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DESIGN AND OPERATION OF A MULTIPLE-INTAKE
WATER QUALITY MONITORING STATION
AT POINT EDWARD

J.D. Fischer and R.C. McCrea

CONTENTS

	<u>PAGE</u>
Introduction	1
Water Delivery System	2
Sampling System	5
Control Circuitry and Modes Operation	8
Acknowledgements	14
References	15
Appendix 1 - Design of Water Delivery System	16
Appendix 2 - Design of Sampling System	21
Appendix 3 - Control Circuitry	30
Appendix 4 - Set-up and Calibration	47
Appendix 5 - System Operation	51
Appendix 6 - Inspection and Maintenance Troubleshooting and Servicing	58

FIGURES

		<u>PAGE</u>
Figure 1.	Water delivery system at Point Edward	3
Figure 2.	Sampling system at Point Edward	7
Figure 3.	Pump and power monitor panel	9
Figure 4.	Centrifuge controller panel	13
Figure 1A.	March pump model 5C-MD	18
Figure 1B.	Submersible pump adapter assemblies	19
Figure 2A.	Schematic of sampling system	22
Figure 2B.	Sampling system fittings	23
Figure 2.1A	True union ball valve	26
Figure 2.1B	Needle valve	26
Figure 2.3A	Sampling system strainer assembly	28
Figure 2.4A	Westfalia continuous flow centrifuge	29
Figure 3.1A	Submersible pump electrical connections	31
Figure 3.2A	Pump and power monitor circuitry	32
Figure 3.4A	Valve actuators employed with valves V1 and V2	37
Figure 3.6A	Power routing to the Westfalia centrifuge	40
Figure 3.7A	Centrifuge controller circuitry	42
Figure 3.7B	Operational characteristics of the lock-out function as controlled by the time-delay relay TD3	44
Figure 3.8A	Vibration sensor that is mounted on the Westfalia continuous flow centrifuge	46
Figure 4.3A	MaxiRex four-channel timer	48
Figure 5.3A	Four chamber bowl assembly for Westfalia clarifier	56
Figure 6.3A	Procedures for troubleshooting a no-flow condition in line 1	64
Figure 6.3B	Procedures for troubleshooting failure of centrifuge start-up.	65

TABLES

	<u>PAGE</u>
Table 1A. Water delivery system fittings and assemblies	20
Table 2A. Sampling system fittings and assemblies	25
Table 3.2A. A listing of pump and power monitor components	33
Table 3.2B. Sample collection permutations utilizing the three basic modes of operation	35
Table 3.7A. A listing of centrifuge controller components	43
Table 6.3A. An outline of procedures for troubleshooting system malfunctions	63

INTRODUCTION

Two monitoring stations were installed in 1986 by the Water Quality Branch-Ontario Region at Point Edward and Port Lambton. The Point Edward station is situated at the outlet of Lake Huron, and provides a means of sampling water entering the St. Clair River. The Port Lambton station is located 42 kms downstream of Point Edward, and 22 kms upstream of the mouth of the St. Clair River.

The Point Edward station is located in the Sarnia Water Treatment Plant operated by the Ontario Ministry of the Environment. The plant intake pipe is used to sample water from a point 100m offshore at a depth of 15m. Raw water is delivered to sampling equipment with three submersible pumps suspended in the low lift well. Each of these pumps capable of providing raw water at a maximum flow rate of 20 L min^{-1} to the sampling system. A Westfalia continuous flow centrifuge was set-up to collect suspended sediment and provide clarified water for sampling purposes. The sampling system is monitored and controlled with several devices to (1) monitor the mechanical condition of the centrifuge and shut it down should destructive vibration arise even when operating unattended, (2) maintain sample integrity despite transient low voltage and power outages, and (3) provide an automatically actuated back-up pump should the primary intake pump fail for any reason.

The main body of this report provides a general description of the water delivery system, sampling system and control circuitry. A detailed description of these systems, including the set-up, calibration, operation, inspection, maintenance, troubleshooting and servicing is provided in the Appendices.

Water Delivery System

The 66-in.¹ concrete intake pipe which supplies the water treatment plant is used to provide a source of raw water to the sampling system. River water enters the concrete intake pipe through a reinforced concrete inlet structure at a point that is one meter off the river bottom and 175 m distant from the low lift well and screen room. A 1.5-in. iron pipe had been previously installed in the concrete intake pipe to obtain a source of non-chlorinated raw water. This pipe provided a support for the triple line intake bundle which must withstand water velocities between 3.0 and 10.7 m s⁻¹ over the course of the year (Cunningham, 1986).

Each 0.75-in. x 1-in. O.D. intake line was prepared for installation by drilling four rows of 6 mm holes at right angles in the final 10 cm of uncapped tubing. The three tubes were taped together with duct tape forming an intake bundle for ease of attachment to the 1.5-in. iron sampling pipe. This pipe lies on the bottom of the concrete intake pipe and extends 12 m from the stilling well. The end of the iron pipe, which forms a 45° angle, faces into the current 75 cm above the bottom of the concrete intake pipe.

The triple line bundle was placed flush with the end of the iron pipe on the downstream side and fastened using gear clamps and 2.5-in. fabric reinforced neoprene hose. The hose was cut in 5 cm lengths and placed at clamping points to prevent abrasion. The bundle was similarly clamped to the top side of the iron pipe at 1 m intervals to a point where the concrete intake pipe enters the low lift well. The low density polyethylene intake tubes were then attached to the inlet side of three pumps using natural polypropylene inlet adapter assemblies.

Footnote:

¹ It should be noted that all pipe, tubing, and adapter dimensions are internal (I.D.) unless stated otherwise.

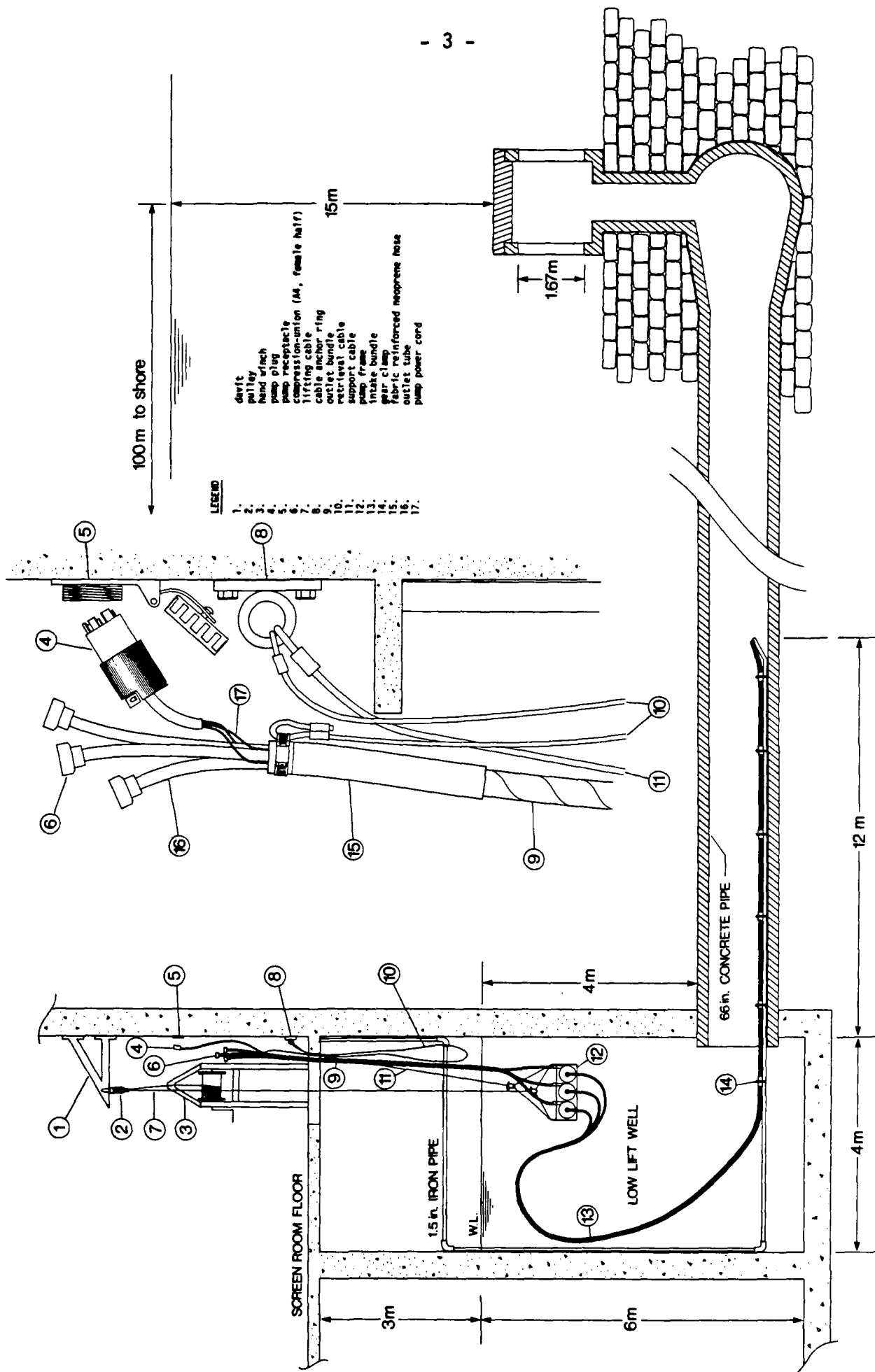


Figure 1. Water delivery system at Point Edward

Natural low density polyethylene was chosen as the tubing material because it will not cause contamination when sampling for trace levels of metals and chlorinated organics. It also has desirable physical characteristics, being both self supporting and flexible. Tubing made of this material is suitable for making underwater connections and it will not degrade over long periods of time. A rationale for the appropriateness of the tubing deployed is presented in the Niagara River sampling protocol (Group A, 1986). Natural polypropylene used as the material for adapter assemblies, fittings, wands and valves has the chemical advantages of natural polyethylene, but it is rigid enough to allow these components to be machined from solid stock. The seals used in the compression fittings and valves are viton, as it is a preferred elastomer for organic contaminant sampling.

The inlet adapter assemblies prevent pump head damage due to cavitation when tubing other than the standard size is used. The pump is designed to operate with a 1-in. intake line, however, a 0.75-in. tube was used to increase water velocity. This increased velocity minimizes the possibility of the tubing becoming clogged with sediment which would otherwise settle out. At a flow rate of 20 L min^{-1} water velocity in the intake tubes is equal to the mean annual cross-sectional river velocity. It is also important to note that there is minimal settling of suspended sediment in the plant intake pipe, as the water velocity is always at least double that of the river.

The pumps were fastened with gear clamps to a pump frame and suspended by a cable in the low lift well. This frame had bracketry to which the inlet adapters were similarly clamped to prevent stress on the pump head assembly.

An outlet bundle consisting of three tubes and power cords for each of the three pumps was held together using duct tape. The tubes were attached to the pumps using outlet adapter assemblies that allowed 0.75-in. tubing to be instead of standard 0.5-in. tubing. The increased tubing size attached to the pump outlet results in a reduction in line

drag and a corresponding increase in flow rate without creating a sedimentation problem. The outlet adapters were restrained to prevent pump head damage by clamping them to brackets on the pump frame.

The outlet bundle was positioned such that it passed through the well opening and onto the screen room floor. Each tube was fitted with a compression fitting-union assembly at this point to facilitate removal of the pump frame from the well. The tubes were then extended to the sampling area located in the screen room.

It should be noted that plumbing and electrical components of the triple pump system are colour coded with red, yellow, and white, both above and below the water surface, to aid in troubleshooting if required.

Sampling System

Three submersible pumps were employed to deliver water to a sampling system for the collection of raw water, clarified water and suspended sediment. Flow through the system was monitored with a pressure sensor and flow transducer, and controlled with a number of manual and electrically actuated valves.

The system has a back-up feature, whereby pump 2 will provide water should pump 1 fail due to line clogging, pump head damage, or motor burnout. The sampling lines extending from these two pumps were plumbed such that either one could provide water to a common filter. Details of the fittings used are outlined in Table 2A and Fig. 2B.

A Y fitting was placed in line 1, as close to floor level as practical, to form a shunt. A simulation valve (valve 4) was installed in the 0.75-in. shunt line to simulate pump failure, and the line leading from the valve outlet extended to a drain. An electrically actuated valve (valve 1) was installed in line 1 such that it was higher than the simulation valve. A pressure sensor was located in line 1 between valve 4 and valve 1, using 0.5-in. tubing and a T fitting.

In line 2 an electrically actuated valve (valve 2) was located below valve 1 and above the level of the simulation valve. The orientation of components is critical for the proper operation of the system.

The outlets of valves 1 and 2 were joined with 0.75-in. tubing and a Y fitting. A length of 0.75-in. tubing was attached to this fitting and extended to a strainer assembly (Fig. 2.3A). The strainer assembly utilized threaded unions on the inlet and outlet side to permit easy removal from the system if required. Raw water passes through a strainer basket containing several hundred 2 mm in holes, to provide a source of raw water to the Westfalia centrifuge that is free of coarse debris. The basket has sufficient capacity to prevent restriction of flow resulting from the expected build up of river borne debris over one week of sampling.

A T fitting was inserted in the 0.75-in. tubing on the outlet side of the strainer. A 0.5-in. tube was attached to the T and extended to a valve at the sink for collection of raw water samples. The 0.75-in. tube on the third port of the T was extended to a throttling valve attached to the centrifuge inlet. At the centrifuge outlet, 0.5-in. tubing was attached and extended to a flow transducer. A T fitting was inserted in this line to accomodate a 0.5-in. tube attached to a valve at the sink. The valves for controlling both clarified water and raw water at the sink had tubing attached on the outlet side of sufficient length to fill sample containers sitting on the floor. Water at the outlet side of the flow transducer was directed to drain using 0.5-in. tubing.

Line 3 provides a source of raw water for an automatic sampler; flow is controlled by a manual valve.

It should be noted that components in the water sampling system connected to pumps 1, 2 and 3, were colour coded with red, yellow and white respectively, as in the water delivery system.

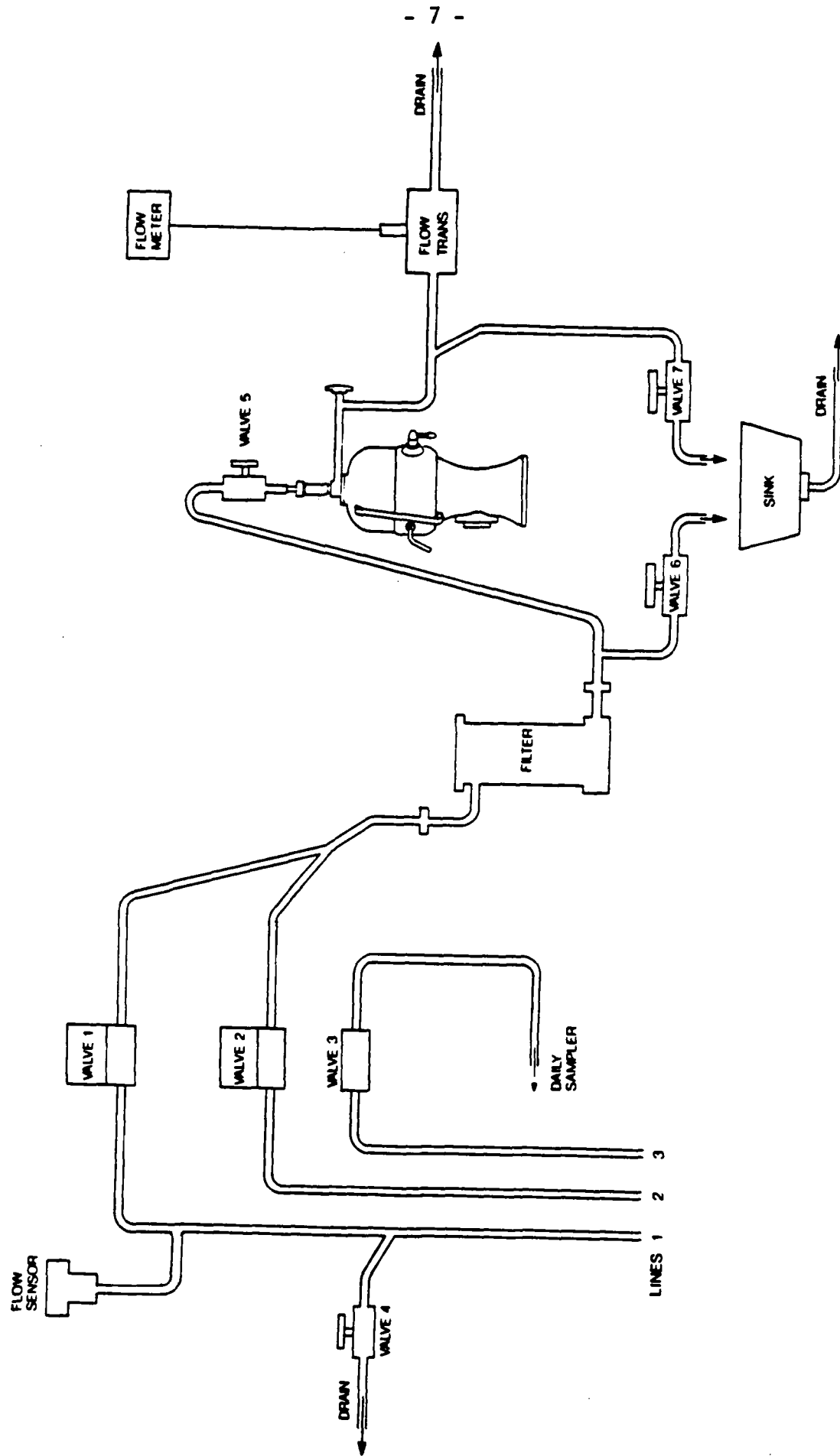


Figure 2. Sampling system at Point Edward

Control Circuitry and Modes of Operation

The control circuitry consists of a pump and power monitor, vibration sensor and centrifuge controller. The pump and power monitor provides several modes of operation for various sampling needs, and enhances the reliability of sample collection and sample integrity. Operation of the Westfalia centrifuge is monitored and controlled by the vibration sensor and centrifuge controller to provide a greater measure of safety to the operator and protection for the clarifier.

The pump and power monitor has three major functions: (1) it controls the operation of the submersible pumps and electrically-actuated valves for the various sampling modes, (2) monitors the power source to the Westfalia centrifuge and shut it down should the voltage fall below the recommended operating level, and (3) provides a signal for remote monitoring of the system.

The monitor has three basic modes of operation (Manual, Timer and Centrifuge) with which water can be supplied by the pumps for various sampling purposes. These include the manual collection of water samples by an operator, automatic collection in a daily sampler and the collection of suspended sediment with a continuous flow centrifuge.

For continuous sampling over an extended period (7 days), a back-up pump can be automatically actuated should the primary pump fail for any reason. This function utilizes pump 1 as the primary pump and pump 2 as the back-up, and is pre-set by engaging the "flow detector" circuitry (Fig. 3.2A). Should pressure drop below a pre-set level in line 1, as measured by the flow sensor, the automatic back-up function is initiated subject to an appropriate time-delay. The time-delay, typically set for 30 seconds, eliminates nuisance tripping of the system. When this time period lapses, power to pump 1 is switched off, valve 1 closes as valve 2 opens and pump 2 is energized.

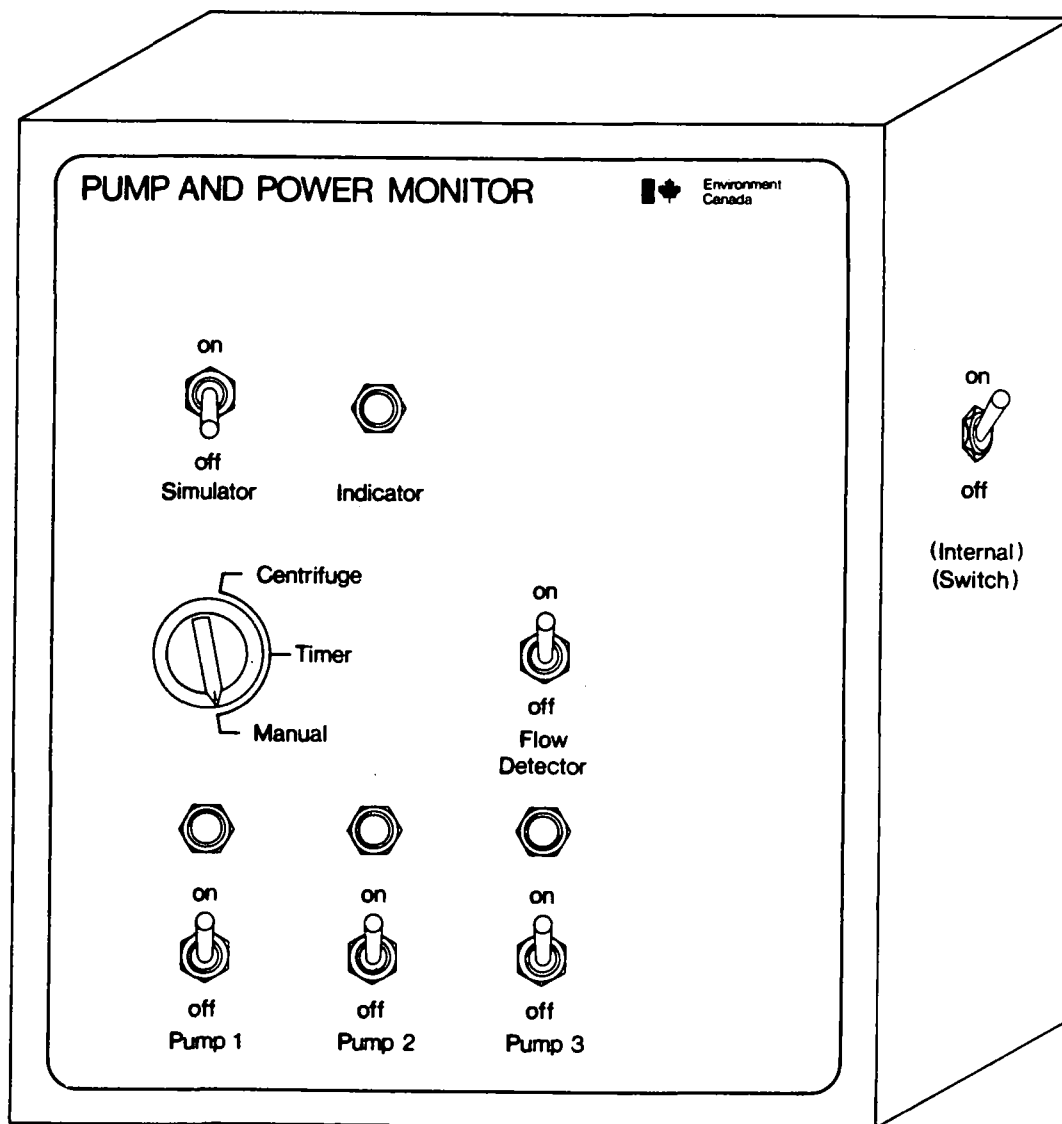


Figure 3.

Pump and power monitor panel

The pump and power monitor is also equipped with an internal switch which dedicates pump 3 to the Timer function even though the mode selector is in the manual or Centrifuge mode. For example, the mode selector can be set on "Centrifuge" for the collection of seston while pump 3 provides water to a daily sampler when signalled by the daily timer. In total, there are 22 different ways of providing water for sample collection purposes; system operation for four main sampling categories are described below.

(i) Collection of Samples by the Operator

Discrete samples can be collected by the operator by setting the mode selector to the Manual position and energizing pump 3. If the time of collection is scheduled, the Timer mode can be used for flushing of sampling line prior to arrival of the operator.

(ii) Collection of Samples with an Automatic Sampler

Hourly, daily or other time-sequenced samples can be collected with an automatic sampling device by setting the mode selector to the Timer position. Pump 3 can be energized as programmed by the timer.

(iii) Collection of Seston

Seston can be collected in a continuous flow centrifuge by setting the mode selector to the Centrifuge position with either pump 1 or 2. If sampling is to be conducted over an extended period (7 days), the flow detector circuitry should be engaged to provide an automatic back-up for pump 1. In this case, switches for pumps 1 and 2 must be in the "ON" position.

(iv) Collection of Seston and Deployment of an Automatic Sampler

Time-sequenced samples may be collected during a period of sediment collection. With the monitor set as described in section (iii), time-sequenced sampling can be initiated by setting the internal timer switch and pump 3 to the "ON" position.

The second major function of the pump and power monitor is to control the 220 V power source to the Westfalia centrifuge and shut it down temporarily should line voltage fall below the recommended operating range. In this event, a lamp on the control panel is simultaneously illuminated to indicate to the operator that there is an inappropriate voltage level. Power to the centrifuge is restored once the line voltage is within the operating range. This voltage monitoring feature is especially important for the collection of seston over extended sampling periods as there is a greater likelihood of transient low voltage. The occurrence of low voltage without this circuitry would terminate the centrifuge run and result in a loss of sample. Operation of the voltage monitoring function can be verified, at any time, with the low voltage simulator switch.

The third function of the pump and power monitor is to provide remote monitoring when seston is collected. Two circuits for diagnostic use can be coupled with a phone patch to indicate whether the centrifuge is operating or not. The information can be used to determine if the stoppage is temporary, due to a power failure or low voltage, or whether it is due to a breakdown of the centrifuge.

The Westfalia centrifuge is equipped with a four-chamber stainless-steel bowl weighing 20 kg. It rotates at 9300 RPM and exerts a force of 9500 g. Power is supplied to the centrifuge via a watertight plug/receptacle assembly. This safety receptacle is controlled by a remote switch located 5m from the centrifuge, behind a 3m diameter vertical pipe. The switch allows the operator to start the centrifuge without having to stand near it, thus risk of personal injury which may arise from a serious malfunction during run-up, is minimized.

A PMC/BETA vibration sensor and centrifuge control unit was mounted on the Westfalia centrifuge to monitor its mechanical condition, and shut it down automatically should destructive vibration develop following the run-up phase. The solid-state vibration switch contains two trip limits, one for alarm and one for shutdown. This unit is equally responsive to faults which present themselves as either low or high frequency vibrations. Low frequency vibrations are usually due to imbalance and misalignment; higher frequency vibrations are indicative of defective bearings or improper gear mesh. An important feature of the PMC/BETA switch is a built-in 3 second time delay which prevents nuisance triggering of the alarm or shutdown functions arising from transient increases in vibration levels. Not unlike many other machines, the Westfalia centrifuge exhibits high vibration during run-up phase. The vibration sensor is equipped with a lock-out which is controlled by a time-delay relay in the centrifuge controller, typically set to lapse 40 seconds following start-up. This lock-out feature allows for lower overall trip settings, and therefore, greater protection during normal operation. It should be noted that the vibration sensor is largely a switching device which provides a signal for the operation of the alarm and shutdown functions in the centrifuge control unit.

The centrifuge controller has three main functions: (1) it provides a signal, to the operator, for the identification of potential problems which may arise from normal wear of the centrifuge and bowl, (2) shuts off the centrifuge should destructive vibration develop, and (3) provides a signal to control the subsersible pump for protection of the centrifuge and bowl, and to prevent a loss of sample.

In the event of minor vibration above the alarm trip setting, yet below the shutdown trip setting, an alarm will sound and a lamp will be illuminated. The lamp will remain on through the entire run as a reminder that the alarm trip setting was exceeded. The alarm may be shut off, while the centrifuge is in operation, by setting the alarm switch in the "OFF" position (Fig. 4). Operation of the alarm circuitry can be confirmed, at any time during the centrifuge run, by holding the alarm

switch in the "test" position. The alarm feature allows the operator to evaluate the condition of the centrifuge and bowl, and schedule corrective maintenance at a time that does not interrupt the sampling schedule. If the shutdown level is exceeded, a power relay in the controller is released, cancelling power to the centrifuge and thus minimizing damage to the bowl and centrifuge.

The centrifuge controller also provides a signal to the pump and power monitor for controlling the intake pump when the mode selector is in the centrifuge mode. In this mode, energization of the pump is delayed 30 seconds following start-up of the centrifuge to allow the clarifier to reach full operating speed prior to water entering the bowl. In the event of a power interruption both the centrifuge and pump will stop. Upon resumption of power, the centrifuge will restart, however, energization of the pump will once again be delayed 30 seconds. This control feature prevents sediment from being washed out of the bowl when the centrifuge is either stopped or spinning at less than full operating speed. This is especially important at Point Edward, because line voltage is routinely interrupted as part of plant operation in order to test the stand by diesel generators.

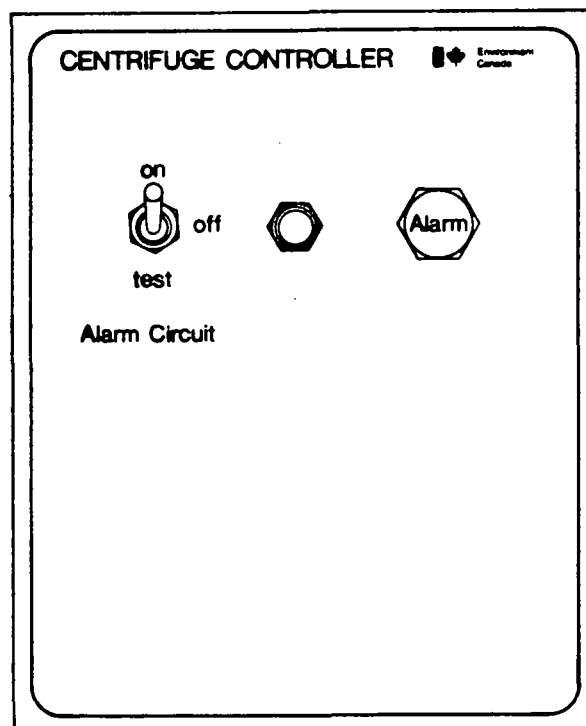


Figure 4.

Centrifuge controller panel

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APPENDIX 1 - Design of Water Delivery System

APPENDIX 1 - Design of Water Delivery System

This section provides a detailed description of the water delivery system and information related to its installation. The station was located at the water treatment plant to collect St. Clair River water from the plant's concrete intake pipe, which due to its construction is free from problems associated with ice jams common in this reach of the river.

The inlet structure has large openings which allow sizable debris to enter the 66 in concrete intake pipe. Under normal operating conditions water passing through the intake pipe can exert considerable force on a sample intake placed within. Due to the potential for damage to the intake device, it was thought that it should have a low surface area and be somewhat streamlined. This was achieved by using open tubing for the intakes, and drilling holes in the last 10 cm of the tubes. These holes provided a means of water entry in the event of the open end becoming clogged with debris.

The triple line intake bundle was fastened to the downstream side of the 1.5-in. iron sampling pipe because the orientation provided it some measure of protection from debris. By placing the inlet of the intake tubes 75 cm off the bottom of the concrete intake pipe, the possibility of sampling sediment containing particle sizes too heavy to remain in suspension was minimized.

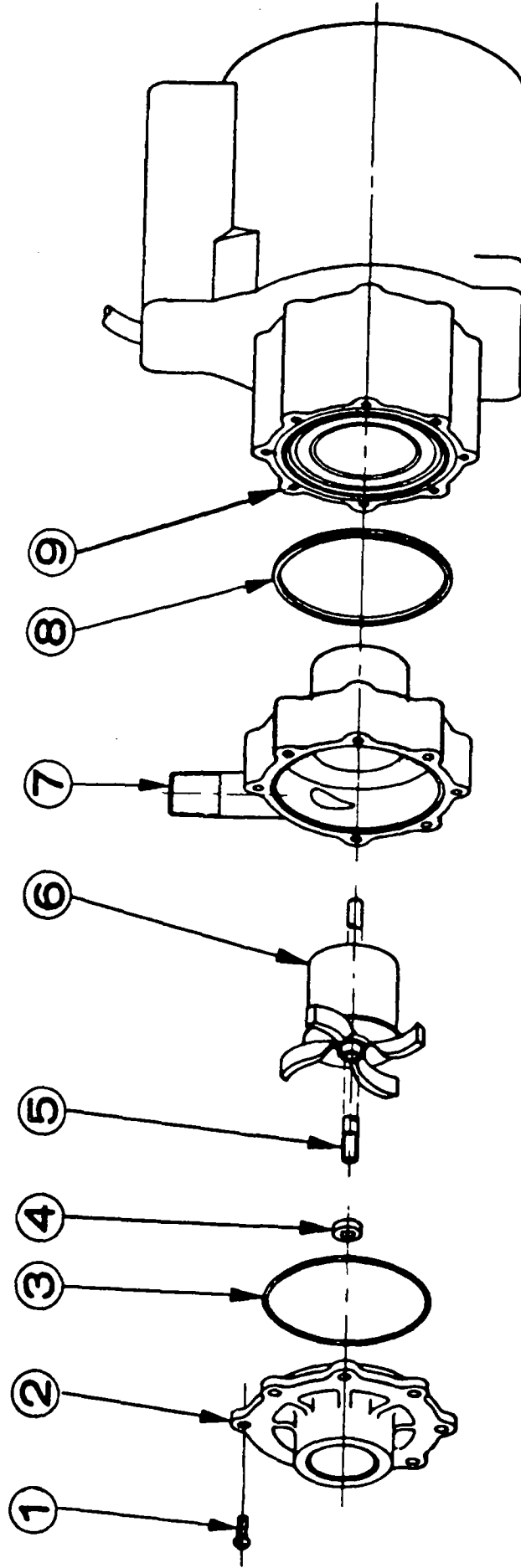
The pump frame, cables and shackles exposed to the pre-chlorination process in the low lift well were stainless steel for corrosion resistance. The "all stainless" gear clamps used throughout the system are equipped with stainless steel screws for ease of removal if required.

The March 5C-MD submersible pumps have a magnetic drive, which eliminates the need for conventional shaft seals and problems associated with lubricant leakage into the pump head assembly. All wetted plastic parts are glass filled polypropylene, and the pump head gasket is made of viton. Both the stationary spindle and thrust washer are made of ceramic.

The intake bundle was attached to the inlet side of the submersible pumps such that there was enough slack to permit the pump frame to be removed from the well and placed on the screen room floor. The inlet and outlet adapters detailed in Figure 1B were of a design recommended by the pump manufacturer to maximize flow rates when using 0.75-in. tubing. The use of compression fittings for tubing attachment to the adapters avoided restriction of tubing I.D., thereby optimizing flow rates. Union connections were used on each side of the pumps to simplify pump replacement.

Three cables assembled with copper nicopress sleeves were used for support and removal of the pump frame. A 0.25-in. diameter lifting cable was fashioned into a bridle and shackled to the frame. This cable was sheathed in 0.5-in. rubber heater hose for a distance of 3 m above the bridle to prevent chafing of the outlet bundle. The other end of the cable was passed through a pulley supported by a davit, and fastened to a hand winch bolted to the screen room floor. This winch provides a means of removing the pumps from the well should servicing be required. A 0.25-in. diameter rubber sheathed support cable was similarly shackled to the frame and then attached to a ring mounted on the screen room wall. This cable supported the pump frame 2 m below the water surface when the winch was not being used.

The support cable passed through a notch cut in the hatch plate so the well could be covered when access was not required. A 6 m long, 0.125-in. diameter retrieval cable was fastened to the outlet bundle above the level of the screen room using a gear clamp. A 50 cm length of fabric reinforced neoprene hose was placed over the bundle to prevent the clamp from cutting into the tubing. This hose also prevented abrasion of the outlet bundle where it contacted the edge of the screen room floor. The free end of the retrieval cable was attached to the same ring as the support cable.



LEGEND

- 1 - Machine screw
- 2 - Cover
- 3 - "O" Ring
- 4 - Ceramic thrust washer
- 5 - Spindle
- 6 - Impeller assembly
- 7 - Pump housing
- 8 - Quad ring
- 9 - 5C-MD motor; magnetic drive

Figure 1A.

March pump model 5C-MD

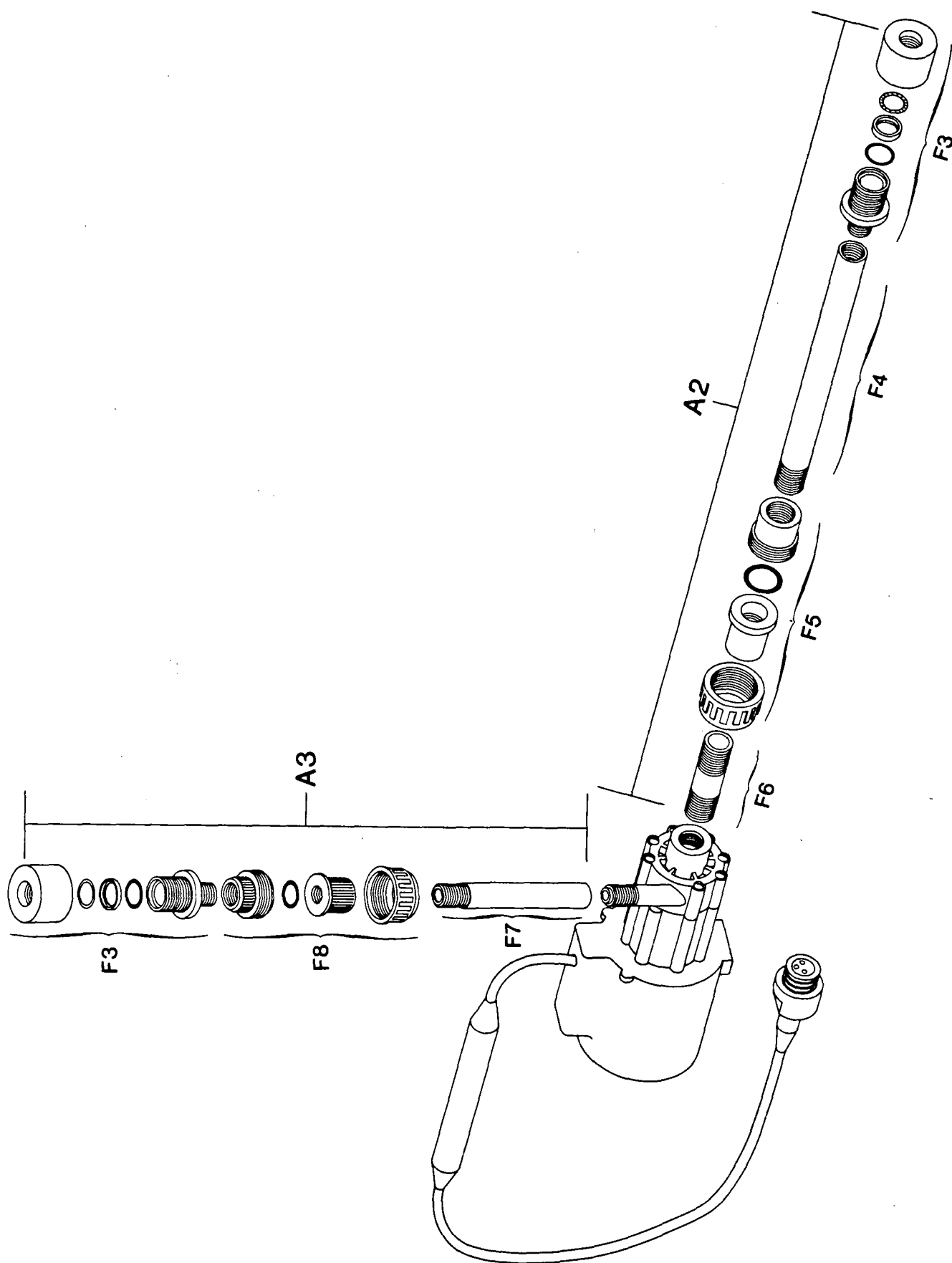


Figure 1B. Submersible pump adapter assemblies

The retrieval cable was long enough to permit the outlet bundle to be disconnected and placed on the screen room floor while lifting the pumps. It was necessary to disconnect the tubing because it was too rigid to allow the pumps to be raised while attached. Should the bundle accidentally fall down the well during pump servicing, the retrieval cable could be used to pull it up onto the screen room floor.

TABLE 1A. Water Delivery System Fittings and Assemblies

FITTING/ ASSEMBLY	NAME	SPECIFICATION
F3	Compression	1" O.D. x 3/4" male NPT, viton O-ring, pp
F4	Intake Adapter	3/4" female NPT x 1" male NPT, pp
F5	Union	1" female NPT x 1" female NPT, viton O-ring, pp
F6	Nipple	1" male NPT x 1" male NPT, pp
F7	Outlet Adapter	1/2" female NPT x 3/4" male NPT, pp
F8	Union	3/4" female NPT x 3/4" female NPT, viton O-ring, pp
A2	Pump Inlet Adapter	(F3-F4-F5-F6)
A3	Pump Outlet Adapter	(F3-F8-F7)
A4	Compression-union	(F2-F5-F2)

NOTE: NPT = National Pipe Thread
pp = Polypropylene

For consistency, the fittings and assemblies are numbered in the manner as shown in reports prepared for the Port Lambton (Fischer and McCrea, 1988) and Niagara-on-the-Lake (McCrea and Fischer, 1988) sampling stations. The plumbing varied somewhat due to differences in the layout of the stations, as a result, the fitting numbers in this and the other reports may not be consecutive.

APPENDIX 2 - Design of Sampling System

2.1 Valves

2.2 Flow detector

2.3 Strainer

2.4 Centrifuge

2.5 Drain

APPENDIX 2 - Design of Sampling System

This section provides a description of the various fittings, assemblies and components of the sampling system. A schematic of the sampling system is provided in Figure 2A; specifications and illustrations of the fittings are presented in Table 2A and Figure 2B, respectively.

2.1 Valves

With the exception of the throttling valve that controls flow to the centrifuge, all manual and electrically actuated valves in the system were ball valves. These natural polypropylene valves had viton seals and Teflon seats, and contained no metal parts. The smooth flow path characteristic of ball valves maximized flow rates through the system.

Ball valves 1,2,3, and 4 were 3/4-in. NPT, while valves 6 and 7 were 1/2 in. NPT. All had brackets welded to the valve bodies which allowed them to be bolted to a flat surface, and valves 1 and 2 were further modified to accept the electric actuators. An illustration of the "True Blue" EBV075 actuators is provided in Fig. 3.4A.

The height of the simulation valve (valve 4) relative to valve 1 was necessary in order to test for proper operation of the back-up pump function. Operation of the back-up pump is tested with pump 1 providing water to the sampling system. Valve 4 was lower than valve 1, and thus when valve 4 is opened, water is diverted to drain instead of rising higher in the system. As a result of the pressure drop in line 1, the pressure switch in the flow detector is released, and a signal is sent to the pump and power monitor for energization of pump 2.

The electrically actuated valves (valves 1 & 2) prevent water from being pumped back to the river in the event of an actual pump failure. For example, if the flow detector sensed the failure of pump 1, pump 1 would be deenergized and pump 2 energized. At the same time valve 1 would close and valve 2 would open, allowing water to pass through the filter. Without these valves in place, water would take the path of least resistance and would be pumped back into the river through line 1.

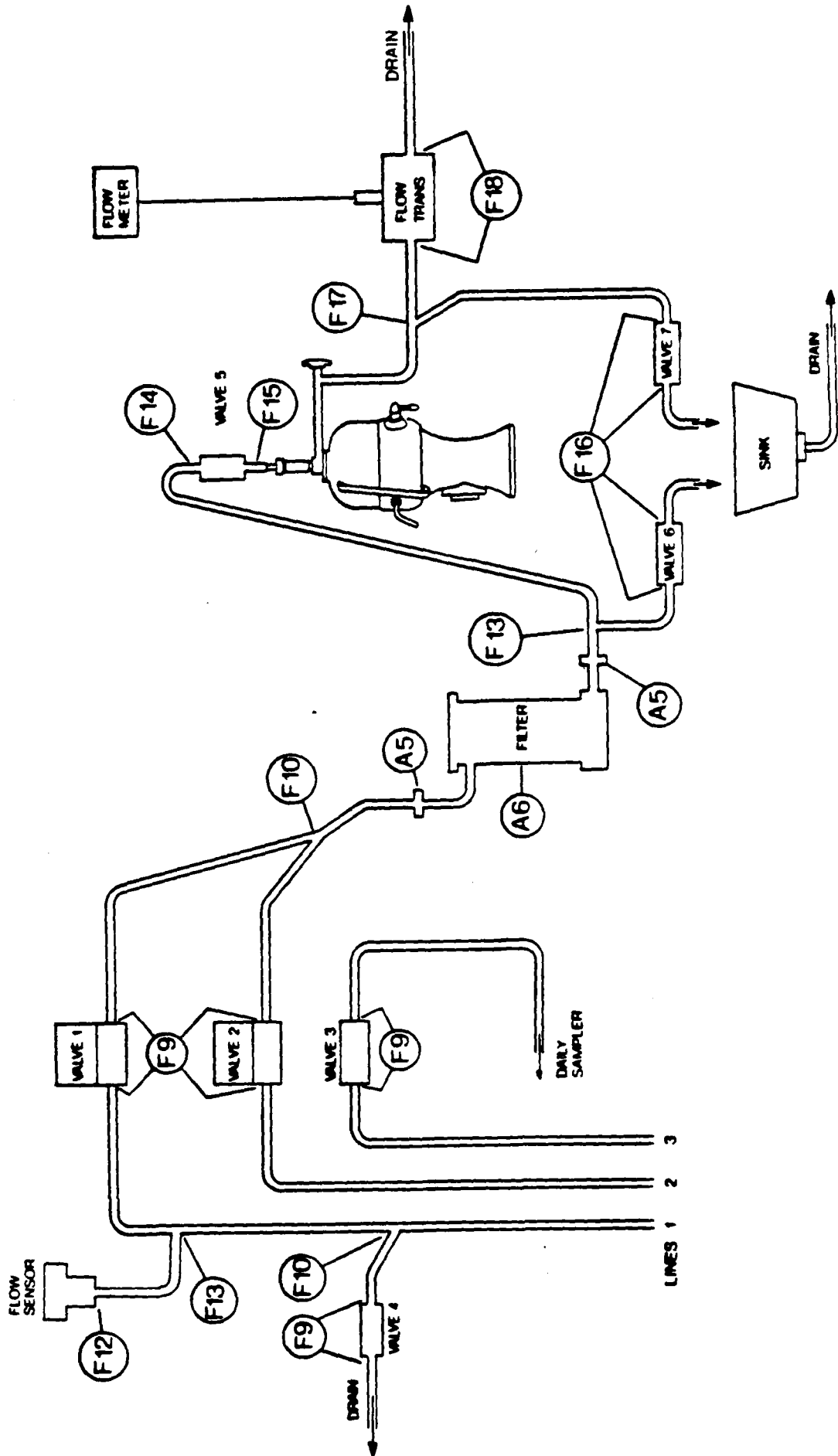
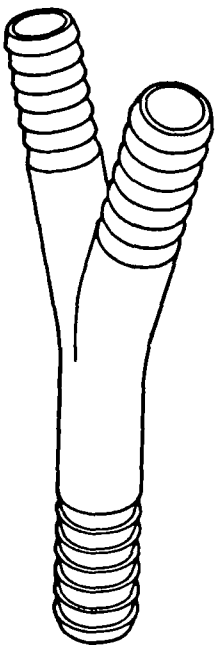


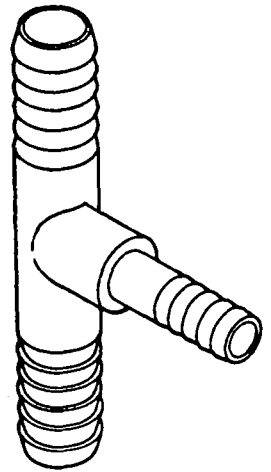
Figure 2A. Schematic of sampling system



F 10



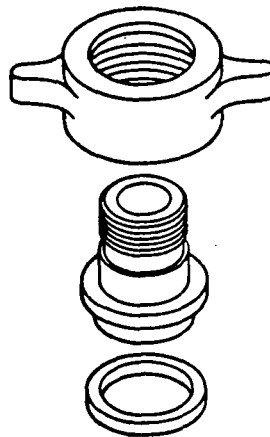
F 12



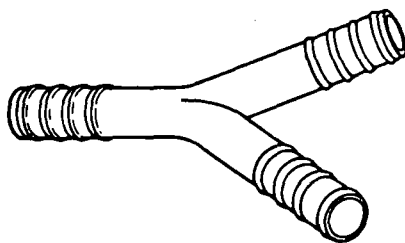
F 13



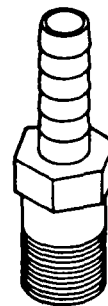
F 14



F 16



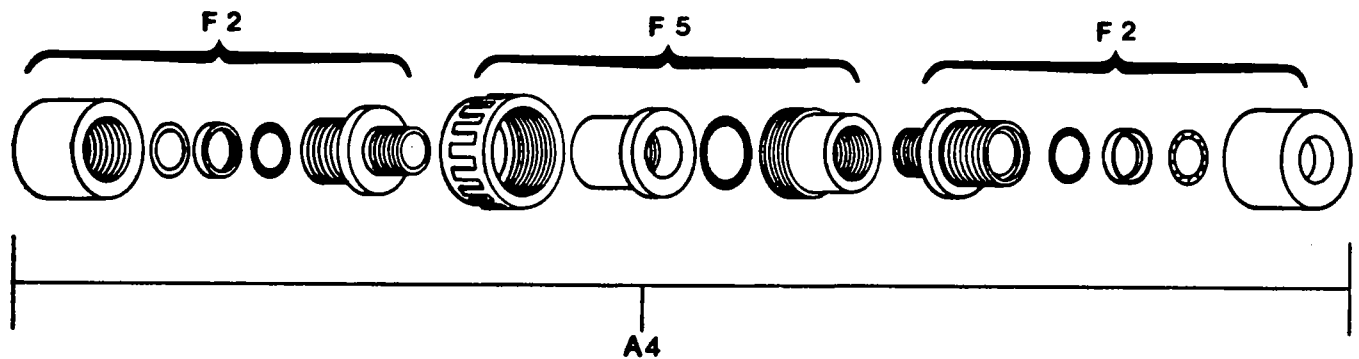
F 17



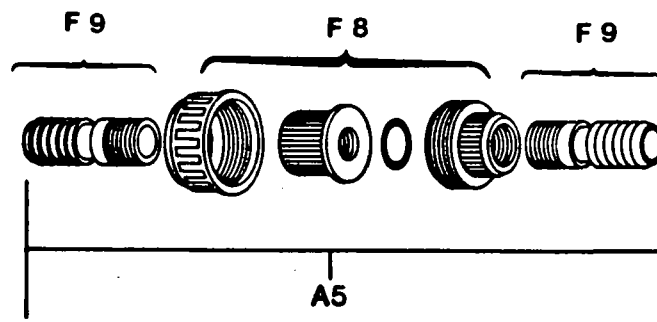
F 18

Figure 2B.

Sampling system fittings



Compression Union Assembly



Insert-Union Assembly

Figure 2B continued. Sampling system fittings

A 1/2 in. NPT polypropylene needle valve (Fig. 2.1B) was used to throttle flow at the centrifuge inlet. Needle valves were not readily available in an appropriate size, so it was necessary to drill the ports out oversize to provide control over a flow range of $0-8\text{ L min}^{-1}$.

2.2 Flow Detector

A United Electric J6S-M2 pressure switch with all internal parts made of stainless steel, was used as the flow detector in line 1. When water flows through line 1, air trapped in the flow detector shunt line is compressed and acts on the detector mechanism. Water does not enter the unit, therefore, fouling of the mechanism by river borne debris is unlikely.

TABLE 2A. Sampling System Fittings and Assemblies

FITTING/ ASSEMBLY	NAME	SPECIFICATION
F2	Compression	1" O.D. x 1" male NPT, viton O-ring, pp
F8	Union	3/4" female NPT x 3/4" female NPT, viton O-ring, pp
F9	Barbed insert	3/4" x 3/4" male NPT, pp
F10	Barbed Y	3/4" x 3/4" x 3/4", pp
F12	Barbed insert	1/2" x 1/4" male NPT, pp
F13	Barbed T	3/4" x 1/2" x 3/4", pp
F14	Barbed insert	3/4" x 1/2" male NPT, pp
F15	Centrifuge inlet	1/2" male NPT, viton O-ring, ss
F16	Insert fitting	1/2" x 1/2" male NPT, pp
F17	Barbed Y	1/2" x 1/2" x 1/2", pp
F18	Barbed insert	1/2" x 1/2" male NPT, ss
F19	Reducing bushing	2" male NPT x 3/4" female NPT, pp
F20	90° elbow	1" female NPT x 1" male NPT, pp
F21	Barbed insert	3/4" x 1" male NPT, pp
A5	Insert - union	(F9-F8-F9)
A6	Strainer	(F9-F19) (F20-F21)

NOTE: NPT = National Pipe Thread
pp = Polypropylene
ss = Stainless Steel

For consistency, the fittings and assemblies are numbered in the manner as shown in reports prepared for the Port Lambton (Fischer and McCrea, 1988) and Niagara-on-the-Lake (McCrea and Fischer, 1988) sampling stations. The plumbing varied somewhat due to differences in the layout of the stations as a result, the fitting numbers in this and the other reports may not be consecutive.

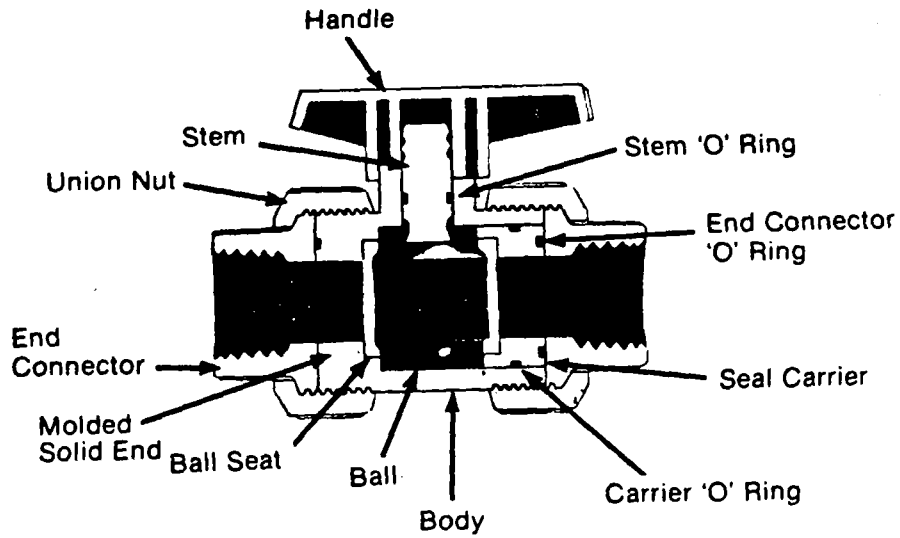


Figure 2.1A True union ball valve

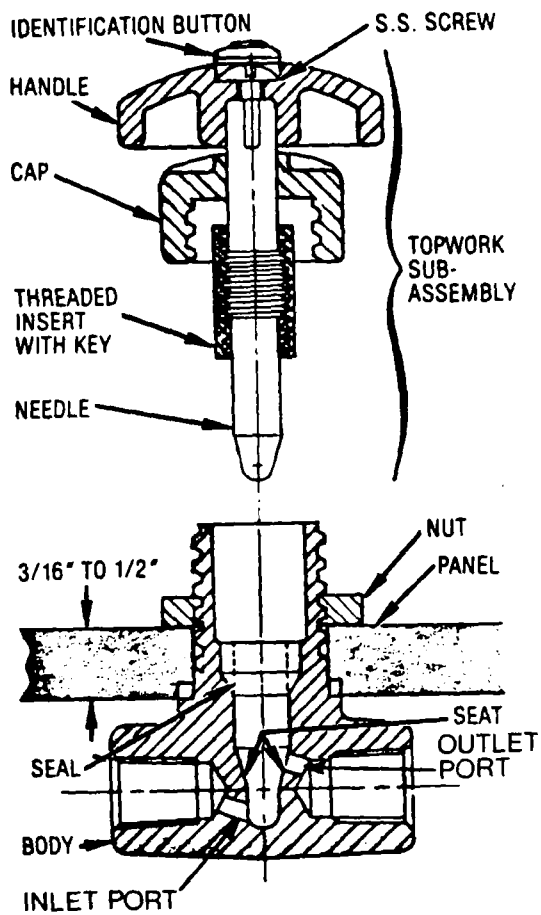


Figure 2.1B Needle valve

2.3 Strainer

The natural polypropylene strainer (Fig. 2.3A) was designed to remove coarse debris from the raw water before it entered the Westfalia continuous flow centrifuge. This coarse filtration is important because the clarifier spins at high speed and large particles can potentially cause an imbalance as well as damage parts of the bowl. In order to prevent fine sediment from building up in the strainer, the unit was designed with a conical outlet at the bottom. As a result, flow combined with the force of gravity keeps sediment moving through the strainer.

2.4 Centrifuge

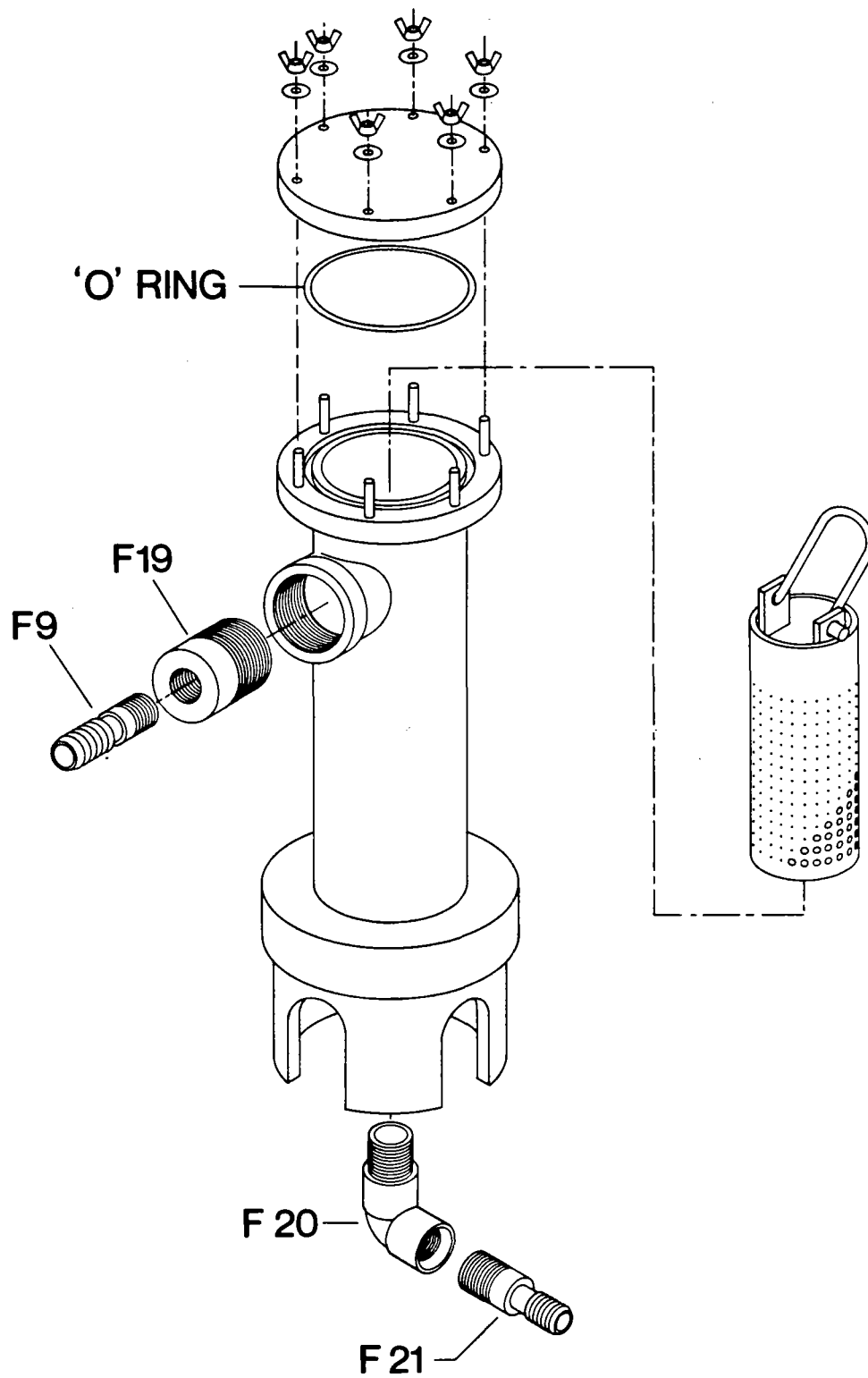
The Westfalia continuous flow centrifuge (Fig. 2.4A) is equipped with a four-chamber stainless steel bowl (Fig. 5.3A), which rotates at 9300 RPM and exerts a force of 9500 g. At flow through rates of 6.5 and 1.2 L min⁻¹ the recovery of suspended sediment from St. Lawrence River water was 81 and 91% efficient, respectively (Roch 1985).

All wetted centrifuge seals and O-rings are made of viton or Teflon. The stock oil filled pressure gauge is not required in this sampling application, thus it was removed from the centrifuge outlet to eliminate potential contamination of the clarified water.

The centrifuge and drive motor were mounted on an aluminum cart complete with 20 cm dia. casters. Two casters are fixed, and the other two are of the swivel type with both brakes and swivel locks to facilitate safe transport of the machine.

2.5 Drain

Clarified water and raw water sampling lines drained directly into a plastic sink for ease of sample collection, whereas the simulation line and centrifuge waste line were directed to a 150 cm x 70 cm x 5 cm aluminum drain tray. The centrifuge sat in this tray which was placed on a 15 cm high concrete pad. Both the drain tray and sink were plumbed into a common drain. Elevation of the tray prevented water from backing up and flooding it when the sink was in use. A second drain fitting is available on the tray if it is needed for future sampling purposes.



ASSEMBLY A6

Figure 2.3A

Filter unit and fittings

LEGEND

- 1 - Feed
- 2 - Discharge
- 3 - Overflow
- 4 - Frame drain
- 5 - Oil drain screw
- 6 - Sight glass
- 7 - Clamps
- 8 - Brake
- 9 - Lock screw
- 10 - Hood
- 11 - Handle connection piece

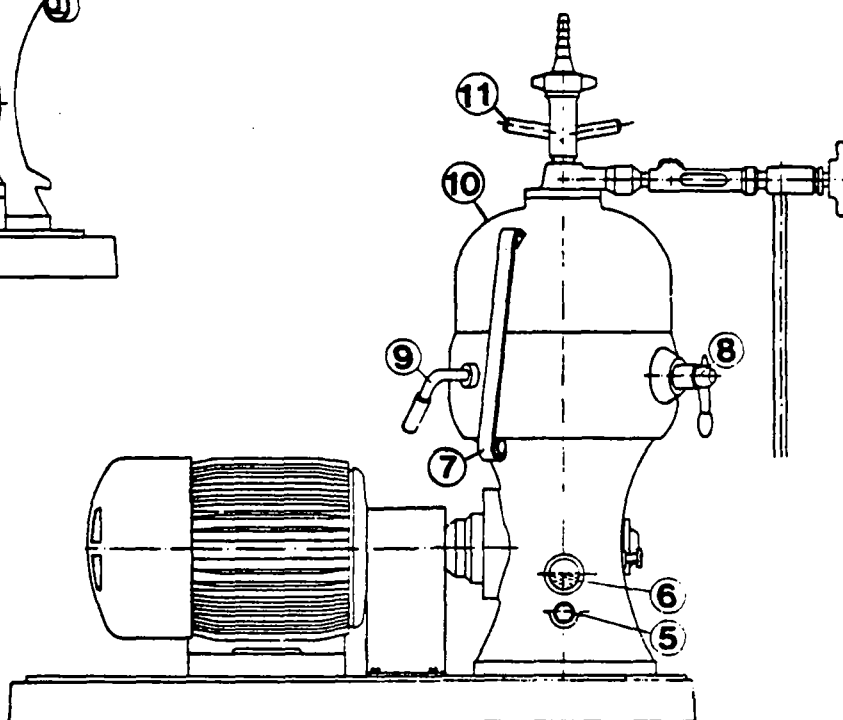
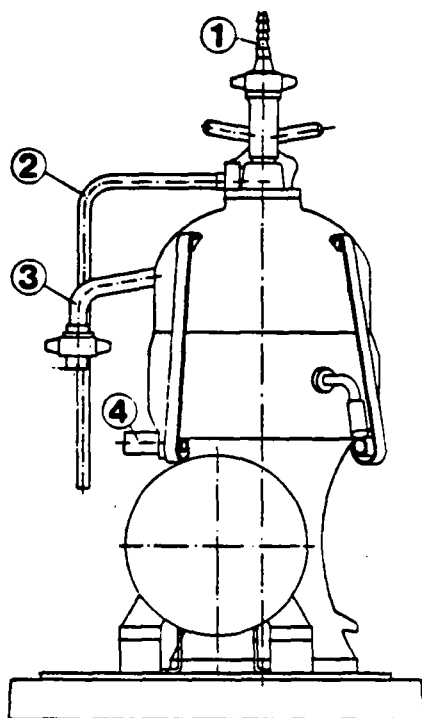


Figure 2.4A

Westfalia continuous flow centrifuge

APPENDIX 3 - Control Circuitry

3.1 Submersible pumps and connectors

3.2 Pumps and power monitor

3.3 Flow sensor

3.4 Actuated valves

3.5 Timer

3.6 Centrifuge energization

3.7 Centrifuge controller

3.8 Vibration sensor

3.9 Centrifuge motor

3.10 Flow transducer

APPENDIX 3 - Control Circuitry

This section provides supplemental information on the design and function of the pump and power monitor, vibration sensor and centrifuge controller, and on peripheral equipment related to the control circuitry.

3.1 Submersible Pumps and Connectors

March 5C-MD magnetic drive pumps are used to deliver water to the sampling system. These pumps are equipped with 1/8 horsepower motors and can draw up to 2.1 amps under maximum load. Under adverse conditions, the magnetic drive acts as a clutch to eliminate motor overload and burnout.

Power to the submersible pumps is provided by the pump and power monitor. For ease of attachment, replacement pumps should be prepared with a 75 cm long power cord (Fig. 3.1A).

3.2 Pump and Power Monitor

The pump and power monitor circuitry, shown in Figure 3.2A, is housed in a Hammond panel box (1414 PH); specific components are listed in Table 3.2A. The circuitry consists of a number of switches, relays and indicator lamps as well as peripheral equipment which includes the electrically-actuated valves, flow sensor and submersible pumps. These components are monitored by a ground fault detector for protection of the operator. Should a ground fault arise, with leakage current in excess of 10 microamps, power to the equipment is automatically disconnected. When the fault is corrected, the breaker supplying power to the pump and power monitor must be switched "OFF" at the panel box to re-set the ground fault detector relay before power can be reapplied to the circuitry.

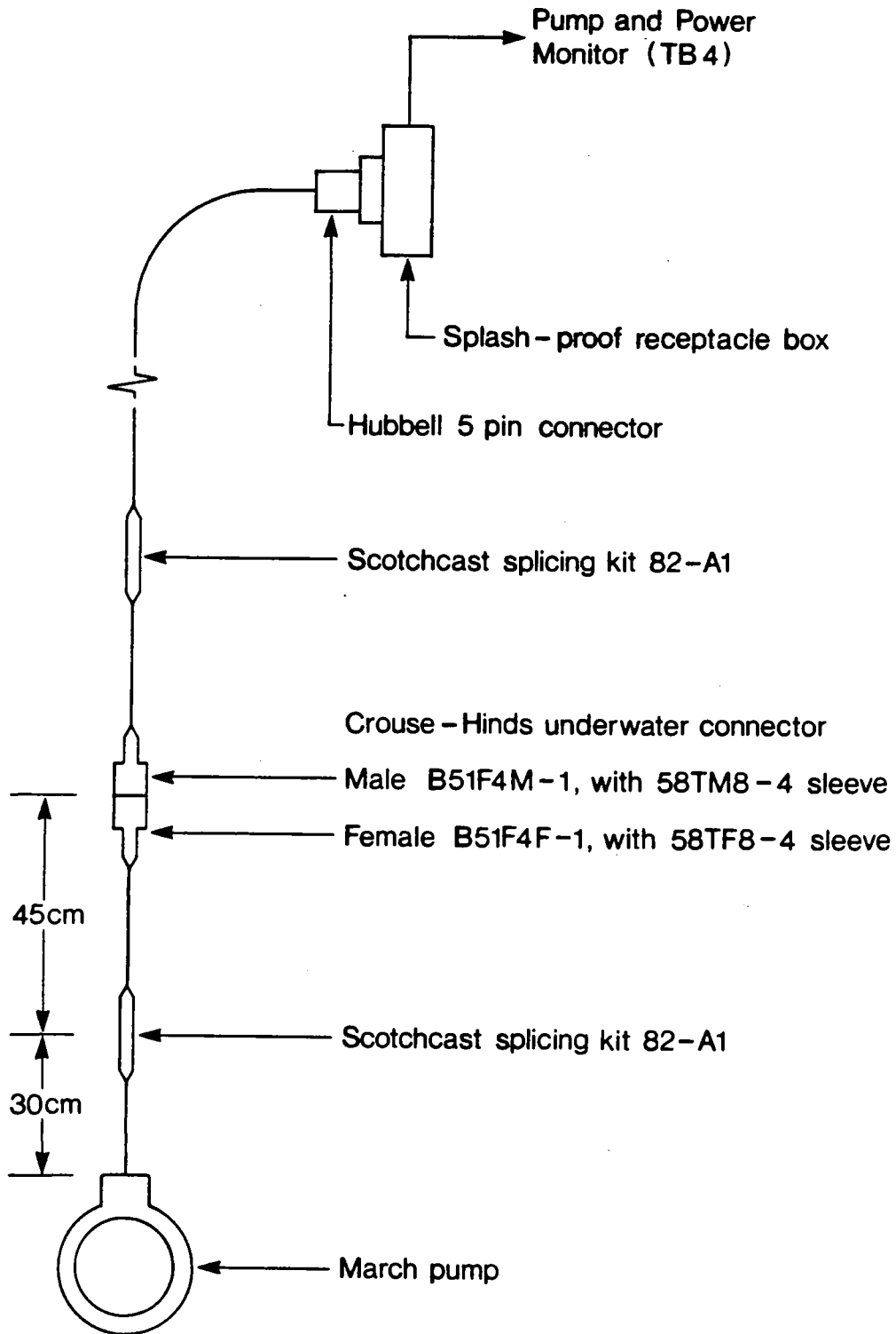
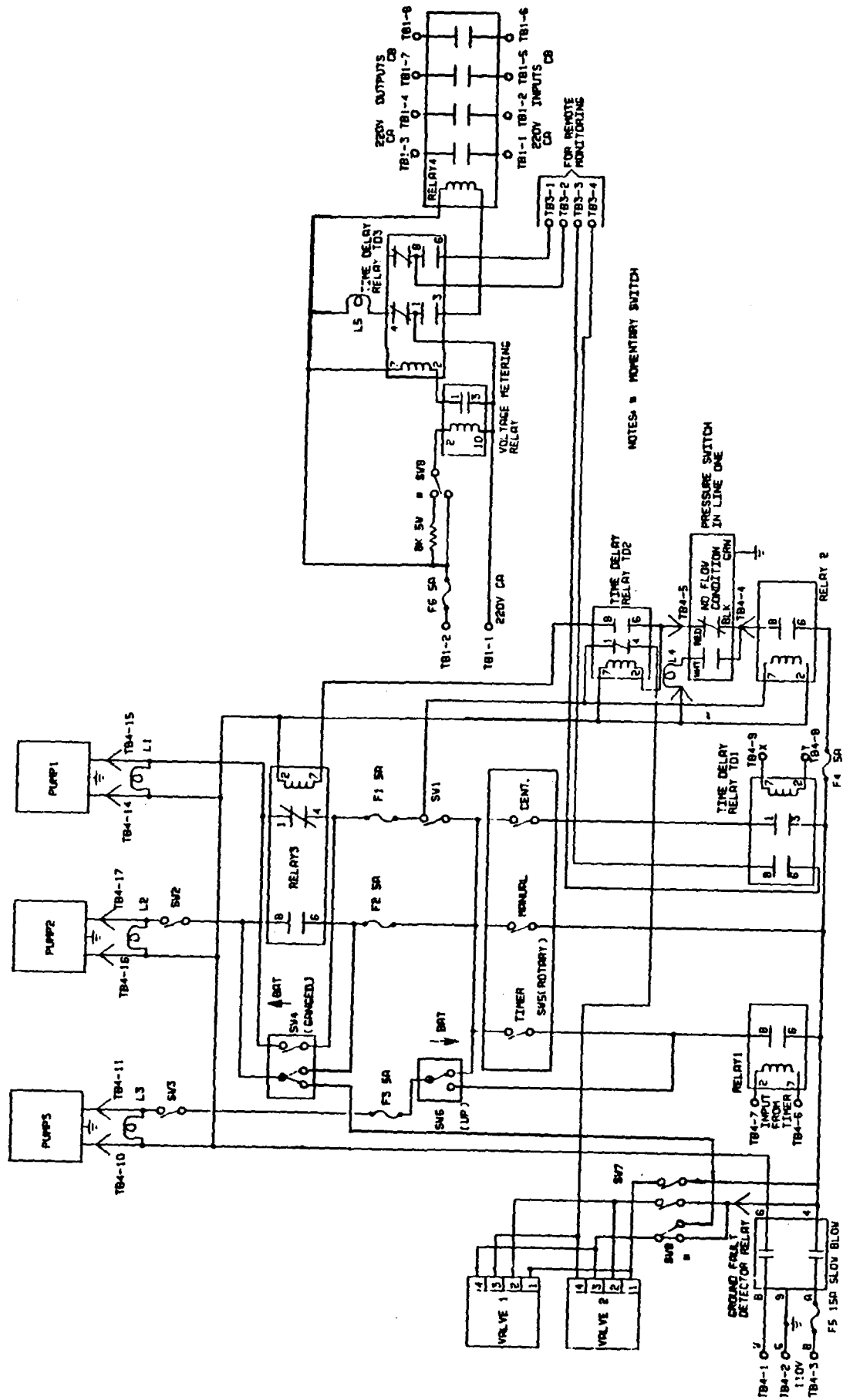


Figure 6.4A

March pump electrical connections



Pump and power monitor circuitry

Figure 3.2A

TABLE 3.2A. A Listing of Pump and Power Monitor Components.

Component Numbers	Type
Connector	Amphenol, 97-3106A-145-2P
Fuse 1,2,3,4,6	Buss, glass 1 1/4", 125V, 5A
Fuse 5	Buss, glass 1 1/4", 125V, 10A
GFD	PB, CZS-01-7000, 120V, 10A, GLC 10 uA max.
Lamp 1,2 & 3	base, Dialight, 125-0408-11-143 lense, Dialight, 125-0408, red, yellow and white bulb, Spectro, neon, Ne-51, 110V
Lamp 4	Industrial devices, 2152A5, Neon, 125V
Lamp 5	base, Dialight, 103-3101-05-103 lense, Dialight, 102-1331-403, red bulb, Spectro, cand., 10S6, incandescent, 220V
Relay 1,2 & 3	PB, KRP11AG, DPDT, 120V, 10A
Relay 4	PB, PM17AY, 240, 30A
Relay 5	PB, KRP11AG, DPDT, 120V, 10A
Relay-Socket	Curtis, cus8, 8-pin octal
Switch 1,2 & 3	JBT, 4222S, on-off SP, 120V, 20A
Switch 4	JBT, 5223S, on-on DP, 120V, 20A
Switch 5	Square-D, Class 901, Rotary on, on, on
Switch 6	JBT, 4223S, on-on, 120V, 20A
Switch 7	JBT, 5222S, on-off DP, 120V, 20A
Switch 8*	JBT, 4226S, on-on*, 120V, 20A
Switch 9*	JBT, 5231S, on-on*, 240V, 10A
Switch Boot	GC, bat handle toggle, 35-060
TD-Relay 1 & 2	NCC, T1K-00120-461, DPDT, 120V, 10A
TB-1	Cinch-Jones, 12-142, terminal block
TB-3	Cinch-Jones, 4-142, terminal block
TB-4	Cinch-Jones, 17-142, terminal block
VM Relay	Electromatic, SJJ 195-220, 220V, 10A
VMR-Socket	Electromatic, S411, 300V, 10A

Note: GFD - Ground Fault Detector

VM - Voltage Metering

* - Denotes that switch is momentary

On Manual mode, energization of the pump(s) is not affected by any of the control components with exception of the ground fault detector. Water can therefore be supplied despite a breakdown of any one or all of the standard and time-delay relays. On Timer mode, the pump is controlled by an external timer through relay R1. The input coil for relay 1 requires a 110 V supply. If used with other timers requiring a different voltage (AC or DC), the relay can be removed from its socket and replaced with a similar relay having the appropriate coil. On centrifuge mode, time-delay relay (TD1) allows the centrifuge to reach full operating speed prior to energization of the submersible pump. Should the centrifuge stop for any reason, power to the pump is cancelled and the time-delay relay is re-set. The signal to relay TD1 is provided by the centrifuge controller via terminals TB6-11 and -12. For ease of removing the centrifuge, should it require servicing, the connection to the pump and power monitor is made with a splash-proof amphenol connector mounted on the centrifuge controller.

The automatic pump back-up function can be engaged with any one of the three modes of operation by setting switches 1, 2 and 4 to the "ON" position. Deployment of the back-up pump (P2) is subject to an appropriate time delay to prevent nuisance tripping at start-up and following power outages. The time delay is typically set for 30 seconds with relay TD2.

Water can be supplied for the Manual, Timer and Centrifuge modes of operation with either pump 1 or 2, as shown in Table 3.2B. Both of these pumps may be deployed simultaneously (option C) for the collection of large volume samples. This pump selection option and option F can also be used for flushing the intake lines. In total, there are some 22 different ways of drawing water for sample collection and flushing purposes without altering the plumbing configuration. Specific operating instructions are provided in Appendix 5.

Power to the centrifuge is monitored and controlled with a voltage metering relay. This device prevents tripping of the centrifuge

TABLE 3.2B. Sample Collection Permutations Utilizing the Three Basic Modes of Operation.

MODE	Pump Selection Alternatives					
	A	B	C	D	E	F
	Pump 1	Pump 2	Pump 1 & 2	Pump 1 or 2	P3	P1+P2+P3
Manual	XT	XT	XT	XT	X	X
Timer	X	X	X	X	X	X
Centrifuge	XT	XT	-	XT	-	-

Note: XT - can be used with or without pump 3 dedicated to the timer mode.

X - can be used with the indicated pump(s) only.

thermal-mechanical breakers in the event of low voltage; its operation is discussed in section 3.6.

Circuits for remote monitoring of the sampling system are located on terminal block 3. Pins TB3-1 and -2 are for confirming the availability of power to the centrifuge and pins TB3-3 and -4 indicate whether the centrifuge is running. Several other remote monitoring functions to verify ground faults, pump status on automatic mode, etc. can be added by directly coupling phone patch circuits to the appropriate relay.

3.3 Flow Sensor

Flow through line 1 is monitored with a United Electric Controls J6S-142 SPDT pressure switch. This unit is equipped with a stainless-steel bellows and has an adjustable pressure trip setting in the range of 0 to 124 kPa (0-18 PSI). Set point repeatability is ± 2 kPa or $\pm .3$ PSI. A neon indicator lamp (L4) was mounted on the pressure switch cover for ease of setting the trip limit, and for verifying the flow condition in line 1. The lamp is illuminated when the flow is above the trip setting.

3.4 Actuated Valves

The water sampling system is equipped with two True Blue ball valve electrical actuators (Figure 3.4A). These actuators control valves in lines 1 and 2 to ensure proper valve orientation should the back-up pump be energized when the system is run unattended. The actuators are equipped with position and motor running lights which indicate the status as follows: green - valve open, red - valve closed, and yellow - actuator motor is rotating.

The valves actuators rotate in quarter turns as signalled by the control circuitry; signals to pin 3 open the valves whereas signals to pin 4 close them. The actuators were wired so that valve 1 and valve 2 are always in opposing positions. When pump 1 is used to supply water to the sampling system, the valves will re-set automatically, if required, so

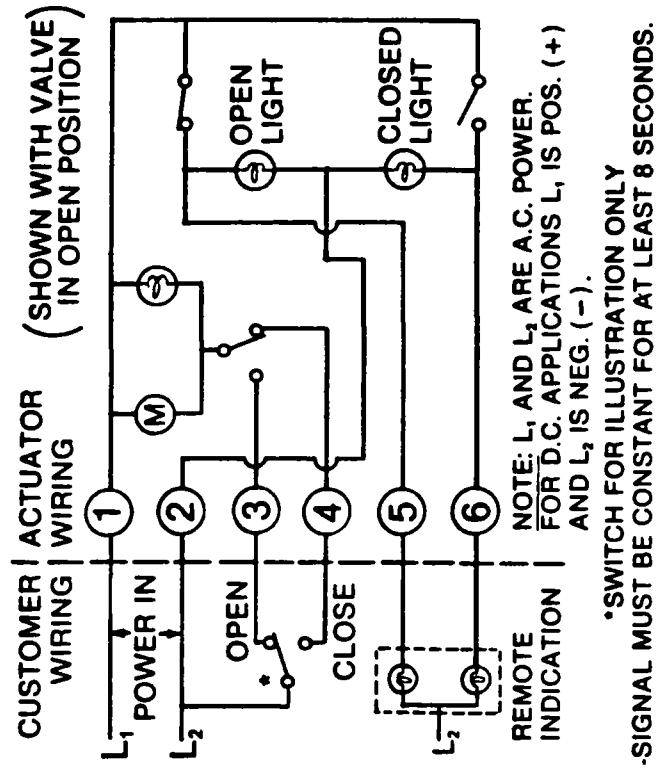
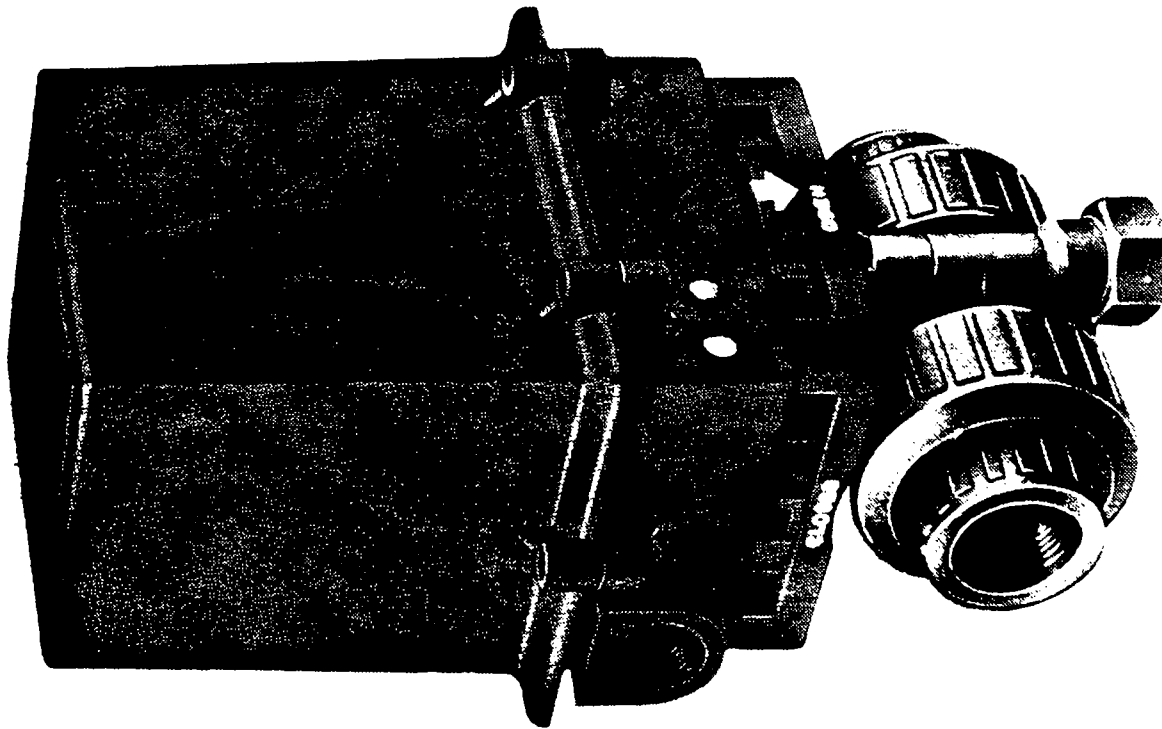


Figure 3.4A

Valve actuators employed with valves V1 and V2

that valve 1 is open and valve 2 is closed. The valves will remain in this orientation regardless of what position pump switches 1, 2 or 3 are then set in. The valves will, however, advance such that valve 2 is open and valve 1 is closed following failure of pump 1 when the automatic back-up function is employed. In addition, the valves may be advanced by the operator with the valve advance switch (SW8). This switch is mounted in a splash-proof receptacle box located near the actuators. The switch must be held in the "advance" position until the valve comes to a complete stop to ensure that the actuator is in a proper orientation for the next rotation. Holding the advance switch for longer periods will not damage the actuator as power to the motor is automatically disconnected upon completion of each quarter rotation.

These actuators are equipped with a thermal overload breaker to prevent motor burnout. Overheating may arise from repeated rotation of the valves in excess of their 50% duty cycle or as a result of overtightening of the valve packing. In either case, power to the motor will be automatically disconnected. When the motor cools to normal operating temperatures, power to the actuators is restored. Should the actuators breakdown, power can be shut off with SW7 and the valves rotated clockwise to the desired orientation with the manual override wheel.

3.5 Timer

Collection of time-sequenced samples and flushing of the sampling lines prior to the arrival of the operator can be achieved by setting the pump and power monitor to the "Timer" mode. A MaxiRex D four channel timer was used to energize the submersible pumps as per the pre-set timer schedules. There is a battery to maintain the timer schedules during line voltage interruptions. Instructions for setting the timer are provided in section 4.3.

3.6 Centrifuge Energization

Power to the Westfalia continuous flow centrifuge is monitored and controlled with several devices (Fig. 3.6A). The voltage metering relay (VMR) in the pump and power monitor prevents nuisance tripping of the thermal mechanical breakers located in the centrifuge motor switch in the event of low voltage. The VMR has upper and lower voltage limits which are adjusted separately. The lower trip limit was set at 205 V, which is below the normal line voltage and above the trip limit of the thermal-mechanical breakers. The upper limit is not critical in this application, and was set well above the normal line voltage. Operation of the VMR can be verified by holding the low voltage simulation switch (SW9) to the "ON" position. A voltage drop across a resistive shunt yields a simulated line voltage in the range of 175 to 185 volts. As a result, power to the centrifuge is momentarily disconnected. The low voltage indicator lamp (L5) can also be used to verify the function of the low voltage circuitry when the centrifuge is not operating.

The remote centrifuge switch (DPST, 30A) is mounted in a Scepter splash-proof receptacle box, equipped with a switch-isolating cover plate. It controls power to the centrifuge receptacle (Arktite NR332). The receptacle has three recessed poles with grounding contacts that make-first and break-last for safety even when contact is broken under full load. An 8 m length of 10/3 type SO cable was used to connect the Arktite plug (NPJ3383) to the centrifuge motor switch (Allan-Bradley).

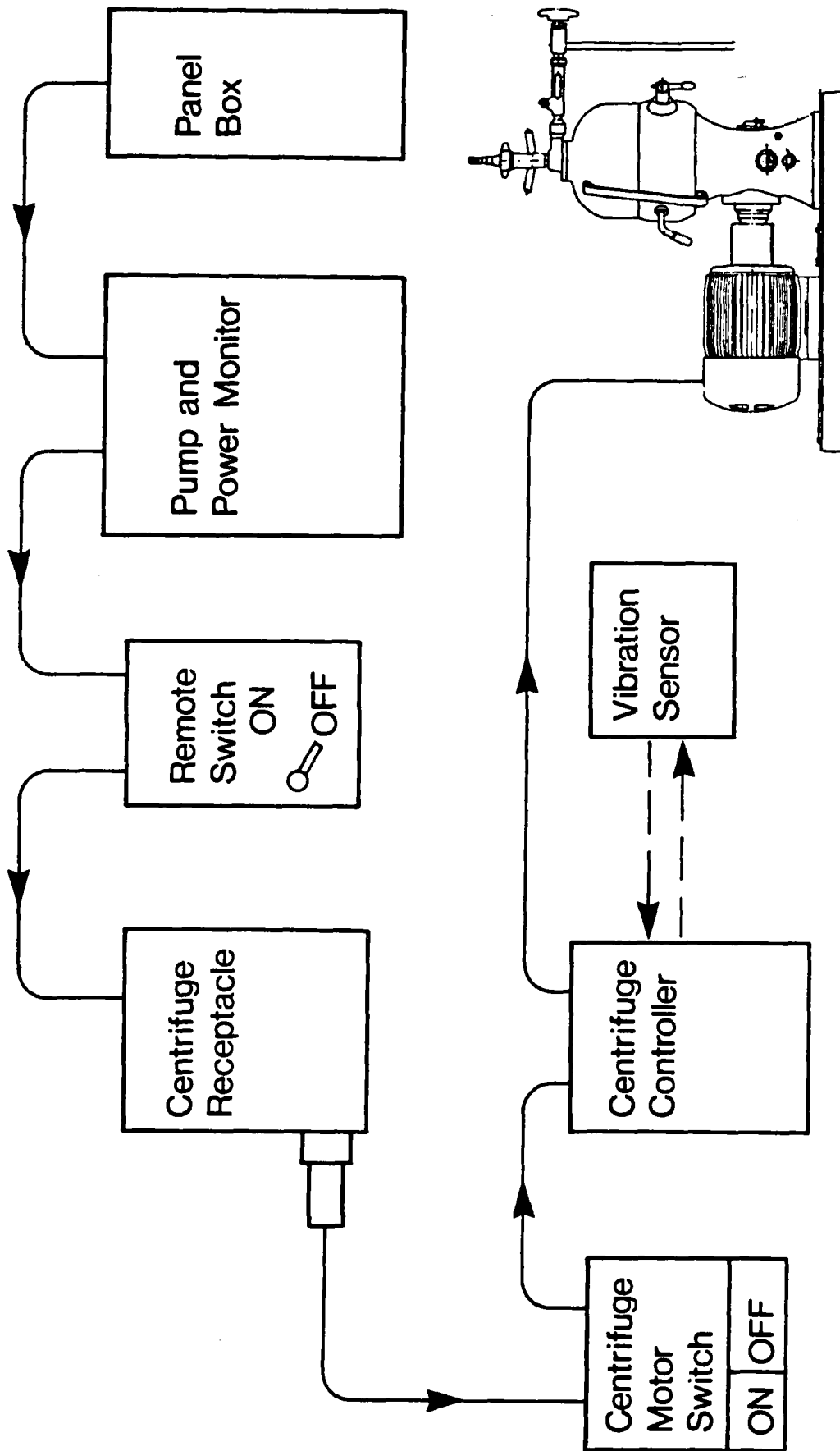


Figure 3.6A Power routing to the Westfalia centrifuge

The motor switch is equipped with thermal-mechanical breakers which prevent motor burnout in the event of excessive current draw. The particular breaker employed should have a cutoff which is no more than 1.5 amps above the operating current. The centrifuge motor switch and controller are mounted on the centrifuge base plate with a single welded bracket, whereas the vibration sensor is mounted directly to the centrifuge gear chamber cover with a machined bracket. Specification and operation of these components are presented in sections 3.7, 3.8 and 3.9.

3.7 Centrifuge Controller

The centrifuge controller is housed in a Hammond panel box 1414PH; the circuitry and specific components are shown in Figure 3.7A and Table 3.7A, respectively. The controller provides power to the vibration sensor and carries out the alarm and shut-down functions as signalled by the sensor; contacts are on terminal block TB6. The Sonalert alarm provides a 95 db signal in the event of a minor vibration. The alarm can be shut off by the operator with switch (SW10), however, the warning lamp (L6) will remain on through the entire run as a reminder that the pre-set vibration level was exceeded. In the event of a major vibration, contacts TB6-5 and -6 will open, releasing relay 6, thus cancelling power to the centrifuge and the signal to the pump and power monitor for energization of the submersible pump. When the cause of the vibration is corrected, power to the controller must be switched off to re-set the vibration sensor before power can be re-applied to the centrifuge.

During the run-up phase, the alarm and shutdown functions are locked out; the period of lock-out is controlled by a time-delay relay (TD3). The relay is typically set at 40 seconds which allows for lower overall vibration level settings and thus greater protection for the centrifuge while it is run unattended. This particular relay (NCC, series S1) is designed such that the alarm and shutdown functions would remain operational in the event of a relay failure as shown in Figure 3.7B.

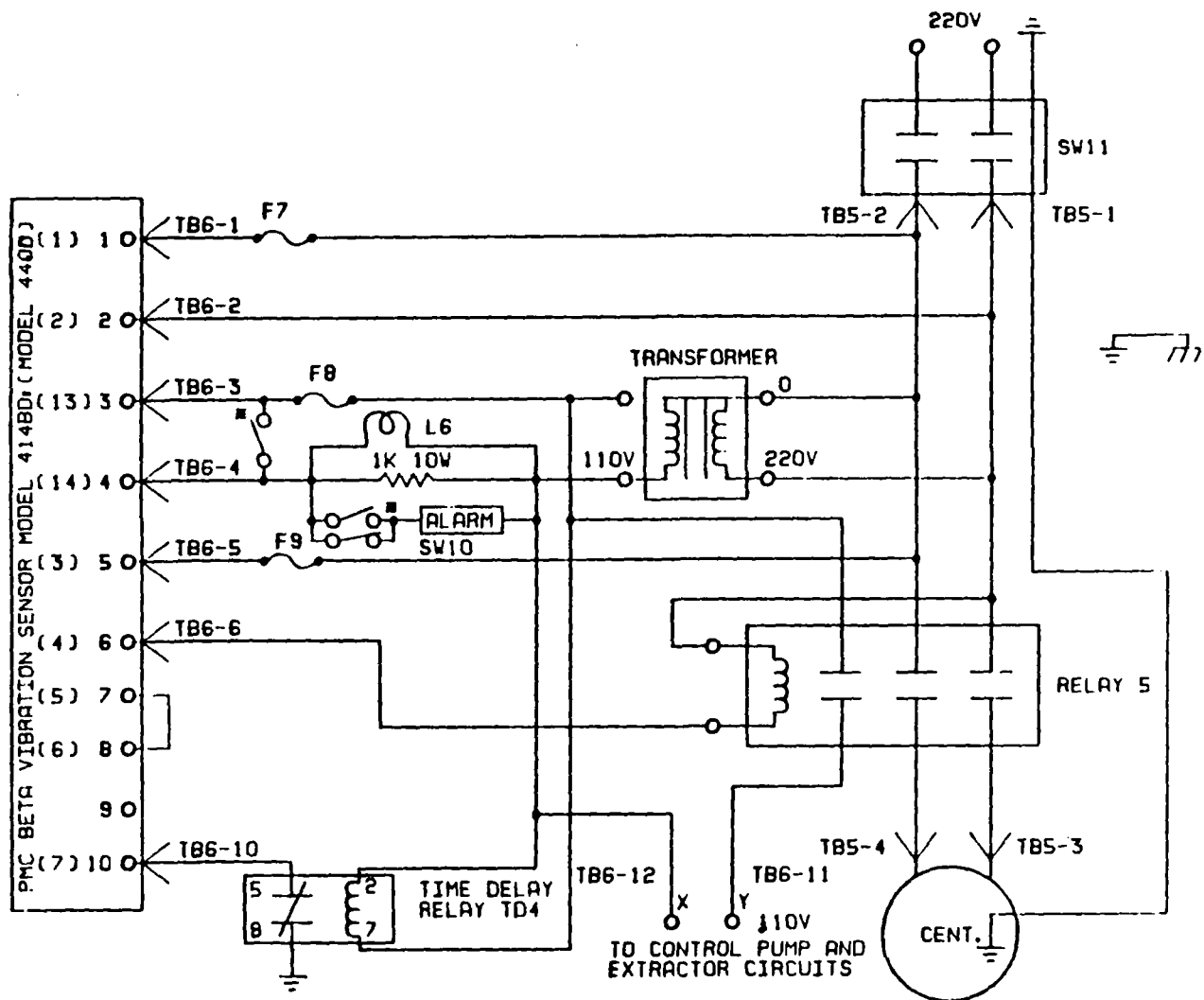
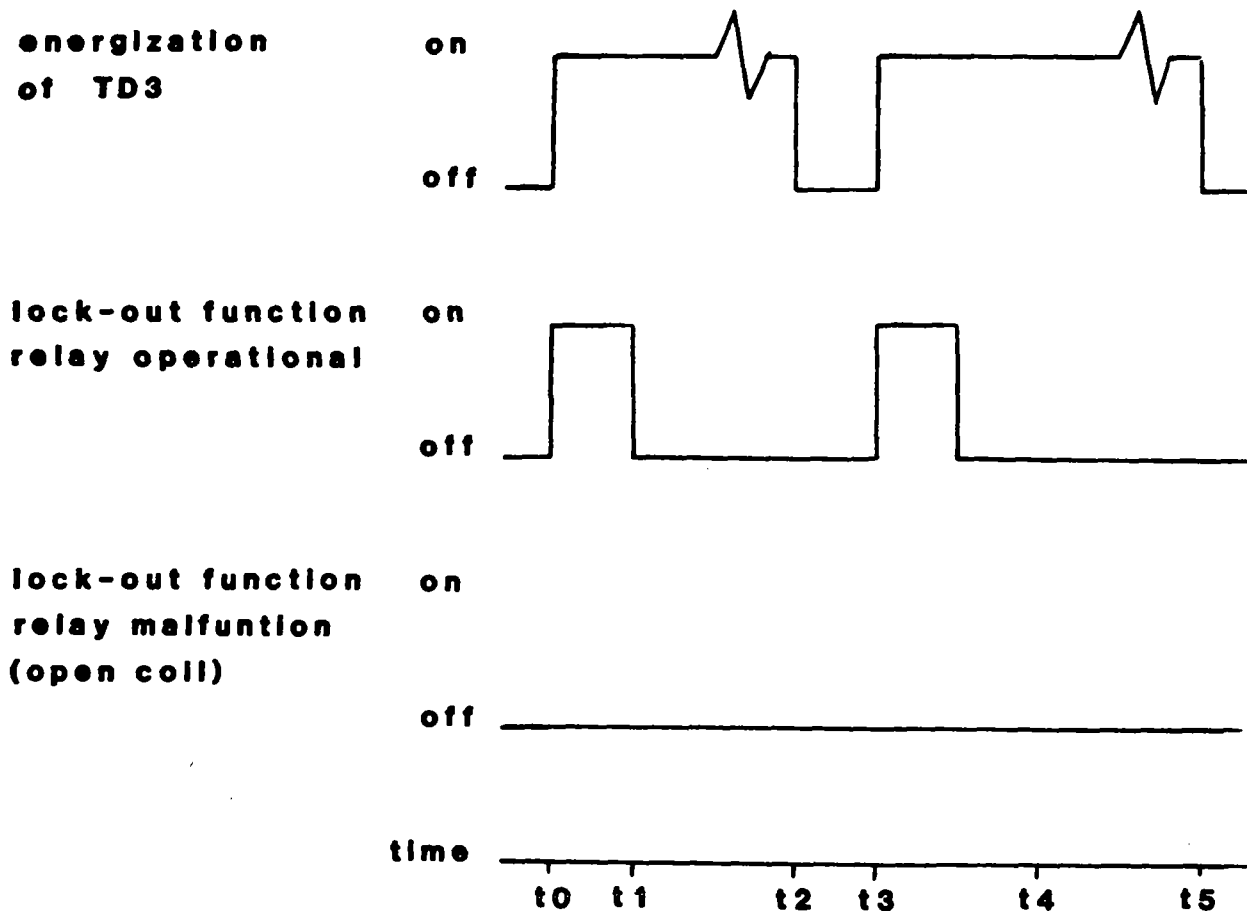


Figure 3.7A

Centrifuge controller circuitry

TABLE 3.7A. A Listing of Centrifuge Controller Components.

Component Numbers	Type
Alarm	Mallory, Sonalert, 30-120V, 2900 HZ
Fuse 6,7 & 8	Buss, glass 1 1/4", 250V, 5A
Fuse 9	Buss, glass 1 1/4", 250V, 1/4A
Lamp 6	base, Dialight, 125-0408-11-143 lense, Dialight, 125-0408, red bulb, Spectro, neon, Ne-51, 110V
Relay 6	PB, PM17AY, 220V, 30A
Switch 5	JBT, 5231L, on-Off-on* DP, 110, 20A
Switch boot	GC, bat handle toggle, 35-060
TB-5	Cinch-Jones, 4-142, size terminal block
TB-6	Cinch-Jones, 12-142, size terminal block
TD-Relay 3	NCC, S1K-00120-461, 120V, 10A
Transformer	Hammond, 170, auto-transformer, 230 to 115V, 50VA
Connector	Amphenol, 97-3102A-145-2P



where t_0 = centrifuge start-up
 t_1 = time delay lapses (40 s) following start-up
 t_2 = power outage
 t_3 = power resumption, centrifuge restarts automatically
 t_4 = time delay lapses (40 s) following start-up
 t_5 = end of centrifuge run

Figure 3.7B

Operational characteristics of the lock-out function
as controlled by the time-delay relay TD3

3.8 Vibration Sensor

A PMC/BETA vibration sensor (440D) was mounted on the gear box cover to monitor the condition of the centrifuge. The sensor has trip limits for shutdown and alarm functions. The shutdown trip limit is set in in.s^{-1} , whereas the alarm trip limit is calibrated as a percentage of shutdown (Fig. 3.8A). Both trip limits have a time-delay window which can be set within the range of 2 to 15 seconds with an adjustable screw located below the shutdown and alarm knobs. The delays were set at 3 seconds to provide a prompt response should destructive vibration arise.

3.9 Centrifuge Motor

The Westfalia centrifuge is driven by a repulsion-start/induction-run 230 V Baldor motor (R-1423) mounted on a cast frame (184). This totally enclosed, fan cooled motor rotates at 1745 rpm and is rated at 1.5 HP. It operates on a single phase source controlled by the centrifuge controller via contacts TB5-3 and -4. The motor must be initially set-up to run with a clockwise rotation; it is connected to the centrifuge with a Lovejoy coupling.

3.10 Flow Transducer

Flow rates through the centrifuge are measured downstream of the centrifuge outlet. A Flow Technology Series II FT0 turbine flow transducer utilizes a bladed rotor to generate the flow signal. The converted transducer output is digitally displayed in L min^{-1} and totalized with a Flow Technology Series III meter. The unit is calibrated in the range of 0 to 6 L min^{-1} and is accurate to $\pm 1\%$ full scale.

For flow rates in the mid to upper flow meter range the transducer should be aligned in an horizontal position. If the centrifuge is used for clarifying water at feed of rates of 1 L min^{-1} or less, the transducer should be aligned in a vertical position with the direction of the flow arrow pointing downwards. In such an application, a throttle valve is required at the outlet side to control back pressure.

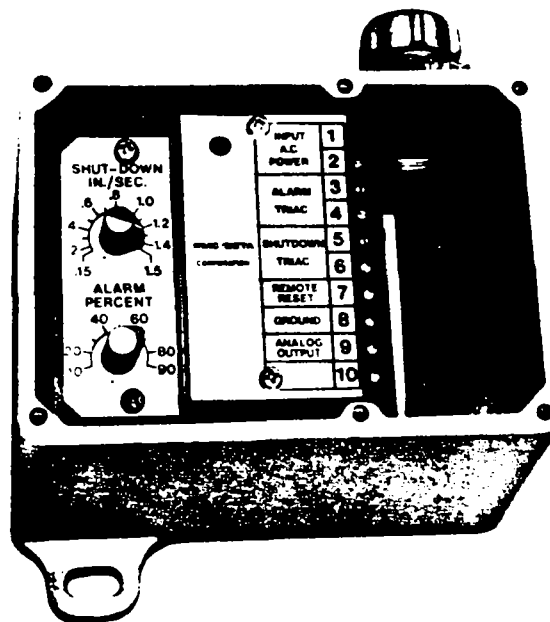


Figure 3.8A

Vibration sensor that is mounted on the Westfalia continuous flow centrifuge

APPENDIX 4 - Set-up and Calibration

4.1 Time - delay relays

4.2 Flow sensor

4.3 Timer

4.4 Vibration sensor

APPENDIX 4 - Set-up and Calibration

4.1 Time-delay Relays

The pump and power monitor is equipped with two NCC T1 series time-delay relays. These relays are precise with a repeatability of $\pm 1\%$, however the time-delay settings printed on the relay may not be accurate. It is advisable that the devices be checked prior to use to ensure proper sequencing of the monitor functions.

The time-delay relays can be calibrated using the timer function as follows:

1. Insert the time-delay relay in the relay 1 socket,
2. Set the mode selector to the "Timer" position,
3. Set SW1 to the "ON" position,
4. Adjust the time-delay control knob to the appropriate position.
5. Set the timer plug in an AC receptacle, and time with a stopwatch until lamp 1 is illuminated,
6. Remove timer plug from receptacle and repeat steps 4 and 5 as required.

4.2 Flow Sensor

The flow sensor is a switching device which controls a signal to the pump and power monitor for use of the automatic back-up pump function. With the centrifuge running, the simulation valve (V4) is throttled to yield a flow of 4.5 L min^{-1} in Line 1. The 0.625-in. internal nut is then slowly adjusted until the lamp on the sensor cover is illuminated.

4.3 Timer

The MaxiRex D4 four-channel timer used to maintain proper sequencing of the continuous extractor functions, can be programmed for up to 62 schedules in a given week, with each requiring an on-time and an off-time. The time and date must be set prior to entering the required schedules; instructions for entering the schedules are provided below.

SETTING THE CLOCK

To set the correct time:

- ### NOTE

1. The day(s) selected do not have to be the same for both the On-Time and Off-Time.
2. Off-Time may be programmed first.
3. The channels controlled will be the channels selected when both an On and Off-Time are showing and **Program** is pressed.
4. Errors can be corrected easily prior to pressing **Program** by repeating Steps 1 and/or 2 above.
5. The **Clear** key in the TEST block can be used to cancel selected entries (day, time or channel) or an entire schedule.
6. Schedules will not **Program** if errors exist, i.e., day(s) are not selected, or On-Time is the same as Off-Time on the same day(s) of the week.

ENTERING SCHEDULES

1. To set an On-Time:

- Press the **[I]** key. I is an International Symbol for On. The I marker will appear beside an upper time display of 0:0000.
- Program the On-Time using the **[h]**, **[m]**, and **[s]** buttons.
Note: The display will revert to current time count after 45 seconds if no buttons are pressed.
- Select On-Day(s), i.e. the day(s) of the week on which to execute the On-Time. Pressing the **[d1-7]** key advances the day marker from 1 to 7 and back to 1. For each and every day to be selected, press the **[Q]** key when the marker is over the desired day. **[Q]** must be pressed at least once, and must be the last key pushed when selecting day(s).
- Select channel(s) to execute this On-Time command. Pressing the **[S1-4]** key advances the marker from S1 to S4 and back to S1. S markers on indicate output relay energised. For each and every channel to use this On-Time command, press the **[Q]** key. **[Q]** must be pressed at least once, and must be the last key pushed when selecting channel (s).

2. To Set an Off-Time:

- Press the **[O]** key. O is an International Symbol for Off. The O marker will appear beside a lower time display of 0:0000.
 - Program the Off-Time and Off-Day(s) as in On-Time programming steps 1. b) and 1. c) above. Pulse operation of the channel can be achieved by programming the Off-Time one second after the On-Time.
 - If the wrong channels were selected in 1. d) above, this can be corrected using the 1. d) procedure.
3. Enter the schedule by pressing **[Program]**. The display will return to present Time.
4. Repeat for all other time schedules.

OPERATION:

- When **[Program]** is pressed, the relays will be energized according to the appropriate program. Time events scheduled up to seven days prior will be executed as required.
- The MaxiRex D4 continues to operate its channels in TEST mode.
- Old schedules continue to be executed while the MaxiRex D4 is in SET mode until the **[Program]** key is pressed. (Note that programs are edited in TEST mode using SET mode keys, so programming rules apply.)
- When two or more channels are scheduled simultaneously, there is a millisecond delay between the operation of each relay; this is caused by the sequential

PROGRAM REVIEW

Always verify all program entries before leaving the site. The TEST group of buttons is provided for this purpose.

- Press TEST **[S1-4]**. The I, O, S1 markers and On/Off-Time colons will be displayed. Programs are recalled from memory by channel number.
- Press **[Check]**. Each schedule will be displayed in the order it was entered. If another channel, say S4, was selected to operate with S1, both S1 and S4 markers will come on for the schedule. This same schedule will also be displayed when reviewing S4 programs.
- When the display shows I 0:0000 and O 00:0000, all channel entries have been seen.
- Press TEST **[S1-4]** to advance to channel S2, and repeat steps 2 to 4 preceding.
- To return to Run mode, press **[Program]**.

EDITING DATA

- While programming in SET mode, **[Clear]** will cancel:
 - Times, if used with **[I]** and **[O]**.
 - Days, if used with **[d1-7]**.
 - Channels, if used with SET **[S1-4]**.
- When reviewing programs in TEST mode, **[Clear]** will CANCEL THE DISPLAYED SCHEDULE from memory.
- When reviewing programs in TEST mode, a given schedule can be re-SET by using:
 - [I]** plus **[h]**, **[m]**, **[s]** to change On-Times.
 - [O]** plus **[h]**, **[m]**, **[s]** to change Off-Times.
 - [I]** plus **[d1-7]**, **[Q]** to change On-Days.
 - [O]** plus **[d1-7]**, **[Q]** to change Off-Days.
 - [I]** or **[O]** plus SET **[S1-4]**, **[Q]** to change the channel(s) programmed.
- To completely restart the entire programming sequence, press the recessed **[Reset]** button with a pen or pencil tip.

N.B.: **[Reset]** completely clears the memory; it "wipes out" clock time, days, and all schedules.

operation of the micro-processor. This is not significant for most applications.

- The Override slide switches provide channel-by-channel selection of relay operation mode:
 - I** signifies constant-on, i.e., relay energised. The S markers will be turned on in the LCD display to indicate override-on.
 - Progr** signifies automatic operation. The S markers and relays will turn on according to the program schedule. When relays activate and de-activate, an audible "click" can be heard.
 - O** signifies constant-off, i.e., relay de-energised. The S markers will be turned off in the LCD display.

4.4 Vibration Sensor

The alarm and shutdown trip limits were set with the centrifuge running at operating speed. With a sample feed rate of 6 L min^{-1} and the alarm set at 50%, the shutdown level was slowly decreased from the maximum vibration setting of 1.5 in. s^{-1} until the alarm sounded. This step was repeated several times to accurately establish the threshold. The shutdown setting was then doubled to avoid nuisance tripping of both the alarm and shutdown functions. The alarm trip remained at 50% of shutdown to provide a means of identifying minor vibration, and changing conditions of the bowl and centrifuge. This allows the operator to schedule corrective maintenance at a time that does not interrupt the sampling schedule.

The alarm and shutdown functions are locked out during the centrifuge run-up phase. The time delay is set with TD3 and should be calibrated prior to use following the procedure outlined in section 4.1. It should be noted, however, that L1 will be illuminated immediately and shut off when the time delay period lapses (step 5).

APPENDIX 5 - System Operation

5.1 Line flushing

5.2 Collection of raw water samples

5.3 Collection of suspended sediment and
complementary water fractions

APPENDIX 5 - System Operation

This section provides specific operating instructions for flushing the intake lines and for the collection of raw water, centrifuged water and/or suspended sediment.

5.1 Line Flushing

All three intake lines can be flushed with or without the operator present by performing the procedures as follows:

A. Flushing the lines - operator present

1. Set mode selector to "Manual".
2. Advance valves V1 and V2 with the valve advance switch, and turn off power to the valve actuators (SW7).
3. Set switches SWP1, SWP2, and SWP3 to the "ON" position.
4. Open the valves V3 and V4.

B. Flushing the lines - unattended

1. Enter the appropriate flushing schedule on the timer set mode selector to the "Timer" position and follow steps 2, 3 and 4 as shown in section 5.1A.

It is advisable that only the pumps to be used in the sampling program be flushed on a regular basis. The submersible pump motors are completely sealed, and do not deteriorate if they are not used for an extended period. Occasional use, however, may prevent clogging of the intake wands.

5.2 Collection of Raw Water Samples

Water samples may be collected by the operator or with a time sequenced sampler as follows:

A. Sampling by operator

1. Set mode selector to "Manual" mode.
2. Set switch SWP3 to the "ON" position.
3. Collect samples from line three by throttling valve V3.

B. Sample collection with a time-sequenced sampler

1. With the sampler attached to line three, set the mode selector to the "Timer" mode.
2. Enter the appropriate sampling schedule on the timer.
3. Set switch SWP3 to the "ON" position and open valve V3.

C. Sample collection with a time-sequenced sampler while the continuous flow centrifuge is operating

1. With the sampler attached to line three, set the internal timer switch to the "ON" position, and follow steps 2 and 3 in section 5.2 B.

5.3 Collection of Suspended Sediment and Complementary Water Fractions

Procedures for preparing the centrifuge bowl, centrifuge start-up, sample collection and centrifuge shutdown are provided below:

A. Preparation and assembly of the four-chamber centrifuge bowl

1. After the sediment has been scraped from the bowl, immerse all components (except the bowl bottom 25l) in a warm water-soap solution.
2. Brush off any residual sediment and rinse with copious amount of water.
3. Rinse components with acetone followed by hexane or petroleum ether, and let air dry.

4. Wipe silicone grease off the bottom of bowl 251 and brass bushing.
5. Wash inner surface of bowl 251 without immersion using a warm water-soap solution; complete bowl cleaning as in steps 2 and 3.
6. Apply "Teflon" spray to the threaded surfaces of the lock-rings (258 and 260) and air dry. Do not apply this spray to threads on the bowl.
7. Assemble bowl components in the order shown in Figure 5.3A.
8. Set vane insert 263 into bowl bottom and rotate until arresting pin snaps into groove in the bowl bottom.
9. Set bowl insert 252, 253, and 255 on vane with the arresting pins engaged in corresponding insert grooves.
10. Set bowl top 259 on bowl bottom such that the arresting cam is engaged into the bowl top groove.
11. Slide bowl lock-ring 260 over the bowl top and thread into the bowl bottom.
12. Insert feed tube 70b, centripetal pump 70a and pump chamber cover in the bowl top.
13. Secure pump assembly with the pump chamber lock ring 258.
14. Attach handle connection piece to the feed tube for ease of transport and cover the opening in the handle connection piece with solvent washed aluminum foil.

Note: It is imperative that the serialized bowl components are not interchanged with parts of a different bowl, as each bowl is balanced individually. Inspection of the "0" marks on internal components is a check to ensure that bowl is being aligned and assembled properly.

B. Centrifuge start-up

1. Check to ensure that the centrifuge remote switch and the centrifuge motor switch are in the "OFF" position.
2. Check that oil in the gear chamber is slightly above the half-way mark in the site glass. Remove spring clamps and hood.
3. Remove spindle cap and wipe off grease and residue from both the spindle and spindle cap.

4. Lubricate spindle with silicon grease, slide spindle cap onto the spindle and depress cap to test spring action.
5. If cap motion is restrictive, repeat step 3. Smooth spindle surface with emery cloth and clean. Repeat step 4.
6. Check brass bushing on the bottom of the bowl to ensure that it is clean, lubricate bushing with silicon grease.
7. Align oval locking depressions with the spindle slot, set bowl on the spindle and lower straight down.
8. Check that locking screws are centred in the locking depressions, if not re-set bowl.
9. Tighten lock screws evenly.
10. Remove aluminum foil from handle connection piece, and unscrew handle from the feed tube.
11. Tighten the bowl lock ring, with the large ring wrench by tapping it a maximum of 3 times in a counterclockwise rotation with a rubber mallet. The "0" marks seldom line-up perfectly.
12. Tighten the centripetal pump lock ring with the small ring wrench as indicated in step 11.
13. Loosen the lock screws and rotate the bowl to ensure free rotation.
14. Set the hood on the frame, secure with spring clamps and attach the handle connection piece to the protruding feed tube.
15. Hold the handle connection piece securely, insert the T-wrench in the handle and tighten by rotating the wrench in a counter-clockwise direction using modest torque.
16. Attach the centrifuge feed hose to the handle connection piece.
17. Set the mode selector to the "Manual" position, set SWP1 or SWP2 to the "ON" position.
18. Advance to V2 if pump 2 is employed.
19. Adjust the centrifuge feed pump for minimal flow; when a trickle of water appears at the centrifuge overflow, shut off the feed pump.
20. Set the centrifuge motor switch to the "Start" position and the mode selector to the "Centrifuge" position.
21. Turn on the flow meter and record the totalizer reading and time of day.

22. Start the centrifuge with the remote switch.
23. After the centrifuge has reached full operating speed and the raw water flow has stabilized, turn on the centrifuge feed pump and adjust for maximum flow rate to flush air out of the feed line.
24. Adjust the centrifuge feed pump for the desired rate.
25. Set the handle screw such that bubbles are barely present in the clarified water, and reconfirm the flow rate.

C. Centrifuge start-up procedures for extended sampling periods with the automatic pump back-up system deployed.

1. Follow steps 1 through 16 in section 5.3B.
2. Set the mode selector to the "Manual" position, set switches SWP1, SWP2 and the flow detector switch to the "ON" position.
3. Follow steps 19 through 25 in section 5.3B.

D. Centrifuge shut-down

1. Shut the centrifuge off with the remote switch and set the motor switch to the "Stop" position.
2. Record totalizer reading, date and time of day.
3. Shut off the centrifuge feed pump.
4. After the centrifuge has come to a complete stop, remove the centrifuge feed hose, handle connection piece, spring clamps and hood.
5. Tighten the lock screws evenly.
6. Loosen the centripetal pump lock ring with the small ring wrench by tapping it in a CLOCKWISE rotation with a rubber mallet.
7. Loosen the bowl lock ring with the large ring wrench as indicated in step 6.

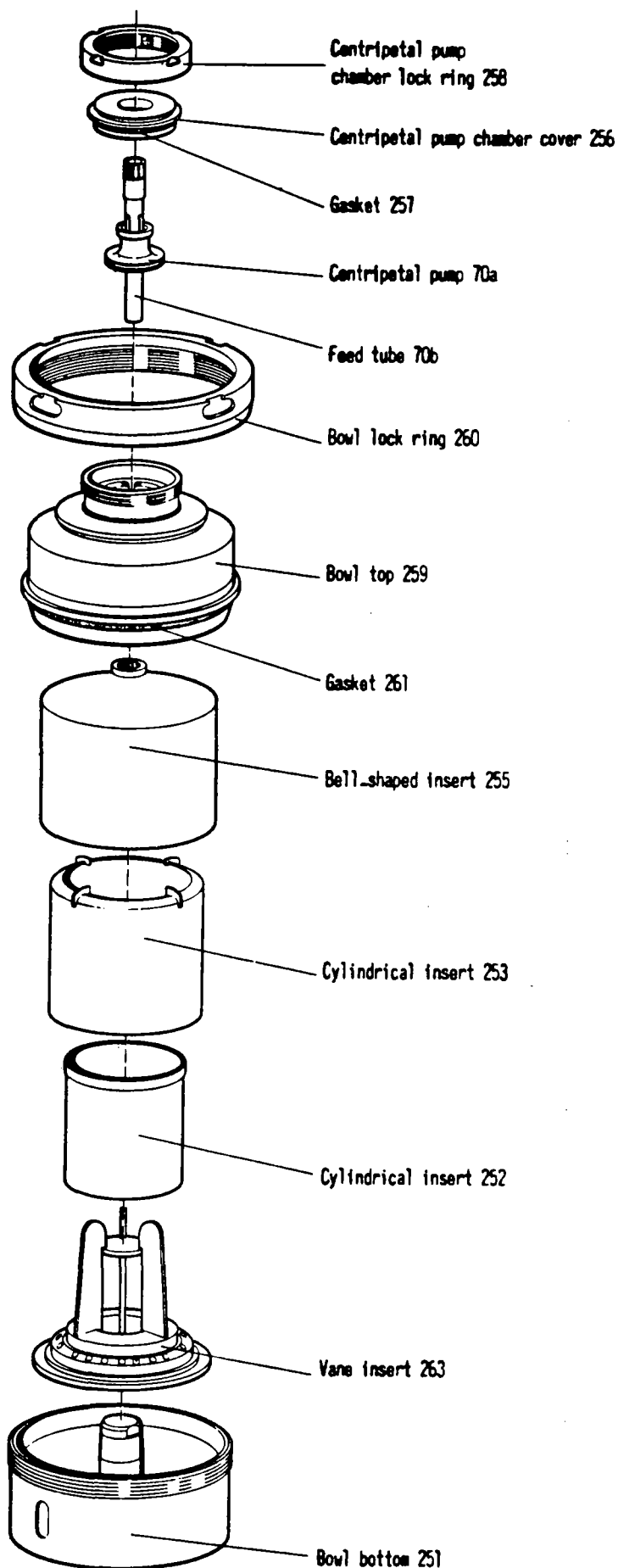


Figure 5.3A

Four chamber bowl assembly for Westfalia clarifier

8. Attach the handle connection piece to the feed tube, loosen the lock screws and remove bowl by lifting straight up.
9. Cover the handle connection piece with aluminum foil.
10. Remove spindle cap, clean spindle and lubricate with silicone grease. Place spindle cap back on the spindle.
11. Place hood on frame.

Note: The above procedures are recommended for flushing the intake lines and for the collection of water and suspended sediment samples. Several other methods of operation are possible, these are identified in Table 3.2B.

APPENDIX 6 - Inspection and Maintenance Troubleshooting and Servicing

6.1 Inspection of the intake and pumps

6.2 Maintenance of the sampling system

6.3 Troubleshooting system malfunction

6.4 Servicing submersible pumps

APPENDIX 6 - Inspection and Maintenance, Troubleshooting and Servicing

This section provides procedures and recommendations for inspecting, maintaining, troubleshooting and servicing the water delivery and sampling systems.

6.1 Inspection of the Intake and Pumps

The intake bundle located within the concrete intake pipe is completely protected from ice damage, but it is still possible that it may be affected by large debris entering the pipe. In addition, routine plant maintenance is carried out from time to time in the location of the low lift well, and these activities may result in accidental damage. The entire intake bundle should, therefore, be inspected annually by divers sometime during the month of December. This time period is most suitable because water requirements of the city are low, making it possible to stop flow in the intake pipe as required.

Water from the sample lines should be routinely tested for chlorine, because a leaking fitting on the inlet side of a submersible pump may result in the uptake of chlorinated water from the low lift well.

The tubing, fittings, adapters, pump heads, pump motor housings, electrical cords and electrical connectors are rated by the manufacturers as resistant to chlorine, however, it would be a good practice to inspect these underwater components periodically to ensure they are not deteriorating.

6.2 Maintenance of the Sampling System

The sampling system requires minimal maintenance. The strainer basket should be removed and inspected every week or two. With the strainer cover removed, the basket handle must be pinched-in to release the basket from a groove in the strainer body. Both the inner and outer surface of the strainer basket should be cleaned thoroughly with a brush.

The centrifuge gear box oil should be drained and replaced every 500 running hours with Westfalia SAE 30 centrifuge oil. The time period between oil changes should not exceed six months. To ensure the removal of most of the fine metallic particules, the centrifuge is drained immediately after a centrifuge run. With a hydraulic jack set under the centrifuge cart (in line with the gear box and near the back edge), the centrifuge is raised and tilted forward for maximum drainage. When drainage is complete the centrifuge is lowered and refilled with fresh oil. It is advisable that the centrifuge be run for several minutes, drained and then refilled for more complete removal of particulates. The centrifuge should be levelled with cedar shims placed under the centrifuge cart wheels.

Flow rate through the centrifuge should be verified with a graduated cylinder on a monthly basis. If the flow, as indicated by the flow meter, is significantly below the measured rate, carefully flush the flow transducer with water and ethanol to remove organic debris. Although the transducer has a rugged outer construction, its internal components are sensitive and fragile, and should be handled and cleaned with considerable care. The unit will be damaged if air is blown through; objects of any kind must not be inserted in the transducer.

The flow rate through the intake lines should be monitored on a regular basis. If a line becomes clogged, it should be back-flushed or purged with a nitrogen compressed gas cylinder as follows:

1. Unscrew union at strainer inlet and attach compressed gas line.
2. Set pressure at 50 PSI and open ball valve to purge line.
3. When gauge pressure drops off (usually after 1 minute) shut off gas and unscrew union connection; air will rush out of tubing.
4. Repeat steps 2 and 3 several times for effective purging.
5. Draw water through the purged line with a vacuum pump to remove air lock. It is important to note that residual air in the pumphead may cause the pump to cavitate and thus burn out in a manner of minutes.
6. Turn on the appropriate pump; repeat steps 1 through 5 if required.

6.3 Troubleshooting System Malfunction

This sub-section provides a guide for identifying and correcting malfunctions of the sampling system. The control devices, which include the pump and power monitor, actuator valves, flow sensor, and centrifuge controller, are equipped with indicator lamps. These lamps can be used to verify the circuitry and identify the faulty component(s). A listing of problems, probable causes and recommendations to resolve the problems are presented in Table 6.3A. Appropriate sections of the appendices should be reviewed where indicated as a first step in the troubleshooting process.

The Potter-Brumfield and NCC relays will not require frequent replacement as their life expectancy is over one million mechanical operations. If a relay or fuse fails, power should be shut off at the panel box prior to replacement.

6.4 Servicing Submersible Pumps

The submersible pumps are located in the low lift well (Fig. 1). Should they require servicing, the pump frame can be removed from the well with a hand winch that is fastened by bracketry to the screen room floor. Inspection and servicing of the pumps requires two individuals equipped with safety belts, and must be performed under direct supervision of plant personnel. The servicing procedure is as follows:

1. Attach safety belts to suitable anchor and slide hatch cover aside under supervision of plant personnel.
2. Tighten lifting cable by cranking on handle of hand winch.
3. Remove pump plug from wall receptacle.
4. Undo colour coded union couplings from each intake line; care should be taken not to lose the "O" rings.
5. Prevent the outlet bundle from falling in well during servicing procedures. If it does, lift it back to floor level with retrieval cable.

6. Raise frame to floor level while assistant holds it clear of well piping with support cable. Be certain that locking device on winch drum is engaging.
7. Raise pump frame above floor level and have assistant pull it onto sample room floor as winch cable is slackened.
8. Place pump plug in wall receptacle.
9. Test operation of motor of the pump being serviced by applying power for 2 seconds.
10. Remove pump plug from wall receptacle.
11. Unscrew sleeves of the appropriate colour coded underwater connector and pull plug apart.
12. Undo threaded union couplings on inlet and outlet adapter assemblies; care should be taken not to lose "O" rings.
13. Loosen gear clamps that hold pump motor and outlet wand.
14. Remove pump from frame.
15. Unscrew the seven machine screws from face of pump head, remove head and quad ring.
16. Inspect pump head; replace head, impeller and/or motor as required.
17. Dry pump head and motor bracket face.
18. Fill motor bracket groove with silicone grease, set quad ring in groove and grease exposed seal surface.
19. Fasten pump head to motor bracket by gradually tightening machine screws with firm and even pressure in a circular pattern until tight.
20. Grease face and thread of underwater connectors with silicon grease, push plug into receptacle and tighten sleeves with wrench using slight torque.
21. Place pump plug in wall receptacle.
22. Test operation of motor by applying power for 2 sec.
23. Remove pump plug from wall receptacle.
24. Set pump in pump frame and attach threaded union couplings on adapter assemblies.
25. Secure pump motor and outlet adapter assembly with gear clamps.
26. Lower pump frame into well while assistant guides it with support cable. Continue until frame hangs on support cable and lifting cable is slack. Ensure inlet bundle is submerged.

27. Reattach colour coded couplings on intake lines.
28. Place plug in receptacle.
29. Draw water through serviced line into a water trap with an oilless vacuum pump to remove air locks. Vacuum is connected to line 1 and 2 at the strainer inlet; connection to line 3 is direct.
30. Repeat step 29 three times to ensure there is no air trapped in pump head.
31. Apply vacuum to line and turn on pump switch. As water nears top of flask, remove flask. If flow stops, immediately shut off pump and repeat step 30. If flow continues, allow pump to operate for several minutes to purge line of air.
32. Repeat steps 29-31 for the remaining two lines.
33. Close hatch cover ensuring cables and bundle are in their respective notches. Protective covering for the outlet bundle must be at floor level to prevent possible chaffing.

TABLE 6.3A. An Outline of Procedures for Troubleshooting System Malfunctions.

Problem	Probable Cause(s)	What To Do
No flow Timer mode only	-timer malfunction -relay failure	-verify timer schedules -change relay R-1
No flow Centrifuge mode only	-relay failure	-change relay TD-1
No flow Manual mode	-line clogged -pump failure -unknown	-back flush, refer to Sec. 6.2 -refer to Sec. 6.4 -refer to Fig. 6.3A
Valves will not rotate	-repeated rotation (overheated) -valve packing too tight (overheated)	-allow motor to cool, see 3.4 -loosen valve packing, allow to cool, refer to Sec. 3.4
Back-up pump malfunction	-incorrect flow sensor setting -relay failure	-adjust trip limit, refer to Sec. 3.3 -change relays R2, R3 and/or TD2
Low voltage circuit malfunction	-voltage metering relay failure -fuse blown	-change VM relay -change fuse F6
Centrifuge inoperative (motor running)	-coupling disengaged -damage to worm-wheel	-engage coupling -to be serviced by machinist
Centrifuge motor inoperative	-electrical fault	-refer to Fig. 6.3B
Centrifuge alarm or shutdown	-excessive vibration	-refer to Sec. 3.8
Centrifuge alarm test malfunction	-fuse blown	-change fuse F6 and/or F10

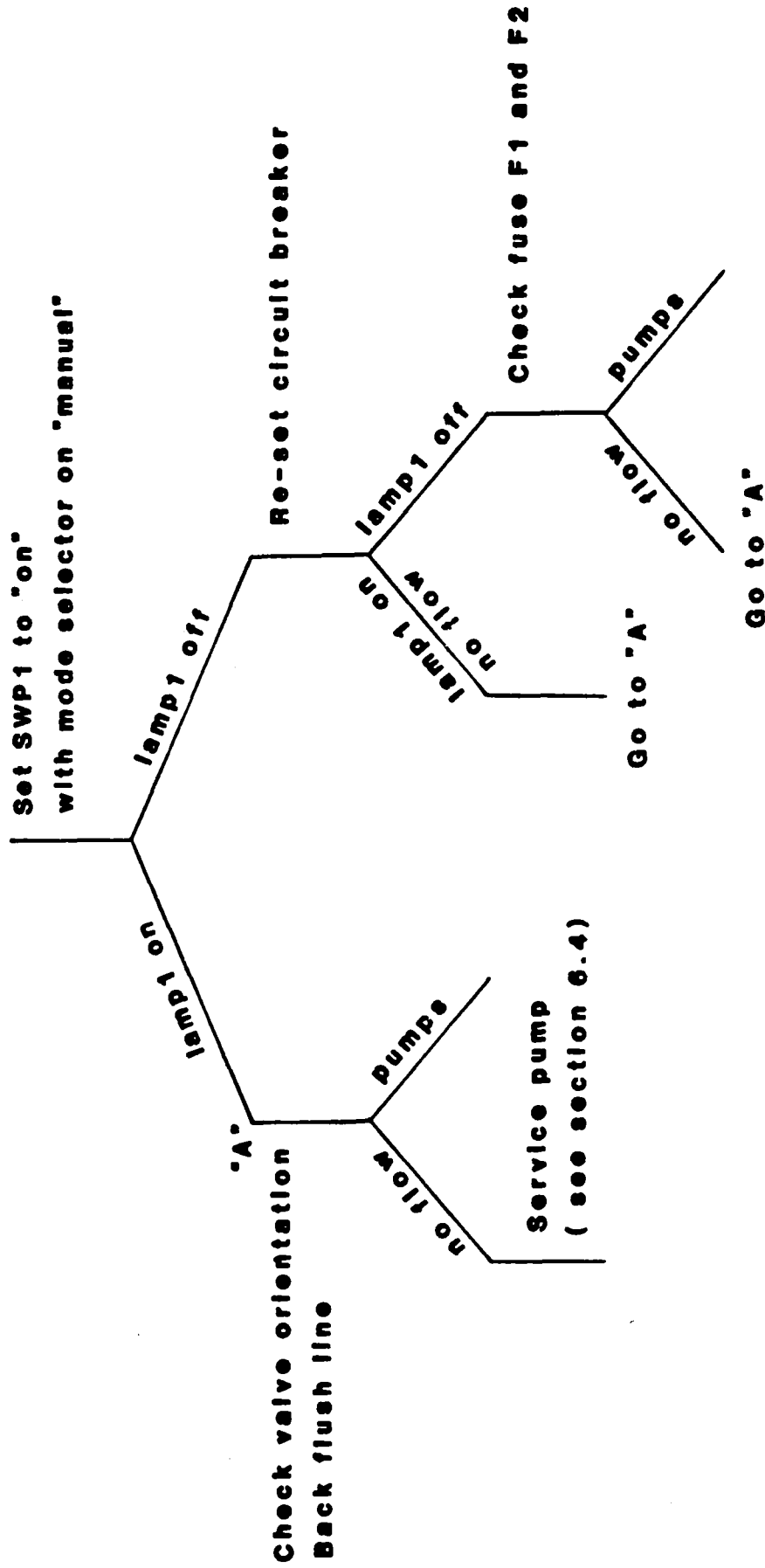


Figure 6.3A Procedures for troubleshooting a no-flow condition in line 1

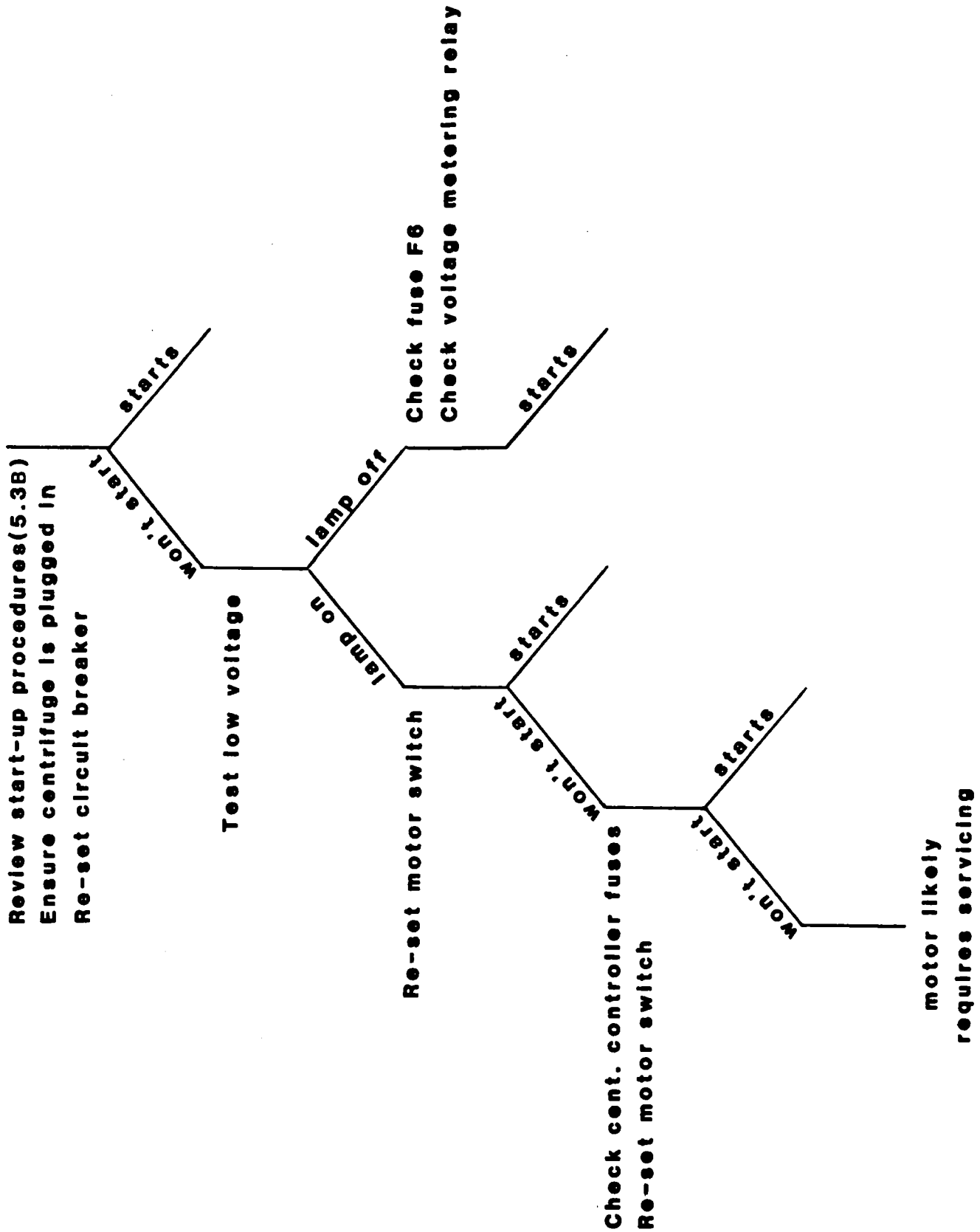


Figure 6.3B Procedures for troubleshooting failure of centrifuge start-up

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