Triplex Pump – Sequence of Operation

Rough Draft – Revised 08-28-07

A. Overview

Booster Pumps are installed at the lower level to boost the pressure on the incoming oil line and allow the oil to get up the hill and into the plant.

The original Booster pumps were installed when the offshore oil flow rate was higher than it is today. Consequently, the Booster pumps (P4 and P6) are oversized. To maintain adequate suction pressure on the Booster pumps, a pressure control valve (PCV-P21) was installed on the discharge line. This valve is controlled by a pneumatic Fisher controller which senses and maintains the upstream pressure by throttling the valve. Since the Booster pumps are oversized, this control valve normally operates in a mostly-closed position. This causes erosion of the valve internals and increases maintenance costs.

To help reduce the wear and tear on the control valve, a new triplex, positive displacement, pump (PAX-100) will be installed at the lower level. This pump will be driven by a variable speed drive (VSD) by way of a PID loop in a PLC.

This document describes the control strategy to be used with the new triplex pump, and the means by which control can be transferred from triplex pump to Booster pump and back again as process conditions require.

B. Auto / Manual System Operation

The entire Lower Level / Booster / Triplex pump system may be run in either Manual or Automatic mode.

Manual

In the Manual mode, each pump can be started or stopped manually from Wonderware (WW). Also, any of the pumps can be started from the Lower Level my pressing the Start button on the front of the MCC bucket for any motor. This will place the system in the Manual mode and start the selected pump.

Automatic

In the Automatic mode, the PLC will decide which pump to run based on a combination of suction pressure, discharge pressure, and flow rate. Whenever a change in pump status is called for, an alarm will be generated and a window will popup in WW asking for confirmation from the operator before making the change.

Selection

Selection between Auto and Manual is done in WW by toggling the Auto/Man button on the “Lower Level Motor Control” screen. This screen is accessible by left-clicking on any of the motors found on the “Lower Level Oil and Gas” screen. Additionally, pressing the Start button on the front of the MCC bucket for any of the motors will place the system in the Manual mode and start the selected pump.

Safeties
In either mode, all safeties are active and will shut down the pumps as required unless they are Bypassed in WW. Bypassing a safety in WW may be done by the Production Foreman, the #1 Operator, or the Tester.

C. Normal Operation with Triplex Pump Running

1. Select the AUTO mode in WW.
2. Press the START button in WW.
3. The PLC will send a start signal to the VSD.
4. The VSD will ramp up to a speed that is determined by the PID loop based on the suction pressure. The VSD speed will throttle to maintain the suction pressure at its setpoint.
5. If operating conditions become too extreme, the pump will shut down or an additional pump will start… depending on the condition.
6. Abnormal conditions include:
    a. High Suction Pressure.
    b. Low Discharge Pressure.
    c. Power Loss.
    d. Communication Failure.
    e. Tripping a safety device.

D. High Suction Pressure

The triplex pump can handle a maximum of 9835 bpd. A process upset offshore or a smart pigging operation can require a greater flow rate than the pump can handle. As the suction pressure rises, the speed of the VSD will ramp up to try and keep the suction pressure at its setpoint. When the VSD is maxed out at 55 Hz, the pressure may continue to rise. When the suction pressure rises above 130 psig:

1. An alarm will be generated in WW and a window will popup asking for permission to start the Backup Booster pump. If the operator selects YES, then the Backup Booster pump will start. (If the operator selects NO, then the system will continue to run with only the triplex pump running and items #2-#5 below will not occur. If only the triplex pump is running and the high suction pressure continues to rise, the platforms will eventually shut down due to high suction pressure.)
2. The Backup Booster pump will start.
    Note: If the Primary Backup Booster pump fails to start, or if the suction pressure does not drop even with the Booster pump running, a window will popup asking permission to start the Secondary Backup Booster.
3. A pressure control valve on the booster pump discharge, PCV-P21, will throttle, trying to maintain pump suction pressure at the setpoint of the Fisher controller. At the same time the VSD will continue to ramp up and down, also trying to maintain the suction pressure at the setpoint of the PID loop.

4. A new transmitter will be installed downstream of the triplex pump (PAX-100-PT1). If this pressure exceeds 500 psig an alarm will be generated, the triplex pump will stop and all oil flow will be handled by the Booster pump.
5. An existing pressure transmitter on the downstream side of PCV-P21 acts as a safety device to shut down all the Booster pumps and the triplex pump when the discharge pressure exceeds 400 psig. This protects the oil line heading up the hill from the lower level.

Anytime a pump is commanded to run, and its running status cannot be confirmed by the PLC, a motor fail alarm is generated.

E. Return to Normal

During the high pressure event, the Booster pump will be running and the VSD will be maxed out at ???? Hz. As the process upset stabilizes, the suction pressure will start to fall. This will cause the VSD to start to slow down. Also, PCV-P21 will start to close which will cause the suction pressure to increase, which in turn will cause the VSD to speed up. It is unclear which of these two drivers will have the greater effect on the VSD speed. It is likely that the VSD will settle down into a new steady state speed… but it may tend to oscillate wildly if the tuning parameters are not correct. (We may need to install an I/P on the valve and drive the valve position always through the PLC.) If the VSD speed and the PCV-P21 valve position settle into new steady state conditions, then the flow rate will drop back down to a normal rate of ???? to ???? bpd. If the system is still in the Automatic mode and the flow rate is within the normal range for ???? seconds (we may need to look at a combination of flow rate, VSD speed, and suction pressure):

Triplex Pump and Booster Pump both Still Running:

1. A window will popup in WW asking permission to stop the Backup Booster Pump. If the operator selects YES, then the Backup Booster pump will shut down. (If the operator selects NO, the system will continue to function with both pumps running and items #2-#4 below will not occur.)
2. The PLC will confirm that the VSD is running, then it will shut down the Backup Booster Pump(s).
3. Normal Automatic mode operation will resume..
    a. The VSD will ramp up to a speed that is determined by the PID loop based on the suction pressure.
    b. The VSD speed will throttle to maintain the suction pressure at its setpoint

Only the Booster Pump Still Running:

1. A window will popup in WW asking permission to stop the Backup Booster Pump. If the operator selects YES, then the Backup Booster pump will shut down and the triplex pump will start. (If the operator selects NO, the system will continue to function with just the Booster pump running and items #2-#5 below will not occur.)
2. The PLC will send a start signal to the VSD.
3. When the PLC confirms that the VSD is running, it will shut down the Backup Booster Pump(s).
4. Normal Automatic mode operation will resume.

a. The VSD will ramp up to a speed that is determined by the PID loop based on the suction pressure.
b. The VSD speed will throttle to maintain the suction pressure at its setpoint

F. Low Pressure on Discharge (pipeline + pump)

The triplex pump needs to pump a minimum of 3000? bpd. During a low flow condition, the discharge pressure of the triplex pump might drop too far, tripping the PSL and shutting down all the Boosters and SDV-R11. To avoid this, a pressure transmitter will be installed on the discharge of the PAX_100 but upstream of PCV-P21. This pressure transmitter will cause a shift from the triplex pump to Booster pump operation before the PSL is tripped. If the triplex pump is running, and the pump discharge drops below 100 psig, then:

1. An alarm will be generated in WW and a window will popup asking permission to switch from the triplex pump to the Backup Booster Pump. If the operator selects YES, then the Backup Booster pump will start and the triplex pump will stop. (If the operator selects NO, the system will continue to function with just the triplex pump running and items #2-#6 below will not occur. Continuing to run with just the triplex pump running may cause the PSL to trip which will shut down all shipping.)
2. The Backup Booster pump will start.
3. The triplex pump will stop and all oil flow will be handled by the Booster pump.
4. Note: a pressure transmitter, PAX-100-PT2, acts as a safety device to shut down all the Booster pumps and the triplex pump if the discharge pressure falls below ???? psig.
   Note: PAX-100-PSL is the safety which protects the pump and the small header between the Booster pump discharge lines and PCV-P21. An additional safety is located on the Gross Oil pipeline downstream of PCV-P21. At this time the function of this secondary device is uncertain.
6. A new transmitter will be installed downstream of the triplex pump (PAX-100-PT1). If this pressure falls below ??? psig an alarm will be generated, the triplex pump will stop and all oil flow will be handled by the Booster pump.
7. An existing pressure transmitter on the downstream side of PCV-P21 acts as a safety device to shut down all the Booster pumps and the triplex pump when the discharge pressure exceeds 400 psig. This protects the oil line heading up the hill from the lower level.

G. Return to Normal

As the process upset stabilizes, the flow rate will rise to a normal rate of ???? to ???? bpd. If the system is still in the Automatic mode and the flow rate is within the normal range for ???? seconds (we may need to look at a combination of flow rate, and suction pressure):

1. A window will popup in WW asking permission to switch from the Booster pump back to the triplex pump. If the operator selects YES, then the triplex pump will start and the

Backup Booster pump will stop. (If the operator selects NO, the system will continue to function with just the Booster Pump running and items #2-#5 below will not occur.)

2. The PLC will send a start signal to the VSD.
3. When the PLC confirms that the VSD is running, it will shut down the Backup Booster Pump(s).
4. Normal Automatic mode operation will resume.
    c. The VSD will ramp up to a speed that is determined by the PID loop based on the suction pressure.
    d. The VSD speed will throttle to maintain the suction pressure at its setpoint

H. Power Loss

A loss of 120 VAC at the lower level will cause the PLC to turn off. All Booster pumps will stop. The solenoid valve for PCV-P21 will de-energize, allowing the Fisher controller to regain control of the valve. As the pipeline pressure rises, the valve will open 100%.

Once power is restored, the system will go to the Manual mode, with all pumps off, and wait further instructions.

Loss of power to the upper level will be monitored by a power loss relay mounted in the main control room and fed from non-UPS power. In the event of an upper level power loss all pumps will shut down and SDV-R11 will close This item needs to be researched. If all the safeties can be integrated into PLC11 such that a loss of WW power will not keep the safeties from working properly, then there is no reason to initiate a shutdown. Note: need to find out where the manual shutdown switches for the Oil and Gas valves is sourced.

I. Communications Failure

SDV-R11 is controlled from the PLC2_Compres PLC, while the Booster pumps and the triplex pumps will be controlled from PLC11_VSD. Because different PLCs control different parts of the shutdown system, it is important to shut down the entire system when a PLC to PLC communication failure occurs.

A heartbeat will be created between these two PLCs. If communication fails for more than ???? seconds all the Booster pumps will shut down and SDV-R11 will close.

This item needs to be researched. If all the safeties can be integrated into PLC11 such that a loss of WW power will not keep the safeties from working properly, then there is no reason to initiate a shutdown. Note: need to find out where the manual shutdown switches for the Oil and Gas valves is sourced.

J. Selecting Auto / Man Control

Selection between Auto and Manual is done in WW by toggling the Auto/Man button on the "Lower Level" screen. Additionally, pressing the Start button on the front of the MCC bucket for any of the motors will place the system in the Manual mode and start the selected pump.

K. Selecting Backup Booster Pump

Selection of the primary and secondary Booster pumps can be made from the "Lower Level" screen in WW.

A checkbox will be added to WW to "lockout" any of the Booster pumps or the triplex pump as required by operations. Obviously, this does not preclude the need to manually lock out a pump whenever maintenance is being performed. The checkbox merely provides a visual check so anyone can see if the pump is "locked out" without having to drive all the way down to the lower level.

L. PCV-P21 Valve Auto / Manual

We may need to install an I/P to control this valve from WW. Also, we may to create a manual override for this valve position.

M. Still to be Resolved

Rick Hurdle is still working on the following questions. He will report back as soon as he is able.

1. How does the Swanson panel control the Gas and Oil shutdown valves?
2. Do we need to have the manual S/D switches for the Gas and Oil S/D valves or can these be driven from WW?
3. Are there other safeties that shut down the Gas and Oil S/D valves that cannot, at this time, be integrated into WW?
4. Can a flame detected shutdown be made to shut down the incoming Gas Valve (SDV-R21)?

N. Safeties

All safeties generate audible and visual alarms in addition to shutting something down. The existing shutdowns for the incoming oil and gross oil need to be researched to find out what they actually do.

The Lubricator and Crankcase shutdowns only shut down PAX_100.

The rest of the shutdowns shut down all pumps and close SDV-R11.

All shutdowns latch and require a Reset button in WW to be pressed before shipping can continue.

Safety	Actions	PLC
USH_Lower_Level	Flame detected for more than 30 seconds. Shutdown all Boosters, close SDV-R11, and SDV-R21.	11_VSD
Incoming Gas PSH (pipeline)	Shutdown SDV-R21	8_Heater
Incoming Oil PSL (pipeline)	Shutdown all Boosters (but not SDV-R11).	11_VSD
Gross Oil Header PT_PSH	Shutdown all Boosters.	10_LowLv
Gross Oil Header PT_PSL	Shutdown all Boosters, close SDV-R11.	10_LowLv
PAX_100_PT1_PSH_Disch	Shutdown all Boosters, close SDV-R11.	11_VSD
PAX_100_PT1_PSL_Disch	Shutdown all Boosters, close SDV-R11.	11_VSD
PAX_100 Lubricator PSL	Shutdown PAX_100.	11_VSD
PAX_100 Crankcase LSL	Shutdown PAX_100.	11_VSD
Lower Level Containment LSH	Shutdown all Boosters, close SDV-R11	11_VSD
Power Loss to the lower level or the Control Room	Shutdown all Boosters, close SDV-R11.	VSD
Communication Failure between PLC2_Compres and PLC11_VSD	Shutdown all Boosters, close SDV-R11.	Compres & VSD
FWKO - LSH	Shutdown SDV-R11.	8_Heater
Flare Scrubber – LSH	Shutdown SDV-R11	8_Heater
Seal Failure - LSH	Shutdown ???	10_LowLv

O. Alarms

Alarms generate audible and visual notifications, but do not shut anything down.

Alarms do not latch. But the alarm condition will be displayed in WW until someone acknowledges the alarm.

Flame detector warning	Flame detected.	VSD
Flame detector fault	Internal flame detector diagnostics.	VSD
TK7_Pit_LAH	Hi Level at TK7-Pit.	VSD
Lower Level Containment LAH	Hi Level at the lower level containment.	VSD
PAX_100_MF	Triplex pump – Motor fail.	VSD
P4_MF	Booster pump P4 – Motor fail.	VSD
P6_MF	Booster pump P6 – Motor fail.	VSD
PAX_100_VSD_SAHL	PAX_100 VSD – Speed Alarm Hi and Lo	VSD
GO_FT_PAHL	Gross Oil flow rate (downstream of PCV-P21) – Flow Alarm Hi and Lo	VSD
OS_PT_PAHL	Oil Shipping pressure (Booster Suction) – Press Alarm Hi and Lo	VSD
PAX_100_PSHL_Disch	Gross oil pressure downstream of the Booster pumps, but upstream of PCV-P21.	VSD
PAX_LSH	Booster Pump Seal Failure – Level Alarm Hi	

P. Notes to Programmer

Normal suction pressure range 105-115 psig
Normal discharge press range 305 psig
Add barrel rate to PLC
Check SDV operation
Check PSL suction, and PSL discharge… Swanson?
PT for suction 0-1000 psig
Breaker installation, clean switchgear, mount relays
PCV-P21 needs to open to 100% when only the triplex pump is running. This is an air-to-open valve… fail closed.
WW to select which pump
Upon loss of power, shut in shipping unless bypassed.

Emergency Gas Valve – Open
Emergency Gas Valve – Closed
Emergency Oil Valve – Open
Emergency Oil Valve – Closed
SDV-R21
SDV-R11

Incoming Oil - PSL
Incoming Gas – PSH

Mode 0 – Standby (Automatic shipping is disabled, Manual shipping is okay).

1. System is in Auto.
2. Start initiated.
    a. Transfer to Mode 1.
3. Valve position Warning.

Mode 1 – Start Triplex.

1. Run Triplex.
2. Drive frequency > 55 Hz and suction pressure > 130 psig.
    a. Transfer to Mode 2.
3. Discharge pressure < 100 psig.
    a. Transfer to Mode 3.

Mode 2 – Hi Suction Pressure – Start Backup.

1. Start 5-second timer.
2. Start primary booster pump.
    a. If timer is > 5 seconds and primary booster is not running, start secondary backup booster pump.
3. Drive frequency < 50 Hz and suction pressure < 110 psig.
    a. Shutdown Booster pumps.
    b. Transfer to Mode 1.

Mode 3 – Lo Discharge Pressure – Start Booster, shutdown Triplex.

1. Start 5-second timer.
2. Start primary booster pump.
    a. If timer is > 5 seconds and primary booster is not running, start secondary backup booster pump.
3. Stop Triplex.
4. Flow rate > 4000 bpd and discharge pressure > 100 psig.
    a. Start Triplex.
    b. Stop Boosters.
    c. Transfer to Mode 1.

Transfer to Stop Mode 4, when:

- PAX_100_PSL_Lube
- PAX_100_LSL_Crank

1. Shutdown Triplex pump.
2. Press Stop to shutdown Boosters.
3. Press Reset.
4. Transfer to Mode 1.

Transfer to Stop Mode 5 whenever:

- OS_PSL
- GO_PT_PSH

1. Shutdown Triplex pump.
2. Shutdown Boosters.
3. Press Reset.
4. Transfer to Mode 1.

Transfer to Stop Mode 6 whenever:

- PAX_100_PT1_PSH_Disch
- PAX_100_PT1_PSL_Disch
- LL_Cont_LSH
- Power Loss
- Comm Fail
- GO_PT_PSL

1. Shutdown Triplex pump.
2. Shutdown Boosters.
3. Close SDV-R11.
4. Press Reset.
5. Open SDV-R11.
6. Transfer to Mode 1.

Transfer to Stop Mode 7 whenever:

- USH

1. Shutdown Triplex pump.
2. Shutdown Boosters.
3. Close SDV-R11.
4. Close SDV-R21.
5. Press Reset.
6. Open SDV-R11.
7. Open SDV-R21.
8. Transfer to Mode 1.