root (Smith) shaft</td>
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<tr>
<td>Smith Input coupling</td>
<td>02-00060</td>
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<tr>
<td>Tokheim Input (Pin)</td>
<td>02-00065</td>
</tr>
<tr>
<td>Tokheim shaft</td>
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<tr>
<td>Tokheim Input coupling</td>
<td>02-00072</td>
</tr>
<tr>
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<td>Rockwell Input Coupling</td>
<td>02-00093</td>
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<td>*Rockwell couplings use shaft PN 02-00028</td>
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<tr>
<td>Brodie to Veeder-Root shaft</td>
<td>02-00009</td>
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<tr>
<td>Brodie Output coupling</td>
<td>02-00008</td>
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<td>Brodie to Brodie shaft</td>
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<td>Neptune Output coupling</td>
<td>02-00020</td>
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<td>Neptune shaft</td>
<td>02-00017</td>
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<tr>
<td>Neptune Input coupling</td>
<td>02-00018</td>
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</table>
Field Power Products Flowmeters plus Veedol-Root Counters

The Perfect Combination

Imhoff, Berg & Company, Incorporated
The 7887 Vooee-Roof Meter Register

The Fluid Power Product's Meter fitted with the 7887 Vooee Root Register is an outstanding choice for recording and displaying delivery data in a wide variety of industries. This system totalizes and displays high speed deliveries and transactions in large easy-to-read figures, and it is ideal for increased efficiency in all kinds of liquid inventory and delivery operations.

The 7891 Vooee-Roof Meter Register and Preset

The Fluid Power Product's Meter fitted with the 7891 Meter Register and Preset combines inventory control and data processing information for a wide variety of industries. This system combines to control and display high speed fluid deliveries and transactions and it is ideal for increased efficiency in all kinds of liquid inventory monitoring and control installations.

The 7890 Vooee-Roof Meter Register and Printer

The Fluid Power Product's Meter fitted with the 7890 Meter Register and Printer provides inventory control records, bill of lading, receipts, or invoices, accounting records, and data processing information in a wide variety of industries. This system produces clean, detailed printed records of high-speed fluid deliveries and transactions, and it is ideal for increased efficiency in all kinds of liquid inventory monitoring and control installations.

The 7671 Solid State Pulse transmitter and the 1871 Pulse Transmitter

These two pulse transmitters mounted to Fluid Power Product's Meter are designed to provide fast, accurate pulses for counters, printers and stepping motors used with remote indicating, totalizing, and data systems. The 1871 transmitter provides a choice of 1 or 10 ppr. The 7671 output pulse can either be dual channel with 50 ppr or single channel with 100 ppr.

Fluid Power Products Positive Displacement Flow Meters

Accepted around the world in the Petroleum, Chemical, Agricultural, Pharmaceutical, Food, Utility and Military Markets, these meters are cost-effective high performance meters. Constant attention to new product development, production design, high standards of manufacture and final testing are the reasons Fluid Power Products meet the most demanding requirements of various types of industry.

DISTRIBUTED BY:

FLUID POWER PRODUCT, INC.

Hwy. 51 N and Genesee Rd.

P. O. Box 400

NCKF, LA 70466-0400

Phone (504) 542-5200

Fax (504) 542-7394

104
LIQUID LEVEL SWITCHES
Liquid Level Switches for Pressure Vessels
L-1200 & L-1100 Float Operated Switches
Also L-1000 Series Float Switches
for Normal Pressure Applications

DESCRIPTION
The L-1200 is a float switch for high pressure vessels, functioning to activate alarms and/or to shut-down equipment when a liquid rises high enough to set the snap-switch. All other models in the L-1000 series operate in this manner, but vary in application, material make-up, pressure rating, and size.

Designed to meet specification for Class I, Division 1, Group C & D hazardous locations, the L-1200 and L-1100 are certified by the Canadian Standards Association. These units are explosion proof constructed and all moving parts coming into contact with a fluid are corrosion resistant.

INSTALLATION
Level switches may be mounted directly onto a tank wall or indirectly by means of stand-off piping and float chamber. For direct mounting of the L-1200 Murphy manufactures a weld collar that is mechanically designed to allow full float travel in switching.

Also manufactured is a float chamber (1500 psi rating) for installations requiring isolation of the float from turbulent or rapidly fluctuating liquid levels. Either mounting should be installed per ASME pressure vessel code.

Examine typical float chamber and weld collar installations. Take special note in float chamber installation of the hammer lug union on the lower horizontal pipe: one or more such unions are necessary to facilitate mounting.

FLOAT SWITCH MODELS:

<table>
<thead>
<tr>
<th>MODEL</th>
<th>DESCRIPTION</th>
<th>MODEL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1200</td>
<td>1500 psi/10.3 MPa pressure rating, 2” NPT, BUOYGLAS® Float, SPDT**</td>
<td>L-1180</td>
<td>15 psi/0.1 MPa pressure rating, 1/2” NPT, Polypropylene Float, SPDT**</td>
</tr>
<tr>
<td>L-1200SS</td>
<td>Stainless steel body and cover</td>
<td>L-1150</td>
<td>15 psi/0.1 MPa pressure rating, 1/2” NPT, Polypropylene Float, SPDT**</td>
</tr>
<tr>
<td>L-1100</td>
<td>1500 psi/10.3 MPa pressure rating, 2” NPT, BUOYGLAS® Float, SPDT**</td>
<td>L-1160</td>
<td>15 psi/0.1 MPa pressure rating, 1/2” NPT, Polypropylene Float, SPDT**</td>
</tr>
</tbody>
</table>

*Also: Model for 400°F Service with Stainless Steel Float.
**All models can be ordered with a DPDT switch, specify by designator DPDT.

ALSO SEE NOTES BACK PAGE

L-1200, L-1100
Works Effectively On:
- Compressor Scrubbers
- Pressure Vessels
- Heater Treaters
- Boilers
- Any Equipment Needs a Liquid Level Monitor

Murphy Buoyglas™ Float:
0.5 specific gravity
(SStainless-steel float is optional: 0.65 specific gravity)
L-1200 Float Chamber

WIRING DIAGRAM

Black N.C. --- White COM
Red N.C. --- White COM
Blue N.C. --- Blue COM
Orange N.C. --- Yellow COM

L-1200 DPDT, L-1100 DPDT +
15-00-0136 Micro Switch Assembly
Switch Rating 10A @ 250 VAC

WIRING DIAGRAM

Black N.C. --- White COM
Red N.C. --- White COM
Blue N.C. --- Blue COM
Orange N.C. --- Yellow COM

REPLACEMENT PARTS

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>L-1100</td>
<td>15-05-0832</td>
<td>Float: BUOYGLADE™, Micro Switch Assembly</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-05-0842</td>
<td>Lever Assembly</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-05-0867</td>
<td>Washer Nylon</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-01-0311</td>
<td>Counter Balance Assembly</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-01-0320</td>
<td>Lever Assembly</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-00-0003</td>
<td>Washer Nylon</td>
</tr>
<tr>
<td>L-1100</td>
<td>15-05-0867</td>
<td>Lever Assembly</td>
</tr>
</tbody>
</table>

† The following parts on the L-1200, L-1200 DPDT, L-1100, and the L-1100 DPDT can be replaced or recalibrated at the factory: O-rings, Guide Shaft assembly, Operating Lever.

‡ L-1200 DPDT, L-1100 DPDT: Replacement parts are the same as the L-1200 and the L-1100 except for Micro Switch Assembly; Part Number 15-00-0136. See wiring diagram above.

A 5/16 diameter x 1" length Float Shaft Extension can be ordered. Ask for Part Number 15-05-0366. Will be shipped loose.

A Stainless Steel float is available, 0.85 specific gravity. Ask for Part Number 15-05-0150 for the L-1200, 15-05-0366 for the L-1100.

Specifications subject to change without prior notice.

[Contact information for various companies included]
INSPECTION
MANHOLE
The KF 16" and the KG 20" Inspection Manholes give excellent service when there is no need for a fill opening or venting. These units are available in steel, aluminum or stainless steel.

The covers are easy to remove for tank inspection.

Standard for both units is a black Buna N gasket, which is held in place by retainer clips welded to the cover.

### KF 16" Inspection Manhole

**OVERALL HEIGHT:** 3 3/8" (Approximately)  
**AVERAGE SHIPPING WEIGHT:** Steel — 14 pounds Aluminum — 6 pounds

<table>
<thead>
<tr>
<th>MODEL</th>
<th>CODE</th>
<th>COVER MATERIAL</th>
<th>WELD RING 16&quot; ID</th>
<th>GASKET CODE</th>
<th>VENT</th>
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</thead>
<tbody>
<tr>
<td>KF</td>
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<tr>
<td></td>
<td>2</td>
<td>Aluminum</td>
<td>Plated</td>
<td>2 Aluminum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>SS 304</td>
<td>Plated</td>
<td>3 Steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>SS 304</td>
<td></td>
<td>12 gauge</td>
<td></td>
</tr>
</tbody>
</table>

### KG 20" Inspection Manhole

**OVERALL HEIGHT:** 3 3/8" (Approximately)  
**AVERAGE SHIPPING WEIGHT:** Steel — 16 pounds Aluminum — 8 pounds

<table>
<thead>
<tr>
<th>MODEL</th>
<th>CODE</th>
<th>COVER MATERIAL</th>
<th>WELD RING 20&quot; ID</th>
<th>GASKET CODE</th>
<th>VENT</th>
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<tr>
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<td>SS 304</td>
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<td></td>
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January, 1987

KNAPFCO — KANSAS CITY, MISSOURI 64150  
4304 Mattox Road  
Telephone:816-741-6600
### KF 16" INSPECTION MANHOLE

<table>
<thead>
<tr>
<th>REFERALS</th>
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<th>304 SS</th>
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### KG 20" INSPECTION MANHOLE

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111
BALL VALVES
Chlorine Service BALL VALVES
Flanged End
MATERIALS

1. End: ASTM A216-WCB Carbon Steel
2. Seat Retainer - C.R.S. or 1214
   (1/8"-1/4"), ASTM A216-WCB Carbon Steel (1/8"-1/4"), A351
   316SS for T316 model (1/8"-1/4")
3. Bolt - Metric
4. Stem - Metric
5. Seat - Virgin PTFE
6. Gasket - Virgin PTFE for Option 01 and 02
7. Thrust Washer - Virgin PTFE for Option 01 and 02
8. Gland Sleeve - AISI 316SS for T316 model (1/8"-1/4")
   AISI 316SS for T316 model (11/16")
9. Gland Retainer - AISI 1012 C.R.S.
   (1/8"-1/4"), ASTM A216-WCB (1/4" and 1/2")
10. Hex Socket Head Bolt - Carbon Steel (1/8"-1/4"), 316SS for T316 model (1/8")
11. Gland Packing - Compound Graphite 9/16"-1" (1-piece), Virgin PTFE 9/16"-1" (4-piece)
12. Stopper - AISI 1018 Carbon Steel (1/8"-1/4"), 304SS for T316 model (11/16")
13. Retaining Ring - 304SS (11/16")
14. Grip Ring - Monel (3/8")
15. Spring - Series 304SS (11/16")
16. Taper Liner - Reinforced PTFE (1/8"-1/4")
17. Washer - Cold Rolled Steel, 304SS for T316 model (1/8")
18. Nut - Cold Rolled Steel, 304SS for T316 model (1/8")
19. Head - Cold Rolled Steel (3/16")
20. Cold Rolled Steel, 304SS for T316 model (1/8")
21. Preload Nut - Cold Rolled Steel (3/16")
22. Cold Rolled Steel, 304SS for T316 model (1/8")

DIMENSIONS - WEIGHT

<table>
<thead>
<tr>
<th>Size</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
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<td>1.58</td>
<td>4.25</td>
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<td>4.45</td>
<td>11.55</td>
<td>.99</td>
<td>127.0</td>
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1/8-24 UNC Top
1/8-24 UNC 28 Top (1/8", 3/8")

4 holes, tapped 3/8-18 UNC (11/16"-8")

DIMENSIONS (inches)

Weight (lbs.)
WATTS CL-F1500 SERIES UNIBODY CONSTRUCTION
ANSI FLANGED END CHLORINE SERVICE BALL VALVES

Watts CL-F1500 Series flanged end Chlorine Service ball valves are specifically designed for use on dry and wet chlorine gas generating, storage and distribution systems.

Available in ANSI 150 lb. configuration equipped with standard Monel ball and stem, these valves provide maximum safety and service life in critical chlorine environments.

Standard features include: multiple chevron style stem packing; unibody design with internal body seal; two-bolt packing adjustment; ANSI end-to-end dimensions and vented ball.

All Watts Chlorine Service ball valves are cleaned and packaged in accordance with Chlorine Institute Recommendations. These valves also include standard locking device and 4-bolt actuator mounting pad for ease of automation. Body material is ASTM A-216 Grade WCB.

ANSI 150 lb. configuration
Multiple Chevron Style Stem Packing
2-Bolt packing adjustment isolates stem packing from handle/stem rotation
Internal body seal insures and plug retention threads are isolated from corrosives
Standard Monel Ball and Stem
Cleaned in accordance with Chlorine Institute Recommendations

PERFORMANCE DATA

VALVE SEAT RATING

SPECIFICATIONS

<table>
<thead>
<tr>
<th>Size</th>
<th>CV Rating</th>
<th>Operating Torque (in.-lbs.)</th>
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<tbody>
<tr>
<td>3/4&quot;</td>
<td>15</td>
<td>60</td>
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<td>1&quot;</td>
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<td>11/4&quot;</td>
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<td>150</td>
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<td>11/2&quot;</td>
<td>90</td>
<td>260</td>
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<tr>
<td>2&quot;</td>
<td>150</td>
<td>360</td>
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<tr>
<td>21/2&quot;</td>
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<td>434</td>
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<td>3&quot;</td>
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<td>608</td>
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<tr>
<td>4&quot;</td>
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<td>6&quot;</td>
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Specified valves shall meet A.N.S.I. B16.34 and Chlorine Institute Pamphlet 6 requirements. Valve is a unidirectional ball valve with vented ball, standard virgin PTFE seats, multiple stem packing and unibody construction. Watts No. CL-F1500 or equal.
HOW TO ORDER:

2" - CL-F1500 - 150 - M/M - 01 - OL

Size: 2"

Series: 150-100

Material: M/M + Monel

Ball/Seal Material: 01 + PTFE

Handle Option: 02 + Duroplast

OTHER CRITICAL SERVICE WATTS BALL VALVES:
- CL-7200 - Threaded End Chlorine Service Ball Valves
- SF-3500-150 - Allny 20 Flanged Ball Valves
- C-7100-M1/S-8100-M1/M - Unibody Ball Valves with Monel Trim

THE WATTS BALL VALVE FAMILY

WATTS INDUSTRIAL PRODUCTS DIVISION

HEADQUARTERS:
Date 622 Lawrence, MA 01844
Phone: 978-689-1811
Telex: 87488 Watts Reg. Label
International Sales:
Watts Regulator of Canada Ltd. Phone: 065-37137
Watts Regulator (Netherlands) Bv. Telex: 47345

PRINTED IN U.S.A.
TANK AIR VENT
"T" VENT

KNAPPCO'S "T" type vent, with standard tapered pipe threads, is suitable for venting underground and above ground storage tanks.

The unit is made of aluminum and both of the openings are equipped with perforated brass screens which are held securely in place.

VE 0012 — 1"
VE 0013 — 1¼"
VE 0014 — 1½"
VE 0015 — 2"

MUSHROOM VENT

The KNAPPCO Mushroom Vent is made of aluminum with standard tapered pipe threads.

The unit has a perforated brass outlet screen with a full venting area.

VE 0016 — 1½"
VE 0017 — 2"
The VE 0005 Vent is a newly designed, pressure vacuum, rollover protection system which meets the most stringent field requirements. (Patent No. 4,593,711.) The design eliminates accidental venting caused by road bounce and eliminates leakage due to surge.

This Vent relieves pressure at 1 PSI and vacuum at 6 ounces per sq. inch and provides complete rollover protection from 0 to 180 degrees.

The KNAPPCO VE 0005 Vent is designed for easy cleaning and maintenance. Replacement parts and gaskets are available.

Relief capabilities of KNAPPCO 2700 Vent:

- Intake — 1243 CFH @ 1 PSI
- Exhaust — 3348 CFH @ 3 PSI

Thread size: 1½ — 12 N
### VE 0005

<table>
<thead>
<tr>
<th>REFERRALS</th>
<th>DESCRIPTION</th>
<th>STEEL</th>
<th>ALUMINUM</th>
<th>PLATED</th>
<th>304 SS</th>
<th>316 SS</th>
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</table>

122
HYDRAULIC PUMP
PVW
OPEN LOOP PUMPS

Cylinder mounted polymerous journal bearings
- Allows operation with low viscosity or other special fluids
- Provides infinite bearing life
- Provides compact design

The industry's largest control selection
- 23 different types
- Field interchangeability without disconnecting from drive or system piping

SAE keyed or SAE splined shaft
- Heavy duty belt drive shafts available

Sealed front shaft bearings
- Allows operation with low viscosity or other special fluids
- Allows side loading

CONTENTS

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Controls - Pressure
Volume
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Pump Combinations
Size and Weights
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Steel shoes with specialty treated faces for increased fluid retention, running on hardened swashblock surface.
- Allows a higher degree of contaminant resistance
- Allows higher pressure operation with longer life
- Provides longer life

Swashblock and saddle with special polymerous bearings
- Allows running on low viscosity or other special fluids
- Permits consistent control reaction
- Eliminates troublesome yoke bearings
- Provides long life

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PERFORMANCE ASSURANCE IS STANDARD WITH EVERY OILGEAR PUMP

Each Oilgear Pump manufactured is shipped with a corporate commitment to stay with the installation until the unit performs as specified.

This total dedication to performance is based upon experience gained since 1922 in matching fluid power systems to a tremendous range of machines and applications.

Oilgear's Performance Assurance is made possible because of the many hydraulic techniques learned over the years in supplying machinery builders and users with unique solutions to hundreds of unusual fluid power problems.

Historically, Oilgear has concentrated all of its energies on hydraulic equipment and systems. Every Oilgear facility is staffed with factory-trained and field-experienced application engineers. These men are backed by a headquarters engineering staff who has access to the records and knowledge generated from these historically successful solutions.

Performance Assurance doesn't stop with the design of the system or the sale of a component. It guarantees that Oilgear engineers will be there—when they are needed—supplying the education, field service, parts and repairs, to make sure each system runs smoothly—and keeps on running.

1. Hardened cylinder surface running on hardened valve plate ("hard-on-hard")
   - Provides greater resistance to contamination
   - Provides longer life
   - Allows operation with low viscosity or other special fluids

2. Valve plate selections
   - Rear or side port connections available

3. Thru-shaft availability
   - Allows for multiple pump installation from a single drive shaft
   - Allows pumps to drive auxiliary devices

4. Three frame sizes with seven capacity ranges allowing greater flexibility to selectively match pressure and capacity.
   - Low/low pressure to low pressure/high flow from the same frame sizes.
## Technical data

### UK-units

<table>
<thead>
<tr>
<th>Code number</th>
<th>OMP 50</th>
<th>OMP 80</th>
<th>OMP 100</th>
<th>OMP 150</th>
<th>OMP 200</th>
<th>OMP 250</th>
<th>OMP 315</th>
<th>OMP 400</th>
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<tbody>
<tr>
<td>Geometric displacement (cm³)</td>
<td>2.96</td>
<td>2.75</td>
<td>2.94</td>
<td>2.50</td>
<td>3.20</td>
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<tr>
<td>Max. speed (rpm)</td>
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<td>1600</td>
<td>1800</td>
<td>2000</td>
<td>2200</td>
<td>2400</td>
<td>2600</td>
<td>2800</td>
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<tr>
<td>Max. torque (Nm)</td>
<td>800</td>
<td>900</td>
<td>1000</td>
<td>1100</td>
<td>1200</td>
<td>1300</td>
<td>1400</td>
<td>1500</td>
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<td>Max. pressure drop (bar)</td>
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<td>1.3</td>
<td>1.4</td>
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<td>Max. oil flow (lpm, UK)</td>
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<td>9.5</td>
<td>10.2</td>
<td>10.9</td>
<td>11.6</td>
<td>12.3</td>
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<td>13.7</td>
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<td>Max. inlet pressure (bar)</td>
<td>250</td>
<td>280</td>
<td>300</td>
<td>320</td>
<td>340</td>
<td>360</td>
<td>380</td>
<td>400</td>
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<tr>
<td>Max. pressure on the shaft seal (without drain)</td>
<td>1100</td>
<td>1110</td>
<td>1120</td>
<td>1130</td>
<td>1140</td>
<td>1150</td>
<td>1160</td>
<td>1170</td>
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<tr>
<td>Max. pressure in drain line</td>
<td>365</td>
<td>385</td>
<td>405</td>
<td>425</td>
<td>445</td>
<td>465</td>
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<td>Max. return pressure with drain line (bar)</td>
<td>200</td>
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<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
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<tr>
<td>Max. starting pressure with unloaded shaft (bar)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
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<td>150</td>
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<tr>
<td>Min. starting torque (Nm)</td>
<td>440</td>
<td>750</td>
<td>975</td>
<td>1200</td>
<td>1425</td>
<td>1650</td>
<td>1875</td>
<td>2100</td>
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</table>

*Intermittent operation: the permissible values may occur for max. 10% of every minute.
*Peek load: the permissible values may occur for max. 1% of every minute. See "Continuous operation/intermittent operation/peek load", page 85.
*The pressure on the shaft seal is calculated as the average between the inlet and return pressures.

---

**Pressure loss curves for Danfoss hydraulic motors can be found on page 74.**

---

[OMP motors have no built-in check valves]
The following function diagrams are for use as described in the section "Selection of hydraulic motor", page 65.

The diagrams are drawn on the basis of function tests on a representative number of motors from our production.

The diagrams apply to mineral based hydraulic oil with a viscosity of 35 cSt and a temperature of 50°C.

Operation at less than 5-10 r/min will be slightly less smooth. See "Min. speed", page 67.

A. Cool range
B. No range (max. 10% operation every minute)

Pressure drop of more than 100 bar (1450 lb/in²) and oil flow of more than 45 l/min (8.8 gpm, U.K.) must not occur simultaneously.

Pressure drop of more than 100 bar (1450 lb/in²) and oil flow of more than 60 l/min (11.2 gpm, U.K.) must not occur simultaneously.

A: Cool range
B: No range (max. 10% operation any minute)
Needle Valves
Series MV

Colorflow Series MV and MVB Needle Valves and Throttling Valves

These high-precision metering and shutoff valves allow extremely close control of fluids used in actuating and governing many types of mechanisms and equipment. Exclusive "Colorflow" scale on the valve stem simplifies returning the valve to a previous setting, conserving time lost in hunting for this setting. Bi-directional flow.

One standard and two optional needle designs for the 1/8" and 1/4" MV valves permit a wide range of flow-rate control.

Series MV Valves are offered in brass or steel. Needles are stainless steel. Choice of angle or in-line designs and all standard port connections.

Maximum operating pressure:
Steel: 5000 PSI (345 Bar) for Models MV200 through MV1220, 3000 PSI (210 Bar) for Models MV1600 and MVBF 1600-3200.
Brass: 2000 PSI (140 Bar)

Needles:
Standard, all models: 30° taper; Optional, MV200 and MV400 only: Dash 2: Fine.
Dash 3: Micro-fine.

Quick Reference Data Chart

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Port Size, in. NPTF</th>
<th>Flow, Max. GPM (L/min)</th>
<th>Pressure at Max. Flow PSI (Bar)</th>
<th>Orifice Area, in. Full Open</th>
<th>C Factor</th>
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</thead>
<tbody>
<tr>
<td>MV200</td>
<td>1/8</td>
<td>3 (11)</td>
<td>200 (14)</td>
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<td>MV200-2</td>
<td>1/8</td>
<td>1.6 (7)</td>
<td>200 (14)</td>
<td>0.0083</td>
<td>0.121</td>
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<tr>
<td>MV200-3</td>
<td>1/8</td>
<td>0.5 (2)</td>
<td>200 (14)</td>
<td>0.0014</td>
<td>0.032</td>
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<tr>
<td>MV400</td>
<td>1/4</td>
<td>5 (19)</td>
<td>130 (9)</td>
<td>0.0316</td>
<td>0.493</td>
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<tr>
<td>MV620</td>
<td>1/4</td>
<td>2.8 (11)</td>
<td>200 (14)</td>
<td>0.0501</td>
<td>0.186</td>
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<td>MV400-2</td>
<td>1/4</td>
<td>0.5 (2)</td>
<td>200 (14)</td>
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<td>MV400-3</td>
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<td>8 (30)</td>
<td>35 (2.5)</td>
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<td>MV620</td>
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<td>8 (30)</td>
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<td>MVBF2400</td>
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<td>300 (1138)</td>
<td>65 (5)</td>
<td>1.53</td>
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</tbody>
</table>

For additional information — call your Parker Sales Office (see listing on page VI).
LEVEL AND TEMPERATURE SWITCHES
LEVEL SWITCH
HIGHEST PERFORMANCE RATING

THE "LH" SERIES LEVEL SWITCHES WILL CONTINUOUSLY CARRY 5.0 AMPS AND WILL SWITCH UP TO 33.0 AMPS.

--- RELAYS CAN BE ELIMINATED IN MANY INSTANCES ---

- VOLTAGE - 5 TO 240 VAC, DC
- BREAKDOWN - 400 VRMS MIN.
- CAPACITANCE - 1.0 PICOFARAD
- INSULATION RESISTANCE - 1X10 OHMS
- INITIAL CONTACT RESISTANCE - 500 MILLIMHOMS

- LEVEL SENSITIVITY - .050
- OPERATING PRESSURE - 50 PSI MAX.
- FLUID COMPATIBILITIES - ANY FLUID (EXCEPT STRONG HYDROCARBON SOLVENTS)
- FAIL SAFE - UNIT WILL OPERATE CONTINUOUSLY IN FREE AIR WITH NO DAMAGE
- SWITCH MODE - LH-013 NORMALLY OPEN (FLOAT UP)
               - LH-012 NORMALLY CLOSED (FLOAT UP)
- MOUNTING - 1/4 NPT THROUGH TOP OR BOTTOM IN VERTICAL POSITIONS

*WHEN SWITCHING EXCESSIVE HIGH INDUCTIVE AND LAMP LOADS CONSULT FACTORY FOR PROPER RECOMMENDATIONS AND/OR TESTING THE COMPATABILITY OF COMPONENTS.

TEMPERATURE CONTROL

6 AMPS 120V. 4 AMPS 240VAC-DC = NON INDUCTIVE FOR RATINGS UP TO 56 AMPS AND 5000 PSI, CONTACT FACTORY

U.L. RECOGNIZED, FILE E-37351 "COMPONENT-TEMPERATURE AND REGULATING CONTROL" CSA LISTINGS: FILE LR2872 "INDUSTRIAL CONTROL EQUIPMENT - MOTOR CONTROLLERS - MISCELLANEOUS"

MODEL NO. 722-A - 1/4 NPT, BRASS, NORM CLOSED
MODEL NO. 723-A - 1/4 NPT, BRASS, NORM OPEN

TEMP. SETTINGS ARE 25°C (77°F) TO 118°C (246°F) IN 5°C INCREMENTS
FOR OTHER TEMP. SETTINGS FROM 38°F TO 350°F AND FOR 2 OR 3 SWITCHES IN A SINGLE 1/2 NPT HOUSING - CONTACT FACTORY.
TEMPERATURE & LEVEL SENSOR
"NEW" HIGHER RATING

"LEVEL" CONTACT RATING - NON INDUCTIVE
CARRY - 3.0 AMPS MAX. @ 110 VAC - DC
300 WATTS @ 110 VAC - DC
BREAK - 1.1 AMP MAX. @ 110 VAC - DC
3.0 AMPS ON MODELS "LH"
VOLTAGE - 5 V TO 220 VAC OR DC

"TEMPERATURE" CONTACT RATING - NON INDUCTIVE
NORMALLY OPEN OR CLOSED
CARRY - 12 AMPS
MAKE OR BREAK - 6 AMPS
AUTO RE-SET - WITH 3 C.
TEMP. SETTINGS - 35 C. (95 F.) TO 115 C. (239 F.)
IN 5 C. INCREMENTS
TEMP. OPTION - TO TURN ON A "HEATER" IN COLD
"LL" OPTION WEATHER USE (5 C.) 38 F.
SETTING

FOR SEPARATE INDICATION OF "TEMPERATURE" AND
"LEVEL" CONNECT WIRES IN PARALLEL AS SHOWN.
FOR SINGLE INDICATION OF BOTH "TEMPERATURE" AND,
"LEVEL", CONNECT IN SERIES AS SHOWN.

INDICATOR, STARTER COIL, ETC.
LIGHT, BUZZER OR RELAY, ETC.

FOR SEPARATE INDICATION OF "TEMPERATURE" AND
"LEVEL" CONNECT WIRES IN PARALLEL AS SHOWN.
FOR SINGLE INDICATION OF BOTH "TEMPERATURE" AND,
"LEVEL", CONNECT IN SERIES AS SHOWN.

APPROVED PURIFICATION CORP., 609 ATLANTIC STREET, STAMFORD, CT. 06902, 203-357-0141
BLACKMER POWER PUMP
BLACKMER POWER PUMPS
INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS
MODELS: GX, QXS, X, XS
2, 2½, 3, 4
(Includes Model XU2)

WARNING

THIS PRODUCT MUST ONLY BE INSTALLED IN SYSTEMS WHICH HAVE BEEN DESIGNED BY THOSE QUALIFIED TO ENGINEER SUCH SYSTEMS. THE SYSTEM MUST BE IN ACCORDANCE WITH ALL APPLICABLE REGULATIONS AND SAFETY CODES AND WARN OF ANY HAZARDS UNIQUE TO THE PARTICULAR SYSTEM.

INSTALLATION

CLEANING PRECAUTIONS

New tanks require careful cleaning to remove weld spatter, slag, scale and other foreign matter before filling with liquid. Suction pipes from the tank to the pump should be flushed before being attached to the pump.

LOCATION

Locate the pump as near the source of supply as possible to reduce detrimental inlet pipe friction. A solid foundation reduces vibration and noise and improves the pump performance. On permanent installations it is recommended that the pumping units be securely bolted to a concrete foundation.

FOUNDATION

When new pump foundations are to be cast in concrete, it is suggested that anchor bolts of the type shown in Fig. 1 be set into the concrete.

This type of anchor bolt allows for slight shifting of position to better line up with the mounting holes in the base plate. When pumps are to be located on existing concrete floors, holes should be drilled into the concrete and foundation bolts anchored therein.

When installing units built on channel or structural steel type bases, care should be taken that the base is not twisted out of shape when anchor bolts are tightened. Shims should be used under the edges of the base prior to tightening of the anchor bolts to prevent distortion.

PIPING

Many pump systems deliver at a rate below the designated capacity of the pump because the system was improperly piped. Before installing any piping, a complete piping diagram should be made, and pipe friction, suction lift, discharge head, vacuum and total pressure on the pump should be computed for the specific liquid being handled, and the desired flow rate. Without these computations it is almost impossible to determine beforehand whether a pumping installation will work properly.

Restrictions in the pipe line, such as elbows, sharp bends, globe valves, certain restrictive-type plug valves and undersized strainers, should be avoided. Use gate or ball valves, not globe valves. The line should be as straight as practical. It should slope downward to the pump, never upward or with upstanding loops. Use pipe of adequate size and strength that has been thoroughly flushed prior to being connected to the pump. Expansion joints, placed at a minimum of three feet (0.91 meters) away from the pump, will compensate for expansion and contraction.

It is very important that there be no air leaks in the intake line. If practical to do so, apply air pressure to the completed pipe line to check for leaks.

The use of check valves or foot valves in the supply tank is generally not recommended with a self-priming, positive displacement pump and can often cause considerable trouble. If a valve in the discharge line is closed while the pump is operating, it forces liquid to recirculate through the pressure relief valve causing the liquid to heat up and expand. A check valve in the suction line prevents the expanding liquid from returning to the supply tank, causing a build-up of pressure on the pump and in the piping system. The result can be excessive leakage at the pump or at the pipe joints. If a check valve is required, locate it near the pump on the discharge side only.
### PARTS LIST NO. 188/C10

#### X1A, X1B - MECHANICAL SEAL - STANDARD

<table>
<thead>
<tr>
<th>REF. NO.</th>
<th>PART NAME</th>
<th>PARTS PER PUMP</th>
<th>XBA PART NO.</th>
<th>XEB PART NO.</th>
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### X2A, X2B - MECHANICAL SEAL - OPTIONAL

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**blackmer/® J. DOHENY RESOURCES COMPANY**

1900 Century Avenue, Grand Rapids, Michigan 49509, U.S.A. • (616) 241-8231 • Tele: 4320x48 • Fax (616) 241-3752

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NOTICE: X2 AND X2A ARE DISCONTINUED MODELS.
STRAINER

A strainer is recommended to protect the pump from damage by foreign particles. Generally, the strainer should be installed in the inlet line, close to the pump, and should have a net open area of at least four times the net size of the pump intake pipe. For more specific applications, refer to the manufacturer's recommendation for proper installation and sizing of the strainer. The strainer should be inspected and cleaned at regular intervals.

ALIGNMENT

The alignment of the motor, the gear reducer, and the pump is often disturbed in transit, and must be checked before the unit is put into operation.

On units where flexible couplings are used, the coupling guard should be removed and a straight edge laid across the two hubs of the coupling, as shown in Fig. 2. The maximum offset should be less than .015" (0.381mm).

![Feeler Gauge](image)

**MISALIGNED**

**CORRECT ALIGNMENT**

Fig. 2 — Alignment Check

With a feeler gauge, or piece of flat steel of proper thickness, check the angular alignment of the coupling halves. Check in four places at 90 degree increments about the periphery of the coupling. Maximum variation in this spacing should not exceed .020" (0.508mm). Misalignment is not desirable. If it does exist, it should not exceed the above limits.

Check the alignment of the pipes to the pump to avoid strains which might later cause misalignment. To check, unbolt flanges or break union joints. Pipes should not swing away or deep down. After pumps have been in operation for a week or two, completely recheck alignment.

GEAR REDUCER ALIGNMENT — GX(S) ONLY

The reducer can be rotated on its mounting to raise or lower the input shaft to facilitate alignment to the motor shaft. First, loosen the four clamp capscrews and two retscrews in the oxide flange. The reducer is then free to rotate. If it sticks, tap it with a mallet. To align the reducer, check the alignment of the two halves of the coupling.

ROTATION

On the X(S) pumps, a right-hand pump rotates clockwise with the intake on the right side when viewed from the driven end.

On the GX(S) pumps, a right-hand pump also rotates clockwise with the intake on the right side when viewed from the driven end. However, due to the gear reducer, the reducer input shaft will rotate counterclockwise.

TO REVERSE PUMP ROTATION

On X(S) pumps, remove the head from the shaft side and reverse the head and shaft so that the shaft protrudes through the head still on the cylinder. On GX(S) pumps, both heads should be removed, and the cylinder reversed.

On both the X(S) and the GX(S) pumps, the vanes must also be reversed in their slots so that the pressure relief grooves face in the direction of rotation. The rounded or wearing edge of the vanes must be outward to contact the bore of the cylinder. See "Maintenance" for removal and replacement of the pump parts.

OPERATION

PUMP PERFORMANCE CHECK

It is usually desirable to make a running check of a pumping system before putting it into operation. The main points to check include: general operation of the system, leakage from piping and equipment, direction of pump rotation, proper pump speed, noise level of the pump, pumping rate, and shut-off pressure.

Whenever a new pump is first started, it should be watched carefully for several hours and checked for signs of malfunction.

If the pump is abnormally noisy, follow the checking procedures outlined under "Pump Troubles and Their Cures."

RUNNING PUMP IN REVERSE

It is sometimes desirable to reverse the pump for draining a line. The pump is satisfactory for this type of operation if a separate pressure relief valve is provided to protect the pump from excessive pressures. When pumping backwards against a possible closed valve, operation in reverse may cause an increase in noise and vibration.

FLUSHING THE PUMP

Liquids which solidify when cold or which might otherwise damage the pump after prolonged contact should be flushed out.

Drain the pump and lines by pumping air. Then pump flushing liquid to suitably clean the pump. Close the discharge line for 30 second intervals (maximum) while pumping. This should be done a few times to flush out the relief valve.

RELIEF VALVE

The pressure setting or range for which the relief valve is set, is marked on a metal tag attached to the relief valve cover. The relief valve should normally be set 15 psi (100 kPa) higher than the operating pressure.
MAINTENANCE

LUBRICATION

Pump bearings should be lubricated every week to every three months, depending on the application, and the operating conditions.

Use: Standard Oil — Amoform All Weather Grease, or an equivalent grease which is compatible with the elastomers and the application.

CAUTION: Excessive greasing pressure can cause grease to be pushed between the mechanical seal face causing seal failure.

It is recommended that you remove the grease relief fitting, and with a hand gun apply grease slowly to the grease fittings on both bearing covers until excess grease begins to come from the grease relief fitting port. Replace the grease relief fitting. It is normal for some grease to escape from the tell-tale holes under the bearing housing for a short time after lubrication.

Before starting the pump, put oil in the gear reducer using the grade oil stamped on the instruction plate attached to the gear case. Each reducer is provided with an oil pipe plug. Remove this plug and fill with oil. Couplings with rubber inserts do not require lubrication. Other couplings are pre-lubricated at the factory, but require frequent lubrication to prevent excessive wear.

PUMP DISASSEMBLY

Before work is started on the pump, be sure the pressure is relieved, and the liquid is drained.

Remove the bearing cover cap screws and slide the bearing cover from the shaft. On the X(S) 2" and 2 1/2" pumps, the dirt shield will come off with the bearing cover. The grease seal, located in the bearing cover cavity, will also slide off with the bearing cover.

The X(S) 2" and 3" pumps are standardly equipped with a lock washer and lock nut installed outside the bearing on each end of the shaft. To remove the bearing locknut, bend up the engaged lock washer tang and rotate the nut counterclockwise.

The X(S) 4" pump is equipped with bearing lock collars. To release the lock collar, remove the jam nuts and loosen the two (2) set screws. The collar can then be slid from the shaft.

When pumping liquids under a high suction lift and rotation or scavenging of the pump exists, period recirculation through the relief valve will result in excessive wear to the valve. When it is necessary to operate under these conditions, a separate bypass valve, piped back to the storage tank, is recommended.

Before removing the head assembly, check for burrs or roughness on the shaft that could damage the mechanical seal O-rings. The head assembly, consisting of the head, bearing, and mechanical seal, can now be removed from the cylinder. To do so, remove the head cap screws and carefully pry the head away from the cylinder with a screw driver. The bearing and seal are slip fit on the shaft and will slide off readily if the shaft is clean and smooth.

NOTE: Tip of bars (to be inserted immediately between head and seal. If placed elsewhere, seal damage is likely (Fig. 3A).

REPLACING VANES ONLY

Vanes can usually be replaced by removing only one head, and sliding them in or out of the rotor end. To prevent push rods from dropping down a vane should only be removed when it is seated in its slot in the rotor (at the 12 o’clock position). Turn the shaft by hand until a vane comes to the 12 o’clock position.
HEAD ASSEMBLY

Before installing the head assembly, make sure the shaft is free of burrs which might cut or nick the mechanical seal O-ring. It will be necessary to install the bottom vanes and push rods before replacing the rotor and shaft. The vanes must be held in place as the rotor and shaft is inserted into the cylinder.

VANES

When installing the vanes, be sure the rounded or wearing edge is outward to contact the surface of the cylinder, with the relief grooves facing in the direction of rotation (refer back to Figure 4). To install the remaining vanes, turn the shaft by hand until an empty slot comes to the 12 o'clock position, insert a vane, and rotate to the next empty slot.

HEAD ASSEMBLY

Before installing the head assembly, make sure the shaft is free of burrs which might cut or nick the mechanical seal O-rings. A small amount of oil applied to the shaft will help slide the parts in place.

Place the head assembly on the shaft with the tell-tale hole in the bearing housing pointing downward. Slide the head against the cylinder.

Install and partially tighten four (4) head caspscrews, 90° apart, on each end of the pump. The caspscrews should be tightened enough to squeeze the head O-ring and allow metal to metal contact between the head and cylinder. Rotate the shaft by hand to test for binding or tight spots. If the rotor does not turn freely, lightly tap the rim of the heads with a lead hammer to center the rotor. Recheck for binding. When the correct position is found, install the remaining head caspscrews and fully tighten all caspscrews.

LOCKNUT & LOCKWASHER —
4(3) 2½” & 3” PUMPS

The pump must be free turning with all head caspscrews tight before making an adjustment on the locknuts. The purpose of locknut adjustment is to center and maintain the pump rotor between the heads.

It is important that the bearing locknuts and lockwashers be installed properly. Overscrewing locknuts will cause bearing failure and/or broken lockwasher inner tang “A” (see Fig. 6). Loose locknuts will allow the rotor to shift against the heater, causing wear.
PUMP TROUBLES AND THEIR CURES

LEAKAGE

New mechanical seals may leak slightly until the mating surfaces have had an opportunity to seat properly. If the leakage becomes excessive or continuous, the mechanical seal should be replaced. Leakage will appear at the tell-tale hole under the bearing housing.

If there is leakage between the pump head and casing, the head should be removed and checked for burrs or dirt. Also, check the face of the casing to make sure it is clean and smooth. Gently file any burrs or rough spots. Head O-rings should be inspected for cuts or nicks, and replaced if found to be damaged.

ESCAPING GREASE

Grease will appear at the grease relief fitting on the bearing cover after normal greasing of the pump. The amount should not become excessive nor continue for an extended period of time. If it continues, remove the grease relief fitting and examine for damage. Replace if necessary.

If excessive grease escapes around the pump shaft, remove the bearing cover and inspect the grease seal for damage. Reinstall the bearing cover with the grease seal centered on the shaft.

NOISE

If a pump has been drained and flooded with air there may be some noise in the relief valve when the pump is next started. It is usually of short duration, and will not damage the pump. Excessive vacuum on the pump due to restricted suction can cause cavitation noise. There are several possible causes of excessive vacuum:

* Inlet piping too small.
* Strainer plugged or dirty.
* Undersized or restricted fittings, such as globe valves, or partially closed valves.
* Suction lift too great.
* Pump speed too high for the viscosity of the liquid being pumped.

If the pump is run for extended periods with a closed discharge, causing the liquid to circulate through the relief valve, vaporization will occur and create excessive noise.

Exceeding the recommended maximum speed can also cause noise in the pump.

If all of the above have been checked, and the pump is still noisy and not delivering the rated capacity, the vanes should be examined for possible damage.

DAMAGED VANES

Vaness can be damaged by the following:

* Pumping liquids which chemically attack the vane material.
* Foreign objects entering the pump.
* Pumping liquids of too high viscosity.
* Excessive heat.
* Incorrect vane installation (see "Replacing Vanes").
* Cavitation.
* Overspeeding.

It is advisable to replace the vanes if they indicate push rod penetration, are worn unevenly, or have raised projections on the wearing edge.

LOW DELIVERY RATE

A low delivery rate may be caused by:

* Restriction in the suction line.
* Resistance in the discharge line.
* Air leaks in the suction line.
* Damaged or worn pump parts.
* Pump speed too low or too high.
**PUMP PERFORMANCE DATA**

| RPM | 450 | 520 | 420 | 350 | 460 | 520 | 420 | 350 | 460 | 520 | 420 | 350 | 460 | 520 | 420 | 350 | 460 | 520 | 420 | 350 | 460 | 520 | 420 | 350 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 460 | 273 | 225 | 176 | 140 | 246 | 232 | 218 | 181 | 205 | 165 | 190 | 150 | 184 | 140 | 127 | 105 | 92 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 |

**MAXIMUM OPERATING LIMITS**

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<th>PUMP MODEL</th>
<th>POWER</th>
<th>VACUUM</th>
<th>MAXIMUM FLOW</th>
<th>TEMP.</th>
<th>WORKING PRESSURE</th>
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**DIMENSIONS -- Inches (mm)**

| PUMP MODEL | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V |
| CWS2       | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CWS4       | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CWS6       | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CWS8       | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CWS10      | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| CWS14      | 1" |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

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*NOTE: Dimensions are approximate. For specific application requirements, refer to Blackmer Material Specifications Sheets. Contact your authorized distributor for more information.*
PUMP PERFORMANCE DATA

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<td>276</td>
<td>100</td>
<td>276</td>
</tr>
<tr>
<td>G65R</td>
<td>100</td>
<td>200</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>276</td>
<td>100</td>
<td>276</td>
</tr>
</tbody>
</table>

COMPANION FLANGES

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Flange Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>G65G</td>
<td>2&quot;</td>
<td>2&quot; Schedule 40 Steel Flange</td>
</tr>
<tr>
<td>G65R</td>
<td>2&quot;</td>
<td>2&quot; Schedule 40 Steel Flange</td>
</tr>
<tr>
<td>G65B</td>
<td>3&quot;</td>
<td>3&quot; Schedule 40 Steel Flange</td>
</tr>
</tbody>
</table>

DIMENSIONS - Inches (mm)

<table>
<thead>
<tr>
<th>Flange Type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>G65G</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>G65R</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>G65B</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
<td>3&quot;</td>
</tr>
</tbody>
</table>

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146
ADDITIVE INJECTION SYSTEM
PNEUMATICALLY PULSED AIR-PAK INJECTOR

© 1992 Gate City Equipment Co., Inc.
Circuitry Valves

Quick Exhaust Valves

- Eliminates the need for large diameter piping or large selector valves.
- Provides quick dumping of exhaust air at the cylinder.

Ordering Information: Select model number for port size desired.

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>INLET PORT</th>
<th>CYL PORT</th>
<th>EXH PORT</th>
<th>PRESSURE RATING</th>
<th>DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV 125</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
<td>1/2 (0.7 to 6.9)</td>
<td>A: 1 1/2 (2.8)</td>
</tr>
<tr>
<td>EV 297</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
<td>1/2 (0.7 to 6.9)</td>
<td>A: 1 1/2 (2.8)</td>
</tr>
<tr>
<td>EV 324</td>
<td>1/2&quot;</td>
<td>1/2&quot;</td>
<td>1/2&quot;</td>
<td>1/2 (0.7 to 6.9)</td>
<td>A: 1 1/2 (2.8)</td>
</tr>
<tr>
<td>EV 384</td>
<td>1/2&quot;</td>
<td>1/2&quot;</td>
<td>1/2&quot;</td>
<td>1/2 (0.7 to 6.9)</td>
<td>A: 1 1/2 (2.8)</td>
</tr>
</tbody>
</table>

Model PR10 Single Pulse Relay Valve

- Converts a continuous supply of inlet air into a momentary pressure pulse.
- Has a minimum pulse pressure of 58 PSIG (4.0 bar) and an operating range of 35 to 150 PSIG (2.4 to 10.1 bar).
- Ideal for applications where an input signal requires pressurized, but its output must go "off" after performing its task.
- The PR10 converts an input into a pulse with sufficient duration and flow to shift a double pilot operated poppet valve. The power valve can then be returned to its original position by an opposing signal.
- For best results, the PR 10 should be as close to pilot port of valve as possible.

Model S10-8 and Model S20-8 Shuttle Valves

- Operates as a 3-way valve with two inlet ports and one outlet port.
- Check ball moves away from the inlet port with the greatest pressure and against the port having the least pressure (a minimum pressure differential of 10 PSIG (.7 bar) is necessary to effect shuttle change).
- Has Buna-N check ball seat.
- 200 PSIG (13.8 bar) maximum.

Ordering Information: Order model no. associated with port size required.

<table>
<thead>
<tr>
<th>MODEL NO.</th>
<th>INLET PORT</th>
<th>OUTLET PORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>S10-8</td>
<td>1/8&quot;</td>
<td>1/8&quot;</td>
</tr>
<tr>
<td>S20-8</td>
<td>1/4&quot;</td>
<td>1/4&quot;</td>
</tr>
</tbody>
</table>

WARNING: Inappropriate or improper use, application, installation, service or maintenance of ARO valves may create a hazardous or dangerous condition or situation. Please carefully read the warning and cautions on every back cover page of the catalog.
Valve Accessories

Model 20308-X Exhaust Silencers
- Used to reduce the exhaust noise of air powered motors and valves.
- Recommended for all high C.F.M. applications. Has high flow capacity and low back pressure with no build up.
- No service required, no replacing of cartridges, compact, corrosion resistant, all metal construction housing.

**Model 20308-X Exhaust Silencer**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>PORT NO.</th>
<th>SIZE</th>
<th>IN. (cm)</th>
<th>LENGTH (IN. (cm))</th>
<th>WEIGHT (LB. (oz.))</th>
</tr>
</thead>
<tbody>
<tr>
<td>20308-1</td>
<td>1/8&quot;</td>
<td>3/16 (5.0)</td>
<td>2 1/2 (6.3)</td>
<td>1.1 (31.2)</td>
<td></td>
</tr>
<tr>
<td>20308-2</td>
<td>1/4&quot;</td>
<td>1/8 (3.2)</td>
<td>3 3/4 (9.7)</td>
<td>2.4 (67.4)</td>
<td></td>
</tr>
<tr>
<td>20308-3</td>
<td>3/8&quot;</td>
<td>1/4 (6.4)</td>
<td>4 3/4 (12.1)</td>
<td>4.5 (127.3)</td>
<td></td>
</tr>
<tr>
<td>20308-4</td>
<td>1/2&quot;</td>
<td>1/2 (12.7)</td>
<td>6 3/4 (17.3)</td>
<td>6.6 (184.6)</td>
<td></td>
</tr>
</tbody>
</table>

Ordering Information: Select model for thread size desired.

Model 20311-X Sintered Bronze Breather Vents
- For use on single acting cylinders and valves to prevent dust from entering parts open to atmospheres.
- 40 micron filtration.
- For vacuum relief or pressure equalization on gear boxes, reservoirs, and air tanks.

**Model 20311-X Vent**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>PORT NO.</th>
<th>SIZE</th>
<th>IN. (mm)</th>
<th>LENGTH (IN. (mm))</th>
<th>WEIGHT (LB. (oz.))</th>
</tr>
</thead>
<tbody>
<tr>
<td>20311-1</td>
<td>1/8&quot;</td>
<td>3.5</td>
<td>7/8 (3.0)</td>
<td>1.1 (31.2)</td>
<td></td>
</tr>
<tr>
<td>20311-2</td>
<td>1/4&quot;</td>
<td>5.5</td>
<td>1 1/8 (2.8)</td>
<td>2.4 (67.4)</td>
<td></td>
</tr>
<tr>
<td>20311-3</td>
<td>3/8&quot;</td>
<td>8.5</td>
<td>3 1/8 (7.7)</td>
<td>4.5 (127.3)</td>
<td></td>
</tr>
<tr>
<td>20311-4</td>
<td>1/2&quot;</td>
<td>11.5</td>
<td>6 1/8 (15.5)</td>
<td>6.6 (184.6)</td>
<td></td>
</tr>
</tbody>
</table>

Ordering Information: Select model for thread size desired.

Model 20312-X Exhaust Muffler
- Sintered bronze air muffler and exhaust diffuser for use on exhaust ports of valves.
- Sound deadening qualities with low pressure drop.
- 40 micron nominal filtration.

**Model 20312-X Exhaust Muffler**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>PORT NO.</th>
<th>SIZE</th>
<th>IN. (mm)</th>
<th>LENGTH (IN. (mm))</th>
<th>WEIGHT (LB. (oz.))</th>
</tr>
</thead>
<tbody>
<tr>
<td>20312-1</td>
<td>1/8&quot;</td>
<td>3.5</td>
<td>1 1/4 (3.2)</td>
<td>1.1 (31.2)</td>
<td></td>
</tr>
<tr>
<td>20312-2</td>
<td>1/4&quot;</td>
<td>5.5</td>
<td>1 1/2 (3.8)</td>
<td>2.4 (67.4)</td>
<td></td>
</tr>
<tr>
<td>20312-3</td>
<td>3/8&quot;</td>
<td>8.5</td>
<td>3 1/2 (8.9)</td>
<td>4.5 (127.3)</td>
<td></td>
</tr>
<tr>
<td>20312-4</td>
<td>1/2&quot;</td>
<td>11.5</td>
<td>6 1/4 (16.0)</td>
<td>6.6 (184.6)</td>
<td></td>
</tr>
</tbody>
</table>

Ordering Information: Select model for thread size desired.

Model 20313-X Exhaust Speed Controls
- Controls the incoming of air flow on exhaust ports of air valves. The speed of operating cylinder may be increased or decreased with adjusting screw. Adjusted position may be locked in place by lock nut.
- Exhaust sleeve is sintered bronze held in position by 2 brass parts.

**Model 20313-X Exhaust Speed Control**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>PORT</th>
<th>LENGTH (CLOSED)</th>
<th>LENGTH (OPEN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20313-1</td>
<td>1/8&quot;</td>
<td>1 1/8 (2.9)</td>
<td>3 1/8 (7.9)</td>
</tr>
<tr>
<td>20313-2</td>
<td>1/4&quot;</td>
<td>1 1/4 (3.2)</td>
<td>3 5/8 (9.5)</td>
</tr>
<tr>
<td>20313-3</td>
<td>3/8&quot;</td>
<td>1 1/2 (3.8)</td>
<td>4 1/4 (10.8)</td>
</tr>
<tr>
<td>20313-4</td>
<td>1/2&quot;</td>
<td>1 3/4 (4.5)</td>
<td>5 1/4 (13.4)</td>
</tr>
</tbody>
</table>

**WARNING:** Improperly or improperly sized, application, installation, service or maintenance of ARO valves may create a hazardous or dangerous condition or situation. Please carefully read the warning and cautions on each, back cover page of this catalog.
Panel Mounted Miniature Control Valves and Indicators

* Uses basic 200 series 3-way valves.
* Each valve can be plumbed to perform as normally passing, normally non-passing, selector, or any two-way function.
* Valves available with push button or rocker type selector.
* Indicators can be viewed at full 180° viewing angle.
* Valves and indicators have positive snap-in design for quick and easy installation.
* Can be stack mounted in multiples using panel cut-out method or ARQ's 59796-X mounting plates.
* Self-adhesive legend sheets available.

Ordering information: Both valves and indicators come complete with mounting plates and legend sheets separately.

59796-X Mounting Plates

<table>
<thead>
<tr>
<th>Model</th>
<th>&quot;A&quot; Dims.</th>
<th>&quot;B&quot; Dims.</th>
<th>Number of Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>59796-1</td>
<td>9/16&quot; (14 mm)</td>
<td>1 1/16&quot; (23 mm)</td>
<td>1</td>
</tr>
<tr>
<td>59796-2</td>
<td>1 1/8&quot; (28 mm)</td>
<td>2 3/8&quot; (80 mm)</td>
<td>2</td>
</tr>
<tr>
<td>59796-3</td>
<td>1 1/16&quot; (23 mm)</td>
<td>3 1/8&quot; (78 mm)</td>
<td>3</td>
</tr>
<tr>
<td>59796-4</td>
<td>2 5/8&quot; (67 mm)</td>
<td>3 3/4&quot; (96 mm)</td>
<td>4</td>
</tr>
<tr>
<td>59796-5</td>
<td>3 5/16&quot; (84 mm)</td>
<td>4 7/16&quot; (113 mm)</td>
<td>5</td>
</tr>
<tr>
<td>59796-6</td>
<td>4&quot; (102 mm)</td>
<td>5 1/8&quot; (130 mm)</td>
<td>6</td>
</tr>
</tbody>
</table>

59724 Legend Sheets

Model 59724-X Legend Sheets are self-adhesive identification legends that fit the 9/16" (14 mm) recessed square on the valves and indicators. Each sheet contains six blank and 37 different (2 each) legends. The dash number represents background color (-1 white, -2 black, -3 green, -4 red).

Panel Mount Indicators

<table>
<thead>
<tr>
<th>Model</th>
<th>Color</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>59811-1</td>
<td>Red</td>
<td>1/8&quot; NPT(F)</td>
</tr>
<tr>
<td>59811-2</td>
<td>Green</td>
<td></td>
</tr>
</tbody>
</table>

3-Way Control Valve Assembly

<table>
<thead>
<tr>
<th>Models/Instant Models</th>
<th>9/16&quot;</th>
<th>Actuation</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube Fittings NPT(F)</td>
<td>Port Type Designation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59803-1</td>
<td>59803</td>
<td>Pushbutton 1-in non- (Momentary) passing</td>
<td></td>
</tr>
<tr>
<td>59804-1</td>
<td>59804</td>
<td>Rocker 3-in passing (Maintained)</td>
<td>2-output</td>
</tr>
</tbody>
</table>

Dimensions and Mounting Information
50 Series Valves
1/8" Ports

3-Way Palm Button

Model 5430-02

Panel Mounted Palm Buttons may be mounted up to 1/8" max. panel thickness.

4-Way Palm Button

Model 5440-02

Panel Mounted Palm Buttons may be mounted up to 1/8" max. panel thickness.

3-Way Roller Cam

Model 5630-00

WARNING: Inappropriate or improper use, application, installation, service or maintenance of ARU valves may create a hazardous or dangerous condition or situation. Please carefully read the warning and cautions on inside back cover pages of this catalog.
Alpha Series Body Ported 4-Way Valves 1/8" & 1/4" Ports

Application Information
- S-ported, 4-way valve enables use of speed controls at valve's exhaust ports.
- Control the valves one of five ways: single solenoid, double solenoid, single pilot, double pilot and solenoid/pilot.
- Class F solenoids are rated for 100% duty cycle.
- A micro circuit relay connector is available and makes the valve TTL compatible.
- Two override methods provide a convenient way to set-up and trouble shoot circuits without electrical power to the solenoids.
- For information on connectors and replacement coils, see pages 53 and 54.
- Solenoid models are also available with molded leads.
- For information on the light emitting seal (L.E.S.) see page 13.

Feature / Benefit Information

Quick change coil can easily be interchanged or replaced by removing nut, sliding existing coil off and a new coil on.

Five actuator options available: single pilot, double pilot, single solenoid, double solenoid and solenoid/pilot.

Plug-in connectors cut installation time and give secure hook-ups.
Each connector is its own junction box, eliminating the need to wire the solenoid to a secondary junction box.

One piece, balanced spool provides quick response and high flow. Urethane seal is bonded to aluminum spool to resist wear.

Specifications

Lubrication: Valves are pre-lubed and can be operated without air line lubrication for an approximate life of 20 million cycles, depending on application. If air cylinders or other air line devices require lubrication, ensure that lubrication oils are compatible with valve seals and of sufficient viscosity to assure adequate lubrication. See Page 62 for list of suggested oils.

Cycles per minute is rated at 600 CPM on all Alpha Valves.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>TYPE</th>
<th>PORT</th>
<th>RANGE</th>
<th>MIN. PILOT PRESSURE</th>
<th>FLOW*</th>
<th>CYLINDER FACTOR</th>
<th>WEIGHT</th>
<th>AMBIENT TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>Spring</td>
<td>1/8&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>0.9</td>
<td>7.1 (201)</td>
<td></td>
<td>0°F to 185°F</td>
</tr>
<tr>
<td>Pilot</td>
<td>Spring</td>
<td>1/4&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>1.5</td>
<td>6.7 (160)</td>
<td></td>
<td>(18°C to 82°C)</td>
</tr>
<tr>
<td>Pilot</td>
<td>Pilot</td>
<td>1/8&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>0.9</td>
<td>8.7 (275)</td>
<td></td>
<td>9°F to 40°F</td>
</tr>
<tr>
<td>Pilot</td>
<td>Pilot</td>
<td>1/4&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>1.6</td>
<td>8.7 (275)</td>
<td></td>
<td>9°F to 40°F</td>
</tr>
<tr>
<td>Solenoid</td>
<td>Spring</td>
<td>1/8&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>0.9</td>
<td>8.7 (275)</td>
<td></td>
<td>9°F to 40°F</td>
</tr>
<tr>
<td>Solenoid</td>
<td>Spring</td>
<td>1/4&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>1.5</td>
<td>6.7 (160)</td>
<td></td>
<td>0°F to 185°F</td>
</tr>
<tr>
<td>Solenoid</td>
<td>Solenoid</td>
<td>1/8&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>0.9</td>
<td>8.7 (275)</td>
<td></td>
<td>9°F to 40°F</td>
</tr>
<tr>
<td>Solenoid</td>
<td>Solenoid</td>
<td>1/4&quot;</td>
<td>50 (3.5)**</td>
<td>25 (1.7)</td>
<td>1.5</td>
<td>6.7 (160)</td>
<td></td>
<td>0°F to 185°F</td>
</tr>
</tbody>
</table>

*SCFM at 80 PSI (5.5 bar) supply and 85 PSI (5.5 bar) downstream pressure.
**Use 80 PSI (5.1 bar) min. pilot pressure for 3-position valves.
†Use for low pressure and vacuum supply.
AIR
COMPRESSOR
T-30 Series

AIR-PAC

Portable, Oil-Less
Heavy-Duty Air Compressors

GENERAL DESCRIPTION:
Performance in tandem with portability makes the Air-Pac T-30 Series our finest, most convenient tank compressor which is perfect for the professional and serious do-it-yourselfer. This compressor includes air storage tanks, and an automatic pressure switch control.

SPECIFICATIONS

- H.F. ........................................ 1.0 @ 1720 RPM
- Voltage .................................... 115 V. 60 Hz
- Starting Voltage (min.) .............. 90 V
- Fuse Requirements ...................... 15 A
- Safety Valve Setting ................... 140 PSI (965.3 KPa)
- Air Displacement ....................... 4.8 CFM (127.4 LPM)
- Air Delivery: ............................. 2.98 CFM @ 90 PSI
- ............................................... (83.54 LPM @ 620 KPa)
- ............................................... (75.66 LPM @ 532 KPa)
- ............................................... (2.56 CFM @ 100 PSI)
- ............................................... (72.22 LPM @ 680.5 KPa)
- Amps at Working Pressure .............. 10.5 A
- Automatic Control: Starts @ 95 PSI
- stops @ 125 PSI (855 KPa)
- ............................................... (851.9 KPa)
- Tank Size .................................. 2 Gal. EACH (Total 4 Gal.)
- ............................................... (T-30 HP) 4.80 Gal. TOTAL
- Weight ..................................... 62 lbs.
- Cord ........................................ 6 ft. (1.83 M)

PSI = Pounds Per Square Inch
KPa = KiloPascals
CFM = Cubic Feet Per Minute
LPM = Liters Per Minute

APPLICATION
Ideal as primary or secondary air source for almost any operation. Particularly suitable for shops, garages, and factories where repetitive use demands high reliability.
GENERAL MAINTENANCE AND SERVICE

FOR SERVICE AND PARTS
For service contact the dealer from whom you purchased the compressor.
To place parts orders: Provide the model data located on the nameplate of the compressor and call your parts department 1-800-323-0620

⚠️ WARNING: Read and understand the information in this owner's manual before operating air compressor.

1. The compressor should be located in a dry, clean, and well-ventilated area.
2. Inspect before use: hose, plug, and cord for signs of damage. Do not use if a deficiency is found. Contact your nearest service center for replacement parts. Never operate a damaged unit.
3. Do not tamper with safety valve as it has been factory set. Any adjustment with this valve could cause serious injury.
4. This air compressor needs no lubrication. Applying oil to any part could result in polluted air delivery to the air-handling equipment.
5. Compressed air must never be aimed at anyone because it can cause serious injury. Keep children away. WEAR EYE PROTECTION.
6. All air compressors generate heat even under normal operating conditions. To avoid serious burns, never touch the air compressor during or immediately after operation.
7. When not in use, wrap cord around compressor and store in dry place. Do not abuse cord.
8. Before servicing, cleaning or removal of any part, shut off power and relieve pressure.
9. This system produces 125 PSI. To avoid rupture and injury, do not operate this pump with components rated less than 125 PSI working pressure (including but not limited to spray guns, hose and hose connections without pressure regulator).

If warranty service or repairs are needed contact your nearest authorized service center. If one does not exist contact the factory. Unauthorized repairs or teardown of the unit will void factory warranty.

SET UP
Location of Air Compressor
Operate air compressor in a clean, dry and well-ventilated area. The air filter must be kept clear of obstructions which could reduce air flow to the compressor. The air compressor should be located at least 12" away from walls or other obstructions that could interfere with the flow of air.

Extension Cords
To avoid voltage drop and power loss to motor, use additional hose instead of an extension cord. If an extension cord must be used, use only a 3-wire extension cord equipped with a 3-blade grounding plug and a 3-slot receptacle that will accept the plug on the compressor. Make sure the extension cord is in good shape.

<table>
<thead>
<tr>
<th>MINIMUM GAUGE FOR EXTENSION CORDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORD LENGTH 25 FEET 50 FEET 100 FEET 150 FEET</td>
</tr>
<tr>
<td>GAUGE 16 14 10 8</td>
</tr>
</tbody>
</table>

NOTE: Wire size increases as gauge number decreases.

Grounding Instructions
⚠️ WARNING: Improper grounding can result in electrical shock. In the event of a short circuit, grounding reduces the risk of shock by providing an escape wire for the electric current. The air compressor must be grounded.

The air compressor cord is equipped with a grounding wire and appropriate grounding plug. The plug must be used with an outlet that has been installed and grounded in accordance with all local codes and ordinances. The outlet must have the same configuration as the plug. Do not use an adapter.

Do not modify the plug that has been provided. If it does not fit the available outlet, the correct grounded outlet must be installed by a qualified electrician.

Inspect the plug and cord before each use. Do not use compressor if there are signs of damage.
**WARNING:** Improper installation of the grounding plug can result in electrical shock. If repair or replacement of the cord or plug is required, do not connect the grounding wire to either flat blade terminal. The wire with the green (with or without yellow stripes) insulation is the grounding wire and must be connected to the grounding pin.

Check with a qualified electrician if the grounding instructions are not completely understood, or if unsure unit is properly grounded.

**OPERATION**

Safety Valve
The safety valve (Item 24 - tank drawings) is designed to prevent pressure in the storage tank from exceeding 140 PSIG.

**WARNING:** Do not tamper with or attempt to eliminate the safety valve.

Thermal Overload Protector:
The compressor motor is equipped with a thermal overload protector. If the motor should overheat, the overload protector will shut the motor off. If this occurs, turn the on/off lever to the off position and allow motor to cool for approximately 5 minutes.

NOTE: Tank pressure must be below 95 PSIG for the compressor to start.

Restart the compressor by moving on/off lever to the on position. If compressor fails to start, check for blown fuse, the compressor may require more time to cool. If the overload protector shuts down the motor frequently, it could be due to low voltage. Common signs of low voltage are:

1. Motor does not get up to power or speed.
2. Fuser or circuit breaker activate when starting compressor.
3. Lights dim or remain dim when compressor is started.
4. Other motor operated appliances fail to operate properly.
5. Too many motor operated appliances on same circuit.

Operating Procedures
1. Make sure on/off lever is in the off position.

**WARNING:** Before using air tools or accessories, check manufacturer's maximum pressure rating. Maximum pressure rating must be above 125 PSIG.

2. Attach air hose and accessory.
3. Turn on/off lever to the on position and allow tank pressure to build.
4. When the motor stops, it has reached cutout pressure and the unit is ready for use.

NOTE: When using an accessory or air tool, pressure in the storage tank decreases. When it reaches a certain low level (cut-in pressure) the motor will automatically restart and raise the pressure in the storage tank.

5. To shut down compressor, simply move on/off lever to the off position.
6. Allow compressor to cool.
7. Drain storage tank (see Storage Tank in Maintenance Section).

**MAINTENANCE**

Air Filter
Inspect air filter (Item 49 - compressor drawing) before each use. Clean filter with soap and water as necessary. If filter becomes clogged or damaged, replace it.

**WARNING:** Never clean air filter with a flammable liquid or solvent. Explosive vapors may accumulate in the air tank and cause an explosion, resulting in serious injury or death.

CAUTION: Do not operate air compressor without air filter.

Storage Tank
Storage tank should be drained after each use or after every four hours of operation to prevent condensation build up and corrosion inside tanks. To drain tank, slowly and carefully open drain fitting (Item 8 - tank drawings), let unit upright and allow water to drain out.

NOTE: When draining tank, watch for debris (rust particles). If there appears to be debris in water, contact your dealer for possible tank replacement. It is recommended the tank be replaced every three years.

**WARNING:** Do not weld on the air tank of this compressor. Welding on the air compressor tank can severely impair tank strength and cause an extremely hazardous condition. Welding on the tank in any manner will void the warranty. If warranty service or repairs are needed contact your nearest authorized servicing dealer. If one does not exist contact the factory. Unauthorized teardown of the unit will void the factory warranty.
**Drawing and Parts List for T-30 Wide Tank Drawing**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pressure Switch</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Unloader Valve</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Bumpers, Self Aligning</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>End Cap</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Pin Cap</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Cross Hinge</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Pin Hinge</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Chain Fitting</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Generator</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Pin Pin Regulator</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Door</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Tapping Head</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Base Tank</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Tubing Insert</td>
<td>2</td>
</tr>
</tbody>
</table>

**Diagram**

1. Head
2. Comp Foot Tap
3. In-Line Cord
4. 22
5. 7
6. 6
7. 10
8. 24
9. 23
10. 26
11. 11
12. 21
13. 20
14. 19
15. 18
16. 17
17. 16
18. 15
19. 14
20. 1
21. 25
22.

---

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**UHAWING AND PARTS LIST FOR T-30 WIDE TANK DRAWING**

<table>
<thead>
<tr>
<th>No.</th>
<th>Part No.</th>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>023865</td>
<td>Cylinder - Foot</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>023718</td>
<td>Cylinder - Head</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>613740</td>
<td>Cylinder - Set Assembly</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>024037</td>
<td>Cylinder - Foot - Assembly</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>026219</td>
<td>Cylinder - Nut</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>026264</td>
<td>Cylinder - Head - Nut</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>026261</td>
<td>Cylinder - Foot - Nut</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>025020</td>
<td>Cylinder - Head - Nut</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>025118</td>
<td>Cylinder - Head - Nut</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>026222</td>
<td>Cylinder - Foot - Nut</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>027081</td>
<td>Cylinder - Head - Nut</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>026010</td>
<td>Cylinder - Foot - Nut</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>026015</td>
<td>Cylinder - Foot - Head</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>026566</td>
<td>Cylinder - Foot - Head</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>624567</td>
<td>Tubing Insert</td>
<td>1</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Head**
- **Comp. Foot Tap**
- **In-Line Cord**

---

**Illustration:**

- Diagram of a tank with various parts labeled.
- Connections and fittings indicated for assembly.

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FLANGED FITTINGS
Series 15 cast steel flanged fittings are provided with raised faces which are included in minimum thickness of flange. Center to face and face to face dimensions are given. Special testing information is shown on pages 21 and 22. Reducing fittings have the same center to face dimensions as those of straight size fittings of the largest opening. For drilling of holes see page 27.
PRESSURE DIFFERENTIAL GAGES
INSTRUCTIONS FOR INSTALLATION & MAINTENANCE OF PRESSURE & VACUUM SWITCHGES®
INCLUDING V, VWC, ABS, EQ, DP MODELS

TYPICAL PRESSURE SWITCHGES®

A SWICHGES® is an indicating mechanical gage, with adjustable limit contacts which may be preset at the factory. It is the sole responsibility of the installer/user to ensure the proper setting before placing it in operation. SWITCHGES® are available in various sizes and shapes to adapt to most applications, for pressure, temperature, liquid level, vibration or speed. These are dry contact type switches for light duty electrical switching and should be used with a Murphy Magnetic Switch or Transformer Relay. Both electrical and mechanical experience is necessary for proper installation and maintenance.

TYPICAL TATTLETALE MAGNETIC SWITCH®

TATTLETALE® Magnetic Switches
Murphy manufactures several, patented magnetic switches for protection of the light duty SWITCHGES® contacts and to ensure positive shut-down of equipment. There are magnetic switches for Capacitor Discharge ignition, Magnetic, or battery systems, and models for electric motor driven equipment. TATTLETALE® are pop-out indicators that show the cause of shut-down. If several TATTLETALE® are used in conjunction with several different SWITCHGES®, the first one out will lockout all other magnetic switches. Be sure the type of Magnetic Switch matches the power source used to trip it.

© Note: At equipment start-up, the magnetic switch reset button must be held in until normal operation occurs, unless SWICHGES® are locked out by time delay or lockout button. (Not applicable for Mag. or C.D. power)

TYPICAL WIRING

SEE BULLETIN M-6797 FOR MURPHY TATTLETALE'S & MAGNETIC SWITCHES

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### BASIC DESCRIPTION

**20 & 25 SERIES PRESSURE/VACUUM SWITCHGAGES**
- **20 Series** (2-1/16", 52mm mounting hole) and 25's (2-11/16", 65mm mounting hole) have steel cases and are diaphragm actuated. The pointer/contact (ground) through the case to complete the switch circuit. The limit contact(s) is wired to power, through a Murphy Magnetic Switch. See diagrams for SWICHGAGE®. Wire color code: Contacts are rated 2A @ 30V resistive (pilot duty); gauge connection is 1/8-27 NPT. See installation and typical wiring diagrams for wire up of SWICHGAGE® and Murphy magnetic switch.

**A20 & A25 SERIES PRESSURE/VACUUM SWITCHGAGES**
- **A20 Series** (2-1/16", 52mm mounting hole) and **A25 series** (2-11/16", 65mm mounting hole) have polycarbonate cases and are diaphragm actuated. These cases have molded, isolated terminals (or switch contacts; the pointer/contact is wired to common or ground; the limit contact(s) is wired to power, through a Murphy magnetic switch. See SWICHGAGE® diagrams for terminal model. Contacts 2A @ 30V resistive (pilot duty); gauge connection 1/8-27 NPT. See installation and typical wiring diagrams on this sheet, for wire up of SWICHGAGE® and Murphy magnetic switch.

#### STANDARD ELECTRICAL DIAGRAMS: 20 & 25 — PRESSURE/VACUUM SERIES

**These diagrams are shown with pointer in the normal operating range.**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>HL MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>ABS MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>EO MODEL</td>
<td>Low NC C NO</td>
</tr>
</tbody>
</table>

Std. Switch Rating: Pilot Duty, 2A @ 30 VAC/DC resistive

#### STANDARD ELECTRICAL DIAGRAMS: A20 — PRESSURE/VACUUM SERIES

**These diagrams are shown with the gauge pointer in the normal operating range.**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>HL MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>ABS MODEL</td>
<td>Low NC C NO</td>
</tr>
<tr>
<td>EO MODEL</td>
<td>Low NC C NO</td>
</tr>
</tbody>
</table>

Std. Switch Rating: Pilot Duty 2A @ 30 VAC/DC resistive

#### STANDARD ELECTRICAL DIAGRAMS: A25 — PRESSURE/VACUUM SERIES

**These diagrams are shown with pointer in normal operating range.**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. MODEL</td>
<td>Low L P H</td>
</tr>
<tr>
<td>HL MODEL</td>
<td>Low L P H</td>
</tr>
<tr>
<td>ABS MODEL</td>
<td>Low L P H</td>
</tr>
<tr>
<td>EO MODEL</td>
<td>Low L P H</td>
</tr>
</tbody>
</table>

Std. Switch Rating: Pilot Duty, 2A @ VAC/DC resistive

Micro-Switch Rating: 3A @ 30 VDC inductive

4A @ 125 VAC inductive
**SPECIAL APPLICATION SWITCHAGES**: ABS, EO, DP, VWC, ST, P-7

**ALARM BEFORE SHUT-DOWN**

**TWO SWITCH OPTIONS**

ABS: SwitchGage with Alarm Before Shut-down

The ABS has a standard, front limit-contact for low pressure equipment shut-down and an internal, SPDT micro switch for alarm before shut-down (see Wiring Diagram). When the low side of the switch SETS (preset point, on falling pressure), the NC side of the switch completes a circuit to activate an alarm. From this point the pressure must increase approximately 10% of scale before the micro switch will RESET and open the circuit; if pressure falls, the shut-down circuit will be completed.

**NOTICE**: The first contact shuts down limit setting (adjustable) and micro switch low point are preset at the factory; settings other than standard are necessary, then specify when ordering.

**FILTER DIFFERENTIAL PRESSURE**

DP: Differential Pressure SwitchGage

Installation: 1) Connect the input side of the filter to the center port; 2) Connect the output pressure to the upper port; 3) Set the limit contact to the manufacturer's filter specifications; 4) Connect wiring to alarm and/or shut-down devices.

**DIESEL AIR CLEANER RESTRICTION**

VWC: Water Column Calibrated, Vacuum SwitchGage

Installation: 1) Mount the VWC away from engine vibration. 2) Run the vacuum line from the gauge to a point between the air cleaner and (a) carburetor on carbureted engine, (b) turbocharger on turbocharged diesels, (c) the engine on naturally aspirated diesels. A flexible section is essential at some point in the vacuum line to eliminate vibration. Be sure the SwitchGage is grounded in a 12 or 24 volt system, and that the alarm uses the same voltage as the battery.

**TROUBLESHOOTING TIPS** (where problem appears to involve Murphy products)

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>PROBABLE CAUSE &amp; POSSIBLE CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine will not start</td>
<td>- Blown fuse in magnetic switch circuit; replace with 14 A fuse.</td>
</tr>
<tr>
<td></td>
<td>- False ground in control circuit; repair.</td>
</tr>
<tr>
<td>False Shutdown</td>
<td>- Open circuit (CLOSED LOOP); repair.</td>
</tr>
<tr>
<td></td>
<td>- Control circuit overloaded by accessories; route accessories.</td>
</tr>
<tr>
<td></td>
<td>- Intermittent shorting in wiring due to wear or insulation breakdown; check all wiring, replace as necessary.</td>
</tr>
<tr>
<td></td>
<td>- CLOSED LOOP circuit has intermittent open or short; check wiring, replace as needed.</td>
</tr>
<tr>
<td></td>
<td>- Vibration causes the magnetic switch to trip; repair, replace or relocate switch as needed.</td>
</tr>
<tr>
<td>SwitchGage® closes but does not trip</td>
<td>- Magnetic switch not being used with switch on or off; replace with correct magnetic switch.</td>
</tr>
<tr>
<td>the magnetic switch or kill the engine</td>
<td>- Magnetic switch not providing power to primary terminal post; replace with correct magnetic switch.</td>
</tr>
<tr>
<td>SwitchGage® closes and kills engine, but it does not trip the magnetic switch</td>
<td>- Magnetic switch binds, prevents trip: adjust or replace the switch.</td>
</tr>
<tr>
<td></td>
<td>- Conventional magnetic switch is used with C.D. ignition: replace the switch with a C.D. designated switch.</td>
</tr>
<tr>
<td>TATTLETALE® tripped out engine is still running (mag or C.D.)</td>
<td>- Loss ground to C.D engine; repair.</td>
</tr>
<tr>
<td>Pointer will not operate properly: inaccurate readings</td>
<td>- Clogged lines or pulsation damper: remove and clean or replace.</td>
</tr>
<tr>
<td></td>
<td>- Kinked or kinked/broken pressure or vacuum lines: replace line.</td>
</tr>
<tr>
<td>Pointer or contact burned in two</td>
<td>- Without exception this condition is caused by incorrect wiring or a short circuit; refer to wiring diagrams and recheck wiring.</td>
</tr>
</tbody>
</table>

If you need additional assistance, contact YOUR LOCAL MURPHY DEALER, or a Murphy representative at one of the offices listed on this form.
TYPICAL INSTALLATION

SWITCHGAGE* INSTALLATION (Refer to drawing):
1. Secure the SWITCHGAGE* in the panel, using the clamp and nuts provided.
   NOTE: Be sure the SWITCHGAGE* and panel are grounded.
2. Connect the pressure or vacuum line, using a 1/8'' NPT adapter at the SWITCHGAGE* end.
   NOTE: Be sure that pressure line is clean and that pipe dope or teflon used on fittings does not block the line.
3. If not in a protruded panel, wire the limit switches to a Murphy magnetic switch or relay.
   NOTE: Pilot duty (2 A @ 30 V resistive) contacts must be protected from high current; disconnect power during wiring.
   TEST: Start equipment; wait for pointer to lift off low contact; check switch; close limit switches to alarm/shutdown; adjust limit contact to correct limit point.

USE THE PROPER TOOLS — DO NOT OVERTIGHTEN

Murphy recommends mounting SWITCHGAGE* and magnetic switches away from excessive vibrations and the use of panel shock mounts whenever vibration may occur. Handle all instruments with care; although durable, these products should not be subjected to rough handling, dropping, or severe vibrations.

Magnetic Switches: Mount with electrical lugs down. If necessary, drill the TATTLETALE® and pilot-stud holes (template provided); clean away burrs and filings. Position the magnetic switch in the panel, making sure the pilot stud is in place. Add TATTLETALE® decal, then washer, then nut and tighten.

BASIC WIRING OF SWITCHGAGE* AND MAGNETIC SWITCH

- Disconnect battery or other power during installation.
- Murphy components are easily wired-up and maintained.

Use good quality wire and terminals. Be sure all connections are clean, complete, and correct. The wiring and the type of magnetic switch differ for various applications, but a knowledge of basic electrical functions and of the circuits necessary for the specific job (what you want to happen), and common sense will make the system work the way you want it to work.

See examples of typical wiring and instructions packed with each magnetic switch.

IMPORTANT, PLEASE READ COMPLETELY

SWITCHGAGE*®, Murphy magnetic switches and valves, properly installed and maintained, are effective, work-ready tools in any preventive maintenance program. For optimum performance, check these tools periodically; look for frozen pointers, kinked or worn tubing, broken wiring or loose connections; close the contacts, then watch for expected results. Replace any damaged or worn parts; clean and repair as necessary. Murphy will repair or replace parts covered by the Murphy two year limited warranty.

- Check the wiring; it must be Correct and Complete; tight connections, unbroken insulation, no accidental grounds, do not run shut-down wires with ignition wiring.
- Check all tubing and connections for leaks.

DO NOT USE ADJUSTABLE WRENCHES

USE THE PROPER TOOLS — DO NOT OVERTIGHTEN

Murphy recommends mounting SWITCHGAGE* and magnetic switches away from excessive vibrations and the use of panel shock mounts whenever vibration may occur. Handle all instruments with care; although durable, these products should not be subjected to rough handling, dropping, or severe vibrations.

Magnetic Switches: Mount with electrical lugs down. If necessary, drill the TATTLETALE® and pilot-stud holes (template provided); clean away burrs and filings. Position the magnetic switch in the panel, making sure the pilot stud is in place. Add TATTLETALE® decal, then washer, then nut and tighten.

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- Disconnect battery or other power during installation.
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- Check the wiring; it must be Correct and Complete; tight connections, unbroken insulation, no accidental grounds, do not run shut-down wires with ignition wiring.
- Check all tubing and connections for leaks.
LCD
ELECTRONIC COUNTER
MODELS CUB 1 & CUB 2 COUNTERS
OPEN UP NEW COUNTING HORIZONS, FROM COUNTING SIMPLE SWITCH CONTACT CLOSURES

- TO HIGH SPEED PULSES FROM TTL, CMOS, OR OTHER ELECTRONIC SOURCES
- AT A PRICE LESS THAN EQUIVALENT E.M. [ELECTROMECHANICAL] COUNTERS

The heart of the CUB is a tiny custom silicon chip developed by Red Lion Controls. This chip contains all of the counting and display circuits in an area less than .025 (0.5mm) square inches. Via "micro-assembly", the chip and other peripheral parts are attached to a substrate with the electrical connections being made ultrasonically - using wire approximately 1/10 the diameter of a human hair. The result is an entirely new concept in counting, that is not only cost effective, but opens the door to counting applications that until now were not economically feasible.

AND HERE ARE SOME MORE ADVANTAGES:

SELF-Powered
Self-Contained batteries eliminate the need for external power and prevent loss of count if power fails. Also provides for remote or portable applications.

Battery operation also means elimination of shock hazards and allows the use of 2-conductor bell wires for access signals and micro-power input signals.

Batteries are easily replaceable (2 "N" Cells, alkaline) and average battery life is four years.

HIGH SPEED
The 5000cps count speed is at least 100 times faster than "high performance" E.M. counters. This opens up vast new application areas that previously were unattainable, or at least, advocated by expensive electronic counters costing 5 to 10 times as much.

FLEXIBILITY
Various access inputs allow use with switch contacts or high speed pulse outputs from electronic sensors and circuits. The reset function can be disabled, set up for front panel reset, remote reset, or both.

NO-WEAR, NO-NOISE
The CUB's micro-circuits can accurately and reliably accumulate enough counts in one hour to completely wear out an ordinary E.M. counter. More over, it can repeat this performance 3500 times (4 years) with just one set of batteries.

RELIABILITY
Internal "micro-assembly" construction withstands many times the "G" forces of shock and vibration compared to conventional construction.

CUB counters also feature elastomeric contacts. This eliminates long-term problems associated with contact corrosion.

Battery operation, a high degree of input filtering, plus an inherent normal mode rejection ratio of more than 1200V @ 5000Hz, provides ultra-high immunity from electrical noise interference.

RUGGED, SEALED FRONT-PANEL CONSTRUCTION
Housed in a die-cast metal case, CUB counters are front panel sealed and designed to meet NEMA 4/1P6 specifications, for wash-down and dust when properly installed.

SPEcIFICATIONS

1. DISPLAY: 6-Digit LCD
   CUB 1 - 0.35" (0mm) high
   CUB 2 - 0.35" (0mm) high
2. POWER SOURCE: No external power required. Operates from 2 "N" type alkaline batteries (supplied separately). Battery life up to 4 years or more. (See Notes, at right.)
3. COUNT & RESET INPUT SIGNALS: Adapts to COM-SWITCH Connectors, Open-Collector Transistor Outputs, and Bi-Polar Drive Outputs as shown in the diagram on preceding page. Counter increments and resets on negative going (pull-down) transition of access or reset signal.
4. OPERATING TEMPERATURE RANGE: 0° to 50°C (32° to 122°F)
5. STORAGE TEMPERATURE RANGE: -30° to +60°C (-20° to +140°F)

USE CUB COUNTERS WITH:

6. COUNTER SPEED: Up to 5000 with switch contact input (counters have internal de-bounce circuits) or up to 50000 with solid-state electronic input (See diagrams on preceding page).

NOTE: Only Alkaline Cells are recommended for use with CUB Counters. DO NOT USE CARBON-ZINC BATTERIES since they have short life times and can lead electrolytes causing internal corrosion damage. When using switch contacts for contact input or remote reset, normally open contact circuits are recommended. Switch contacts that remain normally closed and are opened only briefly to signal a count, can reduce battery life to unwarranted less than 4 years.

USE CUB COUNTERS WITH:

- VCM - VOLTAGE CONVERTER MODULES for isolated, A.C., control voltage count inputs to 28VDC.,
- LCM - LOGIC CONVERTER MODULES for interface with standard logic voltages & outputs,
- PBMA - POWER SUPPLY & INTERFACE MODULE for operation with electronic sensors.

[See Accessory Section Of The Catalogue]
DIMENSIONS, INSTALLATION, & BATTERY INSERTION

After cutting opening in panel, slide the panel gasket over the rear of the counter body, to the back of the head. Then slide counter through the panel cut-out. Install mounting clips on each side of counter body with mounting screws.

CUB 1

The battery cover is held in place by upper and lower clips that capture metal lock ramps on the cover. To remove, insert thumb-and-index finger nail in the gap between the upper and lower clips and the battery cover, and depress the clips slightly to clear the edges of the ramps while pulling out on the cover. To replace cover, simply push into place until both ramps snap into engagement with lock ramps.

CAUTION: Do not deflect clips more than necessary to clear lock ramps. Excessive deflection can cause clips to break off.

CUB 2

Slide battery cover to the left until the right head lip disengages and pops out. To reinstall, insert left head lip into case first, push cover to the left until right head lip drops down and cover snaps back into place. Install batteries as shown below observing proper polarity.

NOTE: Push battery spring clips to the left (toward meter connection) to completely free the batteries when removing or installing batteries. Conductive rubber battery contacts can be torn from their retaining pins if batteries are forced in.

BATTERY COVER REMOVAL & BATTERY INSERTION

CUB 1

1. Avoid long wire runs in cable troughs or conduits with power circuits.
2. Mount the CUB in a panel that is grounded to the machine frame.
3. When using accessory devices such as ICM's or PSM's into the H.S. CNT. inputs, the accessory devices should be mounted near the CUB Counter.

ELECTRICAL CONNECTIONS

Writing rules to ensure evaluation or to ensure that circuits can be made with almost any kind of wire and over distances of hundreds of feet, due to the advantages of low-voltage low-current operation. The inherent noise immunity in buffer filtering built into CUB Counters, permits use of unshielded wiring; however, the following precautions are advisable, especially in high-electrical-noise environments.

ORDERING INFORMATION

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<td>CUB 2</td>
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<td>MAX 2</td>
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NOTES:
1. Batteries NOT supplied with counters, order separately. 2 required per unit.
2. Counters supplied with necessary hardware - includes 2 mounting clips & screws, panel gasket, 2 wire nuts & blue terminal wire.
3. Counters supplied with connector body & wires, yellow & black wires. RED ICA includes terminator body & wire a set of black, white, blue, & yellow terminal wires.
APPLICATION FLEXIBILITY VIA RECONNECT OPTIONS

Selection of desired operating modes is easily done by adding or moving terminal leads in the Input Connector block. The connector body is provided to prevent incorrect insertion, and installed in place by the battery cover to avoid accidental displacement. Connectors are supplied with the 2 leads installed as shown below. A spare blue lead is supplied in the hardware pack.

TO REMOVE TERMINAL insert blade of a small screwdriver into slot of connector body, and gently push in to disengage lock panel. Pull terminal out.

WHEN INSERTING TERMINAL into connector body, make sure the lock panel is toward the slot in the body. Push terminal in until lock panel snaps into slot.

LOW SPEED COUNT INPUT, 60-CPs MAX. [For 250-CPs use note in text]

Pulling the L.S. CNT. Input to Common with a mechanical or solid-state switch increments the counter. The low pass filter (1000 Ohm, resistor and 470pF cap) used with a Schmitt trigger circuit debounces mechanical switch signals. The switch level is 144mV (max. voltage drop 0.5V) when ON OFF-state leakage must be less than 300pA at 3V.

Debounce switches, mercury wetted contacts, snap action limit switches, and silver alloy relay contacts with wiping action are usually satisfactory for generating input signals. Motor starter contacts, tungsten contacts, and brush-type contacts should NOT be used.

NOTE: By parallel connecting both H.S. CNT. and L.S. CNT. inputs, count speed can be increased to 25-CPs if debounce is not needed.

HIGH SPEED COUNT INPUT, 5000-CPs MAX.

Moving the white wire to the H.S. CNT. input allows the CUB Counter to operate at speeds up to 300-CPs, when driven by a bipolar output or external circuits having an output impedance of 3.3Kohms or less. Input drive voltage must be limited to 3.5V maximum to avoid a charging current into the batteries which can cause premature battery failure or leakage. CMOS and TTL Logic outputs can be loaded with a resistor (R) to limit drive voltage, or a voltage divider can be used as shown for the PNP O.C. Transistor output.

INPUT PULLER EXCITATION LIMITS

Connecting the RST. EN. (Reset: Enable) input to Common activates the front panel Reset button. When the front panel reset button is to be de-activated, move the yellow wire from the RST. EN. Input.

When Remote Reset is required, the blue wire in the hardware pack is inserted in the REM. RST. Input. Pulling this input low causes the counter to reset. The REM. RST. can be pulled low by either a mechanical switch or solid-state transistor switch. Switch load and leakage are the same as for L.S. CNT. Input above.

NOTE: The H.C. promotion circuit on the REM. RST. Input causes a delay of approximately three to four micro-seconds.
AIR ELIMINATOR VALVES
AIR VALVES

Air Valves

Air Vents

Air flow from steam and liquid lines. A vacuum check when pressure drops, preventing air from passing back to a tail end, when air accumulates. Used for air and steam lines, tops of risers, and similar locations in pipe systems. Use when venting is desired.

Air Eliminators

Automatically vents air to maintain air pressure in steam or water systems. Can be used in both 50° F and 50° C (10° C) systems. Air flows through the vent, and is released into the atmosphere.

Lockable Air Valves

Maximum Pressure: 200 psi
Maximum Temperature: 105° F

Safety Shutoff Valves

For air lines, when a sudden drop in pressure occurs, automatically closes off the air line to prevent injury or damage.

Cast Iron Air Release Valves

A Low Capacity Valves

Maximizes pressure, maintains a steady flow of air, and prevents siphonage. Ideal for steam and liquid lines. Discharge capacity is 81 cfm at 150 psi. Comes with a female pipe thread.

Slide Safety

Maximizes pressure, maintains a steady flow of air, and prevents siphonage. Ideal for steam and liquid lines. Discharge capacity is 81 cfm at 150 psi. Comes with a female pipe thread.
WATER DETECTION SENSOR
DESCRIPTION:
The 900-911 Water Detection Device was developed to replace the float control and slug valves used on filter separators.

The 900-911 Water Detection Device detects water level in filter separator vessel sumps. When a high water level is detected an alarm light turns on. Personnel can then manually drain the water. The auxiliary contacts can operate an alarm or shut off the pumps, etc.

For years individuals have had difficulty troubleshooting float control and slug valves. The 900-911 is an electric device and is extremely reliable. The 900-911 is easier to diagnose and repair than hydraulically operated devices.

OPERATION:
A donut shaped float is installed on a pre drilled plate. This plate assembly fits on the float control valve mount. The float rides on a stainless steel stem. When the water begins to rise in the sump, this float follows the interface between fuel and water. The contacts inside the stem are activated by the magnet in the float when the water reaches the alarm level. An electronic relay registers this contact closure because of the increase in resistivity of the closed contacts. This method of signal prevents high voltage inside a vessel filled with jet fuel and makes the unit intrinsically safe.
FILTRATION SYSTEM
Note: Requires 36" Clearance to Change Filter
**Morrison**

### Line Strainers -- Bottom Clean Out

#### 285

**Line Strainer Bottom Cleanout**

**Construction Details**
- Body: Cast Iron
- Cap: Cast Iron
- Flange: Maleable Iron
- Strainer: Stainless Steel Type 304

**Part No.** 285-04

**Size** | **Weight**  
-- | --  
1-1/2" | 10 lbs  
2" | 14-1/4 lbs  
2-1/2" | 16-1/4 lbs  
3" | 27 lbs  
4" | 42 lbs

Available with 6, 10, 20, 40, 60, 80 or 100 Mesh. Specify when ordering.

#### 285-C

**Line Strainer**

**Construction Details**
- Body: Female
- Cap: Male
- Flange: Stainless Steel
- Strainer: Stainless Steel
- Screw and Nut

**Part No.** 285-C

**Size** | **Weight**  
-- | --  
1" |  
2" |  
2-1/2" |  
2-1/2" |  
3" | 3 lbs

Available with 6, 10, 20, 40, 60, 80 or 100 Mesh. Specify when ordering.

#### 285-SS

**Line Strainer Stainless Steel Bottom Cleanout**

**Construction Details**
- Body: Stainless Steel - Type 316
- Cap: Stainless Steel - Type 316
- Flange: Stainless Steel - Type 316
- Strainer: Stainless Steel - Type 316
- Screw and Nut: Stainless Steel

**Part No.** 285-SS

**Size** | **Weight**  
-- | --  
2" | 15 lbs  
3" | 27 lbs

Available with 6, 10, 20, 40, 60, 80 or 100 Mesh. Specify when ordering.

#### 285-L

**Line Strainer Bottom CL**

**Construction Details**
- Body: Ductile
- Cap: Ductile
- Flange: Graphite
- Strainer: Stainless Steel

**Part No.** 285-L

**Size**  
2"

#### Ag-Chemical Line Strainer

**285-P**

**Nylon Line Strainer**

**Construction Details**
- Body: Nylon
- Cap: Nylon
- Strainer: Stainless Steel

**Part No.** 285-P

**Size**  
1-1/2"

**30 P.S.I. Operating Pressure**

**Weight**  
1-1/2" | 1-1/2 lbs
APPENDIX C

After-Action Memorandum From the 24th ID DISCOM
MEMORANDUM FROM COMMANDER, DIVISION SUPPORT COMMAND, 24TH INFANTRY DIVISION (MECHANIZED) SUPPORT COMMAND, FORT STEWART, GEORGIA 31314

MEMORANDUM FOR COMMANDER, U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER; SATBE-FL, ATTN: MR. M.E. LE PERA, FORT BELVOIR, VIRGINIA 22060-5606

SUBJECT: Filtration/Additive Unit

1. As we bring our use of the Filtration/Additive Unit (FAU) to a close at Fort Stewart, I would like to personally thank you for your willingness to send it to us and allow us to utilize it in cleaning up our fuel contamination situation. I hope you found its use as beneficial as we did.

2. We found the FAU to be effective, to perform as advertised and believe that there is a definite place in the Army inventory for such a piece of equipment. As you continue development of the FAU and eventual fielding, there are several issues which we recommend be addressed.

   a. Distribution. As we transition to a single fuel, the need to maintain clean fuel is doubly critical. Utilization of JP-8 for the entire force requires that all fuel within the Division be maintained at Aviation specifications all the time. We recommend a minimum of one FAU per Division, to be located in the Main Support Battalion. Under ideal conditions we would prefer a minimum of one FAU per each Forward Support Battalion, the Aviation Support Battalion (ASB) and one in the Main Support Battalion. Fielding of five per Division will strategically place the machines across the battlefield and will ensure that fuel purification capability is within reach of every unit on the battlefield. Also, fielding of five machines will allow the machines to be mutually supportive should the need arise and will also allow cross leveling of them should one become non-operational. We have learned that only one of "anything" can be a problem as the loss of it can bring an operation to a quick and complete halt.

   b. Mission Assignment. Recommend the mission to operate the FAU be assigned to the Quartermaster Corps and ultimately the supply and service companies within the Division. Logic dictates that the mission of fuel purification be assigned to the agency which actually handles the fuel. This provides a single source for customer support and eliminates the "middle man" when a fuel purification mission is to be performed.
AFZP-VS
SUBJECT: Filtration/Additive Unit

c. Militarization. Recommend you continue plans to "Militarize" the FAU. In its current configuration, fittings, filters, and controls are largely exposed. Their exposure increases the danger of damage to the FAU from tree limbs or other items which may be encountered in a field environment. In order for the FAU to be a viable piece of equipment, it must be capable of going to the field and operating in a tactical environment. For example, recommend you consider mounting a "box" over the fittings and hoses of the entire unit in order to protect it from damage. Looking at the Reverse Osmosis Water Purification Unit (ROWPU) design and structure may provide insight into this recommendation. Also recommend you consider redesigning the electrical system (taillights, etc.) to accept a 24 volt system in order for it to be compatible with tactical vehicles. The weight of the FAU requires it to be pulled by either a 2 1/2 Ton cargo truck, a 5 Ton Cargo or a 5 Ton Tractor. Recommend the towing lunette on the trailer be redesigned and relocated if necessary in order to ensure it accepts the towing pintle from the towing vehicle.

d. Miscellaneous. Recommend you add a flexible "wand type" device (3 to 4 feet in length) to the end of the intake hose. This device will assist greatly in reaching fuel cells of all types of vehicles (tracks and wheels) and will also help reach secondary fuel cells on combat vehicles. This capability will enable the FAU to provide a more complete filtration capability.

3. Again, I would like to express my gratitude. The entire petroleum community rose to the challenge and provided detailed and greatly needed assistance. Professionals from your organization, from Southwest Research and from the Army Petroleum Center worked long and difficult hours in order to keep the 24th Infantry Division (Mechanized) combat ready. Please feel free to call if we can be of assistance in the future. My POC is the Division Materiel Management Officer, MAJ Bryan L. Wiles, DSN 870-8993.

ROBERT L. FLOYD II
COL, OD
Commanding
APPENDIX D

After-Action Letter (Point Paper) From Camp Pendleton, 1st Reconnaissance Battalion
United States Marine Corps

From: Commanding Officer, 1st Reconnaissance Battalion
To: Commander, 1st Marine Division, AC/S Logistics
Subj: FUEL FILTRATION AND ADDITIVE UNIT (FAAU)

Encl: (1) U.S. Army Belvoir RD&E Center Special Bulletin
(2) U.S. Army Belvoir RD&E Center FAAU Pamphlet
(3) Trip Report from Mr. G. B. Bessee

1. Background. For at least a year the Battalion has experienced continual problems with the clogging of secondary fuel filters on the light armored vehicles (LAV). All indications are that the cause is fuel contaminated with water, microbiological agents, and sediment.

   a. Bulk fuel delivered to our underground storage tanks is treated on site with a biocide and stabilizer that effectively checks microbiological growth. However, as the fuel is stored over relatively long periods of time both in the underground tanks and LAV fuel cells, it grows increasingly contaminated with water through condensation. Simultaneously, microbiological growth that has been terminated by the biocide additive, along with other particulate matter, settles to the bottom of storage tanks and fuel cells forming sludge. During vehicle operation the sludge is agitated and passes into the fuel system, ultimately clogging the two filters, particularly the secondary (five micron) filter.

   b. The more often fuel is utilized the better, as condensation and algae growth is minimized, as is the formation of sediment. However, LAVs rarely come close to utilizing even half the fuel in their cells during a typical training week. Because this condition exists, and vehicle performance is so adversely affected due to clogged filters, to date there have been four approaches to the problem.

   (1) Fuel cells are "topped off" at all times to limit water formation through condensation.

   (2) Periodic purging of the storage tanks is required. This is not only a costly process, but can also result in the loss of already purchased fuel—now contaminated. There is also the added cost of disposing of it as hazardous waste. Additionally, there is significant lead time required in acquiring this service, and the recovered fuel is only run through a two filter process as opposed to the FAAU's six filters.
(3) Fuel filters are replaced. Filters, of which there are two, cost $25.00 each.

(4) LAV fuel cells are removed from the vehicle for purging. This is a manpower intensive process as it takes two mechanics 18 hours to complete the task.

2. Discussion. The problem of poor fuel quality is apparently widespread as discussed in enclosure (1). The crux of the problem at our level is to find a way to periodically filter the fuel in the storage tanks and LAV fuel cells. We have been proactive in pursuing strategies to identify solutions that are economical, and at the same time minimize labor costs and negative impact on training. Part of this effort has been to seek assistance and recommendations from various agencies responsible for fuel handling within the Division, MEF and Base structures (e.g., G-4, FSSG Bulk Fuel, MCF Bulk Fuel, MWSG Bulk Fuel, etc.). We also sought information through our various LAV specific contacts, for example, MCLB Barstow and Albany, the LAV Program Manager (LAV-PM), etc.

a. CWO2 Shihinski, our maintenance officer, seems to have found a potential solution through the LAV-PM (Engineering Section), U.S. Army Tank Automotive Command (TACOM), Warren, Michigan. He was informed by TACOM that an experimental filtering and additive device was under development by the U.S. Army Belvoir Research, Development and Engineering Center, Ft. Belvoir, Virginia (Enclosure (2)).

b. In December, CWO2 Shihinski contacted Mr. Maurice E. Lepera, Chief of Fuels and Lubricants Division, Ft. Belvoir RD&E. Arrangements were made for the FAAU to be shipped to us as part of the testing and evaluation process. Technical assistance was provided by Mr. Gary B. Bassiee, a representative from Southwest Research Institute. Mr. Bassiee confirmed that any cost would be absorbed by his agency as the device was still under developmental study at Ft. Belvoir. Prior to shipment it was clear that no cost would be incurred by either First Division or the LAV-PM’s office.

c. During the approximately one week in late February that Mr. Bassiee and the FAAU were on site here at Las Flores, our entire stock of fuel was filtered to the 0.5 micron level. This includes the fuel in our storage tanks and 94 LAV fuel cells. The key point is that removal of the fuel cell was not necessary for efficient filtering, and each fuel cell took less than 20 minutes to purge using only the machine and a single operator. We subsequently shipped the unit to 1st Tank Battalion with our own operator, where it is my understanding that over 14,000 gallons of fuel were cleansed.
3. Summary

a. The savings realized in labor, material, and fees to civilian contractors to clean storage tanks are obvious. It is also extremely easy to operate, requiring only about 15 minutes of OJT.

b. A system like the FAAU also has strong application to the Marine Corps as a primarily expeditionary force. Based on our research into the matter, there is no filtration system similar to the FAAU currently organic to the Marine Corps. It is our belief that it would have immediate application both at home and abroad.

(1) The fuel problems experienced during Desert Shield and Desert Storm are legend. The most senior staff noncommissioned officers who serve in the Battalion's maintenance section attest to the difficulties they experienced with contaminated fuel from MPF sources. They also describe severe problems with "bad" fuel delivered long after MPF sources were dry.

(2) As an expeditionary force we routinely deploy to nations that are unlikely to maintain an acceptable level of quality control in fuel storage and shipment. It is likely, therefore, that a deployed force would be required to utilize fuel purchased locally. It is also likely that this fuel would have some level of unacceptable contamination.

(3) In the event of conflict, contingency operations, etc., captured enemy materiel, particularly fuel stocks, have proven useful in relieving the pressure on friendly logistic systems. These stocks could suffer from some degree of either intentional or unintentional contamination.

c. The effectiveness of the FAAU is clearly evidenced by enclosure (3). The point of this paper is to pass on what we believe to be very useful information and recommend involvement in the development and fielding of the FAAU.

J. F. Kelly
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HQ USAF AIR FORCE
ATTN: LEYSF
WASHINGTON DC 20330

CDR
WARNER ROBINS AIR LOGISTIC CTR
ATTN: WRALC/LVR-1 (MR FERAZZOLA)
ROBINS AIR FORCE BASE GA 31098

CDR
USAF 3902 TRANSPORTATION SQUADRON
ATTN: LGTVP (MR VAUGHN)
OFFUTT AIR FORCE BASE NE 68113

Other Organizations

DEPARTMENT OF ENERGY
CE-151, ATTN: MR JOHN RUSSELL
1000 INDEPENDENCE AVE, SW
WASHINGTON DC 20585

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