Appendix K – Regional Water Supply SCADA System Station & Pump PLC Manual (Existing)

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1. SCADA - PLC System

1.1 General Description

The City Of Winnipeg Works And Operations Division has upgraded their existing Regional Water Supply System and installed a Valmet Automation OASYS Supervisory Control And Data Acquisition (SCADA) System. The McPhillips pumping station was the first of several sites which were included in the upgrade. The other sites are:

Deacon
Tache
Shoal Lake
Hurst
MacLean

As part of the system upgrade new Modicon Compact Model 984-145A PLC's were used to replace the existing PLC (s) and/or relay logic. The existing control system and panels have been replaced by new panels which house the Modicon PLC's. The new main control panel (replaces the existing main control panel which housed the old sequencer relays) contains the station PLC (S-PLC) and the three other related PLC's and equipment associated with the S-PLC. There are also several pump PLC's (P-PLC), each in their own local control panel (LCP), installed next to the pump that they are controlling.

An overview of the interconnection of all of these PLC's can be seen on drawing 3153-SKx in Section 6. Drawing 3153-SKx shows a typical routing of the Modbus Plus® communications network. The S-PLC actually consists of four separate PLC's. The primary controller (S-PLC1) and the secondary (redundant) controller (S-PLC33) are essentially identical while PLC-11 is used as a drop controller for the analog I/O while PLC-12 is a drop controller for the analog and pulse I/O modules. There is very little logic contained in PLC-11 or PLC-12. The S-PLC actually contains the logic which is used to read and write from and to the I/O on PLC-11 and PLC-12. The S-PLC is also the master of the station and is the data concentrator for the Valmet Host. The S-PLC is the receptacle for all of the P-PLC data that is transmitted by each P-PLC. The Host computer polls the S-PLC for all information including inputs, outputs, and alarms from all of the P-PLC's. It also sends commands to the S-PLC such as a start or stop pump command which is interpreted by the S-PLC and sent down to the appropriate P-PLC if required.

The P-PLC's each contain I/O and logic to control their respective pump. There are really only two configurations of P-PLC programs and all other programs are identical except for communications related functions.

Redundancy is utilized throughout this system for both communications failures and a S-PLC failure. If a communications route is compromised in one direction the system architecture allows the PLC to re-route and try sending data via an alternate route. A failure of the active S-PLC is also addressed by this system through the use of a redundant S-PLC which remains ready and in the same state as the primary and

which will take over control of the station, transparent to the system, in the event of a primary failure.

1.2 Description of System Control Switches

The system contains several hardware and software switches which control the mode of operation of the sequencer and the PID controllers. The interaction of these switches and the position they have to be in to enable or disable hand control, to allow manual starting and stopping of pumps, etc. is described in this section. Unless otherwise noted the description for the switches applies to both the sequencer and the PID controller.

Figure 1 shows a block diagram depicting the arrangement of the various switches throughout the system. "Mode Control Switches" may be software or hardware switches. Software switches are noted as such.

- SCADA HOST switches MB station address to the secondary PLC and continues polling the coil & register ranges defined for the primary PLC

System Control Switches

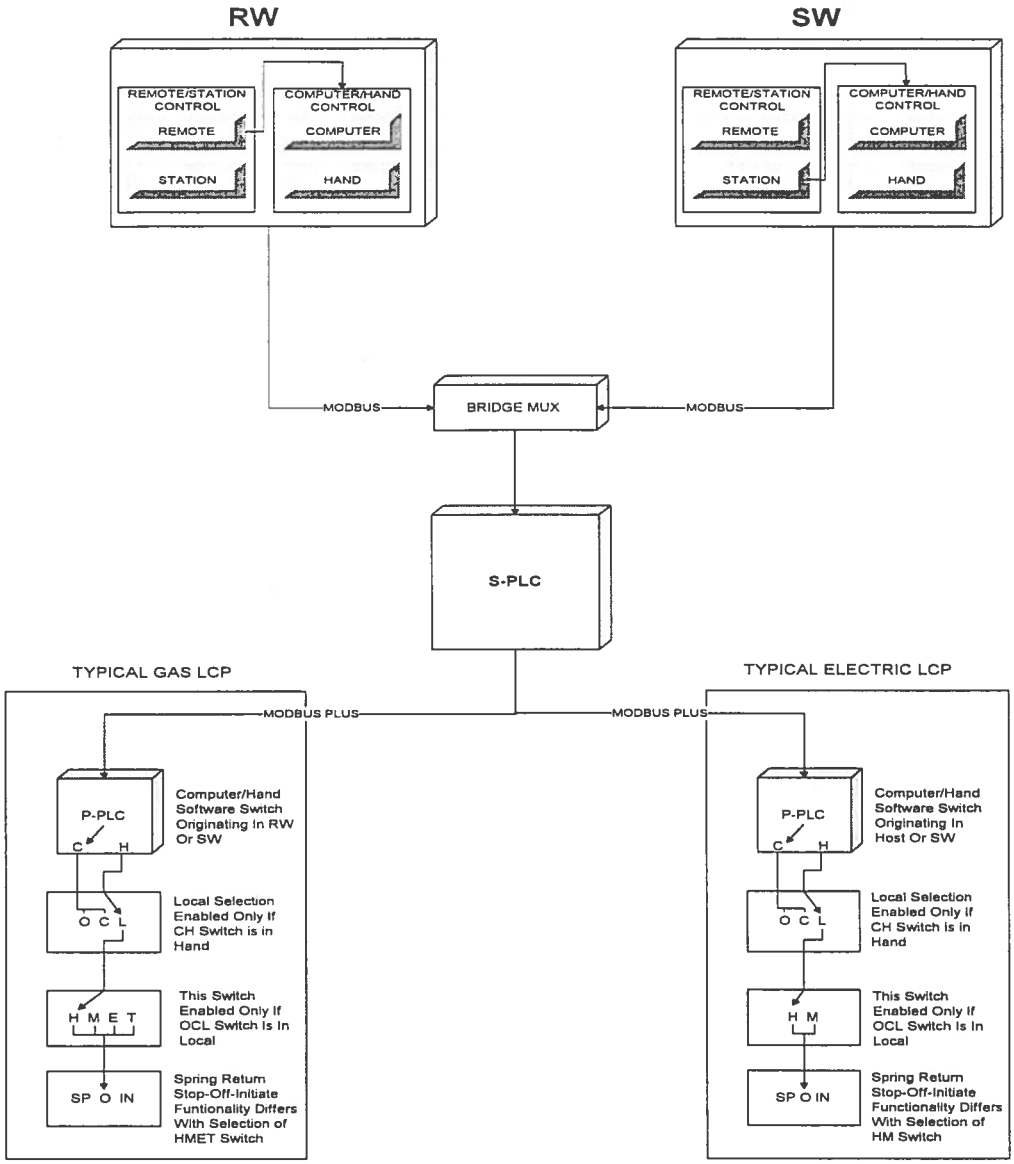


FIGURE 1

1.2.1 Sequencer

Under normal circumstances the Remote Workstation (RW) has control over the operation of the pump station. The RW operator has the ability to allow manual operation of the pumps (sequencer hand mode) or to maintain automatic sequencing via computer control (sequencer computer mode). A software switch, "Computer-Hand", is available for this. He also has the ability to pass control of the sequencer and to relinquish the decision to allow manual operation or not to the Station Workstation (SW). The software switch available for this is the "Remote-Station" switch.

It should be noted that all variables are updated and displayed on both the RW and the SW at all times regardless of the state of the Remote-Station switch.

1.2.1.1 Remote-Station Switch

The Remote-Station (R-S) switch determines whether the RW or the SW has control over the sequencer. If the SW is to be granted control this can be accomplished by one of two methods:

- The RW transfers control by enabling the SW control (R-S switch)
- If communications fails the SW operator can take over control functions by toggling the R/S switch to station mode.

Once the SW has control it maintains it until it releases control back to the RW. If the RW operator requires control after he has relinquished it to the SW this can only be accomplished at the SW.

1.2.1.2 Computer-Hand Switch

The Computer-Hand (C-H) switch determines whether the pump control (sequencer) remains S-PLC controlled or if the control may be transferred to the Local Control Panel (LCP). The C-H switch can be toggled by either the RW or the SW depending on which mode the R-S switch is in. The modes for this C-H switch are:

- Computer - The sequencer is controlled be the S-PLC.
- Hand - The station control may be transferred to the LCP (but may still be controlled by the S-PLC at this time depending upon the status of the O-C-L switch on the LCP). Hand control is also allowed from the SW.

Note: If the C-H switch is in Hand and then an attempt is made to switch it back to Computer a check is made by the S-PLC to ensure that the current pump duty (pumps running) matches the current duty called for by the sequencer. If this is not the case then the mode change back to Computer will not be accepted and the RW (& SW) will display a "Sequencer Does Not Match Current Duty" message. If the sequencer is reset, however, using a sequencer reset command from the RW this forces the sequencer to match the current pump configuration and will then allow a change of the sequencer mode from hand to computer.

1.2.2 Local Control Panel

The Local Control Panel (LCP) houses the P-PLC, its associated I/O, and the three selector switches. Each position on the switch is wired into the PLC I/O so that the P-PLC knows what position each of the switches is in.

1.2.2.1 Off-Computer-Local Switch

The Off-Computer-Local (O-C-L) switch is located on the front of the LCP and provides the following control modes:

Off - causes a quick stop of all associated equipment to occur. Locks out pump locally.

Computer - allows control of pumps by the S-PLC.

Local - enables the local H-M-E-T switch (gas) or the H-M switch (electric).

The Local position is ignored (Computer mode is latched in) if the C-H switch in the RW or the SW is set to Computer. **This means that local control will not be possible until the RW or SW decides to allow local control.** If the communications between the S-PLC and the P-PLC fails then local control is automatically allowed. Once the LCP is in local mode control is maintained by the LCP until the O-C-L switch is switched from the Local position. If any of the pumps are in Local mode then the sequencer is locked into hand mode and is prevented from being allowed to change modes.

1.2.2.2 Hand-Maintenance-Engine-Test Switch

The Hand-Maintenance-Engine-Test (H-M-E-T) switch for the gas pumps (H-M) for the electric pumps) is located on the front of the LCP. It is disabled when the O-C-L switch is not on Local. When the O-C-L switch is on Local the H-M-E-T switch is enabled and the speed control set point is now taken from the manual speed setting potentiometer (also located on the front of the LCP). The control of the startup and shutdown sequence (i.e. valve control, clutch/coupling control etc.) is still handled by the P-PLC but the start and stop are now initiated via the three position spring return Stop-Off-Initiate switch. The following functions are available:

Hand - If the pump was running before switching to this mode it remains running. If it was not running it remains not running. The start and stop are initiated by the Stop-Off-Initiate switch.

Maintenance - This switch position locks out the pump discharge valve and holds it in the closed position. All safety interlocks are still handled by the P-PLC but the operator has the ability to Start/Stop via the LCP Stop-Off Initiate switch and ramp the pump speed via the potentiometer. If the pump was running before switching to this mode it remains running. After the operator switches to Initiate, the discharge valve closes. If the pump was not running it remains not running until the operator switches to Initiate. The pump discharge valve remains closed.

Note: At no time is the pump discharge valve to be open while the pump is not running.

Test - Holding the Initiate switch causes the engine to crank but not start. If the engine was running when this mode was selected a normal stop sequence would occur after the operator selects Initiate. Subsequent holding of the Initiate switch will cause engine cranking.

Engine - The engine only runs (pump does not). If the pump was running before this mode was selected the pump will remain running. After the operator switches to Initiate, a normal stop sequence would occur. Once the stop sequence has reached the beginning of the 5 minute cool down period the speed control is handed over to the potentiometer. If the engine was not running when this mode was selected, after the operator selects Initiate, a normal startup sequence occurs up until the point that the engine is running. At this point the engine ramps to the speed setting on the potentiometer. The clutch does not engage and the pump does not run. The discharge valve also does not open.

1.3 Bridge Multiplexer NW-BM85-000

The RW and SW are connected to the Station PLC (S-PLC) by a Modbus communications link through a bridge multiplexer. The bridge multiplexer has four Modbus ports and a Modbus Plus port allowing Modbus devices to bridge through to the Modbus Plus network. This means that the Remote Workstation and the Station Workstation can connect to the Modbus Plus network and poll any device on the network. The host computers can also poll through the BM85 internal routing tables and communicate directly to the daisy chained Bentley Nevada Monitors. The BM85 internal routing table makes it possible to maintain the same addressing scheme at each of the different pump stations while interfacing to the real world (Valmet Host) using unique addresses for stations on the same Host Computer polling line as required by Modbus protocol.

The Valmet Master at McPhillips Station polls the pump station S-PLC and the Bently-Nevada's using different lines of communications. Some of the stations are common to the same communications line, however, and as a result require distinct addresses at each station. The required addressing is shown below.

	Master Radio		Repeater		Line Driver	Cellular
	Hurst	Tache	Maclean	Deacon	McPhillips	Shoal Lake
S-PLC1	1	2	1	2	1	1
S-PLC33	33	34	33	34	33	33
Bently-Nevada's	41,42,43 44,45,46	47,48,49 50,51,52	41,42,43 44,45,46	47,48,49 50,51,52	41,42,43 44,45,46	

The BM85 allows the PLC's and the Benlty-Nevada's to have the same addressing as they do at all of the other sites by using the internal routing table. The BM85 configuration is shown below.

```
                    MODICON MODBUS BRIDGE/MUX - Ver 1.01
     Copyright (c) 1989 MODICON Inc., Industrial Automation Systems Group
                        MODBUS PORTS CONFIGURATION [V1]
                            [Modbus Plus Address = 64]

<COMMANDS>                                                          [OPTIONS]
<P>PORT NUMBER#        1              2              3              4        [1, 2, 3, 4]
<T>Port Type           master         master         network        slave    [m, s, n, x]
<N>Slave Dev Addr      -              -              -              65       [1 - 247]
<B>Baud Rate           9600           9600           9600           2400     [300 - 19200]
<S>Stop Bits           1              1              1              1        [1, 2]
<R>Parity              none           none           none           none     [n, o, e]
<M>Mode                rtu            rtu            rtu            rtu      [a, r]
<Y>Priority            1              2              3              4        [1 - 4]
<L>Link Timeout        -              -              5              5        [1 - 3000]
<F>Modem Booster       -              -              no             -        [y, n]

>>Valid Commands:[V1 V2 V3 V4 P T N B S R M Y L F]   Keys:[Enter Esc ?-help]<<
```

The internal routing table V2 for the BM85 for each of the ports is shown below. Table V3 is not used.

```
Active Port 1>>v2
                    MODBUS ADDRESS MAP FOR [E1-E32] [V2]
      MAPS: Modbus Address to Destination Address [Port Type: Master]
 Table Modbus   Destination Address        Table Modbus   Destination Address
 Entry Address      (5 bytes)              Entry Address      (5 bytes)

 <E1>   [041]= 000  003  001  000  000     <E17> [000]= 000  000  000  000  000
 <E2>   [042]= 000  003  002  000  000     <E18> [000]= 000  000  000  000  000
 <E3>   [043]= 000  003  003  000  000     <E19> [000]= 000  000  000  000  000
 <E4>   [044]= 000  003  004  000  000     <E20> [000]= 000  000  000  000  000
 <E5>   [045]= 000  003  005  000  000     <E21> [000]= 000  000  000  000  000
 <E6>   [046]= 000  003  006  000  000     <E22> [000]= 000  000  000  000  000
 <E7>   [000]= 000  000  000  000  000     <E23> [000]= 000  000  000  000  000
 <E8>   [000]= 000  000  000  000  000     <E24> [000]= 000  000  000  000  000
 <E9>   [000]= 000  000  000  000  000     <E25> [000]= 000  000  000  000  000
 <E10   [000]= 000  000  000  000  000     <E26> [000]= 000  000  000  000  000
 <E11>  [000]= 000  000  000  000  000     <E27> [000]= 000  000  000  000  000
 <E12>  [000]= 000  000  000  000  000     <E28> [000]= 000  000  000  000  000
 <E13>  [000]= 000  000  000  000  000     <E29> [000]= 000  000  000  000  000
 <E14>  [000]= 000  000  000  000  000     <E30> [000]= 000  000  000  000  000
 <E15>  [001]= 001  000  000  000  000     <E31> [000]= 000  000  000  000  000
 <E16>  [033]= 033  000  000  000  000     <E32> [000]= 000  000  000  000  000


Active Port 2>>v2
                    MODBUS ADDRESS MAP FOR [E1-E32] [V2]
      MAPS: Modbus Address to Destination Address [Port Type: Master]
 Table Modbus   Destination Address        Table Modbus   Destination Address
 Entry Address      (5 bytes)              Entry Address      (5 bytes)

 <E1>   [041]= 000  003  001  000  000     <E17> [000]= 000  000  000  000  000
 <E2>   [042]= 000  003  002  000  000     <E18> [000]= 000  000  000  000  000
 <E3>   [043]= 000  003  003  000  000     <E19> [000]= 000  000  000  000  000
 <E4>   [044]= 000  003  004  000  000     <E20> [000]= 000  000  000  000  000
 <E5>   [045]= 000  003  005  000  000     <E21> [000]= 000  000  000  000  000
 <E6>   [046]= 000  003  006  000  000     <E22> [000]= 000  000  000  000  000
 <E7>   [000]= 000  000  000  000  000     <E23> [000]= 000  000  000  000  000
 <E8>   [000]= 000  000  000  000  000     <E24> [000]= 000  000  000  000  000
 <E9>   [000]= 000  000  000  000  000     <E25> [000]= 000  000  000  000  000
 <E10>  [000]= 000  000  000  000  000     <E26> [000]= 000  000  000  000  000
 <E11>  [000]= 000  000  000  000  000     <E27> [000]= 000  000  000  000  000
 <E12>  [000]= 000  000  000  000  000     <E28> [000]= 000  000  000  000  000
 <E13>  [000]= 000  000  000  000  000     <E29> [000]= 000  000  000  000  000
```

<E14>	[000]=	000	000	000	000	000	<E30>	[000]=	000	000	000	000	000
<E15>	[001]=	001	000	000	000	000	<E31>	[000]=	000	000	000	000	000
<E16>	[033]=	033	000	000	000	000	<E32>	[000]=	000	000	000	000	000

Active Port 3>>v2

MODBUS ADDRESS MAP FOR [E1-E32] [V2]

MAPS: Modbus Address to Destination Address [Port Type: Network]

Table Entry	Modbus Address	Destination Address (5 bytes)					Table Entry	Modbus Address	Destination Address (5 bytes)				
<E1>	[000]=	000	000	000	000	000	<E17>	[000]=	000	000	000	000	000
<E2>	[000]=	000	000	000	000	000	<E18>	[000]=	000	000	000	000	000
<E3>	[000]=	000	000	000	000	000	<E19>	[000]=	000	000	000	000	000
<E4>	[000]=	000	000	000	000	000	<E20>	[000]=	000	000	000	000	000
<E5>	[000]=	000	000	000	000	000	<E21>	[000]=	000	000	000	000	000
<E6>	[000]=	000	000	000	000	000	<E22>	[000]=	000	000	000	000	000
<E7>	[000]=	000	000	000	000	000	<E23>	[000]=	000	000	000	000	000
<E8>	[000]=	000	000	000	000	000	<E24>	[000]=	000	000	000	000	000
<E9>	[000]=	000	000	000	000	000	<E25>	[000]=	000	000	000	000	000
<E10>	[000]=	000	000	000	000	000	<E26>	[000]=	000	000	000	000	000
<E11>	[000]=	000	000	000	000	000	<E27>	[000]=	000	000	000	000	000
<E12>	[000]=	000	000	000	000	000	<E28>	[000]=	000	000	000	000	000
<E13>	[000]=	000	000	000	000	000	<E29>	[000]=	000	000	000	000	000
<E14>	[000]=	000	000	000	000	000	<E30>	[000]=	000	000	000	000	000
<E15>	[000]=	000	000	000	000	000	<E31>	[000]=	000	000	000	000	000
<E16>	[000]=	000	000	000	000	000	<E32>	[000]=	000	000	000	000	000

Active Port 4>>v2

MODBUS ADDRESS MAP FOR [E1-E32] [V2]

MAPS: Modbus Address to Destination Address [Port Type: Slave]

Table Entry	Modbus Address	Destination Address (5 bytes)					Table Entry	Modbus Address	Destination Address (5 bytes)				
<E1>	[000]=	000	000	000	000	000	<E17>	[000]=	000	000	000	000	000
<E2>	[000]=	000	000	000	000	000	<E18>	[000]=	000	000	000	000	000
<E3>	[000]=	000	000	000	000	000	<E19>	[000]=	000	000	000	000	000
<E4>	[000]=	000	000	000	000	000	<E20>	[000]=	000	000	000	000	000
<E5>	[000]=	000	000	000	000	000	<E21>	[000]=	000	000	000	000	000
<E6>	[000]=	000	000	000	000	000	<E22>	[000]=	000	000	000	000	000
<E7>	[000]=	000	000	000	000	000	<E23>	[000]=	000	000	000	000	000
<E8>	[000]=	000	000	000	000	000	<E24>	[000]=	000	000	000	000	000
<E9>	[000]=	000	000	000	000	000	<E25>	[000]=	000	000	000	000	000
<E10>	[000]=	000	000	000	000	000	<E26>	[000]=	000	000	000	000	000
<E11>	[000]=	000	000	000	000	000	<E27>	[000]=	000	000	000	000	000
<E12>	[000]=	000	000	000	000	000	<E28>	[000]=	000	000	000	000	000
<E13>	[000]=	000	000	000	000	000	<E29>	[000]=	000	000	000	000	000
<E14>	[000]=	000	000	000	000	000	<E30>	[000]=	000	000	000	000	000
<E15>	[000]=	000	000	000	000	000	<E31>	[000]=	000	000	000	000	000
<E16>	[000]=	000	000	000	000	000	<E32>	[000]=	000	000	000	000	000

1.4 Bridge Plus NW-BP85-000x

Taken out of Beacon 1 might be taken out of others.

It doesn't really work as intended.

There is no configuration or programming required for the Bridge Plus. This device is used to separate two Modbus Plus Networks. The continuous loop configuration for the communications cable routing is an illegal configuration unless a Bridge Plus is used to separate what is essentially two networks (see Communications section for more).

Some locations have a style of Bridge Plus that provides two ports for bridging between two networks. Another style of BP85 that is used by the City has four ports, port A and B for each of two networks. This style is intended for use where

fully redundant Modbus Plus networks exist and are supported by redundant communications processors within the same PLC processor. The systems used by the City are not capable of supporting two completely independent networks. However, the BP85 with these extra ports operates the same as the BP85 with the two ports. The extra two ports are simply not utilized.

1.5 Taylor Software Pre-formatted Data Screens

ignore

All of the PLC programs were written using Taylor's ProWORK PLUS System Programmer (Micro Version) Version 1.11. This software has since been upgraded and at the time of this writing the City is curently using version 1.36. This software should be used by the programming device to maintain compatibility with the program database files. For information about using the Taylor software see the manuals accompanying the Taylor installation disks.

Several pre-formatted data screens have been developed for use by the system programmer. These screens provide a convenient way of viewing register values and/or bit states within the program. They can also be used to alter register values or force bit values. The pre-formatted screens contain data which has been grouped based on a common function or which may be common to a device. For example one of the screens contains all of the discrete control bits coming from the Host. This allows quick and easy monitoring of Host communications and allows the system programmer to force any of the Host command bits manually.

Some examples of the S-PLC pre-formatted screens are:

chlorin.tfp	Chlorinator configuration
hostalrm.tfp	Alarm bits to the host
hostdisc.tfp	Discrete commands (bits) from the host
hostplc1.tfp	Registers from host to P-PLC1
hostplc2.tfp	Registers from host to P-PLC2
hostplc3.tfp	Registers from host to P-PLC3
hostplc4.tfp	Registers from host to P-PLC4
hostplc5.tfp	Registers from host to P-PLC5
hostplc6.tfp	Registers from host to P-PLC6
hostregs.tfp	Registers from host to S-PLC
pidtest.tfp	PID parameters
power.tfp	Power consumption calculation registers
seqhand.tfp	Sequencer registers and bits - screen information pertaining to sequencer hand
sequence.tfp	Sequencer registers and bits - screen information pertaining to sequencer computer

To access these screens the programming device must be logged in to the S-PLC (Active S-PLC) and on-line. The database selected must be the S-PLC1 or S-PLC33 database. Once on-line and from anywhere within the PLC logic (on any network of any segment) the data menu is accessed by scrolling to the bottom (blue boxed area)

of the screen and pressing the F2 key. This brings up a menu allowing the user to load the screens. Once the screens have been selected (highlighted) and saved the screens are then loaded. The Page Up and Page Down keys can be used to change between data screens Use Alt F to view the data screen as a full page (blocking out the current network from view) and Esc to return to normal view.

These pre-formatted screens can and should be modified by the City maintenance personnel to suit their needs.

2. Station PLC (S-PLC) Program

2.1 Program Description

The S-PLC code has documentation embedded within the code which is intended to act as an aid for anyone wishing to edit or understand the code. The Taylor listing of the code itself quite thoroughly documents in detail such things as where a certain bit may be located throughout the program etc. This manual is a brief supplement to that documentation.

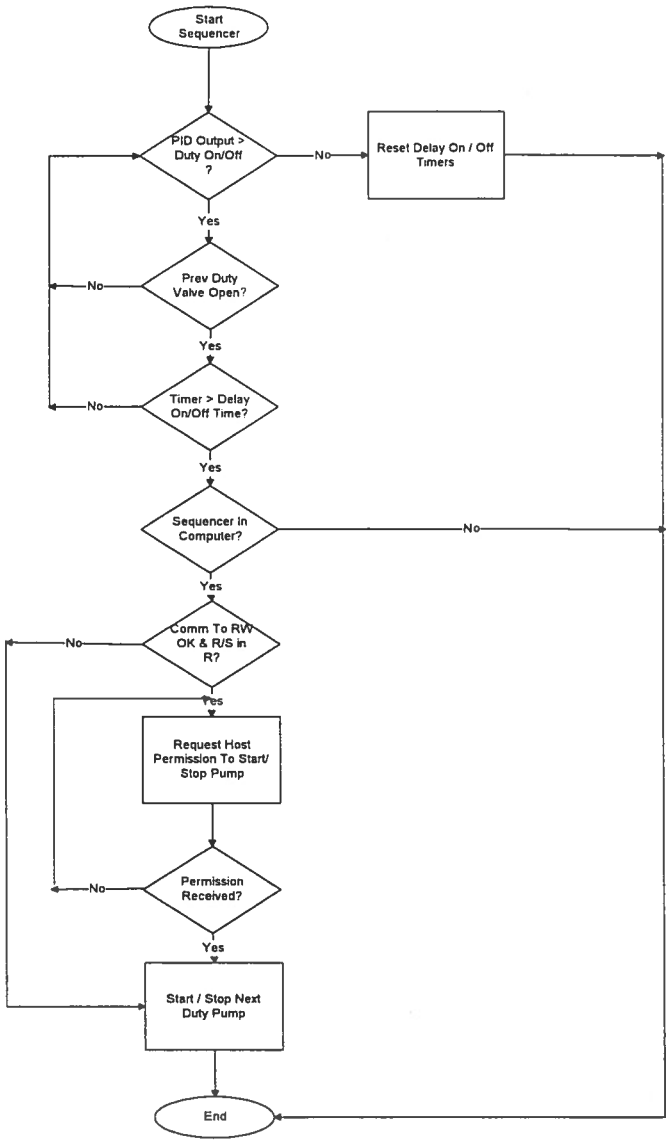
The S-PLC program performs many functions. Its main duties are to act as a data concentrator for the system and to perform all of the sequencer functions such as automatically controlling the header discharge pressure by sequencing on and off pumps and controlling the setpoint of the individual pump controllers. Among the tasks assigned to the S-PLC are:

- Act as a receptacle for P-PLC and PLC-11/12 I/O, status's, and alarm data.
- Relay Host control commands to the appropriate PLC.
- Perform sequencer functions such as duty selection changes in hand, computer immediate, or overnight mode. Automatically sequence on or off the correct next duty pumps as demand changes.
- Control the station discharge header pressure by a PID control loop. Accept setpoint and other PID parameter changes for the host, generate PID related alarms, allow automatic and manual control of the PID output.
- Monitor the status of communications, PLC health, discrete and derived alarms.
- Calculate the combined discharge header flow rate and the total volume.
- Calculate the station power consumption on a 15 minute sliding window basis.
- Monitor and direct chlorinator flow and residual Cl2 analog signals to the correct chlorinator depending on what the current chlorinator configuration is.
- Perform suction and discharge valve open and close functions based on commands from the host or on a station flood alarm. Perform East and West Reservoir percent open positioning functions to allow an operator to enter in a desired percent open setpoint at the host.
- Monitor the loss of 600 VAC power (power failure) and, upon restoration of power, either by manual command from the host or automatically switch the hydro re-transfer switch back to hydro power (on a timed basis).

- Update the non-Active S-PLC with the latest information from the host (and other data) so that it is always in a state of readiness and could take control if required.

The sequencer computer mode is essentially the same as the existing sequencer relay logic. A flow chart of the sequencer in computer mode follows:

Pump Sequencer Flow Chart
(S-PLC)



Notes:

1. The functionality of the Sequencer was developed based on the existing relay logic using drawing Q-McP-158 as a reference.

2. If Sequencer is in Hand the only way it can be switched back to Computer is if the Sequencer matches the current pump running configuration.

FIGURE 2

2.2 Download And Startup Procedure

Ideally the S-PLC's should never be downloaded while the station has any pumps operating in Computer mode. Although it is possible for either the redundant or the primary S-PLC to be downloaded while the sequencer is operating in Computer mode it is recommended that this never be done and that the following steps are followed when downloading a program to the S-PLC.

1. Plug the programming units communications cable into the Modbus port of any of the PLC's CPU module. The comm parameter slide switch (the switch on the bottom) on the CPU module should be set to the default position. This allows a modbus master device such as a programming unit to bridge across to the Modbus Plus network.

2. The MEM slide switch of the S-PLC to be downloaded to will have to be moved off of the protect mode to allow a download. Move only the MEM switch on the S-PLC to be downloaded to and this will ensure that no mistake can be made such as downloading to the wrong PLC.

3. In the Taylor software go On-line and perform a Network Scan. The result of the network scan should display the plc's that are on-line. For example, at McPhillips the result of a scan would show the following addresses:

Address
01
11
12
21
22
24
25
26
33
62
63
64

4. Use the arrow keys and go on-line with the desired PLC. Select the appropriate database to use.

5. In the Taylor software, go to the Loader Operations menu, then to the Read/Write Controller, menu, and then Write to Controller. You will be prompted to stop the controller. This is your last chance to double check the address on the left side of the box at the top of the screen (e.g. D:33). This address tells you what device you are currently logged on to (and are about to stop).

5.1 S-PLC33

If you are about to download to S-PLC33 then S-PLC1 is probably the active S-PLC but you must make sure that it is. S-PLC1 should currently have permission from S-PLC33 to have control over the station - the permissive bit (bit 1 of 41719) is set and so is the Active S-PLC bit 00621. The permissive bit will stay set until it is changed by S-PLC33 (or manually with the programming device). After a download and a subsequent restarting of the processor. S-PLC33 will delay resetting the permissive bit and will delay assuming control until its startup timers are timed out. By this time S-PLC1 will have reported its healthy status to S-PLC33 for some time and when S-PLC33's startup sequence is complete it will begin writing the permissive bit (set to a one) to S-PLC-1 giving S-PLC1 permission to have control.

Note: If neither S-PLC is operating then the preferred order of commissioning is to start up S-PLC33 first followed by S-PLC1. Once S-PLC1 is on-line the system will automatically place S-PLC1 in control (after a few minutes time delay) as the Active S-PLC. This logic is in place to handle the return of station control to S-PLC1 after it has returned to a healthy status. .i.e. Return of station control to S-PLC1 after a failover to S-PLC33 and after S-PLC1 has returned to a healthy status is automatic

5.2 S-PLC1

If you are about to download to S-PLC1 then S-PLC33 is probably the active S-PLC or will soon be. Downloading to S-PLC1 requires less care than the above case since S-PLC1's processor must be stopped. This will automatically create a failover situation and S-PLC33 will assume control. Upon re-starting the processor S-PLC1 will go through its startup timed sequence and will not be able to take control until S-PLC33 is satisfied that S-PLC1 is healthy and has been for at least two consecutive minutes (default time).

Proceed with the download.

6. After the download is complete don't forget to re-start the processor. Monitor bit 00621 in whichever S-PLC you have just downloaded to. After a few minutes the status should change. S-PLC1 will have bit 00621 set to a one while S-PLC33 will have 00621 reset to a zero. Once this has happened S-PLC1 is in control and everything should be operating as it should.

2.3 S-PLC Redundancy

As has already been discussed in section 2.2, the S-PLC has a redundant counterpart waiting to take over the operation of the station from the primary controller. The Valmet Host monitors the status of the Active S-PLC bit (00621) in the redundant S-PLC. If a failover occurs this bit will change state from a "0" to a "1". When this happens the host will automatically begin to poll the redundant S-PLC which will now be the Active S-PLC.

There are several types of failures which will cause a failover to occur:

- S-PLC1 self-diagnostics using STAT function discovers that word 5 indicates a critical failure has occurred. S-PLC1 will send a bad health status to S-PLC33 and S-PLC33 will relieve S-PLC1 of control of the station.

- S-PLC1 processor is stopped. This will normally occur every time a download takes place but may also occur as the result of a failed CPU or a power failure to the S-PLC.

- A complete loss of communications to all plc's will cause the S-PLC to reset its permissive bit and relinquish control until it is given control back. This may occur if the Modbus Plus cable were disconnected for instance. The loss of communications will be detected by the S-PLC and will indicate obvious loss of control of the system. Control will be given back to S-PLC1 automatically, after communications is restored, by S-PLC33 provided that S-PLC33 is on-line. If this should happen when S-PLC33 is not on-line to give control back to S-PLC1 then the permissive bit (41719 bit 1) will have to be set manually through the programming device.

2.4 Communications

2.4.1 Redundancy

The communications network between all plc's is a token ring Modbus Plus network with a data transfer rate of a million bits per second. This provides extremely quick responses to control commands and alarms or status's transferred between plc's. The use of the Bridge Plus (BP-85) in the design of the system architecture provides redundancy in the communications routing which greatly increases the systems tolerance to communications faults. Drawing 3153-SKx in Section 6 shows how the communications cable routing is one continuous loop (through the BP-85). A Modbus Plus network must have a termination point on the network so a continuous loop is normally an illegal configuration. But a continuous loop is desirable since if a failure occurred using the direct (normal) route from device A to device B device A could automatically re-route in the other direction and still reach device B. The BP-85 provides the necessary bridge to make this configuration possible.

2.4.2 Failures

There are three main groups of communicating devices in the system with two main communications routes:

- Host computer(s) to S-PLC(s)

- S-PLC(s) to P-PLC's

The above communications paths are monitored by the S-PLC. Since all communications between S-PLC and P-PLC occurs using MSTR writes the P-PLC's

also monitor communications (between P-PLC and S-PLC) and are able to detect a need to re-route or a complete failure in communications.

If communications from the Host to the S-PLC has failed nothing changes except that if the sequencer was in Computer mode before the communications failure then the S-PLC will now no longer ask the Host's permission to start or stop a pump but will do so on its own. If the sequencer was in hand it remains in hand and nothing changes.

If communications from the S-PLC to the P-PLC's fails then the P-PLC's can be placed in Local mode if the Off-Computer-Local (O-C-L) switch is switched to Local. This is an over-ride (due to the communications failure) that would normally not be allowed unless the sequencer was in hand mode. As soon as one LCP has been switched to local mode the sequencer is forced to hand mode as soon as communications back to the S-PLC is restored.

2.5 Power Demand Calculations

The S-PLC calculates the power consumption (apparent power) which it is charged for by the utility company. This information is made available to the host to be used in deciding whether a power peak may be exceeded if another pump is started.

The Peak Power Calculation is performed once per minute. During that time pulses are accumulated by the pulse counter module. The pulses for Wh and Qh are stored in 15 separate registers (each for a total of 30 registers). A first in first out buffer is used to create a 15 minute sliding window. Every minute the latest 14 pulse accumulations are shifted down by one register and a new pulse total gathered since the last period is calculated and stored in the first of the 15 registers. The raw pulses are kept and used in the calculations to minimize the calculation error (the calculation is performed from raw data to final data only once). The raw pulses for the McPhillips and Maclean Station represent:

Wh pulse input = 8 Wh per pulse

Qh pulse input = 8 Qh per pulse

For the Hurst Station:

Wh pulse input = 12 Wh per pulse

Qh pulse input = 12 Qh per pulse

The formula applied is:

$$VARh = (2 \times Qh - Wh) / Sqrt(3)$$

$$VAh = Sqrt(Wh^2 + VARh^2)$$

The 15 minute peak is calculated by:

load15 = VA1 + VA2 + ...+ VA15

Where:

Wh	= real power
Qh	= out of phase measurement
VARh	= reactive power
VAh	= apparent power
VA1.. VA15	= 1 minute power consumption values for last 15 minutes
load15	= 15 minute sliding window load

2.6 Flow Calculations

At this time only the Shoal Lake S-PLC's are performing flow calculations. The integration of the flow rate at other locations is performed by the SCADA Host.

In order to achieve accuracy in the integration (totalizing) of the analog flow signal an accurate time base is required. One way to achieve this in a Modicon PLC is to extend the length of time over which the input signal is sampled and averaged. By using a T 1.0 timer set to 10 seconds and accumulating samples over the 10 second period any error in the timer due to the PLC scan can be virtually eliminated.

The flow is totalized by the following method:

Once every 10 seconds...

incr (1000's Mega Litres) = rate (Ml/Day) * 10 sec * 1 Day/86400 sec * 1000

then,

Total=Total + incr

The intermediate steps in the calculation are not detailed here but the PLC does perform floating and integer math to preserve resolution. The final result is stored in two consecutive integer registers each of which accumulates to 10000. When the low word reaches 10000 the high word increments by 1. When the register count reaches 9999 9999 the next count will result in 0000 0000. At a flow rate of 400 Ml/Day the registers would roll over to 0 in 250 days.

2.7 Chlorinator Configuration

The S-PLC has analog signals brought in from two residual Cl2 analyzers (RES1 & RES2) and from the two flow meters (FT1 & FT2). Figure 3 on the next page shows the chlorinator signal routing which the S-PLC does based on the contents of the chlorinator configuration register. This register is loaded from the host with a number representing the desired configuration. For example, if the desired configuration is for flow signal 1 added to flow signal 2 sent to chlorinator 2 and residual signal 1 sent to chlorinator 2 then the configuration register would contain a "2". For station specific information on the chlorinator configuration see the SCADA Host manual.

Chlorinator Duty Selection Options
(S-PLC)

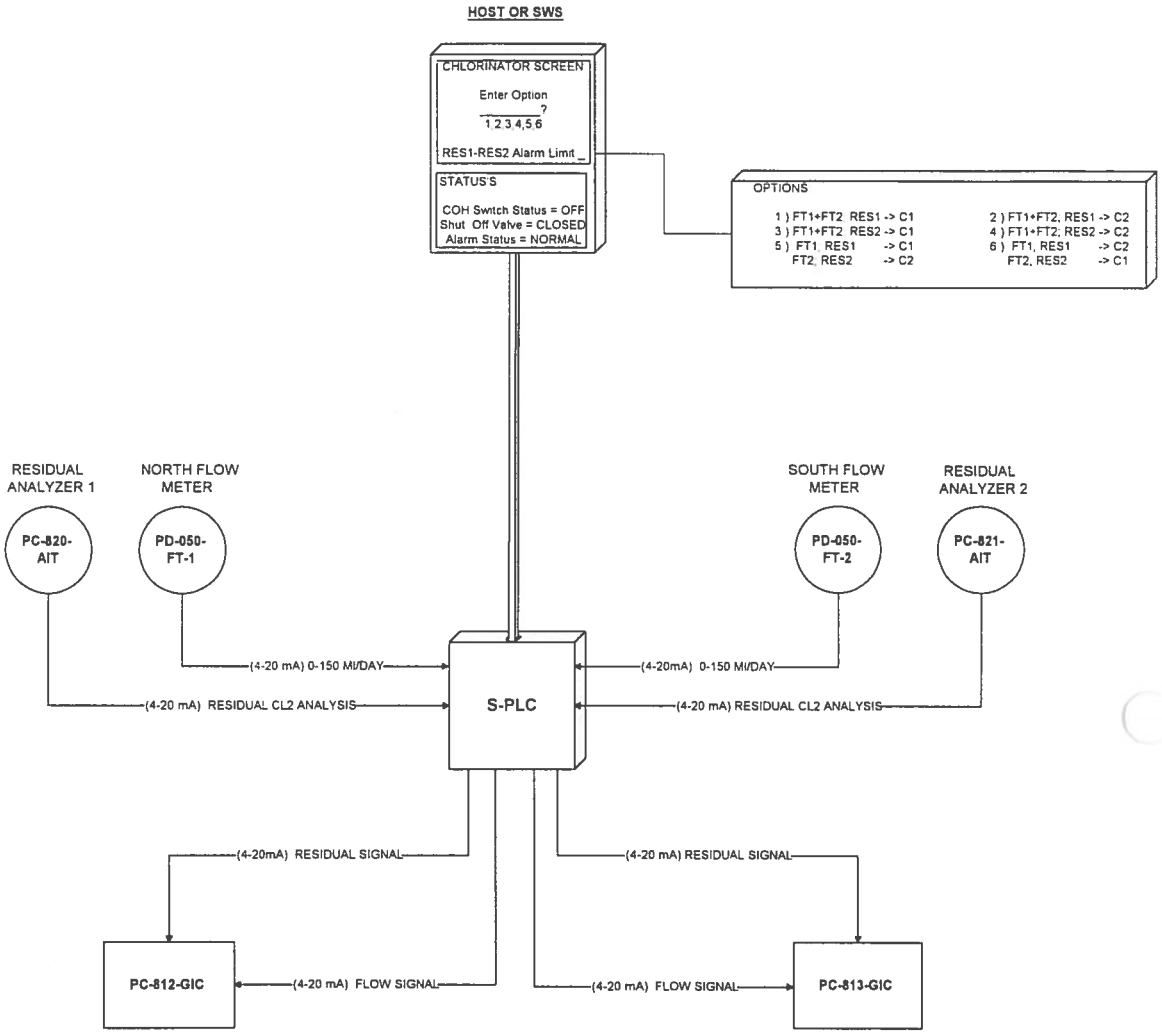


FIGURE 3

2.8 PLC-11 And PLC-12

PLC-11 and PLC-12 have very little code within them. They act as remote I/O controllers and pass the I/O back and forth to and from the S-PLC. The code within PLC-11 and PLC-12 reads the inputs and re-maps them for MSTR transmission to the S-PLC. It also accepts output commands from the S-PLC and maps them to the outputs. PLC-11 has been designated to handle all of the analog and pulse module I/O while PLC-12 manages the discrete I/O. Although the I/O has been distributed this way there is no reason why PLC-11 couldn't also have some discrete I/O and PLC-12 some analog points if that is desired at some time in the future.

The logic controlling the I/O resides in the S-PLC. If, for example a valve open command is issued by an operator at the host this command is first transmitted to the S-PLC. Once the S-PLC has seen the command it performs any logic on it that is necessary and sets an "open valve" (internal) coil as though the I/O were connected directly to the S-PLC. The outputs are re-mapped into registers and continually transmitted to the appropriate PLC. Once the valve is fully open the open status, which is sensed by PLC-12, transmitted to the S-PLC and then re-mapped into internal coils by the S-PLC, is sensed by the S-PLC and the valve open command is reset.

3. Pump PLC (P-PLC) Program

3.1 Program Description

The P-PLC code has documentation embedded within the code which is intended to act as an aid for anyone wishing to edit or understand the code. The Taylor listing of the code itself quite thoroughly documents in detail such things as where a certain bit may be located throughout the program etc. This manual is a brief supplement to that documentation and includes information that may not necessarily be included in the code documentation.

There are five P-PLC's currently for the McPhillips and Maclean Pump Station - one for each of the five pumps. Although there are five pumps there are really only two types of pumps - gas and electric - and therefore two programs. At McPhillips, for example, P-PLC1 - a gas pump program - is the same program as P-PLC5 with the exception of the MSTR segment (communications) while P-PLC2, (P-PLC3), P-PLC4, and P-PLC6 - electric pump programs - are identical except for the MSTR segment. The gas pumps PLC programs at McPhillips and Maclean are virtually identical as are the electric pump PLC programs. Hurst has constant speed electric pumps which are again, a different program than the other electric pumps.

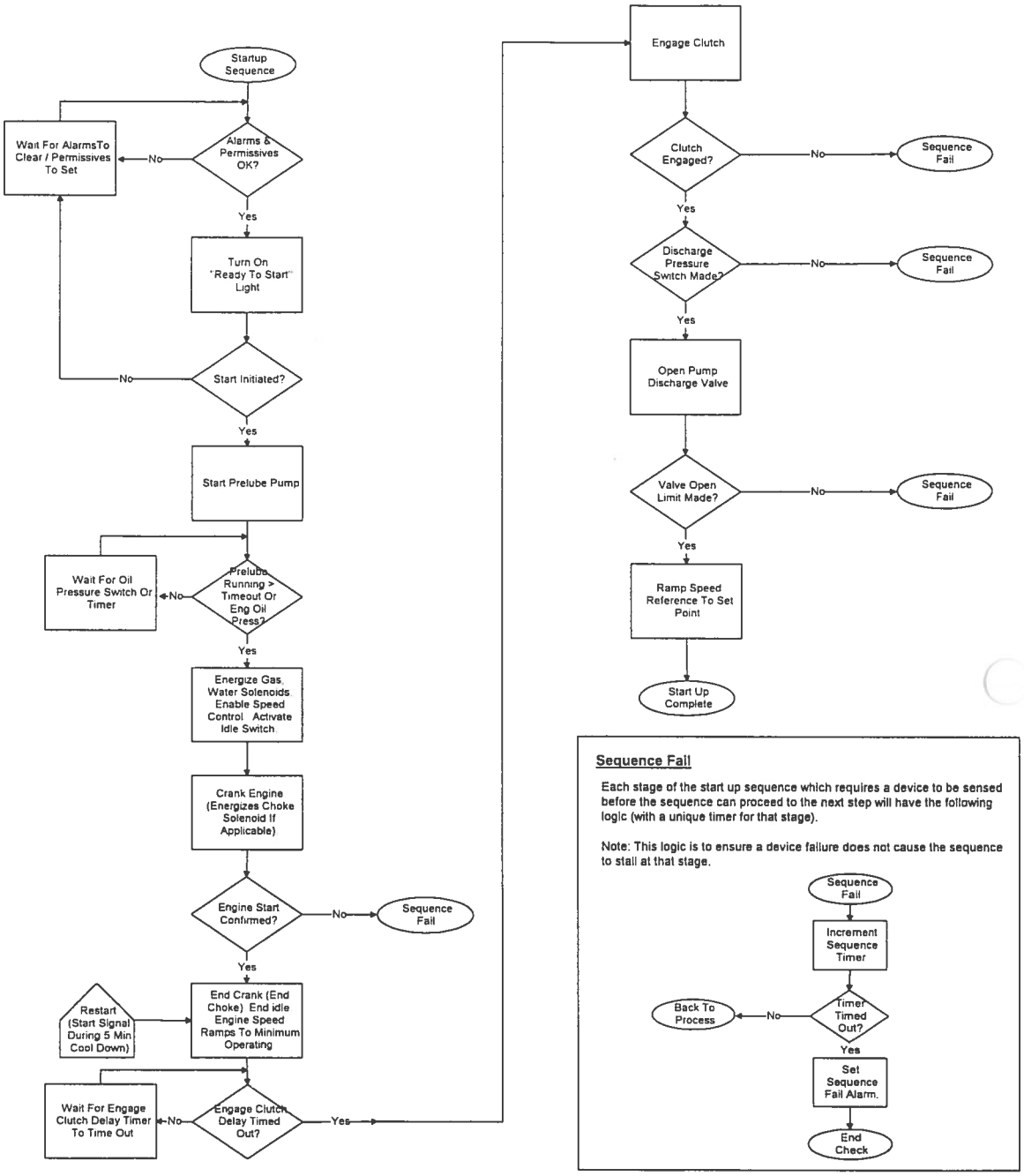
The P-PLC program's main function is to control the pump start up and shut down sequence and monitor alarms for the pump. Among the tasks assigned to the P-PLC are:

- Control the start up and shut down sequence of the pump and discharge valve.
- Monitor hardwired and PLC derived sequence failure and other pump alarms and shut down the equipment as necessary.
- Control the pump speed by a PID control loop, using the pump speed sensor as the process variable. Accept setpoint and other PID parameter changes sent by the Host through the S-PLC, generate PID related alarms.
- Monitor the status of communications, PLC health, etc.
- Linearize the manual setpoint adjustment potentiometer.

3.2 Pump Start Up And Shut Down Sequence

The start up and shut down sequences of the pumps are documented and included here as flow charts . There is a different start up and shut down sequence for the gas and electric pumps.

Gas Pump Start Up Sequence Flow Chart (P-PLC)



Note: If an alarm occurs before the engine is started an immediate stop is initiated. If the engine has started and an alarm occurs then the Pump Stop Sequence Flow Chart is followed.

FIGURE 4

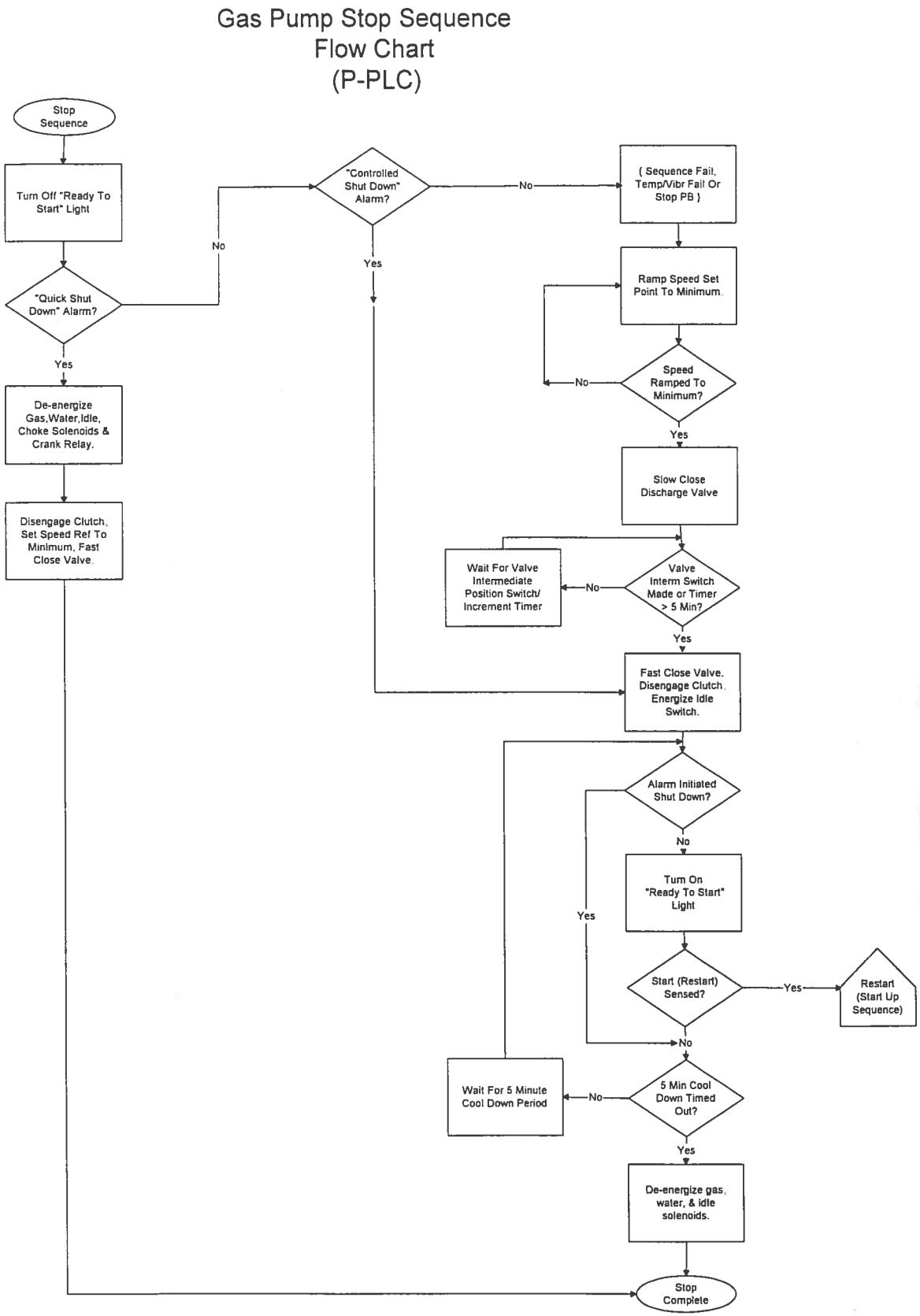

Gas Pump Stop Sequence
Flow Chart
(P-PLC)
Stop Sequence
Turn Off "Ready To Start" Light
"Quick Shut Down" Alarm?
Yes
No
De-energize Gas,Water,Idle, Choke Solenoids & Crank Relay.
Disengage Clutch, Set Speed Ref To Minimum, Fast Close Valve.
"Controlled Shut Down" Alarm?
No
Yes
(Sequence Fail, Temp/Vibr Fail Or Stop PB)
Ramp Speed Set Point To Minimum.
Speed Ramped To Minimum?
No
Yes
Slow Close Discharge Valve
Valve Interm Switch Made or Timer > 5 Min?
No
Wait For Valve Intermediate Position Switch/ Increment Timer
Yes
Fast Close Valve. Disengage Clutch. Energize Idle Switch.
Alarm Initiated Shut Down?
No
Yes
Turn On "Ready To Start" Light
Start (Restart) Sensed?
Yes
Restart (Start Up Sequence)
No
5 Min Cool Down Timed Out?
No
Wait For 5 Minute Cool Down Period
Yes
De-energize gas, water, & idle solenoids.
Stop Complete

FIGURE 5

Electric Pump Start Up Sequence Flow Chart (P-PLC)

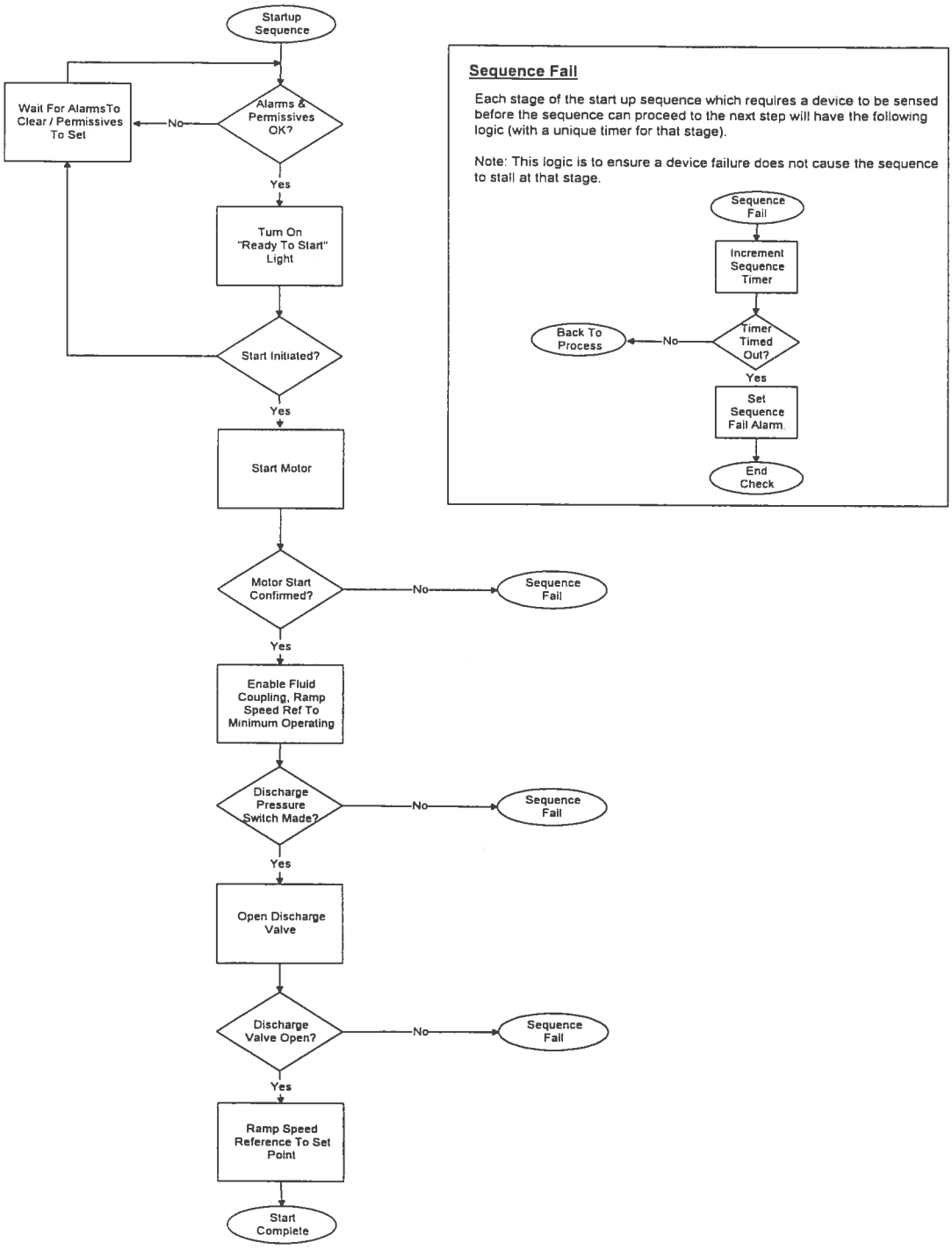


FIGURE 6

Electric Pump Stop Sequence Flow Chart (P-PLC)

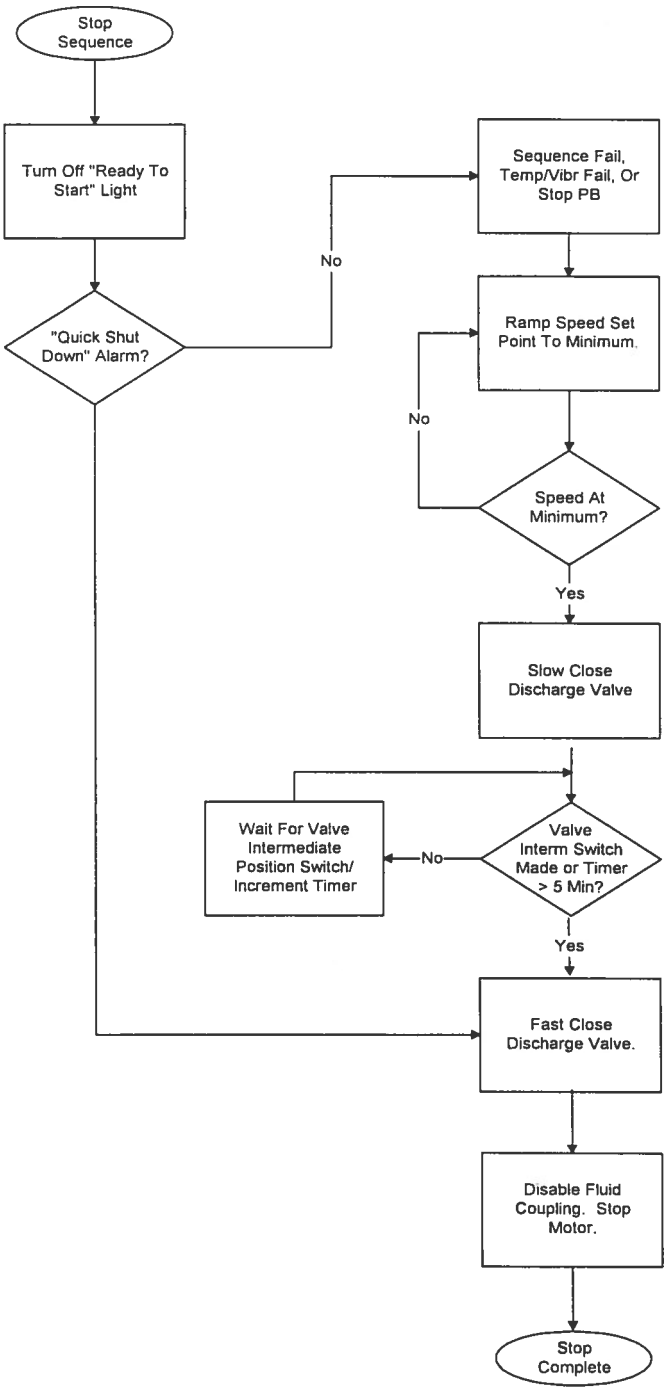


FIGURE 7

3.3 Linearization of LCP Set Point Potentiometer

The potentiometer on the LCP is connected as shown in the following figure:

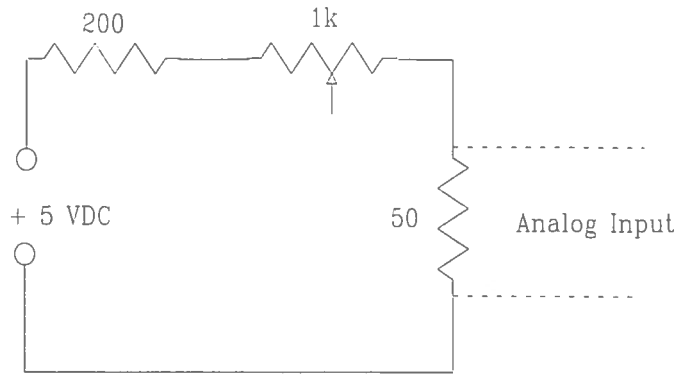


FIGURE 8

Varying the pot from 0 to 1K does not produce a linear relationship between the current and the physical position of the pot. i.e. at mid position the pot is at 500 ohms, the current in the loop is 6.6666 mA, not 12 mA which is what a person using the pot would expect. Because of this a linearization has been done on the pot. The graph below shows five points of the measured potentiometer response versus the physical position of the potentiometer (in percent). The graph also has an overlaid desired response curve.

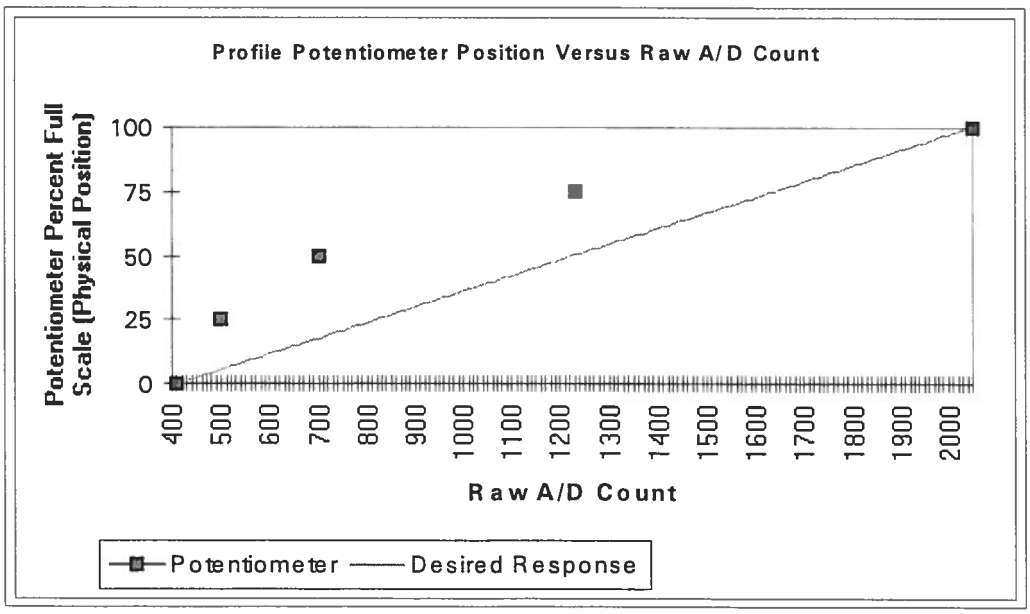


FIGURE 9

The linearization was done by applying four separate line segments to the overall curve. The equations of the line segments are as follows:

1. For a raw A/D count of 1229 to 2048: $y = 0.5x + 1024$
2. For a raw A/D count of 700 to 1229: $y = 0.78x + 681$
3. For a raw A/D count of 500 to 700: $y = 2x - 173$
4. For a raw A/D count of 410 to 500: $y = 5.96x - 2153$

Applying the above equations to the potentiometer analog input in the PLC program yields the following curve:

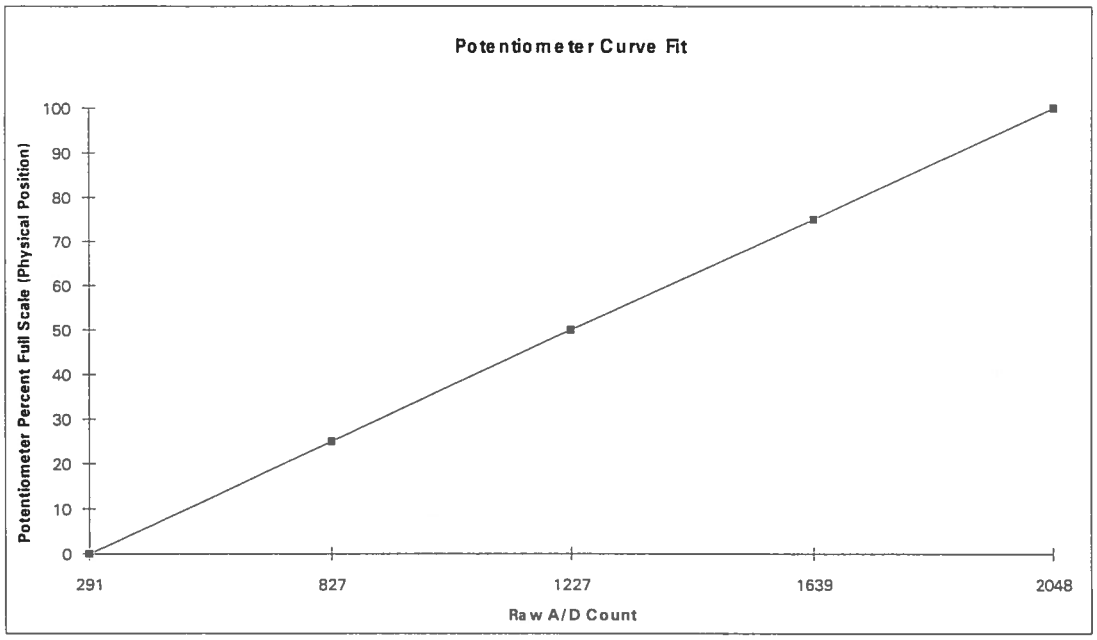


FIGURE 10

3.4 Alarms and Shutdowns

3.4.1 Immediate Shutdown (ISD)

An immediate shutdown means that all outputs controlling equipment are switched to an off or stop state condition without waiting for any sequences to occur. Usually this also means that the controlling bit itself is turned off. This means that the valve will be told to fast close, the clutch (fluid coupling) will disengage, and the engine (motor) will stop all at once.

Bit 00900 in the PLC logic controls the ISD of all equipment. If this bit is off then an ISD will occur. If any new ISD is to be added to the logic the shutdown bit should be added in series with all of the other shutdown bits controlling bit 00900. All shutdown bits in series with 00900 must pass power during a normal (no-alarm) state and must interrupt the power flow to 00900 when an alarm occurs.

The events which cause an ISD are listed below. For ease of identifying whether the SD bit is software generated or if a field device causes the SD the letters 'SG' and 'FD' will be used respectively. Also note that if a bit is identified as a FD then its corresponding PLC input number = bit number + 10000 - 800. For example if a FD identifies an internal bit, say 00812, then the corresponding input number is 10012.

3.4.1.1 Gas Engine ISD's 00900

- **Incorrect Loss Of Clutch Engaged Status** (SG:00932) - Once the clutch is engaged this alarm logic is activated. If the clutch comes off its engaged status without being told to by the PLC an ISD occurs.

- **Low Engine Water Level** (FD:00817) - A switch wired fail-safe causes an ISD if the engine water level is too low.

- **Engine Overload** (FD:00818) - A switch wired fail-safe causes and ISD if the engine overloads. This switch is tied to a vacuum hose and will show an alarm condition if the engine is not running. Logic has been added to bypass this alarm when the engine is not running and to only activate it after the engine has been running for at least 5 seconds to provide enough time for the engine to develop a vacuum.

- **Engine Overspeed/Underspeed** (FD/SG:00820) - The engine has a hardwired overspeed switch which grounds the magnetos causing an engine shutdown independently of the PLC if an overspeed condition occurs. If this switch indicates an alarm condition the PLC logic will cause an ISD. A software generated shutdown will likely occur before the hardwired shutdown since logic uses the engine speed signal to cause an ISD at just less than 1200 rpm.

  The engine underspeed is a SG shutdown which checks the speed of the engine while the clutch is engaged and the valve is not closed. If the speed is too slow an ISD will occur.

- **Low Engine Oil Pressure** (FD:00821) - This is a switch wired fail-safe. The switch shows an alarm condition when oil pressure is low or when the engine is not running. In the same way as the overload switch is bypassed the low oil switch is bypassed while the engine is not running and the alarm logic is only activated once the engine has been running for at least 20 seconds.

- **Engine Temperature/Vibration Trip** (FD:00828) - This is a common trip coming from the Bently-Nevada Temperature/Vibration monitor. It is wired fail-safe. If the Bently-Nevada detects a temperature or vibration trip associated with the engine the PLC causes an ISD.

- **ISD Bit From S-PLC** (SG:00407) - This bit is sent by the S-PLC to all PLC's via Modbus Plus. At present it is only linked to the station flood shutdown in the S-PLC (via PLC-12). If a station flood is detected this bit will be sent by the S-PLC and will cause an ISD.

- **Off Switch** (FD:00809) - The O-C-L switch on the LCP can be used to cause an ISD at any time by switching the O-C-L switch to off. Note - the LCP does not have to be in local for this to work.

- **Loss Of Engine Speed Signal** (SG:00943) - If the speed signal drops below 500 rpm for longer that 3 consecutive seconds at any time while the engine is operating an ISD will occur. Separate protection is provide if the pump speed signal is lost (see Fast Shutdown).

- **Overcrank or Fail To Start** (SG:00914) - If the engine is cranked for longer than the time-out period (currently 45 seconds) an ISD will occur. This ISD is probably not really an ISD because presumably if the engine has failed to start there is very little to shut down.

- **Clutch Disengage Failure** (SG:00937) - During a shutdown (other than an ISD) the clutch may have been engaged and is asked to disengage by the PLC. Normally at this stage the engine would go into a cool down period before actually shutting down. If, however, the clutch fails to disengage properly within a specified period of time after being asked to do so, this ISD will occur.

3.4.1.2 Electric Motor ISD's 00900

- **Reverse Spin** (FD:00812) - This input comes from a reverse spin detection module and is wired fail-safe. If a reverse spin is detected a FSD will occur. If this condition should occur, in all likelihood a loss of speed signal alarm would likely have been the initial shutdown.

- **Pump Temperature/Vibration Trip** (FD:00811) - This is a common trip coming from the Bently-Nevada Temperature/Vibration monitor. It is wired fail-safe. If the Bently-Nevada detects a temperature or vibration trip associated with the pump the PLC causes an FSD.

- **Discharge Valve Failure** (SG:00912) - The discharge valve is timed for any open and close action. Failure to open or close within a specified period results in an alarm and sequence failure. There are three alarms grouped under discharge valve failure:

  - **Discharge Valve Open Failure** (SG:00909) - The open request enables a timer which, when timed out, sets this alarm. When the open limit is sensed the timer is halted and reset (see also NSD - sequence fail).

  - **Discharge Valve Close Failure** (SG:00910) - The close request enables a timer which, when timed out, sets this alarm. When the close limit is sensed the timer is halted and reset.

- **Discharge Valve Intermediate Failure** (SG:00911) - The close request enables a timer which, when timed out, sets this alarm. When the intermediate limit is sensed the timer is halted and reset. The combination of this alarm and the close failure alarm will tell the operator where the failure occurred (i.e. did the valve open beyond the intermediate switch, is the intermediate switch questionable etc.)

IMMEDSD

- **FSD bit from S-PLC** (SG:00407) - The S-PLC sends the electric P-PLC's this bit which is actually set by the station flood bit in PLC-12.

- **Function 86 Lockout** (FD:00813) - This is a hardwired (fail safe) alarm coming from the function 86 relay in the mcc section of the corresponding pump.

- **Motor Winding Temperature** (FD:00816) **MACLEAN ONLY** - This fail safe alarm comes from a switch module which has a motor winding rtd connected to it.

  Power Failure (SG:00409) - This shutdown bit causes a FSD and is used in logic to prevent other shutdowns such as reverse spin (which would possibly occur during a power failure) from locking out the pump. This bit is should really be identified as both SG and FD since it is sent by the S-PLC which sets the bit to a 0 (power failure) based on a power failure switch status.

- **Off Switch** (FD:00801) - The O-C-L switch on the LCP can be used to cause an ISD at any time by switching the O-C-L switch to off. Note - the LCP does not have to be in local for this to work.

3.4.2 Fast Shutdown (FSD) - Gas Only

A fast shutdown means that the discharge valve is fast closed, the clutch is disengaged, and the engine goes into a cool down period where it idles for 5 minutes before shutting down. It is an 'ISD' for the pump only.

QUICKSD

Bit 00901 in the PLC logic controls the FSD of all equipment. If this bit is off then a FSD will occur. If any new FSD is to be added to the logic the shutdown bit should be added in series with all of the other shutdown bits controlling bit 00901. All shutdown bits in series with 00901 must pass power during a normal (no-alarm) state and must interrupt the power flow to 00901 when an alarm occurs.

The events which cause a FSD are listed below:

- **Reverse Spin** (FD: 00824) - This input comes from a reverse spin detection module and is wired fail-safe. If a reverse spin is detected a FSD will occur. If this condition should occur, in all likelihood a loss of speed signal alarm would likely have been the initial shutdown.

- **Pump Temperature/Vibration Trip** (FD: 00827) - This is a common trip coming from the Bently-Nevada Temperature/Vibration monitor. It is wired fail-safe. If the Bently-Nevada detects a temperature or vibration trip associated with the pump the PLC causes an FSD.

- **Discharge Valve Failure** (SG:00912) - The discharge valve is timed for any open and close action. Failure to open or close within a specified period results in an alarm and sequence failure. There are three alarms grouped under discharge valve failure:

  - **Discharge Valve Open Failure** (SG:00909) - The open request enables a timer which, when timed out, sets this alarm. When the open limit is sensed the timer is halted and reset (see also NSD - sequence fail).

  - **Discharge Valve Close Failure** (SG:00910) - The close request enables a timer which, when timed out, sets this alarm. When the close limit is sensed the timer is halted and reset.

  - **Discharge Valve Intermediate Failure** (SG:00911) - The close request enables a timer which, when timed out, sets this alarm. When the intermediate limit is sensed the timer is halted and reset. The combination of this alarm and the close failure alarm will tell the operator where the failure occurred (i.e. did the valve open beyond the intermediate switch, is the intermediate switch questionable etc.)

- **FSD bit from S-PLC** (SG: 00408) - This bit is currently not used in the gas pump but it is sent down to all gas P-PLC's by the S-PLC and is available for some future use.

3.4.3 Normal Shutdown (NSD)

A normal shutdown means that the discharge valve closes slowly (normally), the clutch disengages and the engine goes to idle (cool down). For the electric pump the motor turns off when the discharge valve intermediate switch is detected. For the gas pump the intermediate switch causes the clutch to disengage and the engine to go to idle.

Bit 00902 in the PLC logic controls the NSD of all equipment. If this bit is off then a NSD will occur. If any new NSD is to be added to the logic the shutdown bit should be added in series with all of the other shutdown bits controlling bit 00902. All shutdown bits in series with 00902 must pass power during a normal (no-alarm) state and must interrupt the power flow to 00902 when an alarm occurs.

The events which cause a NSD are listed below:

- **Temperature/Vibration Monitor Fail** (FD:GAS 00825 | ELEC 00809) - A loose wire, bad rtd, bad vibration transducer, or a faulty Bently-Nevada monitor would cause this alarm and a NSD.

- **Sequence Failure** (SG:00913) - There are several alarms grouped under this common alarm. Although a sequence failure causes a NSD some of the alarms grouped as a sequence failure are put under this group for annunciation purposes only and may actually cause an ISD to occur (see ISD alarms above). Any of the alarms below would cause a sequence failure and a NSD.

  - **Clutch Sequence Failure** (SG:00907) - **GAS ONLY** If the clutch fails to engage within a specified period after being asked to do so this alarm will occur.

  - **Discharge Pressure Sequence Failure** (SG:00908) - If the discharge pressure switch is not made within a specified period after the clutch is engaged during a normal startup this alarm will occur. Note - this alarm is ignored if the pump is not in Computer or in Hand mode if in Local control.

  - **Discharge Valve Open Failure** (SG:00909) - The discharge valve is timed for any open and close action. Failure to open or close within a specified period results in an alarm and sequence failure. The open request enables a timer which, when timed out, sets this alarm. When the open limit is sensed the timer is halted and reset.

  - **Overcrank or Fail To Start** (SG:00914) - **GAS ONLY** This will cause a sequence failure and also an ISD to occur (see ISD above).

  - **Loss Of Pump Speed Signal** (SG:00941) - If the pump speed signal drops below 500 rpm at any time while the pump is operating in Hand mode (not Maintenance) this will cause a sequence fail. This alarm provides protection for pump overloading conditions, a broken pump shaft, improperly working clutch, and prevents operation of the pump without proper speed signal feedback for the speed PID loop.

  - **Loss Of Engine Speed Signal** (SG:00943) - **GAS ONLY** This will cause a sequence failure and also an ISD to occur (see ISD above).

  - **Incorrect Loss Of Clutch Engaged Status** (SG:00932) - **GAS ONLY** This will cause a sequence failure and also an ISD to occur (see ISD above).

  - **Loss Of Run Status** (SG:00946) - If the engine is has started and the run status has been seen by the PLC then any subsequent loss of this run status for more than 5 consecutive seconds (immediate for electric's) will cause a sequence failure.

3.5 Lockouts

There are several lockouts in the P-PLC logic that prevent the pump from starting or re-starting. The lockouts can be grouped into two categories; lockouts that require a reset at the local control panel (LCP) and lockouts that do not require a reset. Lockouts that do not require a reset perform functions like temporarily preventing the pump from re-starting based on a timer or locking out a function while a certain

mode exists. Note that in order to reset at the LCP the sequencer must be in Hand and the LCP's O-C-L switch must be switched to Local.

3.5.1 Lockouts That Require A LCP Reset

- **FAILLKOUT** ***Fail Lockout*** (SG:00934) - Any of the shutdowns in the ISD list, the FSD list, a sequence failure, or a temperature/vibration monitor failure will cause a lockout requiring a reset at the LCP.

3.5.2 Lockouts That Do Not Require A LCP Reset

- **LOCALLKOUT** ***Local Lockout*** (SG:00916) - If the sequencer is in Hand and the O-C-L switch on any LCP is in Local then the logic prevents the sequencer from being put in computer mode.

- **RESTRTLKOUT** ***Re-Start Lockout*** (SG:00933) **ELECTRIC ONLY** - This lockout prevents the motor from re-starting until the re-start timer times out. The timer starts timing on the rising edge of the motor run status and is currently set for about half an hour. This means that if the motor is started then until half an hour of run time or stop time (or combination of) has expired the motor will not be allowed to re-start.

- **STOPLKOUT** ***Stop Lockout*** (SG:00931) **ELECTRIC ONLY** - This lockout is a two minute lockout after the motor has stopped to allow time for the motor to stop spinning as a result of inertia. No indication other than the 'Ready to Start' light being off is provided for this lockout (this lockout is not sent to SCADA although the Ready to Start status is). After the two minute period expires the Ready to Start light comes on (provided no other lockout exists) and the pump can be re-started.

3.6 Timers

Timers play an important role in such things as determining the balance between safety of equipment and personnel and prevention of undue shutdowns of equipment. Whenever an action is requested by the PLC and the PLC requires feedback from some external device as to whether the action has been completed or not there will likely be a timer in the logic to alarm or shutdown.

Most of the timers are changeable from the SW or the RW (a password may be required). Some of the timers are 'hard coded' and are only changeable from the PLC programming device. The timers that are changeable from the SW or RW are written to the P-PLC's by the S-PLC since the SW and RW communicate to the S-PLC and not to the P-PLC's. If an attempt is made to change any of these timer values using the PLC programming device at the P-PLC the timer value will be written over by the S-PLC almost immediately. Any of these timer values must be changed using the SW or RW or by using the PLC programming device at the S-PLC.

3.6.1 Timers That Are Changeable From The SW or RW

The registers for the timers vary from pump to pump and pump station to pump station. Please refer to the S-PLC database for register information.

- **PRELUBDLY** ***Prelube Delay*** **(GAS ONLY)** - When the gas engine starts its startup sequence is preceded by the prelube pump running. The requirement in the logic for the next step in the sequence (cranking) is for the prelube pressure switch to make or this time to time out.

- **CLTCHDLY** ***Clutch Delay*** **(GAS ONLY)** - Once the engine is running this delay occurs before the clutch is engaged. This allows the engine time to run at minimum speed for a short time before the clutch is engaged.

- **CLTCENTIM** ***Clutch Engage Time*** **(GAS ONLY)** - If the clutch is being requested to engage by the PLC then it has this much time to make the engaged limit before a sequence failure occurs.

- **COUPLDLY** ***Coupling Delay*** **(ELEC ONLY)** - Once the motor is running this delay occurs before the fluid coupling is engaged. This allows the motor time to run at minimum speed for a short time before the fluid coupling is engaged.

- **DSHPRSTIM** ***Discharge Pressure Time*** - Once the pump is running and pumping against the closed discharge valve it has this much time to make the discharge pressure switch before causing a sequence fail.

- **DSVOPNSTIM** ***Discharge Valve Open Time*** - When the PLC requests the discharge valve to open the valve has this much time to make the open limit switch before a sequence fail and discharge valve fail occurs.

- **DSVCLSSTIM** ***Discharge Valve Close Time*** - When the PLC requests the discharge valve to close the valve has this much time to make the closed limit switch before a discharge valve fail occurs.

- **DSVINTSTIM** ***Discharge Valve Intermediate Time*** - When the PLC requests the discharge valve to close the valve has this much time to make the intermediate limit switch before a discharge valve fail occurs.

- **COOLDNDLY** ***Cool Down Delay*** **(GAS ONLY)** - After a FSD or a NSD the engine goes into an idle condition. It stays in the idle condition for this amount of time.

- **STARTIM** ***Start Time*** - For the gas engine this is the overcrank time. This is the amount of time the logic will allow after requesting a start until it sees the run status before it causes a sequence fail.

- **RESTARTIM** ***Re-Start Time*** **(ELEC ONLY)** - This is the time which must pass after the starting of the motor before a re-start of the motor will be allowed by the PLC. This time can be running time or stopped time or a combination of both.

3.6.2 Timers That Are 'Hard Coded'

The timers that are hard coded should almost never have to be adjusted once they have been set up during commissioning. These timers can be changed directly in the PLC by using the programming device.

- Low Engine Oil Bypass Timer (40810 GAS ONLY) - This timer is used to bypass the low oil switch until the motor has been running for awhile.

- Overload Bypass Timer (40811 GAS ONLY) - The overload switch is in an alarm state when the engine is not running and therefore must be bypassed until the engine has been running for awhile.

- Clutch Disengage Failure Timer (40812 GAS ONLY) - If the clutch fails to disengage after being asked to do so within this period of time a sequence failure occurs.

- Motor Stop Time (40818 ELEC ONLY) - After the motor has at least this much time must pass before a start is allowed. This timer is meant to provide enough time for the motor to stop rotating before re-starting.

- S-PLC Health Verify Timer (40821) - This is used as a S-PLC heartbeat monitor. If the S-PLC doesn't send a bit (which means it's alive and well) within this period of time an alarm occurs and the logic allows the operator to take control of the pump at the LCP even if the sequencer was in computer when communications failed.

- Delay Before Enabling Remote Reference Select (40822 GAS ONLY) - The remote reference select signal tells the Woodward Governor to use the analog setpoint from the PLC as a speed reference. This would cause the engine to ramp to minimum speed at startup. This timer can be used to delay ramping to minimum speed if desired.

- Delay Before Sensing Loss of Speed Sensor (40823) - Since the engine speed can sometimes be a little erratic and to alleviate any possible noise problems this timer is used to filter out sporadic speed fluctuations.

- Loss Of Run Status (40825 GAS ONLY) - Once the run status has been sensed it must be lost for this period of time before a loss of run status alarm is set (sequence fail).

4. Booster Stations

There are two Booster Stations in the system; Tache and Deacon. These stations are different from the Pump Stations in the way the pumps operate. There is also no sequencer and pumps are not automatically started by the S-PLC. The exception to this is if the pumps were running at the time of a power failure and the 'Auto-Restart After Powerfail' flag is set. Upon restoration of power following a power failure the pumps will restart.

4.1 Tache

Tache has three electric pumps. The pumps do not have an individual pump PLC as is the case everywhere else in the system. The logic for the pumps is contained in the S-PLC while the I/O for the pumps is in the I/O PLC that forms part of the S-PLC. Each of the pumps does have a local control panel with start and stop buttons, computer/hand switch, alarm lamps, etc. The control philosophy with respect to acquiring local control of the pumps is consistent with the other stations. The control must first be granted from McPhillips and then control must be returned by the Tache operator.

The pump discharge valves are motor operated (MOV's) and are controlled by the PLC via open and close relays. These relays are pulsed rather than maintained to control the rate at which the valve opens and closes. These valves can be opened without necessarily running the pump. They must be closed, however, to start the pump. The PLC logic handles these tasks.

4.2 Deacon

Deacon has three electric pumps. Each of the pumps has its own pump PLC and the architecture of the booster station is the same as for the pump stations.

The pump discharge valves have I/P's and are controlled by the PLC's via a 4-20 mA signal. These valves can be opened without necessarily running the pump. They must be closed, however, to start the pump. The PLC logic handles these tasks.