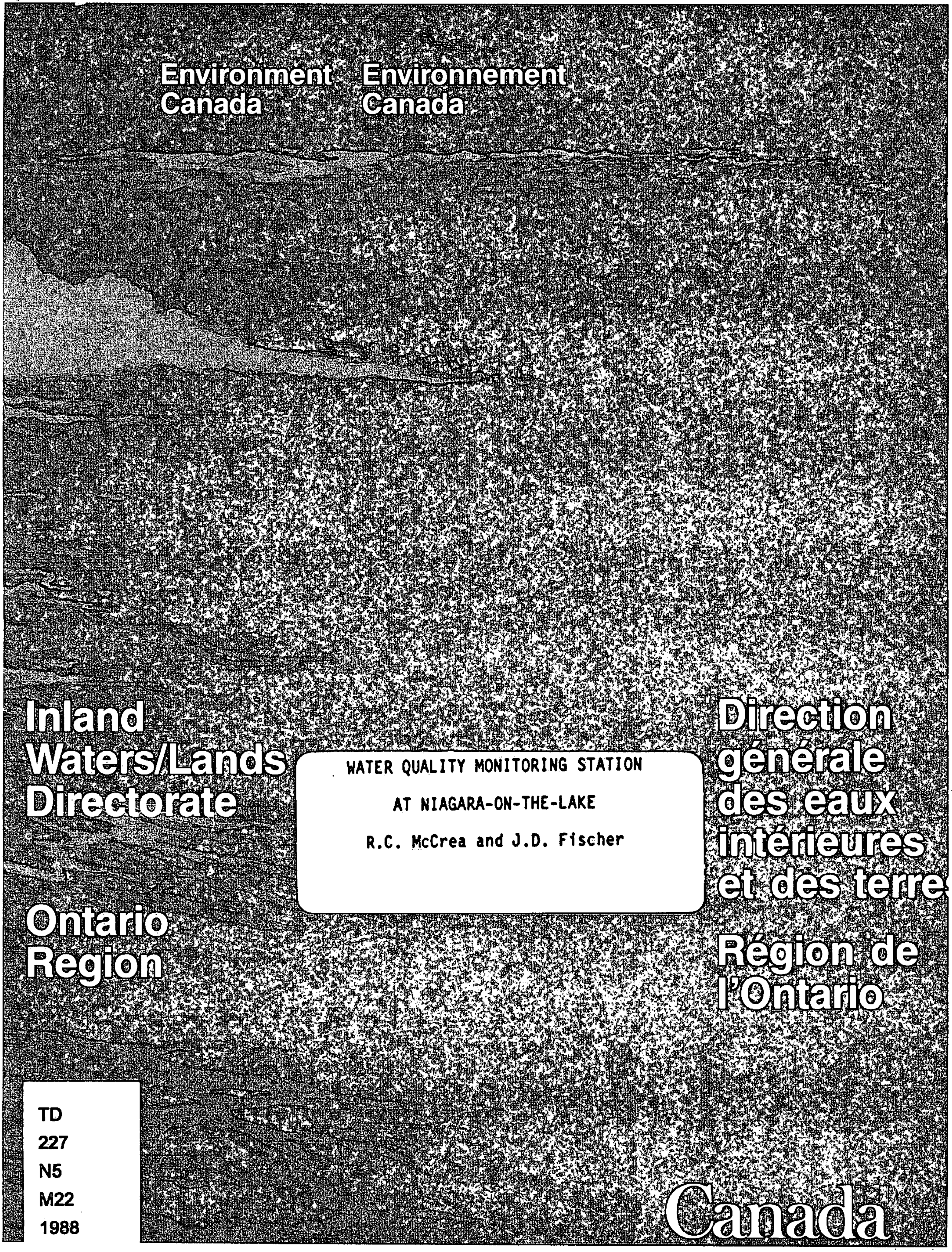

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WATER QUALITY MONITORING STATION AT NIAGARA-ON-THE-LAKE

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Inland Waters/Lands Directorate

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Direction générale des eaux intérieures et des terres

Région de l'Ontario

Canada

DESIGN AND OPERATION OF A MULTIPLE-INTAKE WATER QUALITY MONITORING STATION AT NIAGARA-ON-THE-LAKE

R.C. McCrea and J.D. Fischer

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Introduction

A triple-line water intake system was installed at the Water Quality Branch-Ontario Region monitoring station at Niagara-on-the-Lake (NOTL) in June 1986. This work was carried out as part of an experiment to assess the feasability of continuous time-integrated sampling and as a general upgrade to the existing system. The intake was setup a few metres downstream of the existing intake (Kuntz et al, 1982) to effectively sample the same water.

The sampling system is housed in a laboratory trailer located at the abandoned NOTL water filtration plant. It is equipped with a Westfalia continuous flow centrifuge for the collection of suspended sediment. The centrifuge supplies clarified water to a continuous flow extractor designed to isolate and integrate organic contaminants over a 7-day period. This extraction system has a daily solvent dump and refill cycle to maximize the recovery efficiency; a complete description is presented in McCrea et al, 1987. 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

A stainless steel cylindrically-shaped intake cage was installed 50 m from the west shore of the Niagara River adjacent to the abandoned NOTL water filtration plant. It was suspended 6 m above the river bed with a sub-surface float and anchored with a 340 kg railway wheel (Fig. 1). At the time of installation, the water depth and elevation were 13 m and 75.2 m, respectively (Lake Ontario, International Great Lakes Datum).

The intake cage supports and protects three 1.5-in. natural polypropylene intake wands[1]. Each wand has a total of one hundred 6 mm holes drilled along their 0.5 m length with a combined cross-sectional area that is 10 times greater than the intake tubing. The wands do not reduce the pumping rate, yet serve as a coarse pre-screen to prevent debris from clogging the intake lines or damaging the pumps. The inside surface of the wands has a machined taper which yields a smooth flow pattern and optimizes the pumping rate.

The three 0.75-in. natural polyethylene lines were attached to C-type brackets on the intake cage and secured with gear clamps. The end of each line was connected to an intake wand; a description of the specific couplings and assemblies is provided in Appendix 1. The intake bundle extending from the cage was sheathed in reinforced neoprene hose. It was secured to a rubber-sheathed 0.25-in. stainless-steel anchor cable, at 0.5 m intervals, from the cage to a point 2 m above the river bed. The bundle formed a gentle curve, at the river bed, to minimize stress fatigue of the intake lines and to allow the bundle to be bent back and rebound intact should it be struck by submerged debris. To minimize the possibility of damage, which may arise from debris travelling along the river bed and scouring due to ice jams common in this reach of the river, the bundle was entrenched in 0.5 m of sand on the side slope and encased in the filtration plant intake pipe that extends from a point 25 m offshore to the stilling well.

[1] - It should be noted that all wand, tubing and adapter dimensions are internal (ID) unless stated otherwise.

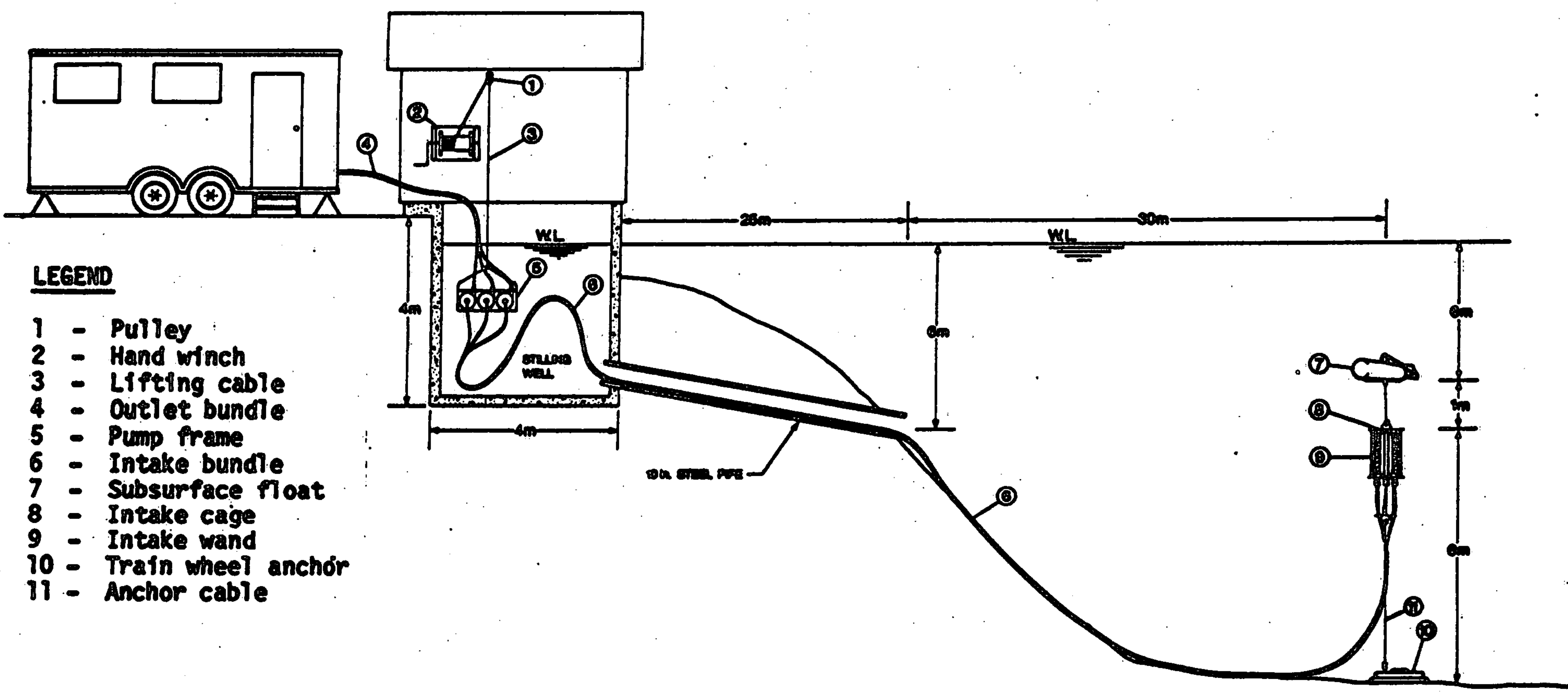

Figure 1. Water delivery system at Niagara-on-the-Lake

The intake lines were attached to the inlet side of three submersible pumps with inlet adapter assemblies. These tapered adapters were specifically designed for attachment of the 0.75-in. intake tubing to the 1.0-in. NPT pump inlets; they prevent pump cavatation which is often experienced when intake tubing, having a smaller ID than the pump inlet, is directly attached. This intake configuration optimizes in-line velocity, and therefore, reduces line clogging and the loss of suspended sediment from the sample water.

The pumps were fastened with gear clamps to an aluminum pump frame which was suspended by a steel cable in the stilling well. A hand winch, mounted on the shed wall, allows the operator to raise the pumps out of the well should servicing be required. For ease of pump replacement, power to the pumps was supplied via threaded underwater connectors.

The pump outlet bundle consists of three 0.75-in. lines and power cords. The lines were attached to the 0.5-in. NPT pump outlets with outlet adapter assemblies. These assemblies have threaded union couplings which facilitate pump replacement. The 0.75-in. outlet tubing reduces line drag as compared to the standard 0.5-in. pump outlet tubing and does not create a sedimentation problem. The flow rate, as measured at the outlet of the water delivery system, was 20 L min^{-1} from each of the three lines.

The outlet bundle, complete with power cords and a heat tracing cable, was run from the stilling well to the lab trailer. The outdoors portion of the bundle was insulated with a closed cell natural rubber foam and wrapped with a heat shrink tape for abrasion resistance.

Sampling System

In the trailer, the three pump outlet lines were plumbed to the sampling system to provide a source of water for the continuous flow centrifuge (pumps 1 and 2) and water for discrete sampling by the operator or collection with an automatic sampler (pump 3). 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 (Fig. 2). Details of the fitting used are outlined in Appendix 2 .

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 which allows the operator to simulate failure of pump 1 by diverting water from line 1 to 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 1 and the shunt line 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. This orientation was necessary 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 filter assembly. The filter assembly utilized threaded unions on the inlet and outlet side to permit easy removal from the system if required.

Raw water passes through a filter basket, which contains several hundred 2 mm holes, to provide a source of raw water to the Westfalia centrifuge that is free of course debris. The basket has sufficient capacity to prevent restriction of flow resulting from the expected buildup of riverborne debris over one week of sampling.

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, are colour coded with red, yellow and white respectively, as in the water delivery system.

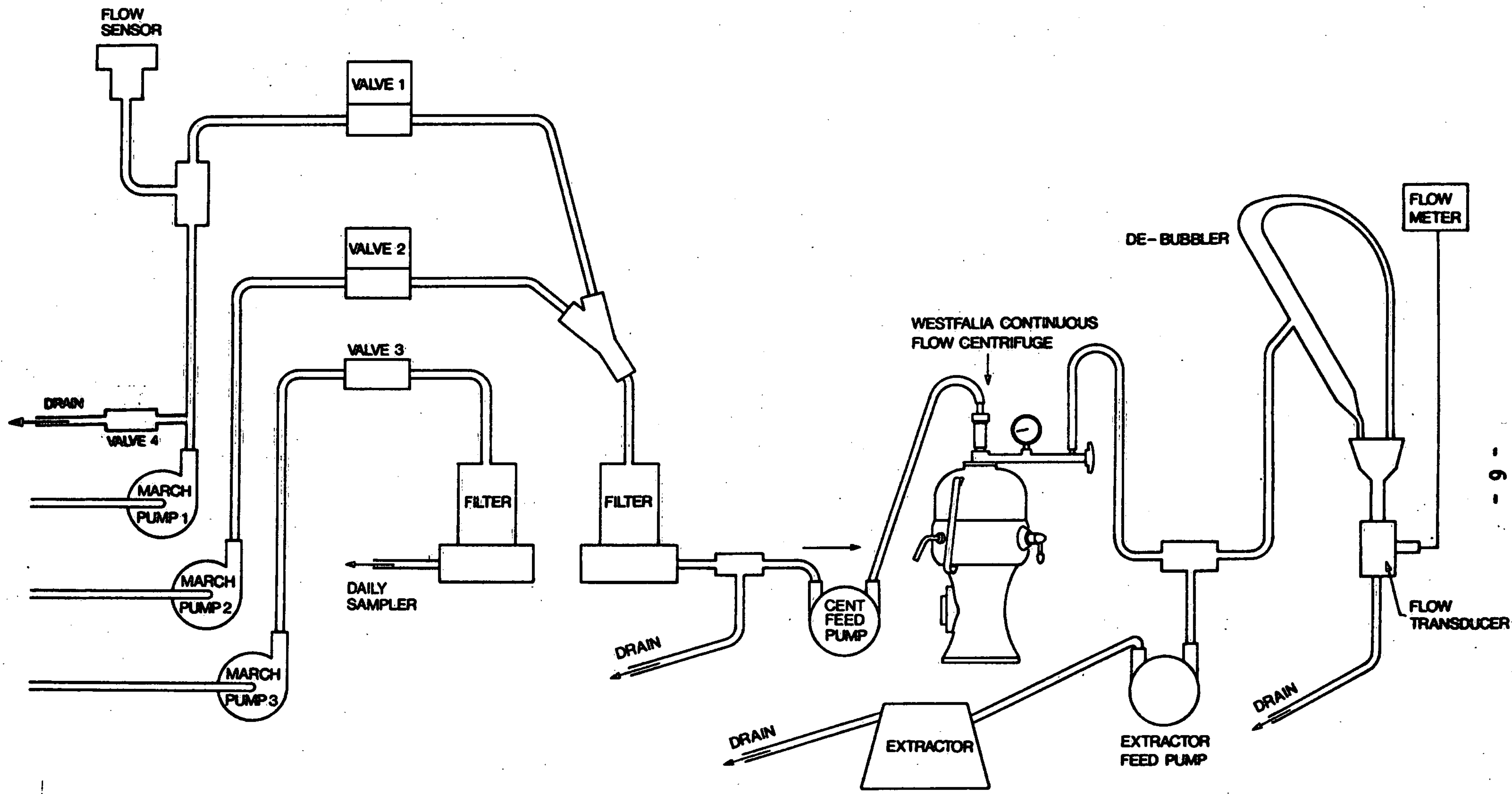

Figure 2. Water sampling system at Niagara-on-the-Lake

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) control the operation of the submersible pumps and electrically-actuated valves for the various sampling modes, (2) monitor the power source to the Westfalia centrifuge and shut it down should the voltage fall below the recommended operating level, and (3) provide 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). 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.

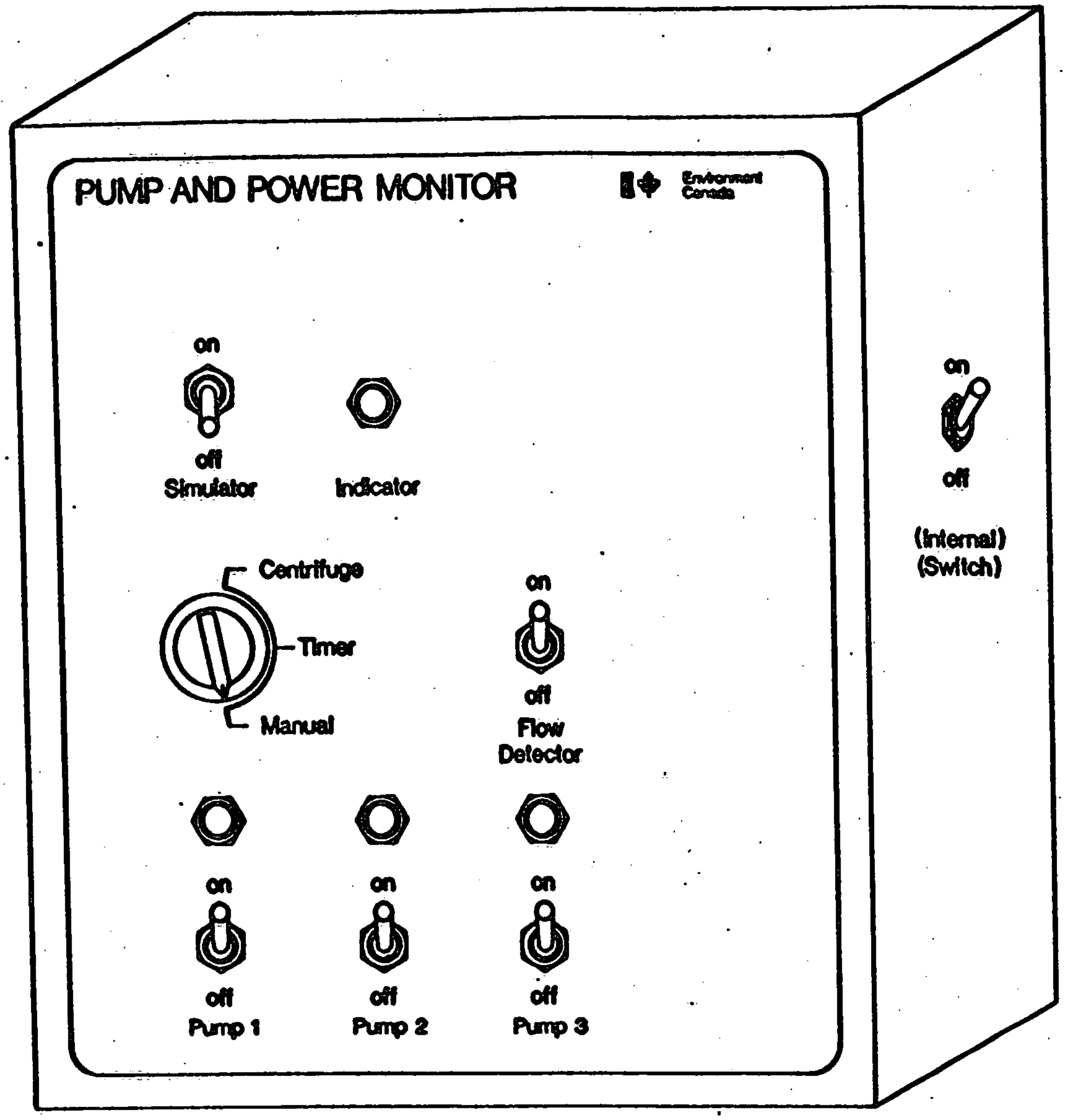

Figure 3. Pump and power monitor panel

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 stopage 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 by the trailer door, allowing the operator to start the centrifuge while standing outside of the trailer. Risks to the operator which may arise from a serious malfunction during run-up are 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, whereas 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 unit, 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) provide a signal, to the operator, for the identification of potential problems which may arise from normal wear of the centrifuge and bowl, (2) shut off the centrifuge should destructive vibration develop, and (3) provide a signal to control the subersible 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 interupt 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.

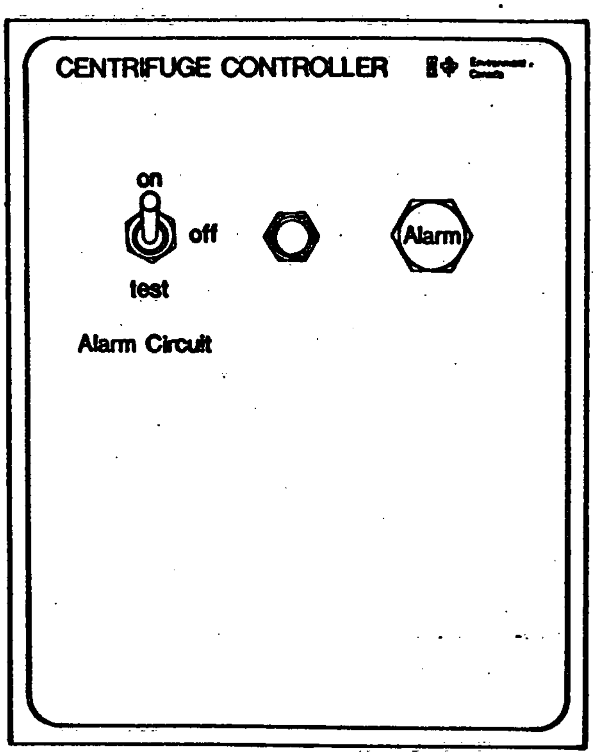

Figure 4. Centrifuge control panel

ACKNOWLEDGEMENTS

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APPENDIX 1 - Design of Water Delivery System

APPENDIX 1 - Water Delivery System

This section provides a detailed description of the various components of the water delivery system, illustrations of the major intake assemblies and information on materials used.

A sub-surface float of aluminum construction having a buoyancy of 115 kg was used to maintain the stainless-steel intake frame in mid-column. The three intake wands were held in the frame with "all-stainless" gear clamps. The above intake structures are shown in Figure 1A; specific components of the intake wand assemblies are presented in Table 1A and Figure 1B.

The intake tubing was attached to the intake wands with compression fitting F2. This tubing was extruded from a low density polyethylene formulation, and has desirable physical characteristics, being both self supporting and flexible. It is suitable for making underwater connections and will not degrade over long periods of time. The tubing formulation is commonly referred to as natural polyethylene, and is free of pigments, fillers and metal stabilizers. In view of the contact or residence time, the tubing will not contaminate the water samples in this application. A rationale for the appropriateness of the tubing deployed is presented in the Niagara River Sampling Protocol (Group A, 1986). The fittings and intake wands were made of natural polypropylene. This material has effectively the same chemical advantages as natural polyethylene and yet it is rigid enough that the components can be machined from a solid stock. The seals used in the compression fittings were made of viton which is a preferred elastomer for heavy metal and organic contaminant sampling.

The intake bundle was passed through the 10 in. cast iron intake pipe to the abandoned well. The intake lines were attached to March 5C-MD submersible pumps. These impeller pumps have a magnetic drive which eliminates the need for conventional shaft seals and problems associated with lubricant leakage into the pump head assembly (Fig. 1.C). All wetted plastic parts are made of glass filled-polypropylene. Both the stationary spindle and thrust washer are ceramic and the pump head gasket is made of viton. The inlet and outlet pump adapter, shown in Figure 1D, are made of natural polypropylene.

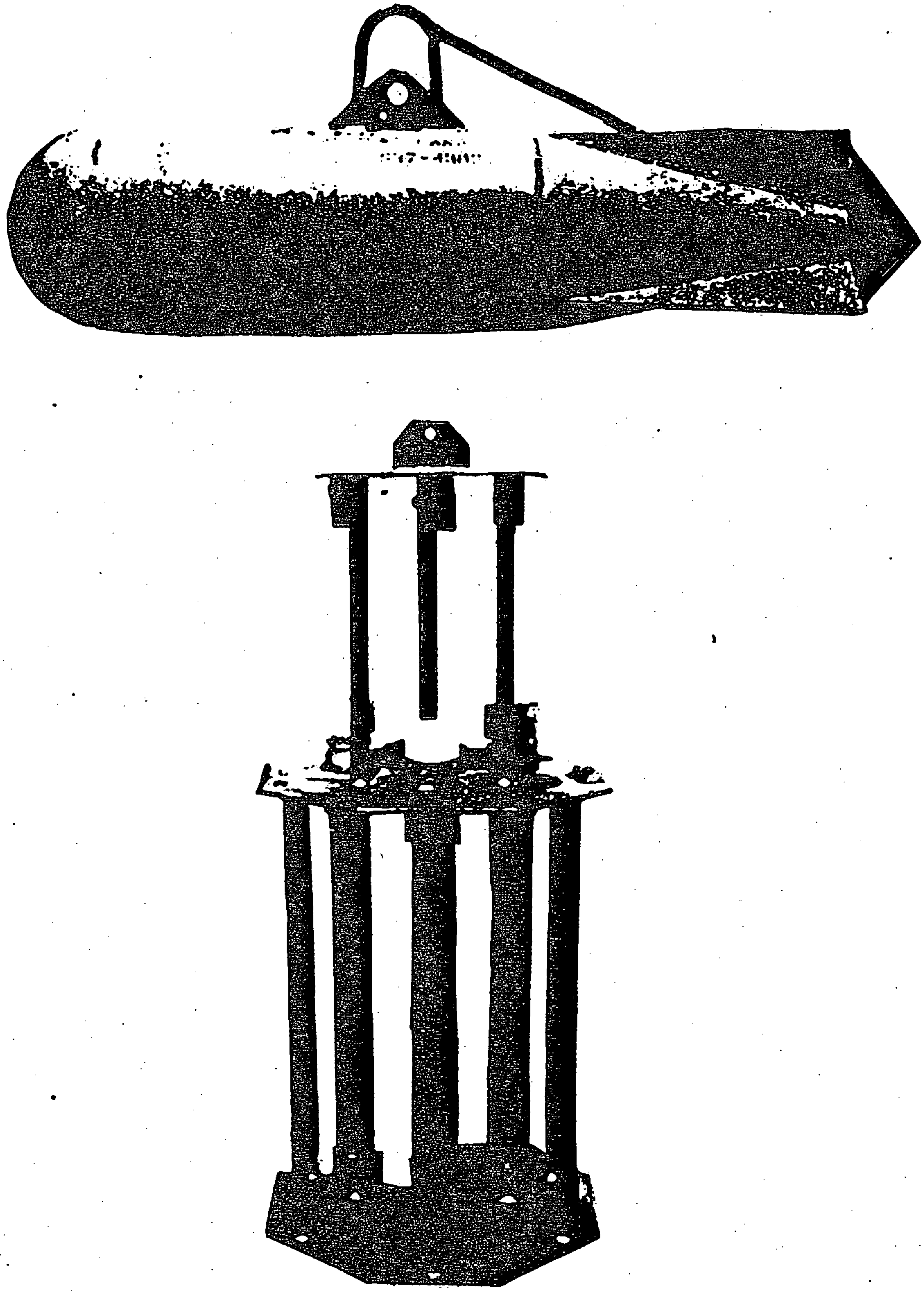


Figure 1A. Water intake structures

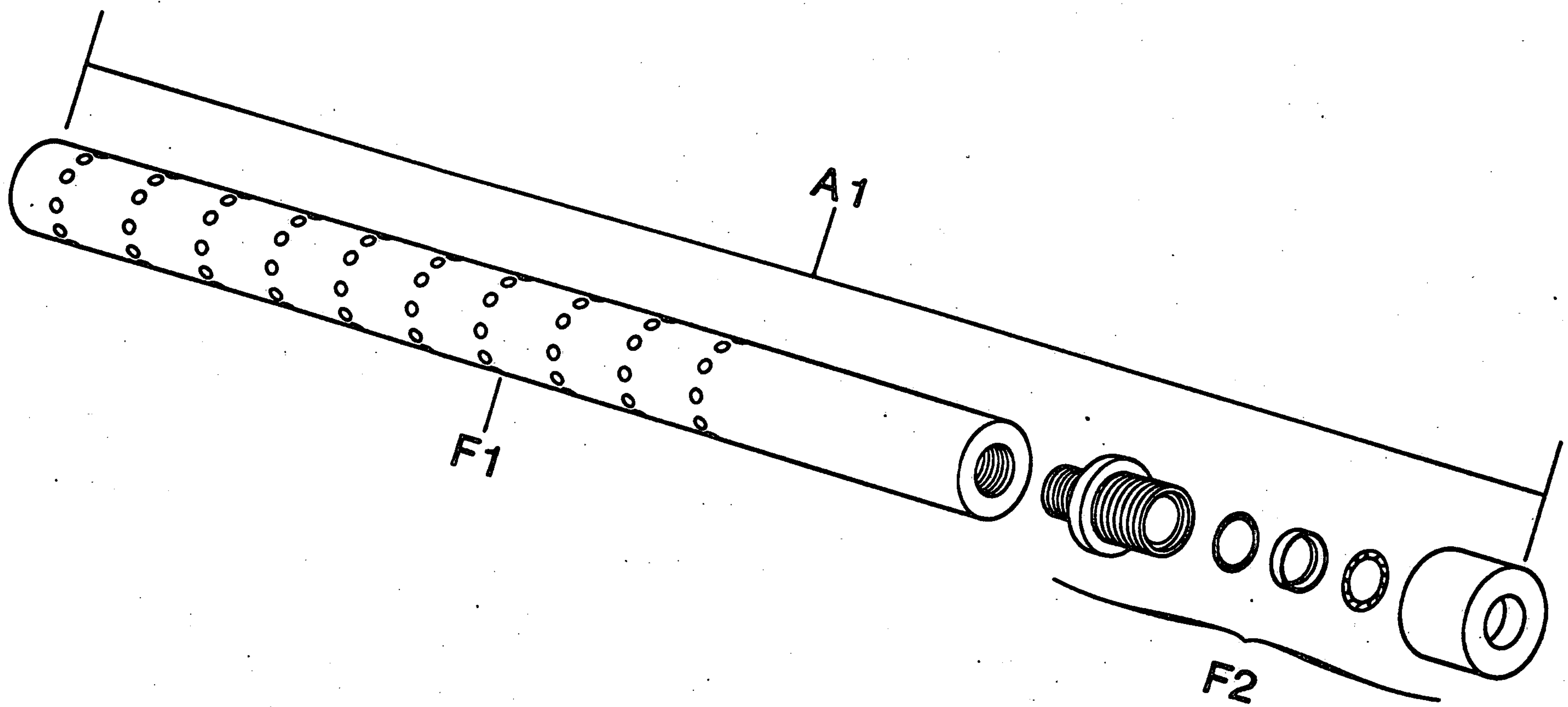
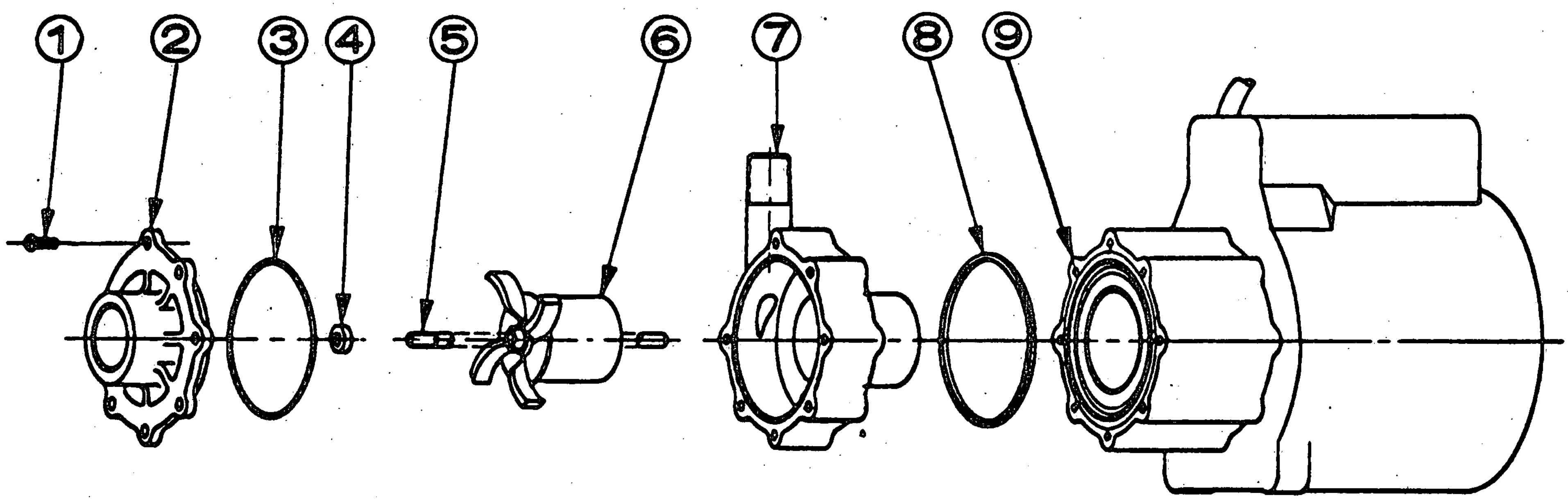


Figure 1B. Intake wand assembly



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

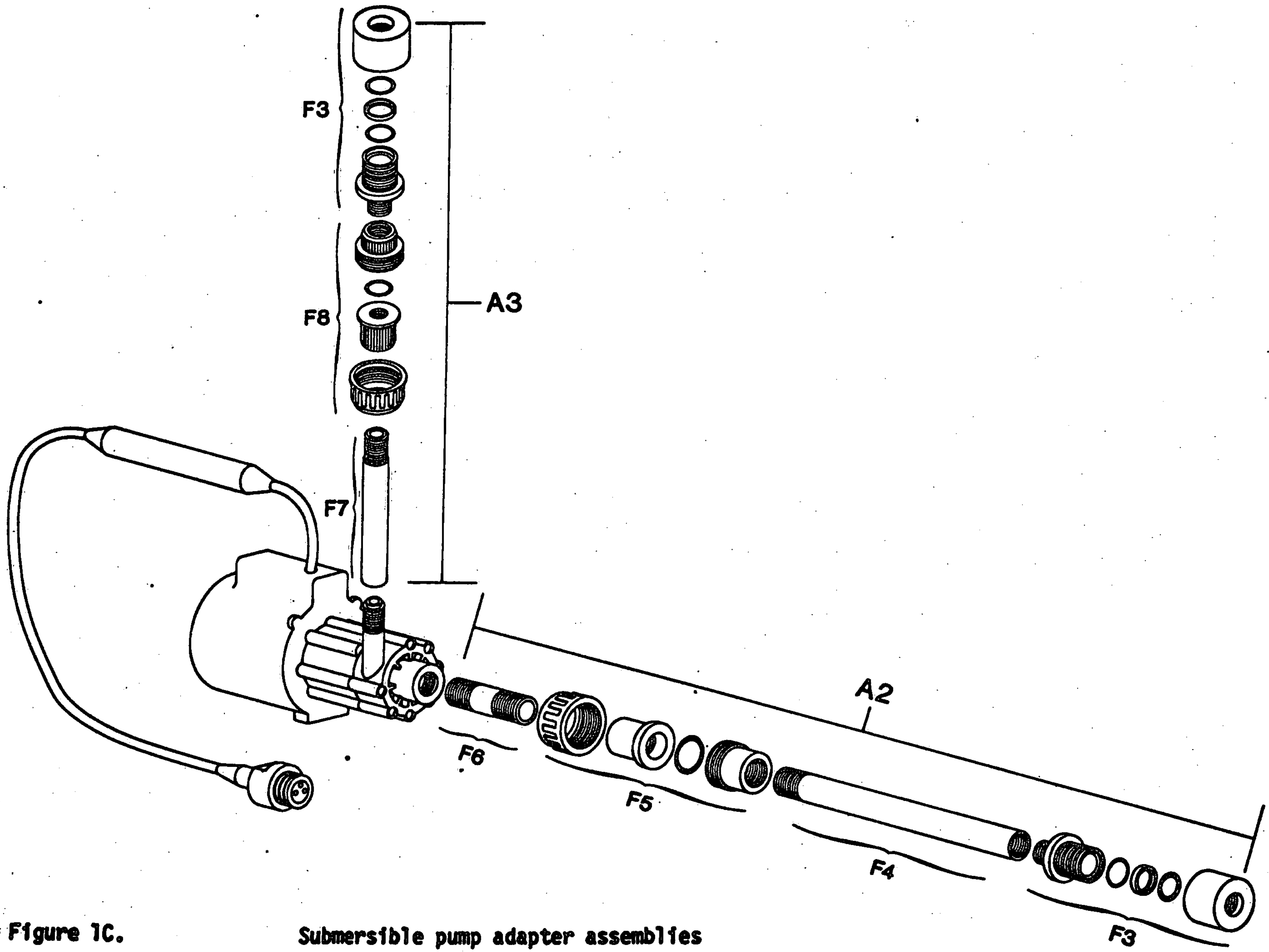


Figure 1C. Submersible pump adapter assemblies

Table 1A. Water delivery system fittings and assemblies

FITTING/ ASSEMBLY	NAME	SPECIFICATION
F1	Intake Wand	1" female NPT, pp
F2	Compression	1" O.D. x 1" male NPT, viton O-ring, pp
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
A1	Intake Wand	F1 - F2
A2	Pump Inlet Adapter	F3 - F4 - F5 - F6
A3	Pump Outlet Adapter	F3 - F8 - F7

NOTE: NPT = National Pipe Thread
pp = Polypropylene

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

All manual and electrically-actuated valves in the system were ball valves. They are made of natural polypropylene and have viton seals and Teflon seats. Brackets were welded to the valve bodies to provide an effective means of securing the valves to the wall of the laboratory trailer. The stem of valves V1 and V2 were also modified to accept the electric actuators. An illustration of the "True Blue" actuators EBV075 is provided in Figure 3.4A.

The simulation valve (V4) was situated well below valve 1 to test for proper operation of the back-up pump system. Operation of the system is tested with pump 1 providing water to the sampling system. The simulation valve is opened to divert the incoming water to drain rather than flowing through sample line 1. 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 V1 and V2 prevent water from being pumped back to the river in the event of an actual pump failure. For example, if the flow detector sensed a no-flow condition in line 1, pump 1 would be de-energized and pump 2 would be 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.

2.2 Flow Detector

An all stainless-steel United Electric pressure switch J6S-M2 was used as the flow detector in line 1. When water flows through line 1, air

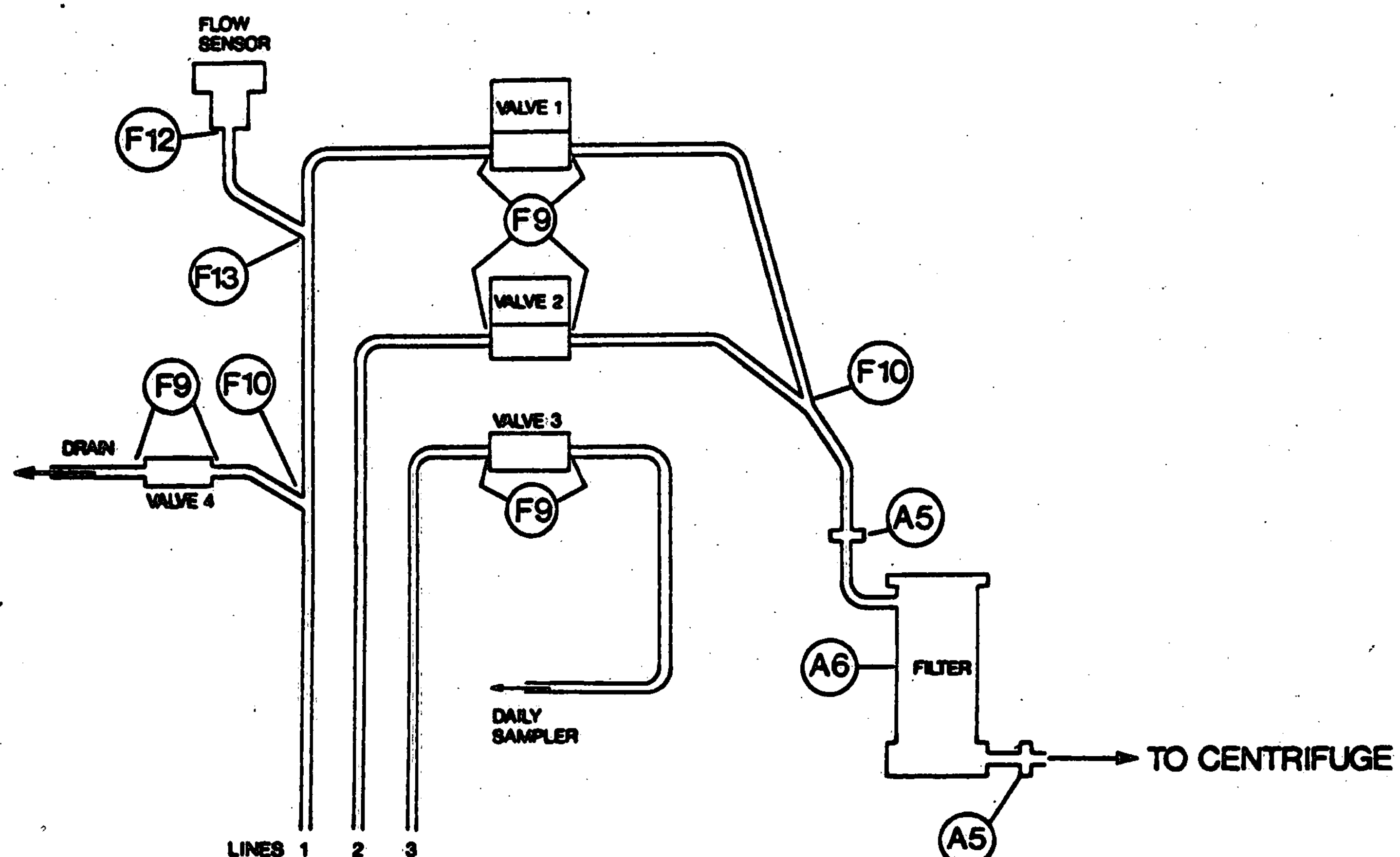
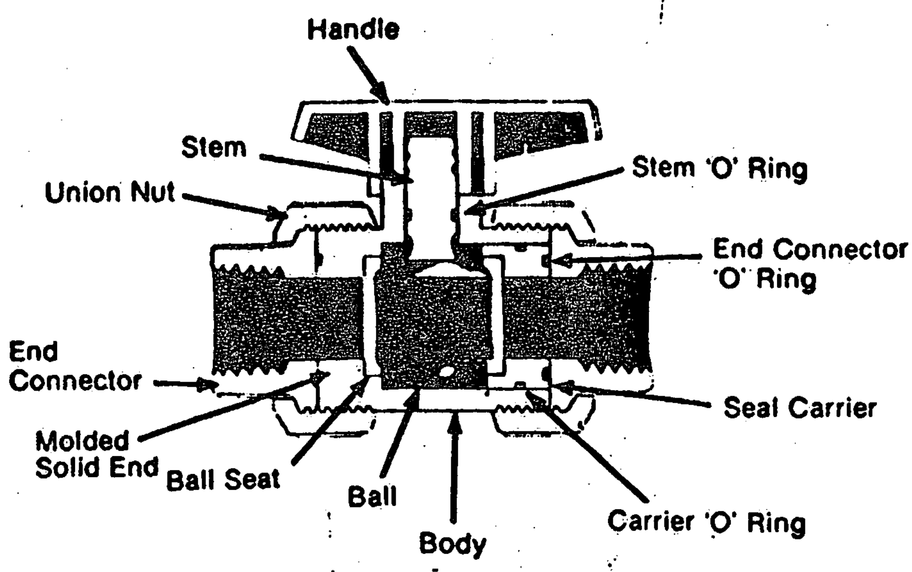
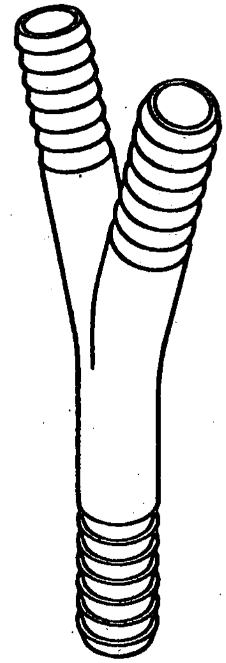


Figure 2A. Schematic of water sampling system



Valves V1,V2,V3 & V4



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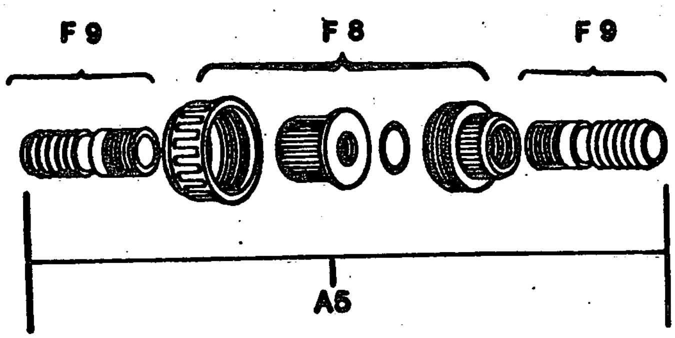

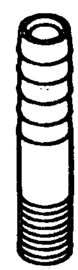

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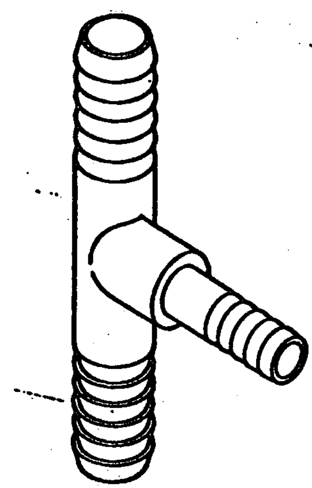

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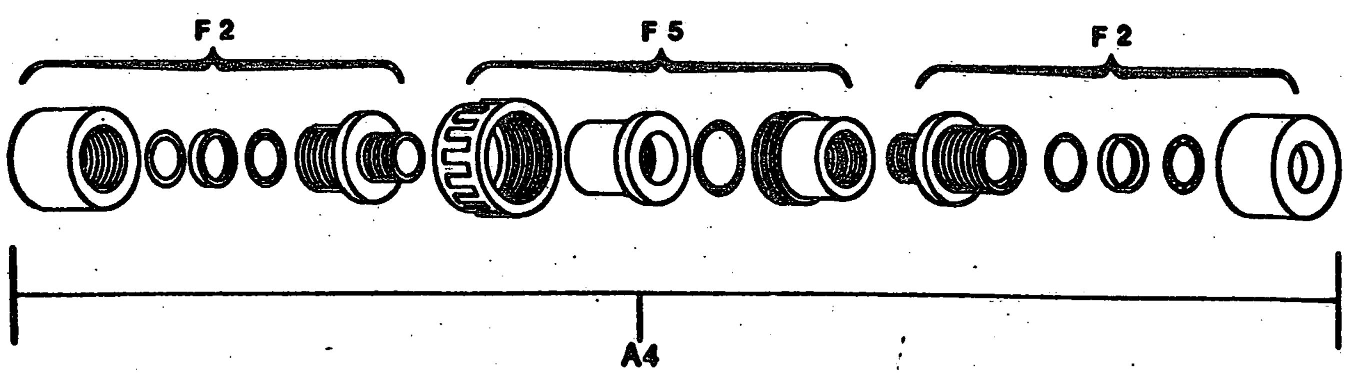


Figure 2.3A Filter unit and fittings

trapped in the flow detector shunt line is compressed and acts on the detector mechanism. Fouling of the mechanism by riverborne debris is unlikely, as the sample water does not enter the unit.

2.3 Filter

The in-line filter was fabricated from a natural polyproplene stock (Fig. 2.3A). It was designed to remove course debris from the raw water fed to the Westfalia centrifuge, and thus prevent damage or imbalance of the bowl which may have resulted from large particles entering the clarifier when it is spinning at 9500 rpm. The filter was oriented in a vertical position, and has a conical outlet located at the bottom of the unit. Owing to the shape, configuration and flow through the unit, fine sediment does not readily build-up in the filter.

2.4 Centrifuge

The Westfalia continuous flow centrifuge (Fig. 2.4A) is equipped with a four-chamber stainless-steel bowl, 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; it was removed from the centrifuge outlet to eliminate potential contamination of the clarified water.

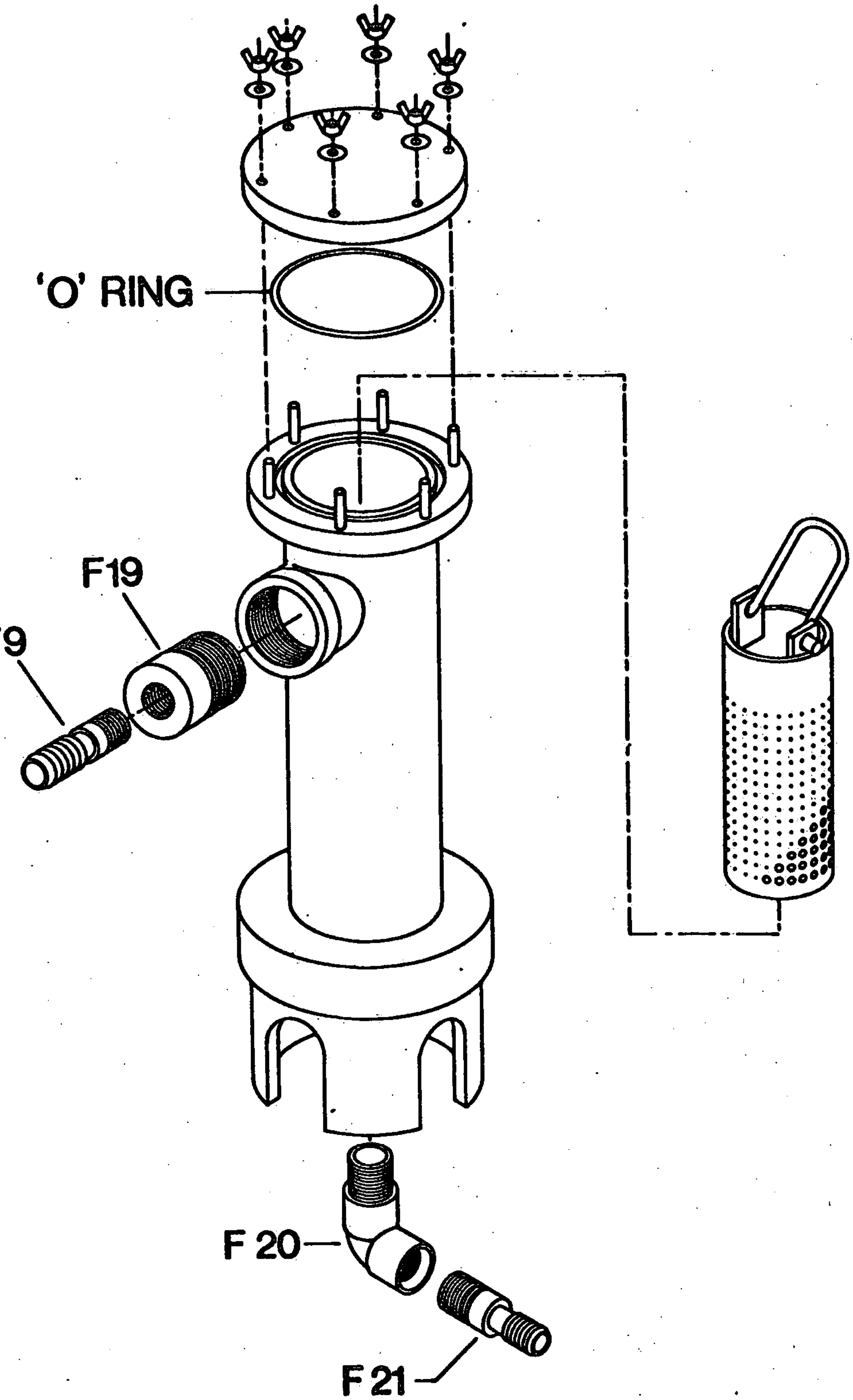
The centrifuge and drive motor were mounted on an aluminum cart complete with 20 cm dia. casters. Two casters are of the fixed type, and two are of the swivel type equipped with both brakes and swivel locks to facilitate safe transport of the machine.

TABLE 2A. Water sampling system fittings and assemblies.

FITTING/ ASSEMBLY	NAME	SPECIFICATION
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
F19	Reducing bushing	2" male NPT x 3/4" female NPT, pp
F20	90^{0} elbow	1" female NPT x 1" male NPT, pp
F21	Barbed insert	3/4" x 1" male NPT, pp
A4	compression-union	(F2-F5-F2)
A5	insert-union	(F9-F8-F9)
A6	strainer	F9-F19) (F20-F21)

NOTE: NPT = National Pipe Thread
pp = Polypropylene

For consistency, the fittings are numbered in the manner as shown in reports prepared for the Port Lambton and Point Edward (Fischer and McCrea, 1988). Due to differences in the layout of the stations, the plumbing varied somewhat and, as a result, the fitting numbers presented in this and the other reports may not be consecutive.



ASSEMBLY A6

Figure 2.3A Filter unit and fittings

LEGEND

1 - Feed
2 - Dischargé
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

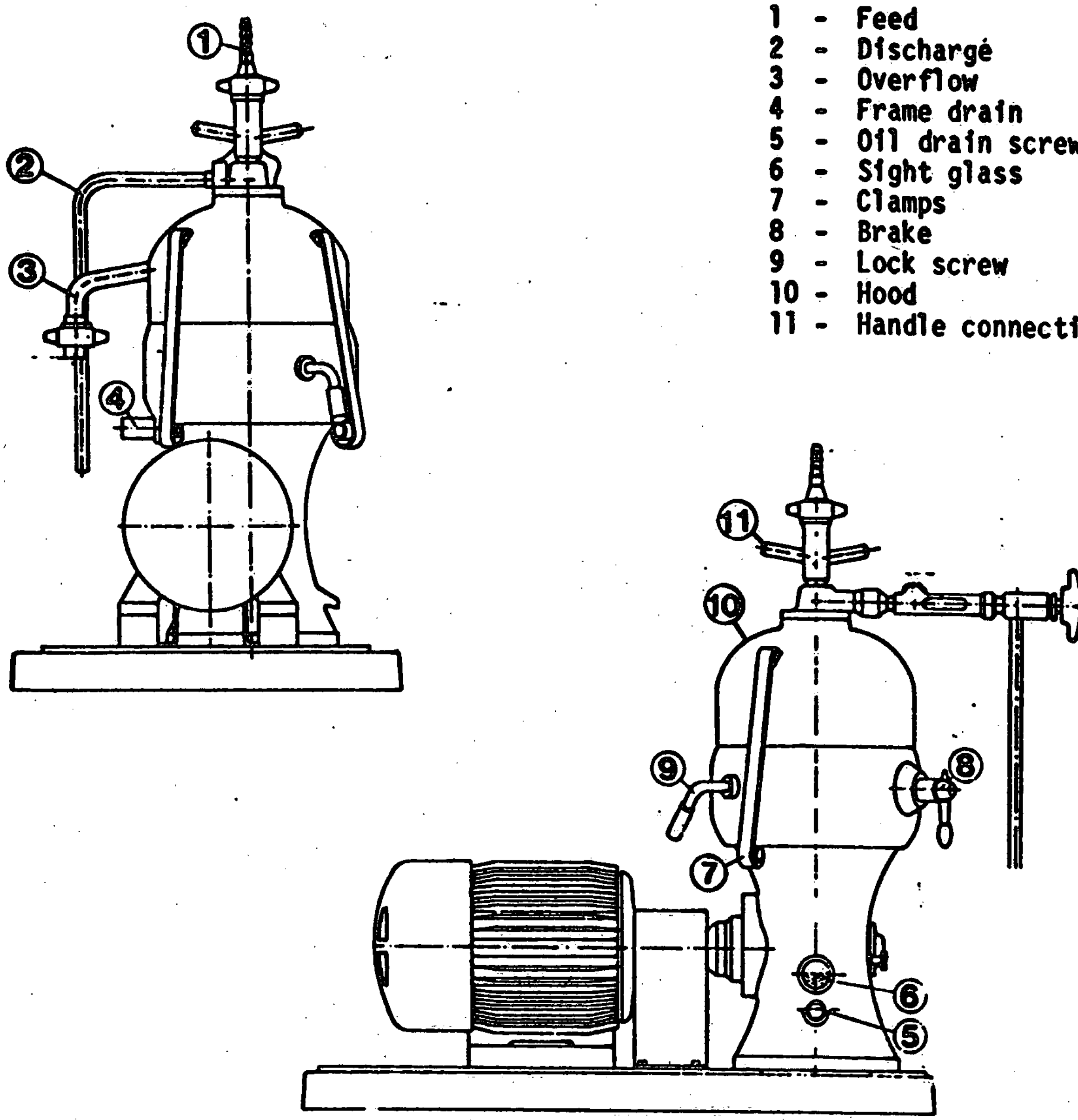


Figure 2.4A Westfalia continuous flow centrifuge

2.5 Drain

Owing to the continuous sampling experiment, a second centrifuge was used in the NOTL laboratory trailer. Under each centrifuge was placed an aluminum tray which served as a catch basin for the centrifuge and a drain for the return lines. The trays have two 8 cm cup-shaped devices, 8 cm indepth; they were fitted with a 1.5 NPT insert which served as a downspout. The return or waste lines were placed in the cups, which kept the tray dry during normal operating conditions.

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.

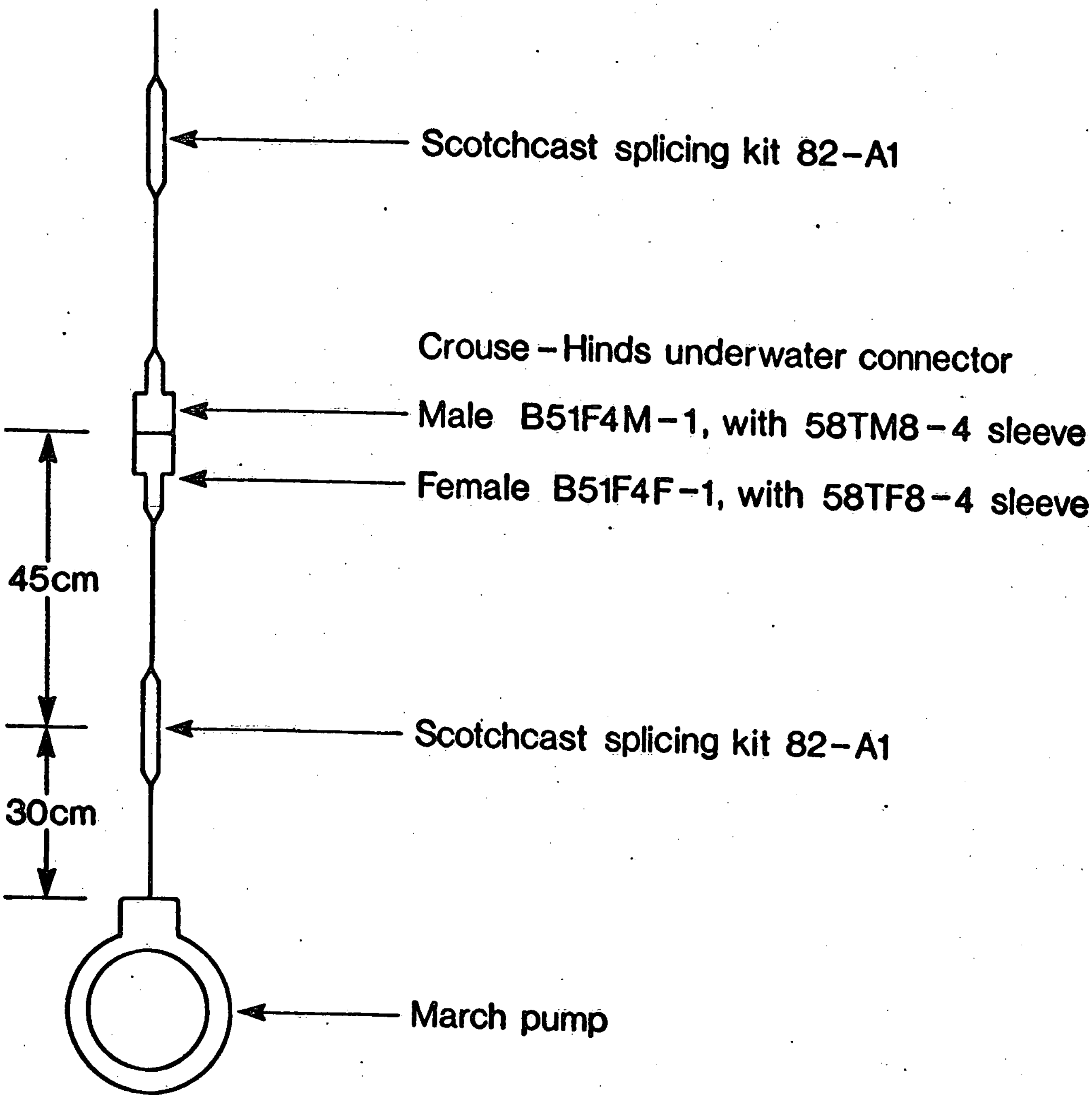


Figure 3.1A Submersible pump electrical connections

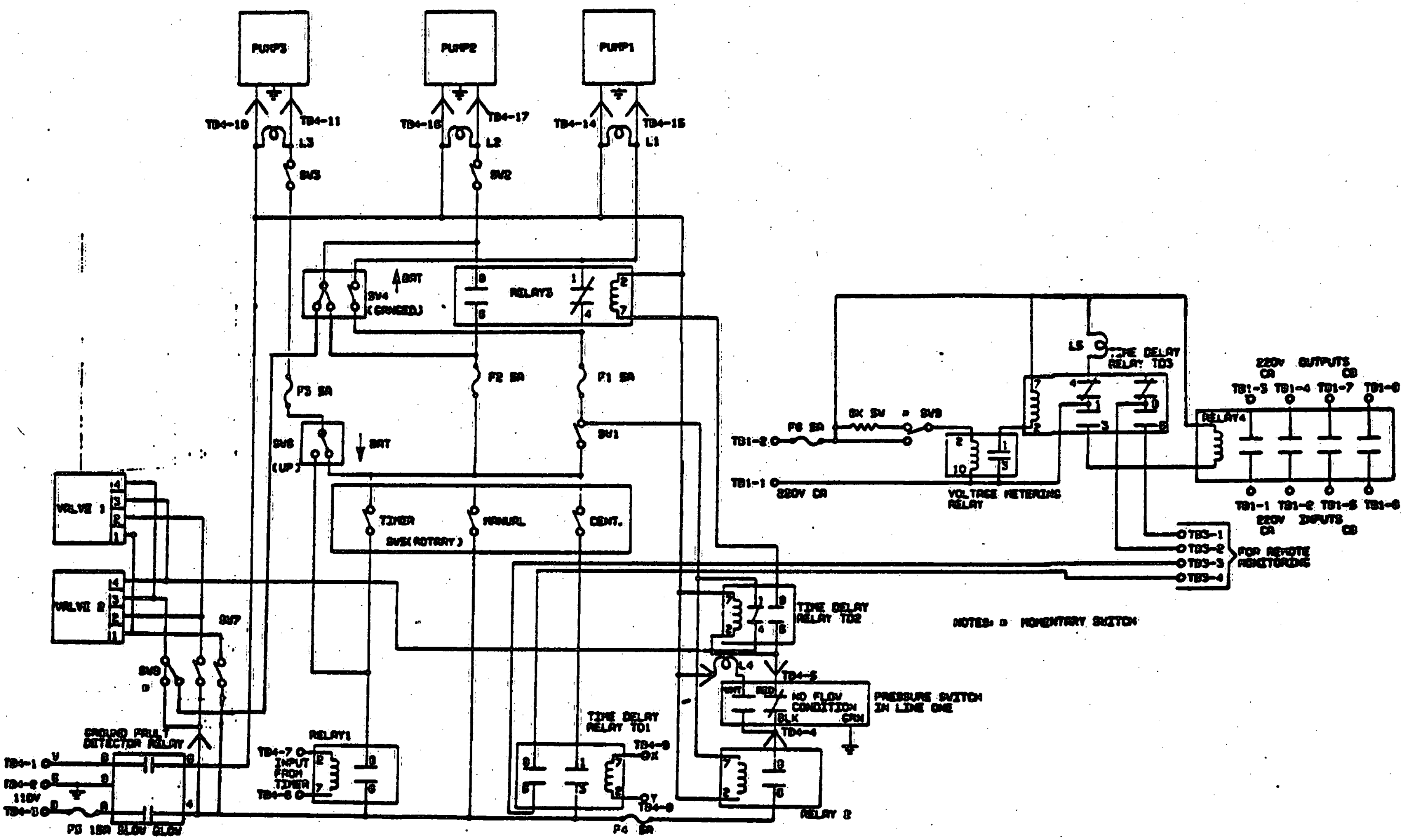


Figure 3.2A Pump and power monitor circuitry

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 $\pm$ 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

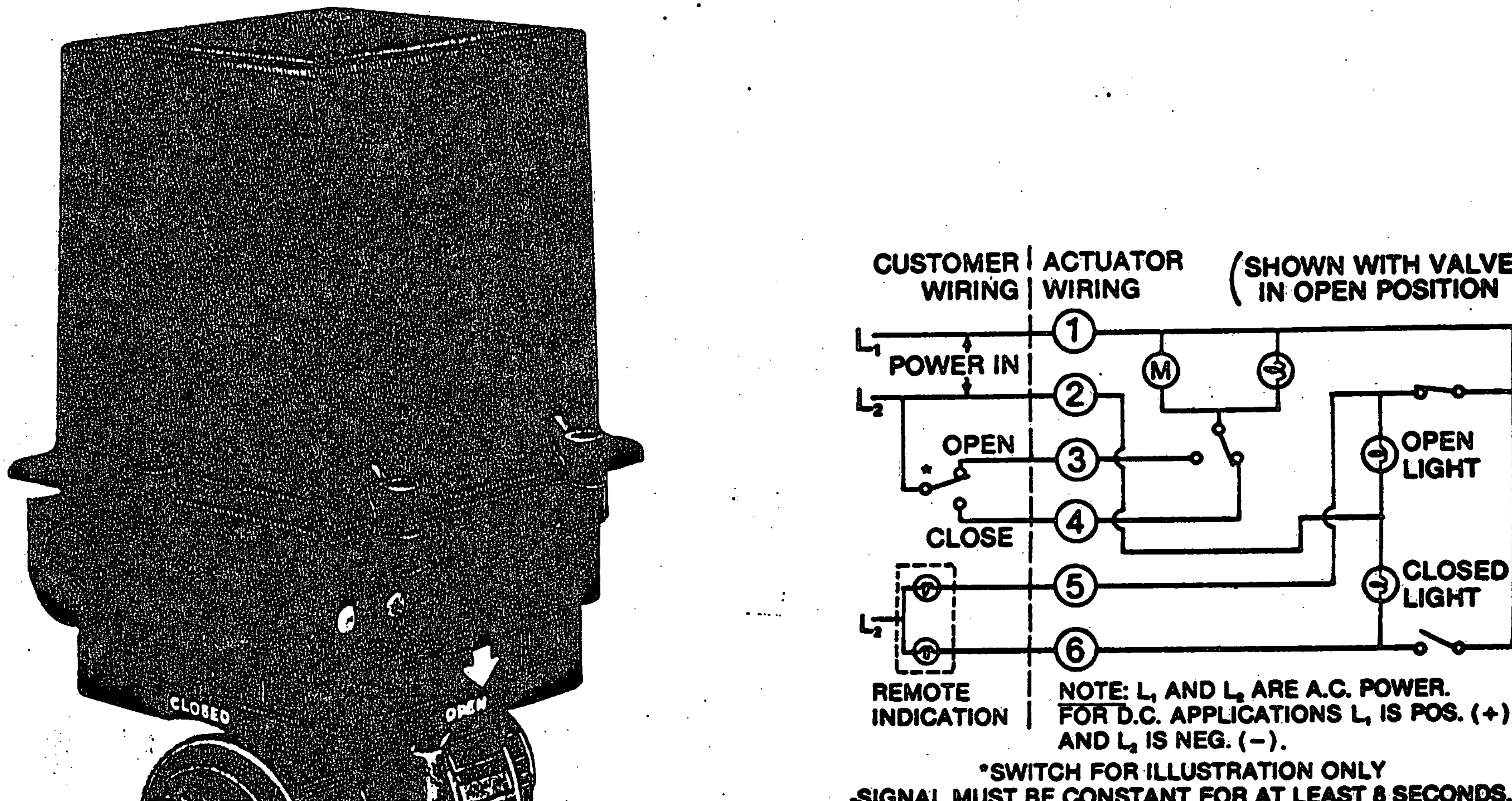


Figure 3.4A Valve actuators employed with valves V1 and V2

required, so 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 power cord which extends from the timer input (TB4-6 and -7) on the monitor can be directly interfaced with the existing AMF-Paragon timer (model EC712) to energize the submersible pumps as per the pre-set timer schedules.

A MaxiRex D four channel timer was used to control operation of the continuous extractor; this included the daily dump of the extract, refill of fresh solvent and energization of the recirculation pump. In addition, the timer provided a signal to control the energization of a heater used in the recycling of the extractant. It was wired such that the heater would only be on when the centrifuge was running, as shown in Figure 3.5A. Instructions for setting of the timer schedules 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, 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).

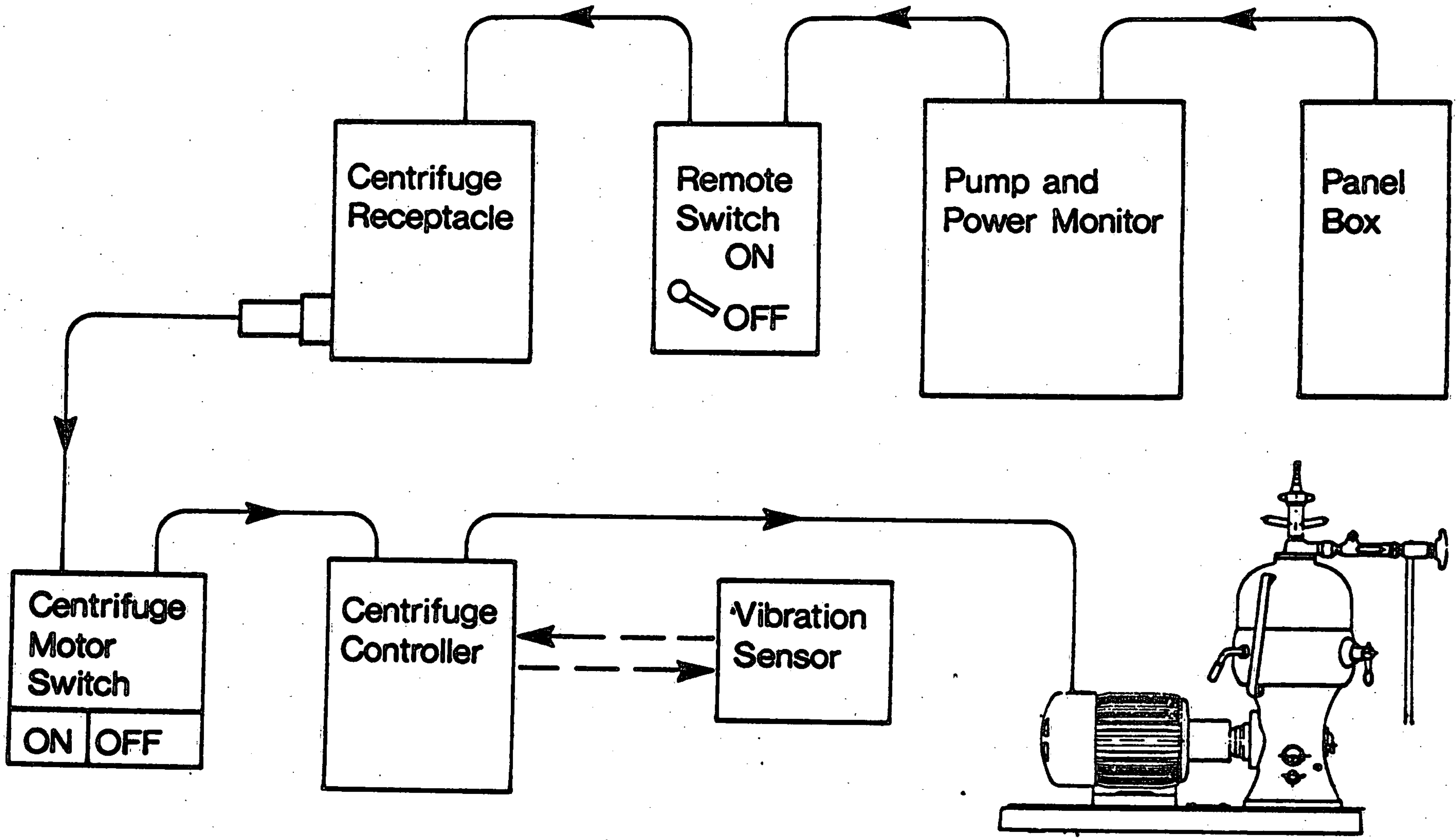


Figure 3.6A Power routing to the Westfalia centrifuge

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.

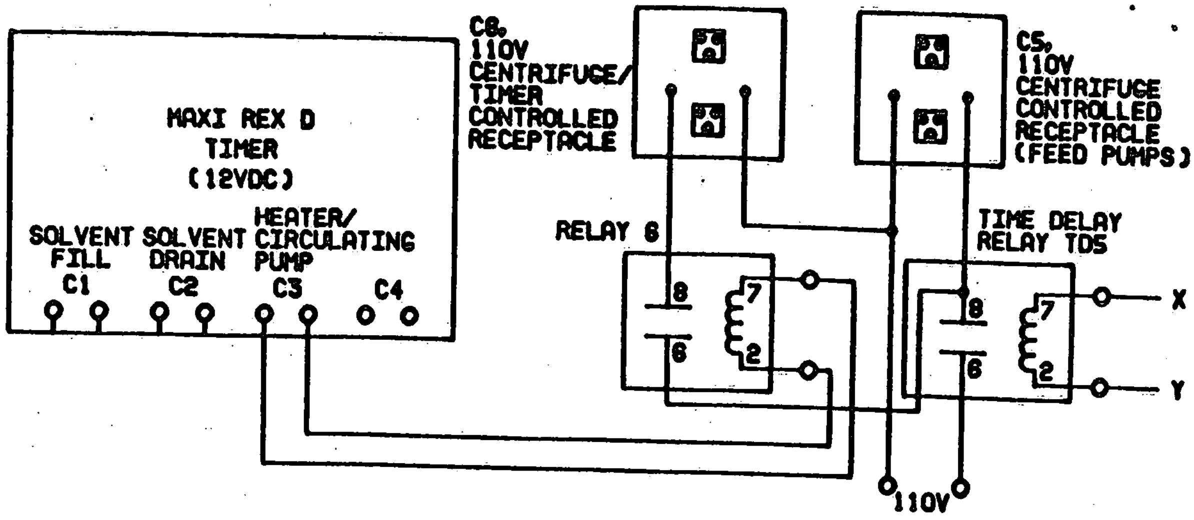


Figure 3.5A Circuitry for control of the continuous extractor

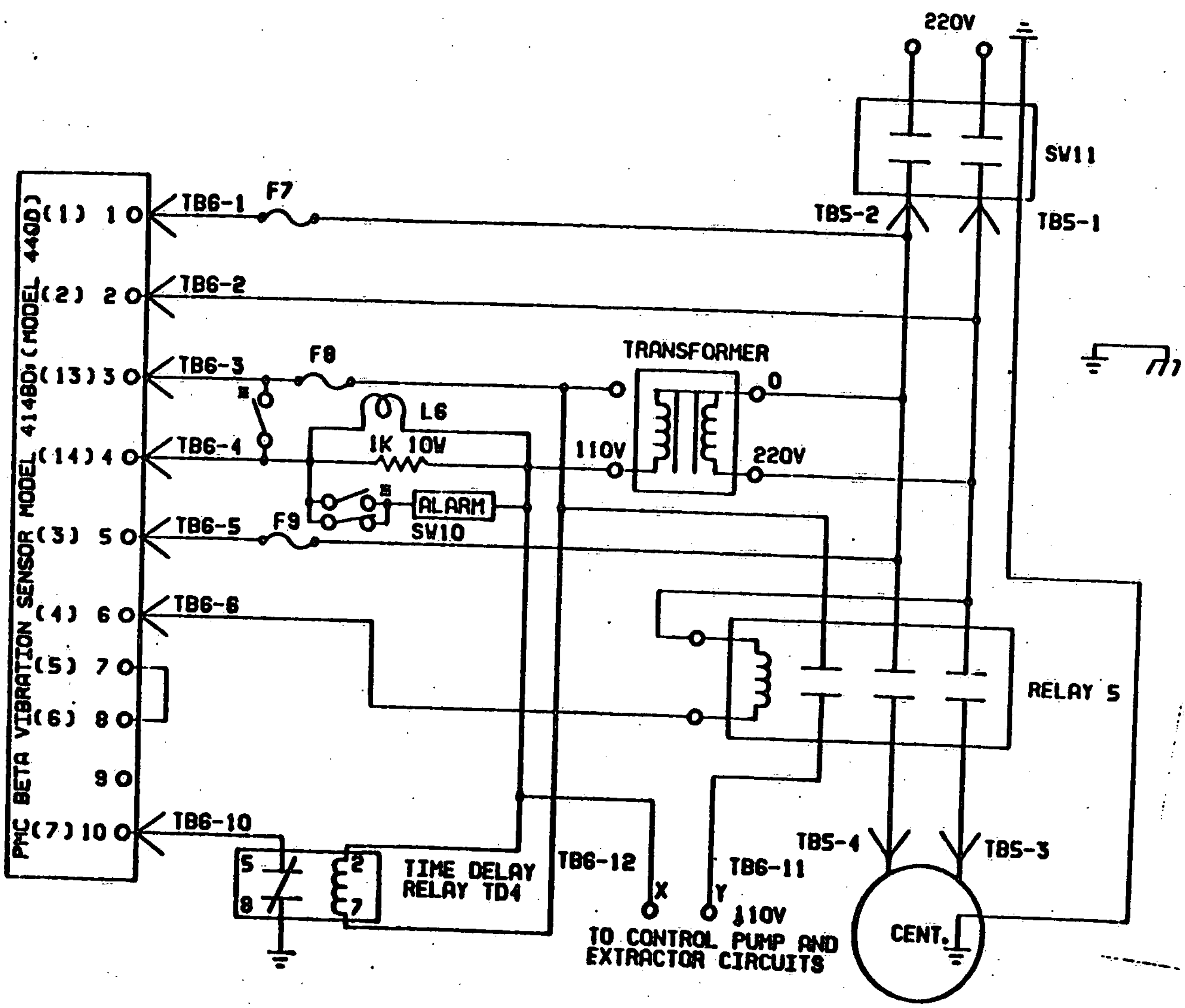
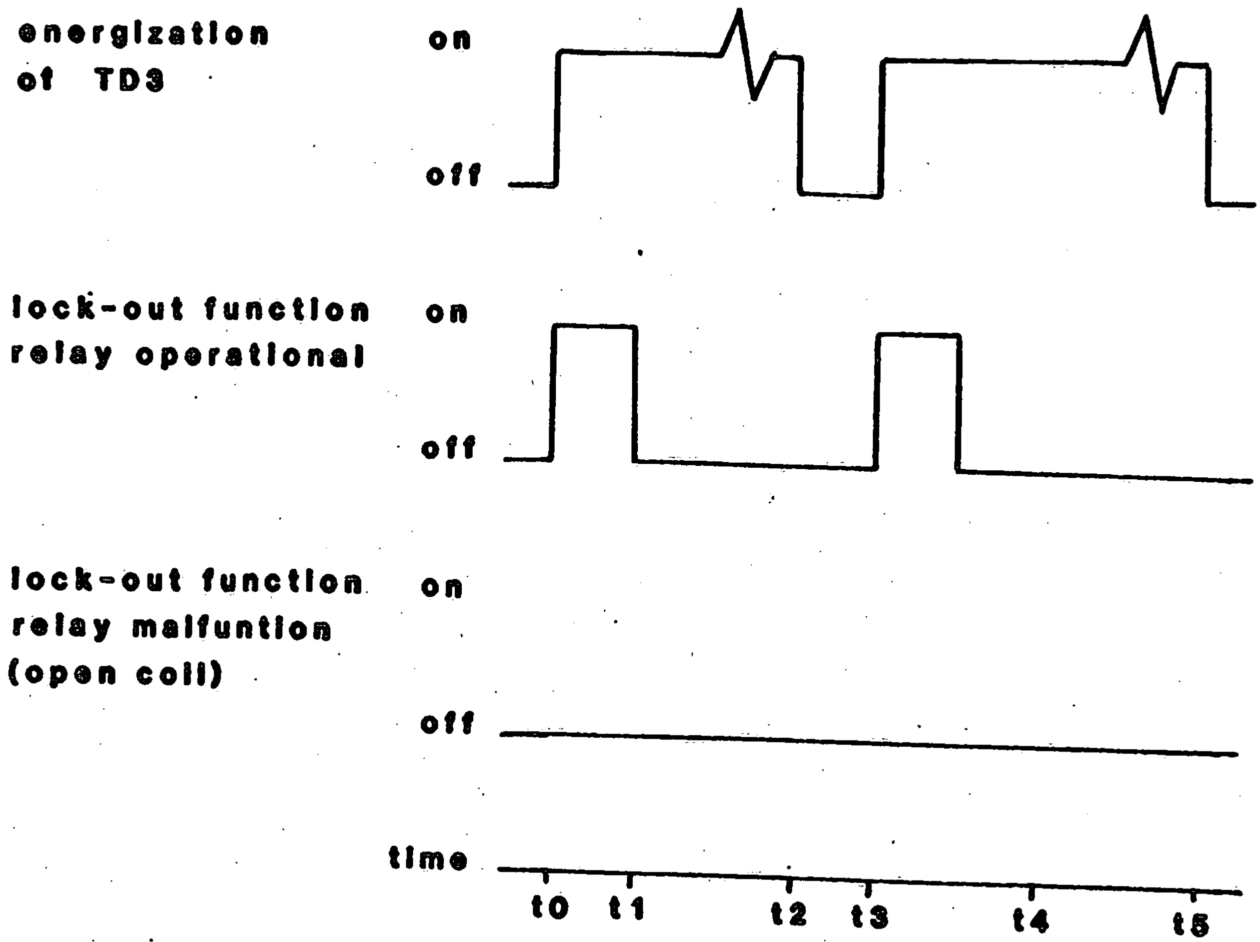


Figure 3.7A Centrifuge controller circuitry

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, terminal block
TB-6	Cinch-Jones, 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, and 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 FTO 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.

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.

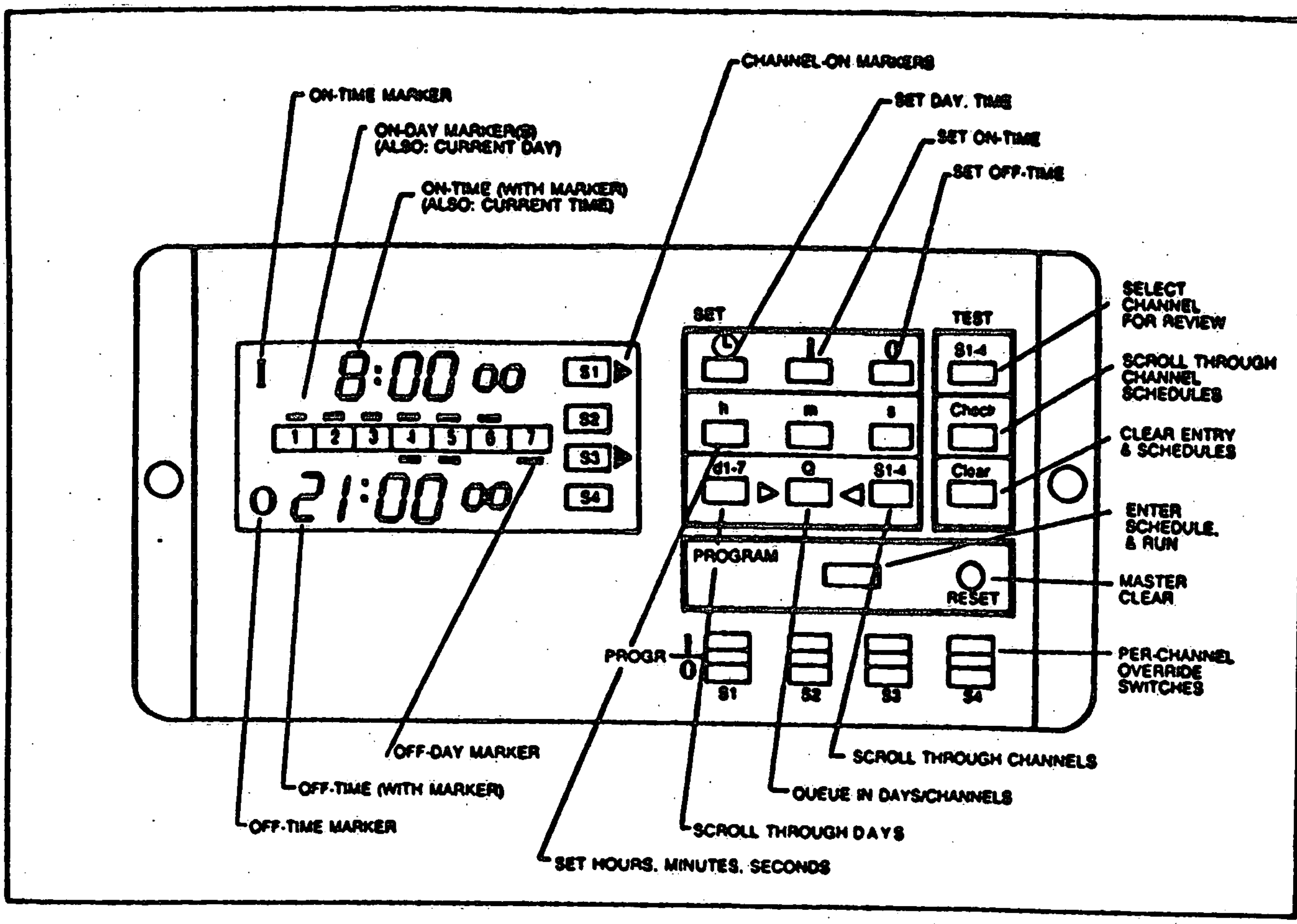


Figure 4.3A MaxiRex four-channel timer

SETTING THE CLOCK

When the MaxiRex is first powered, the time display will show 0:00oo and the day 1 marker will be lit, indicating midnight of day 1. The time display will immediately start counting by seconds.

To set the correct time:

1. Press the clock [🕒] key in the SET block. The seconds count will stop.
2. Select the correct hour by pressing the h key. Note 1:00 p.m. is displayed as 13:00.
3. Use the [m] key to select the correct minute after the hour.
4. The [s] key may be used to select the exact second, as desired.
5. Use the [d1-7] key to select today. Either Sunday or Monday can be designated as day 1.
6. Press the [Program] key to enter the clock setting. The seconds count will restart.

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:*
   a) Press the [I] key. I is an International Symbol for On. The I marker will appear beside an upper time display of 0:00oo.
   b) 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.
   c) 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 [O] key when the marker is over the desired day. [O] must be pressed at least once, and must be the last key pushed when selecting day(s).
   d) 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 [O] key. [O] must be pressed at least once, and must be the last key pushed when selecting channel (s).

2. *To Set an Off-Time:*
   a) Press the [O] key. O is an International Symbol for Off. The O marker will appear beside a lower time display of 0:00oo.
   b) 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.
   c) 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.

PROGRAM REVIEW

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

1. 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.
2. 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.
3. When the display shows I 0:00oo and O 00:00oo, all channel entries have been seen.
4. Press TEST [S1-4] to advance to channel S2, and repeat steps 2 to 4 preceding.
5. To return to Run mode, press [Program].

EDITING DATA

1. While programming in SET mode, [Clear] will cancel:
   a) Times, if used with [I] and [O].
   b) Days, if used with [d1-7].
   c) Channels, if used with SET [S1-4].
2. When reviewing programs in TEST mode, [Clear] will CANCEL THE DISPLAYED SCHEDULE from memory.
3. When reviewing programs in TEST mode, a given schedule can be re-SET by using:
   a) [I] plus [h], [m], [s] to change On-Times.
   b) [O] plus [h], [m], [s] to change Off-Times.
   c) [I] plus [d1-7], [O] to change On-Days.
   d) [O] plus [d1-7], [O] to change Off-Days.
   e) [I] or [O] plus SET [S1-4], [O] to change the channel(s) programmed.
4. 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:

1. 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.
2. The MaxiRex D4 continues to operate its channels in TEST mode.
3. 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.)
4. 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 operation of the micro-processor. This is not significant for most applications.
5. The Override slide switches provide channel-by-channel selection of relay operation mode:
   a) I signifies constant-on, i.e., relay energised. The S markers will be turned on in the LCD display to indicate override-on.
   b) 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.
   c) 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 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, emerse all components (except the bowl bottom 251) 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, 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 the 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.
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 protuding 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 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.

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.

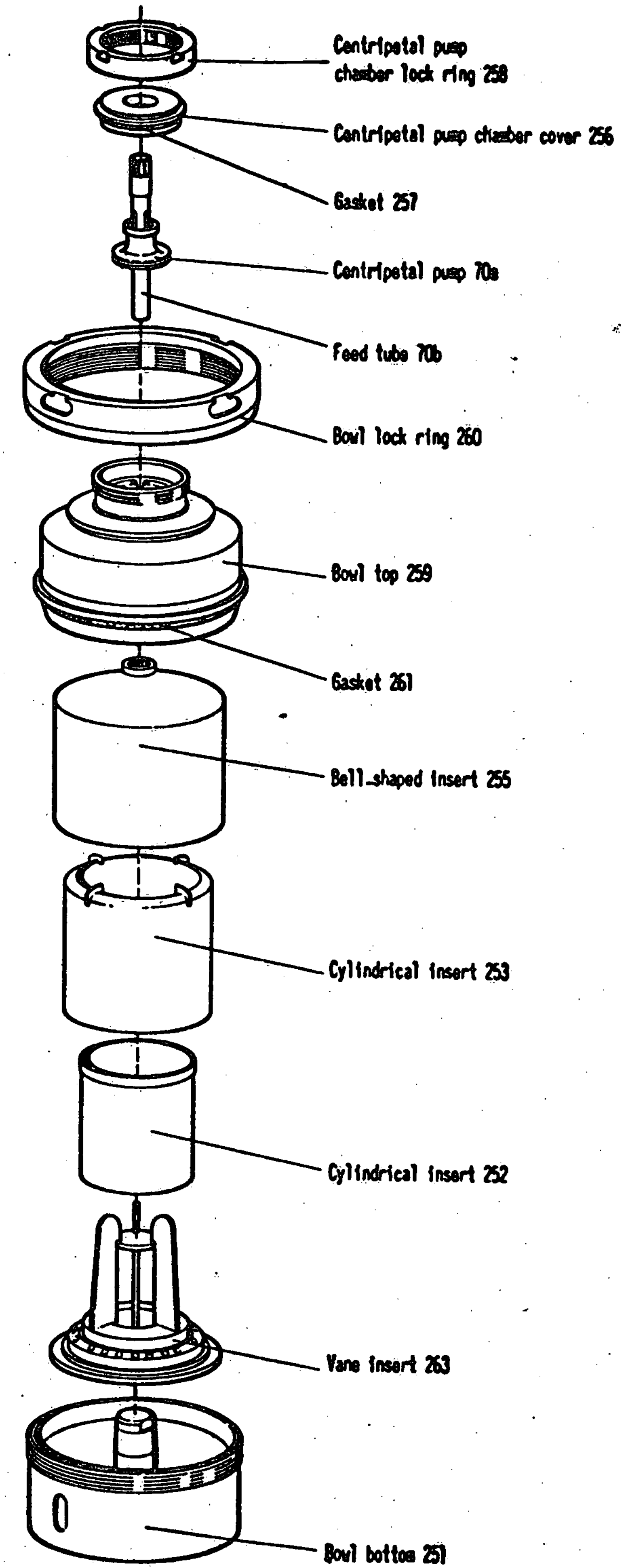


Figure 5.3A   Four chamber bowl assembly for Westfalia clarifier

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, 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

The intake cage and wand assemblies were suspended in mid-column with a sub-surface float . The intake system may become damaged as a result of ice jams in the lower Niagara or when struck by logs or other submerged debris, and should therefore be inspected annually by divers. Should the float develop a leak or the intake lines become severed, water with a higher sediment load may be drawn from near the river bed. It is therefore advisable that the suspended sediment concentration be routinely reviewed to assess the integrity of the water intake on an on-going basis.

6.2 Maintenance of the Sampling System

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

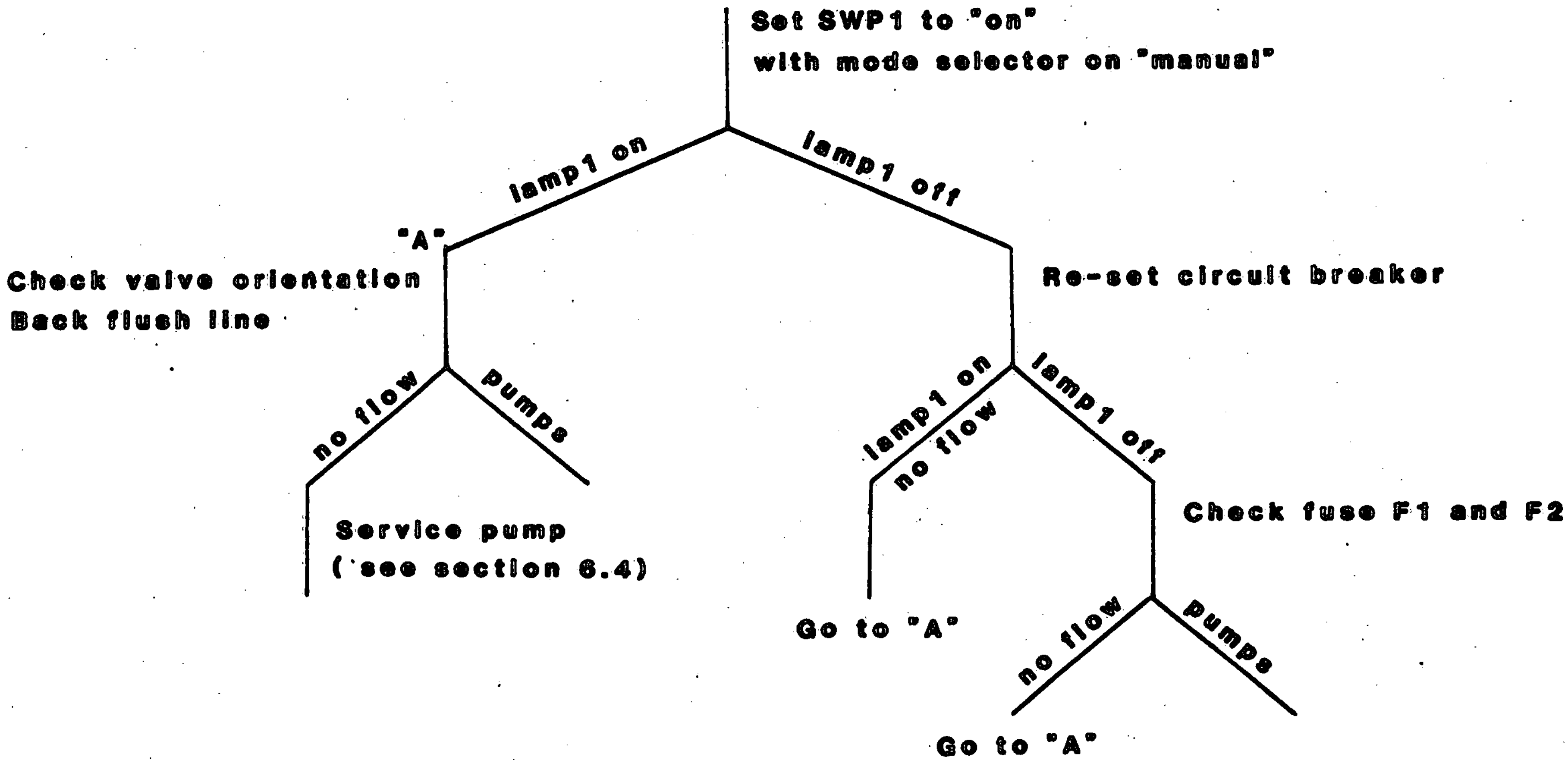
The submersible pumps are located in the stilling well. Should they require servicing, the pump frame can be removed from the well with a hand winch mounted on the shed wall. Inspection and servicing of a submersible pump requires two individuals equipped with safety belts, and should be carried out as follows.

1. Attach safety belts to a suitable anchor.
2. Remove insulation cover from well.
3. Undo colour-coded union couplings from each of the intake lines; care should be taken not to lose the "O" rings.
4. Re-arrange the well boards to allow sufficient space for raising the pumps.
5. Release winch lock, raise pump frame and set it on one of the well boards.
6. Test operation of the pump motor by applying power for 2 seconds.
7. Turn off power at panel box.
8. Unscrew sleeves of the appropriate colour coded underwater connector and pull plug apart.
9. Undo threaded union couplings on inlet and outlet adapter assemblies; care should be taken not to lose "O" rings.

10. Loosen large gear clamp and remove the pump from frame.
11. Unscrew the 7 machine screws from face of pump head, remove head and quad ring.
12. Inspect pump head.
13. Replace motor, pump head, and/or pump impeller as required.
14. Dry pump head and motor bracket face.
15. Fill motor bracket groove with silicone grease, set quad ring in groove and grease exposed seal surface.
16. Fasten pump head to motor bracket by gradually tightening machine screws with firm and even pressure in a circular pattern until tight.
17. Grease face and thread of underwater connectors with silicon grease, push plug into receptacle and tighten sleeves with wrench, using modest pressure.
18. Turn on power at panel box.
19. Confirm operation of motor by applying power for 2 seconds, and then turn off power at panel box.
20. Set pump in pump frame and attach threaded union couplings on adapter assemblies.
21. Secure pump motor with gear clamps, lower the frame into the well to desired depth and lock winch.
22. Align intake lines so that they are below the pump frame.
23. Draw water through each line with a vacuum pump to remove air lock.
24. Turn on power at panel box and test serviced pump to ensure that it is operating properly.
25. Re-arrange boards over well and replace the insulation cover if required.

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, see 6.2 -refer to section 6.4 -refer to Figure 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, see 3.4
Back-up pump malfunction	-incorrect flow sensor setting -relay failure	-adjust trip limit, see 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 Figure 6.3B
Centrifuge alarm or shutdown	-excessive vibration	-refer to section 3.8
Centrifuge alarm test malfunction	-fuse blown	-change fuse F6 and/or F10



NOTE: The indicator lamps for pumps 1, 2 and 3 enable the operator to perform a simple test without the aid of a meter to diagnose no-flow conditions. As indicated above, if lamp 1 is not illuminated when pump 1 is in the "ON" position, pump 1 is not necessarily at fault, and the appropriate fuses should be checked first. It is important to note that diagnosis of no-flow problems should be performed with the mode selector in the "Manual" mode as the pump(s) are effectively hard-wired. No-flow conditions in Timer and Centrifuge modes only are indicative of fault in the circuitry; see (Table 6.3A).

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

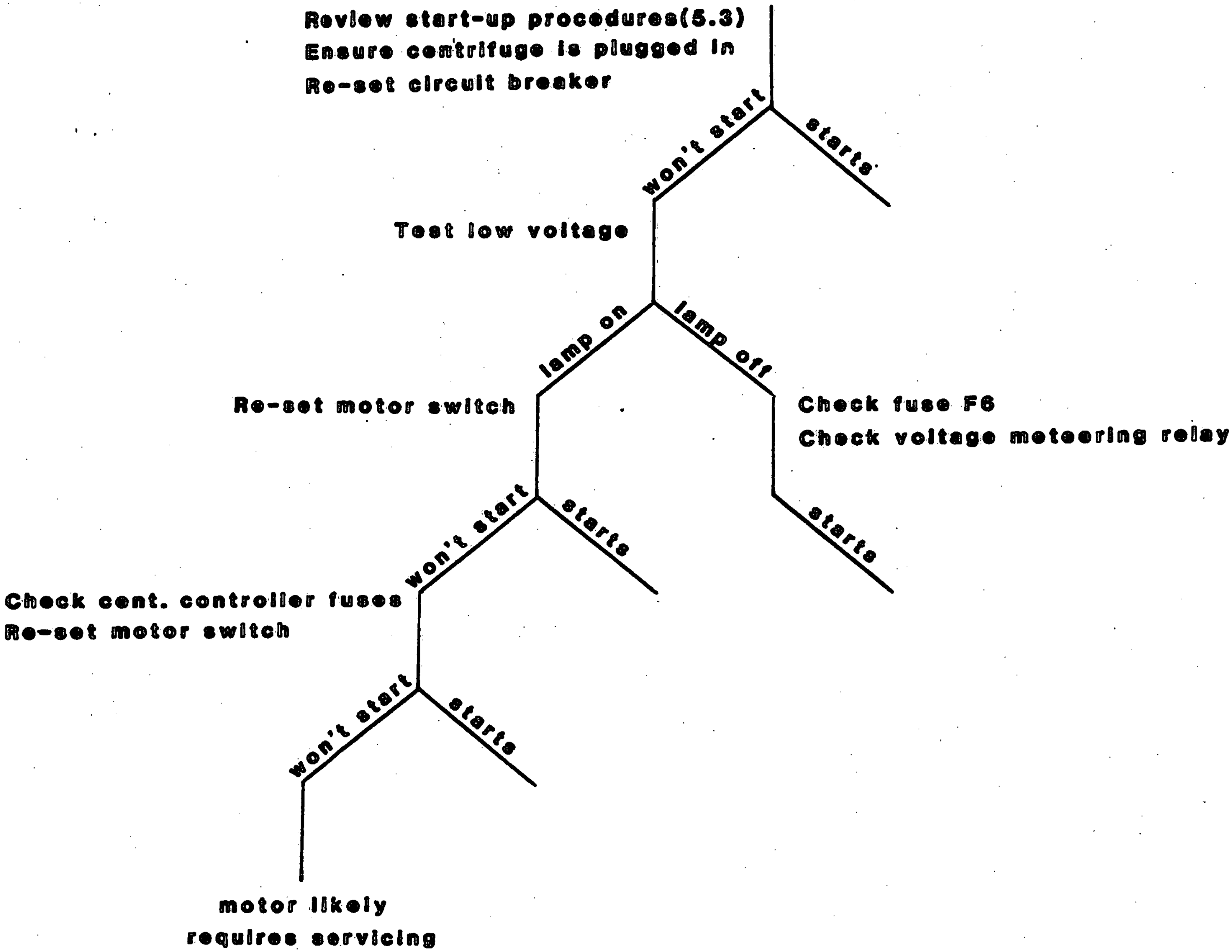


Figure 6.3B Procedures for troubleshooting failure of centrifuge start-up.

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