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2. OPERATION

2.1 GENERAL INFORMATION

This section provides valuable information and procedures to assist the end user in understanding and solving a variety of problems that may be encountered during the design, development and optimization of their current or future liquid management system.

2.1.1 Components

Each liquid management system consists of a Controller Module, Motor/Base or Actuator Module and a Pump Module.

2.1.1.1 Controller Module

The Controller Module contains the electronics to operate the system. The operator can control and monitor the operation of the system from the Controller Module. A variety of Controller Modules are available to meet a wide range of operating parameters.

2.1.1.2 Motor/Base Or Actuator Module

The Motor/Base Module for a rotary system and the Actuator Module for a linear system (2000 series) provide the drive mechanism for the Pump Module. Different configurations are used to match the requirements of the application.

2.1.1.3 Pump Module

The positive displacement piston pump is constructed of precision machined ceramic and other chemically resistant materials. Piston geometry, liquid port locations in the cylinder, and piston motion provide positive control of the valving function that provides volumetric repeatability not found in other designs. The piston/cylinder set has a diametral clearance of about 0.00010 inches, eliminating the need for piston seals or rings. A variety of Pump Module sizes and options are available including; materials of construction, pump cases, water (liquid) gland, and connector selections.

2.1.1.4 Application Liquid(s)

The application liquid, provided by the end user, must be considered part of the liquid system due to variations in liquid properties. A system designed for a particular volume and rate requirement may be inappropriate for another application with the identical volume and rate requirement, but using a different liquid.

2.1.1.5 System Interface

In addition to a wide range of control features, options and accessory equipment, IVEK liquid management systems can easily be interfaced as a whole system subcomponent with a computer, customized motion control systems and a wide variety of other peripheral devices as required by a specific application. The appropriate procedural and specification documentation for all included system options and accessories are contained in this manual.

2.1.2 Fluidics Evaluation

IVEK offers free application analysis to determine the suitability of our equipment for the end user's application. IVEK's expertise in chemical, biotechnical, electronic, mechanical, and fluidics engineering is drawn upon as needed for each application.

2.1.3 System Accuracy Factors

2.1.3.1 Rotary System

There is a single mechanical linkage component between the pump piston and its drive element. This precision spherical bearing transforms circular drive motion into elliptical thrust motion (reciprocation). Having this single contact point reduces the number of mechanical slip and wear points.

2.1.3.2 Linear System

The mechanical linkage component between the pump piston and its drive element is a shaft coupling and a lead screw with an anti-backlash drive nut. Having this single contact point reduces the number of mechanical slip and wear points.

2.1.3.3 Common Factors

Displacement accuracy is based on a simplified positive stroke mechanism with no secondary linkages to produce stroke-to-stroke mechanical errors and no gravity actuated or spring loaded valves to introduce random valve seating errors.

Valving is performed by a flat on the piston that is mechanically aligned with one cylinder port during the intake portion of the piston stroke and aligned with the other port during the discharge portion of the stroke. The flat alignment is controlled by the driving actuator. The valve action is, therefore, mechanically precise and free of random closure variations.

Fluid Slip is a term commonly used to describe the migration of liquid around the internal moving parts of gear, lobe, and vane pumps. It is the volumetric difference between physical component displacement and liquid throughput of a pump system. Slip loss refers to the liquid that passes through the clearance space (approximately 0.00005 inches) between the piston and the cylinder wall. Since this clearance represents a restrictive passage of essentially constant dimension, the slip rate is determined by viscosity, pressure and time. Assuming constant liquid viscosity and pressure, slip will be a smaller factor in a high repetition rate pump (short time per stroke) than in a low repetition rate pump. As viscosity increases and pressure decreases, time becomes a less significant contributor to slip loss. The clearance can be modified to compensate for viscosity.

The clearance between the piston and cylinder wall must be optimized for the liquid being pumped in order to minimize the loss due to fluid slip.

2.1.3.4 Prevailing Factors

Flow-Rate Stability (Repeatability) is principally related to consistency in fluid slip rate and stroke repetition rate. These functions are related to external system load factors such as viscosity and differential pressure.

Repeatability within the Pump Module is influenced by fluctuations of liquid differential pressure and fluctuations of liquid viscosity. When these factors are controlled, reproducible pumping accuracy as high as 0.1% can be expected.

2.2 OPERATION

The stepping motor Controller Module is designed with linear rate speed control. Linear rate selection allows for very accurate, repeatable control of the dispense, particularly in continuous flow and Dispense mode and at both, very high or low speeds. This unique linearity allows corresponding accuracy to be achieved from unit to unit, permitting dispensers to be “stacked” in order to create synchronized, multichannel systems.

The controller features a torque limited drive system that provides superior system longevity and is well suited to a large variety of applications. The same concept can easily be used for a single cycle dispenser or continuous mode metering pump. A wide variety of options are available including; indicating counters, preset counters, preexisting system interface connections and customized software.

There are four distinct operating modes; Prime, Meter, Dispense and Empty. Each mode performs a specific operation. Prime fills the Pump Module and tubing with liquid. Meter provides a continuous flow of liquid at a precise rate. Dispense provides a discrete amount of liquid at a precise rate. Empty returns the liquid back to the feed reservoir. All modes of operation may not be available on all types of controllers.

2.2.1 Prime

Prime is used for filling the pump liquid circuit (inlet tubing, pump chamber, outlet tubing) at initial start-up and for eliminating air bubbles in the circuit. This is required to correctly setup the system for liquid metering and dispensing. The pump is self priming (pump chamber does not need to be wetted to prime), but there are a few exceptions depending on the nature of the specific application. Once the system has been primed it is ready for metering or dispensing. Some controllers do not have a separate ‘Prime’ mode, but use the ‘Meter’ mode for the prime operation.

NOTE

If your system does not have a Prime mode, Meter mode is used to fill the liquid circuit.

2.2.2 Meter

Meter mode is used for continuous pumping of liquid. Meter is very similar to prime. The difference is prime gets the system setup for dispensing or metering of liquid, and meter is for the intended use of the system.

In Meter mode, the rate of liquid flow is directly controlled, but the volume of liquid displaced is not directly controlled. The volume of liquid dispensed is the result of the rate and the length of time the system is activated.

Different Controller Modules use different ways to adjust the rate on models that have Meter mode. Digispense Controller Modules fix the rate for Meter mode using front panel controls (speed controlled only by operator). Digifeeder Controller Modules use an analog signal to control the rate. Maintainer Controller Modules regulate the rate to keep an analog signal at a setpoint.

2.2.3 Dispense

Dispense is used to deliver a discrete, specific volume of liquid at a specific flow rate.

The Controller Module provides an accurate adjustment of both the rate and volume of the dispense.

The exact volume of liquid dispensed is dependent on the volume setting and the configuration of the Pump Module.

2.2.4 Empty (Clean)

Empty is used to empty the pump inlet tubing, pump chamber, and outlet tubing of liquid when metering and(or) dispensing operations are completed. This is the reverse of Prime mode and is used to return liquid to the supply reservoir rather than forward into a waste container.

2.3 SYSTEM SETUP

General operating practices provide the best guidelines for locating the components of the system. The motor/base and Pump Modules must be closer to the dispensing location as the volume decreases and desired accuracy increases. The Controller Module should be located for ease of use during all phases of operation and maintenance. Refer to Table 2.4 should problems arise during setup.

2.3.1 Supply Connections

The supply reservoir must provide an adequate supply of material to the inlet of the pump. These requirements are highly dependent on the application and the liquid. The flow rate and liquid viscosity will influence the selection of inlet tubing and the pressure required at the pump inlet. For example, some applications allow inlet tubing with an inside diameter of one sixteenth of an inch and the reservoir level with the pump, while other applications require inlet tubing with an inside diameter of one quarter of an inch and a liquid pressure of sixty psi for satisfactory operation.

NOTE

The supply tubing inner diameter should always be as large or larger than the discharge tubing.

2.3.2 Discharge Connections

Discharge tubing requirements are also dependent on the application. For some critical low-volume applications, the relative height of the dispense tip and the supply reservoir is critical to proper performance. Many dispensing applications benefit from a short length of tubing with rigid walls connecting the pump to the dispense tip with any movement of the tubing constrained. High flow rate applications benefit from flexible discharge tubing that can reduce pulsations and peak fluidic pressures.

2.3.3 Power Connections

Make sure the power switch is in the "0" (off) position. Connect power to the Controller Module. The incoming power must match the power entry module.

2.3.4 Setup Checks

Prior to turning the system on, perform the following checks:

- The supply tubing is secured (mechanically and fluidically) to the supply reservoir.
- The supply tubing connection in the supply reservoir is submerged in the liquid.
- No unnecessary loops of supply tubing exist.
- All bends in the supply tubing have a radius large enough to prevent the possibility of kinks or other constrictions in the liquid path.
- The supply tubing is secure on the inlet fitting of the pump.
- The discharge tubing is secure on the outlet fitting of the pump.
- No unnecessary loops of discharge tubing exist.
- All bends in the discharge tubing have a radius large enough to prevent the possibility of kinks or other constrictions in the liquid path.
- The discharge tubing is secured (mechanically and fluidically) to the dispense tip holder or directly to the dispense tip.
- The dispense tip is secured in place.

2.4 SETUP FOR PRIMING OPERATION

WARNING

WHEN PRIMING WITH HAZARDOUS LIQUIDS, APPROPRIATE PROTECTIVE OUTERWEAR HAS TO BE WORN BY ALL PEOPLE IN THE AREA.

2.4.1 Adjust Pump Displacement

2.4.1.1 Rotary Pump

The pump displacement for a rotary pump should be more than halfway to maximum displacement. Refer to Chapter 5 for instructions on adjusting the Motor/Base Module found on this system.

If the displacement is too low, air bubbles in the pump chamber will not be evacuated, with a resulting severe reduction in accuracy.

2.4.1.2 Linear Pump

No adjustment of the linear pump or its actuator is required.

2.4.2 Turn On Power

Turn the main power ON by pressing the 'I' side of the power switch.

2.4.3 Set Controller Module For Priming

Refer to Chapter 3 for instructions regarding proper controller setup for priming, initiating and terminating the priming sequence.

2.4.4 Monitor Priming Progress

Allow liquid to fill the inlet tubing, pump chamber, outlet tubing. Lightly tap on the inlet and outlet tubing to assist with purging air bubbles from the system.

Priming can be stopped when air bubbles are no longer visible in the tubing and/or Pump Module sight glass (if supplied) and the liquid stream exiting the nozzle is as expected.

NOTE

Depending on the specific application, it may be necessary to degas the liquid being dispensed or metered.

Depending on the specific application it may be necessary to pressurize the liquid circuit to improve the flow characteristics of the liquid being dispensed or metered.

2.5 SETUP FOR METER OPERATION

2.5.1 Adjust Pump Displacement

2.5.1.1 Rotary Pump

The pump displacement on a rotary pump determines the liquid dispensed for a single rotation. Refer to Chapter 5 for instructions on adjusting the Motor/Base Module found on this system.

The total volume dispensed is determined by multiplying the liquid displacement times the number of rotations (volume strokes) of the motor.

2.5.1.2 Linear Pump

No adjustment of the linear pump or its actuator is required.

2.5.2 Turn On Power

If the power is not already on, turn the main power ON by pressing the 'I' side of the power switch.

2.5.3 Set Controller For Metering

Refer to Chapter 3 for instructions regarding proper controller setup for metering, initiating and terminating the metering sequence.

2.6 SETUP FOR DISPENSE OPERATION

2.6.1 Adjust Pump Displacement

2.6.1.1 Rotary Pump

The pump displacement on a rotary pump determines the liquid dispensed for a single rotation. Refer to Chapter 5 for instructions on adjusting the Motor/Base Module found on this system.

The total volume dispensed is determined by multiplying the liquid displacement times the number of rotations (volume strokes) of the motor.

Liquid flow rate during the dispense is a combination of the pump displacement adjustment and the rotational speed of the motor.

There are a variety of displacement and volume stroke settings that can be used for an application. The best setting is determined by the application requirements (i.e. splash, cycle time..). If IVEK performed an applications test, refer to the application notes to assist in setting the optimum displacement and volume strokes.

2.6.1.2 Linear Pump

No adjustment of the linear pump or its actuator is required (or possible).

2.6.2 Turn On Power

If the power is not already on, turn the main power ON by pressing the 'I' side of the power switch.

2.6.3 Set Controller For Dispensing

Refer to Chapter 3 for instructions regarding proper controller setup for dispensing, initiating and terminating the dispense sequence.

2.7 SETUP FOR EMPTYING OPERATION

This procedure will pump the liquid in the tubing and pump chamber back into the supply reservoir. If this is not desirable, the liquid supply can be removed and the instructions for priming can be followed to pump the liquid in the system through the dispensing tip into a waste container.

2.7.1 Adjust Pump Displacement

2.7.1.1 Rotary Pump

The pump displacement for a rotary pump can remain at the displacement used during metering or dispensing. If a very low displacement was used, the displacement can be increased to reduce the time necessary to empty the system. Refer to Chapter 5 for instructions on adjusting the Motor/Base Module found on this system.

2.7.1.2 Linear Pump

No adjustment of the linear pump or its actuator is required (or possible).

2.7.2 Set Controller For Emptying

Refer to Chapter 3 for instructions regarding proper controller setup for emptying, initiating and terminating the emptying sequence.

2.7.3 Monitor Emptying Progress

Allow liquid to be evacuated from the inlet tubing, pump chamber and outlet tubing prior to shutting the system off.

2.8 GENERAL CLEANING AND DECONTAMINATION

Routine cleaning and(or) decontamination is extremely important in order to prolong the life and ensure the proper function of all liquid management system components.

2.8.1 Definitions

In the following sections, the terms cleaning and decontamination are differentiated as follows:

2.8.1.1 Cleaning

The removal of gross biological and molecular contamination and(or) process liquids from the liquid path including the pump cylinder, inlet/outlet tubing and respective connectors and dispensing tips or cannula. Cleaning will also refer to the surface cleaning of the controller and Motor/Base Modules or any critical working surfaces of any additional system components.

Cleaning may be required when the system is idle for long periods of time to prevent the piston from becoming seized in the cylinder.

2.8.1.2 Decontamination

Recommended procedure for the elimination of biological and(or) molecular contaminants that would have a negative effect on the application process liquids through a qualified sterilization or depyrogenation process including chemical sterilants or steam sterilization.

2.8.2 Guidelines

Due to the large variety of process applications utilizing IVEK liquid management systems, this section provides general recommendations regarding cleaning and decontamination practices and procedures. It is ultimately the responsibility of the end user to ensure that a complete evaluation of cleaning and decontamination of this system and its components is performed. It is also imperative that all operating personnel are correctly trained in the proper methods and are diligent in their maintenance of cleaning and decontamination procedures.

If periodic tear-down for detail cleaning of any system component is required, refer to the appropriate mechanical diagram included in this manual for instructions on disassembly and assembly of that system component.

Always use the utmost care when disassembling and assembling component parts. Take special care when handling the Pump Module piston and cylinder set to avoid damage.

2.8.3 Cleaning Procedure

After the liquid system has been emptied as described in Section 2.7, a suitable cleaning liquid is pumped through the system.

Cleaning can be accomplished with either a forward circulation, forward/reverse circulation or a single-pass procedure. In any case, sufficient cleaning liquid must be used to remove any accumulations of the process liquid from the piston and cylinder.

2.8.3.1 Circulation Cleaning

Connect the supply and discharge tubing to a container of cleaning liquid. The system is operated in the Prime mode in forward until there is confidence the tubing and pump chamber are clean.

The supply of cleaning liquid must be large enough to ensure the application liquid cleaned from the system does not form a significant concentration in the cleaning liquid. It may be necessary to change the cleaning liquid if the concentration of the application liquid is too high.

2.8.3.2 Forward/Reverse Circulation Cleaning

Connect the supply and discharge tubing to a container of cleaning liquid. The system is operated in the Prime mode alternating between forward and reverse until there is confidence the tubing and pump chamber are clean.

2.8.3.3 Single-Pass Cleaning

Place an adequate amount of cleaning liquid in the supply reservoir and place a waste container under the dispense tip to collect the used cleaning liquid. The system is operated in the Prime mode until there is confidence the tubing and pump chamber are clean.

2.8.3.4 Recommended Compatible Cleaning Liquids

Following is a partial list of cleaning liquids. Contact IVEK Corporation for other suggestions if required.

- 1M Sulfuric Acid
- 1M Ammonium Hydroxide Solution
- Deionized or Distilled Water
- 70% Isopropanol Alcohol
- Detergents

2.8.4 Decontamination Procedure

NOTE

In all applications requiring sterilization or depyrogenation of the system Pump Module and(or) liquid circuit components, the end user is wholly responsible for the qualification and validation of that process. *IVEK Corporation will recommend and advise the end user regarding acceptable practices and procedures only to the extent they are compatible with the design limits and materials of the components making up the Pump Module and liquid circuit. Decontamination procedures will be highly dependent on the operational requirements of the user.*

2.8.4.1 Liquid Sterilants.

For systems that have been qualified by the end user for a clean or sterilize in place process, follow the instructions for cleaning in Section 2.8.3 for application of the liquid sterilant through the liquid circuit and Pump Module.

2.8.4.2 Steam Sterilization.

Pump Modules can be manufactured to be compatible with steam sterilization procedures.

For systems that have been qualified by the end user for a steam sterilization process, follow the end user's appropriate instructions and protocols for preparation and sterilization of the Pump Module and liquid circuit.

2.8.5 Storage

Storage refers to any extended time that the system remains idle. The main concern is liquid drying in the piston/cylinder area, causing the piston to seize in the cylinder. The duration of idle time that requires storage procedures is based on the liquid, Pump Module configuration, and operating environment. The system can be stored wetted with cleaning liquid, disassembled, or a liquid loop can be made.

2.8.5.1 Wetted With Cleaning Liquid

Leave the liquid circuit and Pump Module assembled in place. Load the liquid circuit with a compatible cleaning liquid or other liquid and leave the system wet. Prior to the next use, the storage liquid can be purged during setup for operations.

2.8.5.2 Disassembled

If it is desired not to leave cleaning liquid in the system, after rinsing with cleaning liquid as described in Section 2.8, empty the system of cleaning liquid as described in Section 2.7.

Disassemble the liquid circuit and Pump Module, remove the piston from the cylinder and store the component parts disassembled until the pump is again required. The components can be stored either dry or immersed in an appropriate liquid. The instructions for disassembling the Pump Module are found in Chapter 7.

If applicable, the disassembled liquid circuit and Pump Module components may be immersed and soaked or further cleaned in an ultrasonic cleaning device using a compatible cleaning liquid.

2.8.5.3 Liquid Loop

Fill a loop of flexible tubing with a compatible cleaning liquid or other chemical that will thin or neutralize the last liquid pumped. Connect one end of the tube to the pump inlet port and the other to the outlet port. Cycle the pump a few times in any operational mode to insure the piston and cylinder are wetted by the cleaning liquid. With this loop positioned above the pump head, the ceramic surfaces and seal areas will stay moist and mobile for extended idle periods.

2.9 COMMON FLUIDIC PROBLEMS AND SOLUTIONS

Following is a list of common fluidic problems. Based on our past experience these are the problems our customers face most often. See Table 2.3 for other possible problems and solutions.

2.9.1 VAPORIZATION

Vaporization is also referred to as Cavitation.

Low pressures in the pump chamber during the intake stroke can lead to the formation of bubbles. Bubbles present in the pump chamber provide a source of compliance that reduces the repeatability of the pump displacement. This compliance can also adversely affect the ‘fluid shear’ at the dispense tip also reducing repeatability.

2.9.1.1 Liquid Pressure

Increasing the liquid pressure in the pump chamber during the intake portion of the pump cycle will reduce the tendency for bubbles to form.

Increase Supply Tubing I.D. - Liquid flow rate combined with tubing restrictions will result in a lower pressure in the pump chamber. Changing to supply tubing with a larger inside diameter, with the resulting lower linear flow velocity, will reduce the pressure drop across the supply tubing, thereby increasing the pressure in the pump chamber.

Reduce Suction Lift Height - If the reservoir is lower than the pump, the resulting negative liquid head will reduce the pressure in the pump chamber. Raise the supply reservoir to reduce the negative liquid head pressure.

Pressurize Supply Container - If physical constraints (including supply tubing length) do not allow the supply reservoir to be raised, it may be necessary to use a closed and pressurized supply container.

Reduce Liquid Viscosity - Heating the liquid, if permitted by the process, can reduce the viscosity of a highly viscous material and reduce problems with pressure. Often a small change in temperature can have a dramatic effect on the pressure drop across the supply tubing. The actual heating should occur in the supply reservoir, with tubing and pump heaters being used only to prevent heat loss.

Modify Liquid - Changing the formulation of the liquid may be a viable means to reduce viscosity. Slight additions of a thinner or changes to the formulation may have a dramatic effect on the pressure in the pump chamber.

Reduce Flow Rate - In the same manner that larger supply tubing reduces linear flow velocity, and therefore pressure drop, reducing the volumetric flow rate through the pump will increase the pressure in the pump chamber. The reduced linear flow through the pump's inlet port will be added to the effect of reduced pressure drop across the supply tubing to provide additional increased pressure in the pump chamber.

Pulse Dampers - Pulse dampers provide the most benefit to rotary systems. This is because of the sinusoidal flow as a function of time (analogous to half-wave rectification in the electrical world).

The simplest method for pulse suppression is to use a combination of resilient tubing between the pump/liquid circuit and a restriction to create back pressure. The back pressure will cause the tubing to flex and absorb pulsations. Because of its elastic properties and excellent memory, unreinforced silicone tubing functions as a good pulse damper. Other similar materials will work, but use only unreinforced tubing as reinforcement takes away the resilience.

WARNING

Always shield this type of arrangement so a possible tube rupture will not endanger people or equipment. IVEK personnel are available to help devise suitable pulse suppression systems for any application.

Pump Fittings - A different style of fitting between the Pump Module and tubing, with a larger inside diameter, will reduce liquid flow restrictions.

2.9.1.2 Degas Liquid

Liquids that have a high amount of dissolved gas may need to be degassed before being pumped. Low liquid pressures in the pump chamber during the intake stroke will cause the gas to come out of liquid. When pressure increases again at the end of the intake stroke, and possibly increases further during the discharge stroke, the bubbles may even go back into liquid and not be visible at the discharge side of the pump. The presence of the gas bubbles in the pump chamber reduces volumetric repeatability.

2.9.2 Poor Dispense Repeatability

2.9.2.1 Incomplete Priming

An air bubble in the pump chamber will reduce volumetric repeatability. The changes in pressure that occur during intake and discharge will change the size of the bubble, and therefore affect the volume of liquid being displaced. In many systems, the pressure is low during the inlet stroke causing the bubble to increase in size, and high during the outlet stroke causing the bubble to decrease in size. In all cases, the bubble will reduce the liquid displaced while all other conditions, such as pump displacement, remain constant.

Repeat The Priming Operation - Ensure the pump displacement is greater than half of the maximum displacement. Watch for air bubbles in the tubing (unless the tubing is opaque).

2.9.2.2 Incorrect Dispense Tip

It is important that the liquid separate at the same position in the dispense tip for each dispense. Any variation in the position of the liquid in the dispense tip will correspond to a variation in the dispense volume.

Experimentation with various sizes of tubing and/or tips is recommended to optimize application liquid delivery. Generally, it is advisable to start with the larger size discharge openings and progressively reduce the size until the desired liquid delivery conditions are obtained. When low volumes are being dispensed, very small diameter dispense tips may be required. Tapered tips are recommended for many low volume dispensing applications.

2.9.3 Avoiding Bubble Problems

2.9.3.1 Sources Of Bubbles

The familiar bubbles that form on the inside walls of a container of tap water after it stands for a period of time at room temperature demonstrate the typical liquid degassing that results from pressure reduction (water line pressure to atmospheric) and/or temperature elevation (from ground ambient to air ambient). In this case, the bubbles contain air, carbon dioxide, or other gaseous materials carried in the water with only small quantities of vaporized water present.

Some liquids respond to agitation, pressure changes, and/or temperature changes by chemically separating into liquid and gas fractions. Other liquids simply vaporize, physically changing from liquid to gaseous form. Examples of liquids releasing gas or changing from liquid to gaseous form in response to agitation and/or temperature/pressure changes are numerous in the modern technical environment.

2.9.3.2 Errors Produced

A common cause of trouble in metering pump applications requiring low flow rates is a gas bubble trapped within the cylinder of the Pump Module. It expands on the suction stroke and contracts on the discharge stroke, allowing little, if any, liquid to pass through the pump. Such bubbles, though often attributed to leaks in fittings and seals, can sometimes be traced to gases released by the pumped liquid in response to pumping agitation or pressure/temperature changes. This potential source of metering pump error can be effectively controlled in most liquid circuits.

2.9.3.3 Liquid: Degassing

Many techniques have been devised to compensate or correct for air bubbles in the application liquid. The most common practices for bubble control employ a liquid degassing procedure. This is accomplished by using a vacuum desiccator and(or) an ultrasonic bath.

2.9.3.4 Guidelines

The following guidelines should be followed to avoid air bubbles.

- Carefully follow priming procedures to insure no bubbles remain trapped in the liquid path.
- Avoid application liquid temperature/pressure fluctuations.
- Remove free gasses utilizing a qualified degassing procedure.
- Provide flooded suction.
- Install a bubble trap at the inlet port.

- Assess the system's physical setup. A vertical alignment of ports, with inlet port down and discharge port up will assist with the removal of air bubbles during initial priming and subsequent operations.
- Provide pressure control so that inlet and discharge pressures remain essentially constant during pump operation.
- Avoid multiple connection points where bubbles can be trapped.

2.9.4 Pulsations At Discharge

Pulsations problems occur more frequently on rotary systems than on linear systems. This is because of the repeated intake/ discharge cycle and the sinusoidal flow rate profile that produces high peak flows and periods of zero flow.

Resilient tubing on the discharge side will tend to reduce pulsation at the discharge point.

A lower pump displacement operating at a higher rate (producing the same average flow rate) produces pulsations that are easier to dampen.

To overcome pulsation problems for some applications, IVEK provides double-ended rotary systems (pump on each end of motor/base) with the pumps out of phase. Thus one pump is discharging while the other is intaking (zero discharge flow from second). A pulse dampener is available as an option on some models.

IVEK's application department can also be contacted for assistance in optimizing the discharge to smooth pulsations.

Table 2.1 Conversion Chart

MULTIPLY	BY	TO OBTAIN
cubic centimeters	1	milliliters
cubic centimeters	1000	microliters
gallons	3785	milliliters
grams	0.03527	ounces
grams	1/spec. grav.	milliliters
grams	1000/spec. grav.	microliters
inches	2.54	centimeters
inches of mercury	0.4912	psi
liters	1000	milliliters
liters	0.2642	gallons
cubic millimeters	1	microliters
milliliters	1000	microliters
nanoliters	0.001	microliters
ounces (fluid)	0.02957	liters
ounces (fluid)	29.57	milliliters
pounds	453.6	grams

Table 2.2 Formulas

TEMPERATURE:	(9/5 x °C) + 32 = °F 5/9 x (°F-32) = °C
VISCOSITY:	Centipoise = Centistokes x Specific Gravity 1 pascal-second = 1000 centipoise (cp) (Pa-s) 1 KPa-s = 1,000,000 cP

Table 2.3 Common Dispensing Problems And Solutions

PROBLEMS/CONCERNS	COMMON SOLUTIONS
Accuracy (flow volume stability)	1. Change dispense tip (preferably tapered) and increase ejection velocity to optimize shear characteristics. 2. Stabilize pump head. 3. Ensure positive displacement is occurring. 4. Ensure no air is entrapped in pump chamber, fittings, or outlet line due to improper priming. 5. Check for cavitation.
Cavitation ("starving the pump")	1. Locate reservoir and inlet tubing above dispenser. 2. Increase ID of inlet tubing. 3. Rate may be too high; adjust accordingly. 4. Feed pressure may be necessary to assist material into pump chamber.
Post Dispense "Stringing" or "Oozing"	1. Ensure no air is entrapped in pump chamber, fittings, or outlet line due to improper priming. 2. May need drawback feature to mechanically drawback material inside tip. 3. Use latex tip with dispense slit to "cut" string off. 4. Degas material if there is a noticeable amount of entrapped air since this can cause oozing.
Pulsations	1. Incorporate pulse dampers in outlet tubing. 2. Replace outlet tubing with a more flexible type. 3. Operate at high RPM/low displacement ratio. 4. Utilize dual ended pumps set out-of-phase.
Viscous Material	1. Ensure dispensers have sufficient high torque capability (double, triple stack motors). 2. Use modified pistons designed for viscous material. 3. Apply cavitation solutions. 4. Heat material in reservoir and/or in-line. 5. Optimize piston/liner clearance for specific material.
Sterility	1. Flush with approved sterilant. 2. Autoclave pump head. 3. Steam in place.
Pump Seizure	1. Examine cleaning schedule and procedures. 2. Use modified pistons designed for material properties. 3. Apply viscous material solutions, if viscosity is the cause. 4. Incorporate a gland system for continuous piston flushing. 5. Use special UV pump head for UV curable material. 6. Filter material prior to dispensing if particles are causing seizure.
Abrasive Liquids	1. Alumina ceramics can handle most abrasive materials without wear. IVEK supplies Al_2O_3 (90 Rockwell) and Zirconia MgO partially stabilized TTZ (74 - 79 Rockwell).
Chemical Compatibility	1. Ceramic piston and liner are extremely chemically inert and will not be affected by most chemicals (call IVEK for confirmation). 2. Pump case material (Tefzel, Delrin, or 316 SS) also offers a high degree of chemical resistance. Other materials available upon request. Contact IVEK to confirm compatibility of the expected procedure with our dispensing equipment.

Table 2.4 Common Operational Problems And Solutions

PROBLEM	PROBABLE CAUSE	POSSIBLE SOLUTION
No power, nothing works.	AC power may be absent or inadequate. Unit not plugged in.	Connect power to the Controller Module. Make sure the incoming power matches the power entry module.
	Fuse is blown.	Unplug main power cord from outlet. Remove fuse from rear panel fuse holder. Test fuse conductivity. Install good fuse of proper rating and size in rear panel fuse holder.
	Supply Breaker is tripped.	Check or reset breaker at panel.
		If none of the above solves the problem, contact IVEK technical support for assistance.
Power is on, Controller Module accepts trigger, motor spindle fails to rotate and motor makes a sound that fluctuates in tone. * This condition does not harm the system.	A Pump Module or motor malfunction can cause this problem.	Turn off Controller Module power. Remove Pump Module from Motor/Base Module. Turn on Controller Module and try again.
		If the motor operates correctly, the Pump Module may need to be cleaned or serviced.
		If none of the above solves the problem, contact IVEK technical support for assistance.
Power is on, Controller Module accepts a trigger, (START indicator illuminates, STOP indicator does not), motor spindle fails to rotate, and motor is silent.	A motor malfunction can cause this problem.	Turn off Controller Module power. Check to ensure Motor/Base Module is properly connected to Controller Module. Turn on Controller Module and try again. If the motor operates incorrectly, servicing may be necessary to the motor or the Controller Module. Return complete Controller, Motor/Base and Pump Modules to IVEK Corporation for repair.
Unable to zero or calibrate Pump Module.	Pump Module inlet restricted.	Check for cavitation.
		Check inlet tube for blockage.
		Check bulk container for vacuum buildup.
Air trapped in pump cylinder or outlet tubing. Unable to purge.	Pump too slow.	Increase rate on Controller Module.
	Low displacement.	Increase displacement.
	Leak in system.	Inspect inlet and outlet tubing, ferrules and nuts, replace if necessary.

Table 2.4 Common Operational Problems And Solutions		
PROBLEM	**PROBABLE CAUSE**	**POSSIBLE SOLUTION**
Pump Module operational, but not dispensing liquid.	Output nozzle clogged.	Clean / Replace nozzle.
	Air leak on input side of Pump Module.	Check connections.
	Clog in liquid line.	Clear clog.
System operational, but Pump Module binding or misfiring.	Pump Module is dirty.	Completely disassemble Pump Module, inspect and clean.
	Suction side is restricted (back pressure viscous liquid).	Remove restriction.
Controller Module power on and operational, but will not actuate motor.	Motor cable faulty.	Remove power and check connection of cable between Controller and Motor/Base Module, repair faulty cable.
	The stroke pushwheel is set at 0.	Change setting.

NOTE

This is a list of general problems, refer to the appropriate chapter for additional Common Operational Problems And Solutions tables.

Table 2.5 Glossary

ACTUATOR - Mechanism which converts electrical, hydraulic, or pneumatic power into mechanical power.

ANGULAR ORIENTATION - This references the orientation of the piston in a rotary system, relative to the motor face, with the piston and cylinder of the Pump Module mounted on the Motor/Base Module. The angular orientation sets the reciprocal stroke travel of the piston.

BUBBLE CLEAR - Automatic cycle in a linear system providing a means of removing small bubbles of air or gas from the pump chamber. Selected from the control panel.

CALIBRATED - Any gauge, meter, pump, etc. that has been systematically checked / adjusted to a known, certified standard.

CAVITATION - The sudden formation and collapse of bubbles in liquids by means of mechanical forces which create low pressure.

CLEAN LIQUIDS - Application liquids or reagents which have been aseptically prepared via a filtration, distillation or other sterilization process to a controlled level of acceptable molecular and(or) biological contamination.

CLEAR FAULTS - 1) The 'clear faults' command must be issued prior to any commands which would cause motion in a Actuator Module or motion control device in a system which is faulted. This command responds with the identity of the fault being cleared and additional information for certain faults. 2) To manually reset the system due to any fault condition that may occur.

COMMAND STRING - A series of characters sent to a controller which has a serial interface to control its operation.

COMPATIBLE LIQUIDS - Any liquid that has been evaluated and qualified as having no negative effect on the liquid management system components.

CONTINUOUS METER - Operating mode to produce a continuous liquid flow as long as a control signal (and liquid) is supplied. **Note:** This mode only applies to the Digifeeder 2002 system and utilizes two pumps driven by linear actuators which alternate in operation between intake and discharge cycles. All other systems use Meter mode.

CONTROLLER MODULE - The module in a system containing the electronics for controlling and monitoring system operations.

CYLINDER - Pump Module component which houses the piston.

DEAD VOLUME - Liquid occupying areas within the system which is not replaced during each cycle or removed during a purge.

DEFLECTION - 1) The deviation from zero or other neutral value by the indicator of a measurement instrument. 2) The movement of a structure or structural part as a result of stress.

DEGASSING - Generally, referring to the evacuation of free gasses from the application liquid.

DIRECTION - 1) Controller mode function used to select forward or reverse motion of liquid flow through the Pump Module and liquid circuit. 2) For some rotary systems, flow direction can also be changed by adjusting the pump displacement angle to the other side of the "zero" point (zero angle where pump has zero displacement).

DISPENSE MODE - Controller mode function used to deliver a discrete, specific volume of liquid at a specific flow rate as the result of a triggering action.

DRAWBACK - Operation which automatically reverses liquid flow at the end of a dispense to improve repeatability and string breaking. The drawback volume is generally a fraction of the dispense volume.

DRIVE SYSTEM - 1) The system configuration relative to the controller and Motor/Base Module including electronics, software, drive motor and braketry options. 2) Mechanical components which transmit power. 3) Electrical circuitry which controls and powers a motor, solenoid, or other electrical-to-mechanical converter.

EMPTY MODE - Controller mode function used to return liquid in the inlet tubing, pump chamber, and outlet tubing to the supply reservoir, when metering and(or) dispensing operations are completed.

FAULT - A condition where the system controller has detected an improper condition or state of the equipment. The existence of the fault will be indicated on the system controller until the fault is cleared by a specific action.

FAULT DELIMITER - Pertains to a system with a serial interface. A character, in the response command, which identifies the subsequent value as a fault identifier and which separates it from preceding values.

FLOW VOLUME - 1) Rotary System: The flow magnitude, (and direction), relative to the pump size and due to the angular deflection of the Pump Module cylinder with respect to the "zero" point on the calibration scale of the specific Pump Module. 2) Linear System: The flow magnitude, (and direction), relative to the pump size and due to the selected controller settings.

LIQUID CIRCUIT - The assembled Pump Module connectors, inlet/outlet tubings and dispensing tip/cannula.

FLUID SHEAR - The separation of the dispensed liquid from the liquid remaining in the dispense tip. Optimizing several factors, such as the dispense tip geometry and dispense rate, improves fluid shear and the repeatability of the dispense volume.

FLUID SLIP - Commonly used to describe the migration of liquid around the internal moving parts of a pump. It is the volumetric difference between physical component displacement and liquid throughput of a pump system.

FLUID SLIP LOSS - Refers to the liquid which passes through the clearance space, (~.00005") between the piston and the cylinder wall. The clearance between the piston and cylinder wall must be optimized for the liquid being pumped in order to minimize the loss due to fluid slip.

GLAND - Provides for washing the rear portion of the piston by a liquid passing at a rate of ~2 to 5 ml/min through a groove in the cylinder wall. The gland prevents the liquid being dispensed from accumulating at the rear of the piston, thereby greatly reducing the possibility of a seized pump.

HALL EFFECT - In a current-carrying semiconductor bar located in a magnetic field that is perpendicular to the direction of the current, the production of a voltage perpendicular to both the current and the magnetic field. This physical effect is used in position sensors.

HARDNESS - 1) The relative resistance of a mineral to scratching, as measured by the Mohs' scale. 2) The relative resistance of a metal to denting, scratching or bending.

HARDWIRED SIGNALS - Electrical signals between two control devices connected with dedicated conductors.

INTERFACE - 1) A point or device at which a transition between media, power levels or modes of operation is made. 2) The hardware and signal specifications for linking two units of electronic equipment.

LED INDICATORS - Light Emitting Diodes. Utilized as system condition or mode indicators and warnings.

LINEAR ACTUATOR - The assembly in a linear system which drives the piston in the attached Pump Module. The linear actuator produces separate rotational movement for valving and linear movement for liquid displacement. The linear actuator in a linear system corresponds to the motor/base assembly in a rotary system.

LINEAR MOVEMENT - Movement along a straight line.

LINEAR RATE - Rate of the linear component of a movement.

LINEAR SYSTEM - One of two major types of precision liquid dispensing or metering systems available from IVEK Corporation. The controller of the linear system can separately command the linear (displacement) and rotary (valving) motions of the piston. The liquid displacement is constant over time, limited by acceleration and deceleration at the beginning and end of the motion. The Digispense 2000 and Multispense 2000 are linear systems.

LOAD MODE - Linear controller mode used to load the pump cylinder when empty or when the volume is less than the next volume of liquid required to dispense or meter. The automatic load function can be set to Manual, Empty, or Every.

LOAD RATE - The pumping rate, of a linear system, during the load cycle in microliters per second, (ml/s). The same controller setting is used for loading and priming.

MECHANICAL VALVING - Valve ports are opened and closed via mechanical actuation. This is in contrast to check valves which open and close as a result of fluid pressure/flow.

METER MODE - Controller mode function used for continuous pumping of liquid. METER is very similar to PRIME. The difference between the two is PRIME gets the system setup for dispensing or metering of liquid and METER is used for constant flow, liquid metering.

MICROMETER - Rotary Pumps, (B, C and D sizes); An optional micrometer scale assembly mounted to the Motor/Base Module. Used for position finding or fine adjustment and not for gross pump head movement.

MOTOR/BASE MODULE - The module in a rotary system which drives the piston in the attached Pump Module. The Motor/ Base Module produces a combined rotary and linear movement which synchronizes the liquid displacement and valving functions. The module consists of a motor, spindle, spindle sensor, base frame and adjusting mount for the Pump Module.

NOISE - Any unwanted disturbance within a dynamic elect-rical or mechanical system. This can include electrical, electromagnetic, or acoustical energy.

OPERATING PARAMETERS - 1) All specified values utilized during system operation in order to achieve the desired performance of the system. 2) The system controller values regarding volume, rate and direction, or Pump Module displacement setting, or controller settings for motion control devices incorporated with the system.

OPTICALLY ISOLATED SIGNAL - Signals which are coupled using a device that connects signals from one electronic circuit to another by means of light. More correctly, the signals are electrically isolated and optically coupled between the two circuits.

PISTON - Pump Module component. Part of the piston/cylinder set.

PNEUMATIC - Actuated or operated by compressed air or other gas.

PORTS - Openings in the Pump Module cylinder and housing allowing the flow of liquid through the Pump Module assembly during operation.

PRIME MODE - Used for filling the pump liquid circuit, (inlet tubing, pump chamber, outlet tubing), at initial start-up. Also for eliminating air bubbles in the circuit.

PRIME RATE - Motor speed during a prime operation. In a linear system, the prime rate and the load rate use the same setting. In a rotary system, the prime rate may be the same as the dispensing rate, or a separate setting may be used.

PULSATIONS - Cyclical fluctuations of liquid flow.

PULSE DAMPER or PULSE SUPPRESSOR - Mechanical device inserted into the outlet tubing of the liquid circuit to dampen liquid pulsations.

PUMP MODULE - Liquid management system assembly consisting of the precision ceramic piston/cylinder set, protective housing, mounting hardware and fittings.

PUMP SEIZED - An event whereby the ceramic piston and cylinder set become locked or “frozen” together.

REFERENCE CYCLE - In a linear system, an operational cycle during which the controller determines the absolute linear and rotary position of the linear actuator. After the power
is turned on, or after a fault, a reference cycle must be completed before any other operation of the linear actuator can take place.

ROTARY MOVEMENT - The motion, (rotation) of a part or device around an axis.

ROTARY SYSTEM - One of two major types of precision liquid dispensing or metering systems available from IVEK Corporation. The rotary system has a single mechanical coupling which translates the rotation of the motor into the combined linear (displacement) and rotary (valving) motions of the piston. The angular adjustment of the Pump Module determines the piston displacement for each dispense cycle. The controller does not have separate control of the linear and rotary motions of the piston. Liquid displacement is sinusoidal and corresponds to one rotation of the motor shaft (half is zero flow and half is 50% of sinusoid). The Digispense 700, Digispense 800, Multispense 900 and Multispense are rotary systems.

ROTARY VALVE - A device in which the rotation of a part performs the valving function.

SANITARY PUMP - Pump Module option designed to conform to the cleansing standards of the US Food and Drug Administration.

SELF PRIMING - A pump requiring no pre-wetting or pressurization procedure before being able to initiate liquid flow.

SPECIFIC GRAVITY - The ratio of the density of a fluid to the density of water. The specific gravity of a fluid must be considered when making gravimetric measurements (weighing) of the output of a volumetric pump.

SPINDLE - Component in the Motor/Base Module of a rotary system, which couples the motor shaft to the piston. The spindle contains a spherical bearing which accepts the piston drive pin.

STEPPER MOTOR - A digital device which converts electrical pulses into proportionate mechanical movement. Each revolution of the motor shaft is made in a series of discrete identical steps. The design of the motor usually provides for clockwise and(or) counterclockwise rotation.

TORQUE - A force that tends to produce rotation or twisting.

TORQUE LIMITED DRIVE - Motor function which will preclude piston breakage by causing the motor to stall in the event of a pump seizure.

TOTALIZER - Controller option displaying total motor turns or dispense triggers.

VALVING - Selectively opening the liquid path between the pumping chamber and one of the liquid ports.

VALVING OPERATION - Rotating the piston in a linear system to change the port communicating with the pumping chamber without displacing liquid.

VALVING SPEED - The rotational speed during valving in a linear system.

VARIABLE DISPLACEMENT - Capability of changing the volume of liquid moved by the piston for each stroke through either electrical or mechanical means.

VISCOSITY - The measure of a fluid's tendency to resist a shearing force. The viscosity of a fluid affects the degree to which it resists flow under an applied force. Viscosity can remain constant, increase, or decrease as shear rate (flow rate) increases. Absolute viscosity is generally measured in centipoise. Kinematic viscosity includes the influence of the specific gravity of the fluid and is generally measured in centistokes.
Kinematic Viscosity X Specific Gravity = Absolute Viscosity

WET OPERATIONS - Refers to the operation of the liquid management system. It is preferable to avoid running the pump dry. For extended periods, most application liquids will provide the necessary lubrication and cooling to prevent chirping, binding or seizure.