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WNG01: ACTUATOR CONTROLS
Test Plan

For Michael Malcom

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Approvals for Rev 0.1

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Revision History

Revision	Date	Description	By
0.1	2018-10-11	Initial Draft	Nuvation

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Term	Description

1 Introduction

The North American P51 Mustang has two thermostatic actuators that open and close the air outlet doors of the coolant and oil radiators. Adjusting the position of these doors ultimately change the operating temperature of the engine.

The thermostatic actuators can be operated automatically using the existing electro-mechanical control system which is comprised of relays, switches and a diatstat. The diastat is used to sense the coolant and oil temperatures to provide feedback to the control system. These diatstats are beginning to wear out and it is becoming increasingly hard to find diastats that still function properly.

1.1 Purpose

The purpose of this project is to modify the existing thermostatic actuators with a digital controller that replaces the existing electro-mechanical controller. This document describes the test plan to be performed on the actuator controls system.

1.2 Scope

This tests in this document apply to the actuator controls hardware and firmware.

1.3 Assumptions

The set of functional tests mentioned in this document are performed in a typical office environment that validates the electrical hardware, firmware, and mobile application.

1.4 Related Documentation

The following documentations are related to this document:

- WNG01_Mobile_SDD
- WNG01_HDD

2 Test Setup

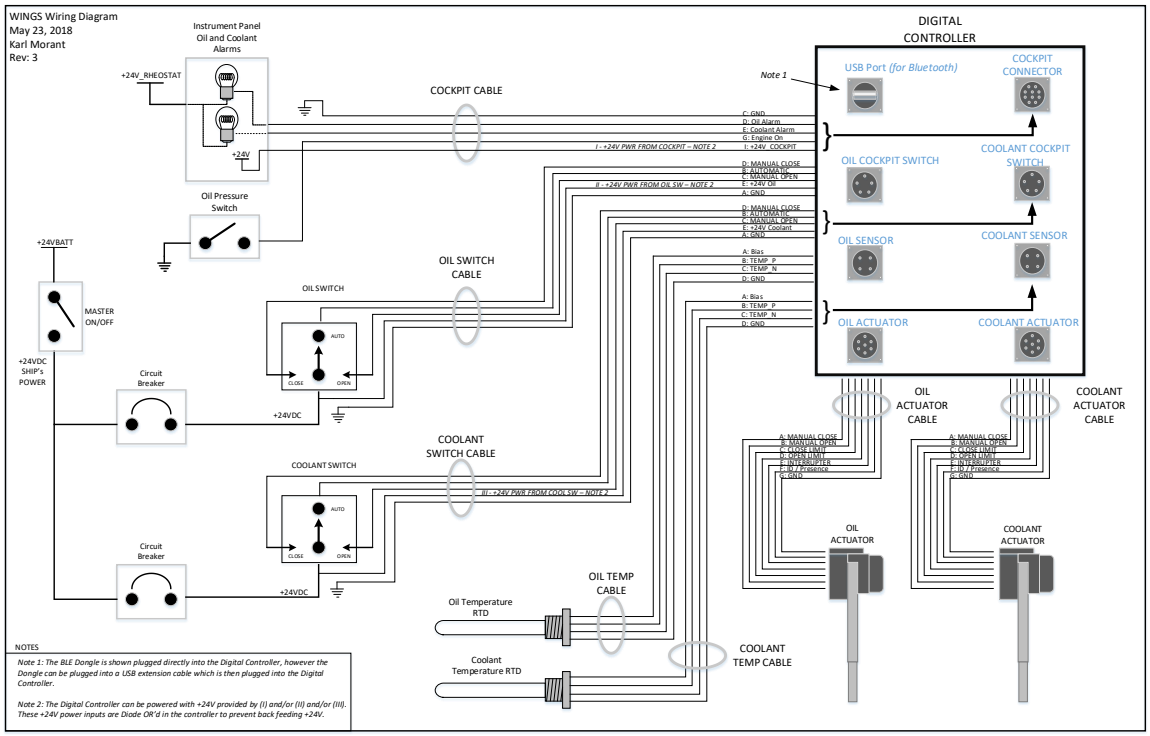

Figure 1: System Wiring Diagram

The wiring diagram for the digital controller is shown above. For the purposes of testing the controller the same connections will be made; however each input and output will be wired to a test PC to allow rapid testing on inputs and monitoring of outputs in an automated fashion.

The oil and coolant systems will be tested separately; therefore only four cables are required at a time: coolant/oil cockpit switch input, coolant/oil temperature sensor, coolant/oil actuator, and the cockpit connector.

The test PC will require a total of 12 USB-controlled relay channels to activate the Digital Controller outputs, and a DAQ with at least 4 general purpose inputs for monitoring the outputs from the Digital Controller.

2.1 Coolant/Oil Cockpit Switch Cable

This cable will run from USB-controlled relays on the test PC to the Digital Controller. The relays will normally be pulled high (+24V), and activating the relay will pull them to ground. There are three relay outputs from the test PC to control to the Manual Close, Manual Open, and Auto signals as shown in the wiring diagram. Additionally +24V power will be supplied via a relay that can gate power via this connector.

2.2 Coolant/Oil Temperature Sensor Cable

This cable will run from USB-controlled relays on the test PC to the Digital Controller. A resistor in the range of 120 Ohms will normally be placed in parallel, representing a PTD100 element at approximately 125 degrees Celsius. This will be hotter than is acceptable for the coolant system and should trigger a temperature warning in the Digital Controller. Three additional USB relay inputs will allow additional resistance to be placed in parallel to simulate high, mid, and low temperatures (but within normal operating range) to cause the Digital Controller to open and close the door actuators in response.

2.3 Coolant/Oil Actuator Cable

This cable will run from USB-controlled relays, and a DAQ with at least 4 general purpose inputs, on the test PC to the Digital Controller. The relays will normally be pulled high (+24V), and activating the relay will pull them to ground. There are four relay outputs from the test PC to control the Close Limit, Open Limit, ID/Detection, and Interruptor signals as shown in the wiring diagram. The Close and Open signals are +24V-level outputs from the Digital Controller to drive the door actuators to open and close – these outputs will be wired to the two general purpose inputs on the DAQ attached to the PC.

2.4 Cockpit Connector Cable

This cable will run a USB-controlled relay, and a DAQ with at least 4 general purpose inputs, on the test PC to the Digital Controller. The relay will normally be pulled high (+24V), and activating the relay will pull them to ground. The relay will be used to supply the Oil Pressure Switch signal as shown in the wiring diagram. The Oil Alarm and Coolant Alarm are open-drain signals that require pull-up to +24V, and then will be connected to 2 general purpose inputs on the DAQ attached to the test PC.

3 Test Procedure

The following tests demonstrate the functionality of the Actuator Controller hardware and firmware. For the purposes of keeping this section concise, tests to be repeated for both the coolant and oil systems are listed together and the test is considered a pass only if both the oil and coolant systems have passed their individual test. It is expected the automated system will run through all tests on one actuator system, and then be reconfigured by a test operator and re-run through all the tests on the second actuator system. Therefore, the results from each actuator run should be stored, and only if both actuators' tests have passed is a given test said to have passed.

These tests assume the controller is set to maintain the temperature to the mid-normal temperature level that can be set through the USB relays

A test matrix detailing 24 tests is shown in the table below. The tests below provide a description of how to run each test listed in the matrix, following the same order as the table.

Table 1: SEH Test Matrix

Inputs									Outputs				
Engine State / Oil Pressure (0 - Off, 1 - On, X - Don't Care)	Auto Mode (0 - off, 1 - active, X - Don't care)	Manual Open Mode (0 - Off, 1 - Enabled, X - Don't care)	Manual Close Mode (0 - Off, 1 - Enabled, X - Don't care)	Open Limit Active (0 - Off, 1 - Activating, X - Don't care)	Close Limit Active (0 - Off, 1 - Enabled, ^ - Activating, X - Don't care)	Interrupter Active (0 - Off, 1 - Enabled, P - pulse, X - Don't care, !P - missing Pulse)	Temperature (X - Don't Care, OT - Over Temperature Threshold)	dT (Temperature - target temperature) (X - Don't care, dT < -threshold , -threshold < dT < +threshold)	Error State (X - don't care, ^ - Activating, v - Clearing)	Open Actuator (X - Don't care, 1 - Active, 0 - inactive, P - pulsed, ^ - Activated, v -	Close Actuator (X - Don't care, 1 - Active, 0 - inactive, P - pulsed, ^ - Activated, v -	Notes	ATP Test Cases
X	1	1	X	X	X	X	X	X	^	1	X	Error: Modes Mutually Exclusive	
X	1	X	1	X	X	X	X	X	^	X	1	Error: Modes Mutually Exclusive	
X	X	1	1	X	X	X	X	X	^	1	1	Error: Modes Mutually Exclusive	
X	X	X	X	1	1	X	X	X	^	X	X	Error: Limits switches Mutually Exclusive	3.4.2
X	X	X	X	0	X	1|P	X	X	^	0*	0	Error: * Actuators were not recently activated and ** not at limit switch.	
X	X	X	X	X	0	1|P	X	X	^	0	0*	Error: * Actuators were not recently activated and ** not at limit switch.	
X	X	X	X	X	X	X	>= OT	X	^	X	X	Error: Error state is activated if temperature > over temp threshold regardless of other states.	3.1.3,3.4.1
X	X	X	X	X	X	X	X	X	1	X	X	Error: Controller disconnected causes alarm	3.4.4
X	X	X	X	X	X	X	X	X	1	X	X	Error: Controller overtemperature causes alarm	3.4.5
X	X	X	X	X	X	X	X	X	^	X	X	Error: Controller Resetting / or abnormally reset.	3.1.5,3.3.7,3.4.6
X	X	X	X	0	X	!P	X	X	^	1	0	Error: Missing Interrupter pulse shortly after open and open limit not activated.	3.4.3
X	X	X	X	X	0	!P	X	X	^	0	1	Error: Missing Interrupter pulse shortly after close and close limit not activated.	3.4.3
X	X	X	X	X	X	X	< OT	X	v	0	0	Clear Error: *** Controller coming out of normal reset	3.3.7,3.4.1
1	1	0	0	0/^	X	P	X	+threshold < dT	X	P	0	Open Actuator activated until Interrupter pulses. Interrupter within x seconds. Actuator activated within y seconds where y depends on rate of change in dT.	3.1.x
1	1	0	0	X	0/^	P	X	dT < -threshold	X	0	P	Close Actuator activated until Interrupter pulses. Interrupter within x seconds. Actuator activated within y seconds where y depends on rate of change in dT.	3.1.x
1	1	0	0	X	X	0	X	-threshold < dT < threshold	X	0	0	No Actuator activity if temperature within limits.	3.1.x
0	1	0	0	X	X	0	X	X	X	0	0	No Actuator activity.	3.1.6
X	0	0	0	X	X	0	X	X	X	v/0	v/0	No Actuator activity.	3.2.6
X	0	1	0	0/^	X	P	X	X	X	^/1	0	Open Actuator activated. Remains active even after Interrupter pulses. Interrupter pulse within x seconds. Eventually Open Limit Switch Activated if held long	3.2.11
X	0	0	1	X	0/^	P	X	X	X	0	^/1	Close Actuator activated. Remains active even after Interrupter pulses. Interrupter pulse within x seconds. Eventually Close Limit Switch Activated if held long	3.2.11

3.1 Test for Mutually Exclusive Modes – Manual Open and Auto

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode on, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, enable Manual Open, wait 5 seconds, and verify an Alarm has been triggered by the invalid state of Auto and Manual modes enabled at the same time.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.2 Test for Mutually Exclusive Modes – Manual Close and Auto

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode on, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, enable Manual Close, wait 5 seconds, and verify an Alarm has been triggered by the invalid state of Auto and Manual modes enabled at the same time.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.3 Test for Mutually Exclusive Modes – Manual Close and Manual Open

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, enable Manual Close and Manual Open signals, wait 5 seconds, and verify an Alarm has been triggered by the invalid state of Auto and Manual modes enabled at the same time.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.4 Test for Both Limits Activated Trigger Alarm

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, enable Open and Close Limit signal, wait 5 seconds, and verify an Alarm has been triggered.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.5 Actuators Moving Without Activation – Close Door

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Ensure the Digital Controller is not signaling to open or close the actuators. Then, provide several interruptor pulses followed by a Close Limit Active to simulate the door closing when not commanded to do so (assume 15 seconds total for this pattern). Wait 5 seconds, and verify an Alarm has been triggered by the unexpected actuator motion.

Repeat the same test for both the Oil and the Coolant System.

Test time: 30 seconds (oil) + 30 seconds (coolant) = 60 seconds

3.6 Actuators Moving Without Activation – Open Door

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Ensure the Digital Controller is not signaling to open or close the actuators. Then, provide several interruptor pulses followed by a Open Limit Active to simulate the door closing when not commanded to do so (assume 15 seconds total for this pattern). Wait 5 seconds, and verify an Alarm has been triggered by the unexpected actuator motion.

Repeat the same test for both the Oil and the Coolant System.

Test time: 30 seconds (oil) + 30 seconds (coolant) = 60 seconds

3.7 Test for Going Over Temp Causing Alarm

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, set temperature to high level (beyond normal range), wait 5 seconds, and verify an Alarm has been triggered by reaching the open limit.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.8 Test for Actuator Disconnect Alarm

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, disconnect the relay from the ID/Presence Detect pin on the relevant actuator. Wait 5 seconds then verify an Alarm has been triggered.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.9 Test for High Temp Causing Alarm (Manual Intervention Test)

NOTE: This test is performed manually on a single board. It uses the same physical test setup as the rest of the tests, and requires a script on the test PC to set the outputs to the appropriate states and monitor for the alarm; however, the heating up of the PCB to cause the alarm is itself a manual test. It should be run separately from the other automated test cases.

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Instruct the test operator to use a heat gun to heat the PCB temperature sensor to a level outside of the valid range (upwards of 125 degrees Celsius).

Wait not longer than 30 seconds to see that an Alarm for both oil and coolant has been triggered by an overheating PCB.

Test time: 40 seconds (oil and coolant as a single test) = 40 seconds

3.10 Test for Watchdog Reset Causing Alarm (Manual Intervention Test)

NOTE: This test is performed manually on a single board. It uses the same physical test setup as the rest of the tests, and requires a script on the test PC to set the outputs to the appropriate states and monitor for the alarm; however, the resetting of the PCB to cause the alarm is itself a manual test. It should be run separately from the other automated test cases.

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Instruct the test operator to manually short to ground the WDO_N signal (U33-1), and wait 30 seconds to allow that to happen. Verify that both the Oil and Coolant Alarms have been triggered.

Disable the power to the Digital Controller. With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a high level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Test time: 50 seconds (oil and coolant as a single test) = 50 seconds

3.11 Test for Missing Pulses on Close Actuator Command

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, set the Manual Close input to the ON state. Do NOT simulate a moving actuator by sending interruptor pulses (this would indicate a stuck or failed actuator). Wait 5 seconds, then verify an error Alarm has been activated.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.12 Test for Missing Pulses on Open Actuator Command

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Then, set the Manual Open input to the ON state. Do NOT simulate a moving actuator by sending interruptor pulses (this would indicate a stuck or failed actuator). Wait 5 seconds, then verify an error Alarm has been activated.

Repeat the same test for both the Oil and the Coolant System.

Test time: 15 seconds (oil) + 15 seconds (coolant) = 30 seconds

3.13 Verify Errors Cleared on Reset

First run the test of *3.12 Test for Missing Pulses on Open Actuator Command* and verify that an error alarm is indicated for either Oil or Coolant.

Disable the power to the Digital Controller. With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power, wait 10 seconds, and verify no error is displayed by the system.

Repeat the same test for both the Oil and the Coolant System.

Test time: 25 seconds (oil) + 25 seconds (coolant) = 50 seconds

3.14 Actuators Opening Normally Due to Temperature

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a low-normal level. Enable power, and wait 5 minutes to ensure the temperature stabilizes and the Digital Controller has a chance to fully close to the actuators. Interruptor pulses must be generated to simulate a motor closing to the point of the Close Limit being active if required.

Then, set the temperature to a high-normal level. Interruptor pulses must be generated to simulate an actuator opening to the point of the Open Limit being active if required. Wait 5 minutes and ensure the Digital Controller has commanded the Actuator to open all the way to the Open Limit activated limit.

Repeat the same test for both the Oil and the Coolant System.

Test time: 600 seconds (oil) + 600 seconds (coolant) = 1200 seconds

3.15 Actuators Closing Normally Due to Temperature

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a high-normal level. Enable power, and wait 5 minutes to ensure the temperature stabilizes and the Digital Controller has a chance to fully open to the actuators. Interruptor pulses must be generated to simulate a motor closing to the point of the Open Limit being active if required.

Then, set the temperature to a low-normal level. Interruptor pulses must be generated to simulate an actuator closing to the point of the Close Limit being active if required. Wait 5 minutes and ensure the Digital Controller has commanded the Actuator to close all the way to the Close Limit activated limit.

Repeat the same test for both the Oil and the Coolant System.

Test time: 600 seconds (oil) + 600 seconds (coolant) = 1200 seconds

3.16 No Actuator Activity When Oil Switch On, Auto Mode On, and Temperature Stable at Operating Range

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power.

Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. The test passes if no Actuator movement is commanded by the system.

Repeat the same test for both the Oil and the Coolant System.

Test time: 300 seconds (oil) + 300 seconds (coolant) = 600 seconds

3.17 No Actuator Activity When Oil Switch On, Auto Mode Disabled, and No Manual Commands

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power.

Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Set the temperature to a high-normal level. Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Set the temperature to a low-normal level. Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Repeat the same test for both the Oil and the Coolant System.

Test time: 900 seconds (oil) + 900 seconds (coolant) = 1800 seconds

3.18 No Actuator Activity When Oil Switch Off, Auto Mode Enabled, and No Manual Commands

With the power to the Digital Controller disabled, set Oil Pressure Switch to off state, Auto Mode on, Manual Close off, Manual Open off, and temperature to a mid-normal level. Enable power.

Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Set the temperature to a high-normal level. Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Set the temperature to a low-normal level. Wait 5 minutes and ensure that neither the Open Actuator nor Close Actuator signal is activated by the Digital Controller. This portion of the test passes if no Actuator movement is commanded by the system.

Repeat the same test for both the Oil and the Coolant System.

Test time: 900 seconds (oil) + 900 seconds (coolant) = 1800 seconds

3.19 Ensure Manual Open Functions Normally

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Ensure the actuator simulator is not fully opened and the Open Limit is not activated by the simulator. Enable power.

Set the Manual Open signal to active state. Ensure that the Open Actuator signal is activated by the Digital Controller. Continue providing Interruptor pulses with the simulator until the Open Limit is activated by the simulator. Ensure the Open Actuator signal is still active. Disable the Manual Open signal.

Repeat the same test for both the Oil and the Coolant System.

Test time: 30 seconds (oil) + 30 seconds (coolant) = 60 seconds

3.20 Ensure Manual Close Functions Normally

With the power to the Digital Controller disabled, set Oil Pressure Switch to on state, Auto Mode off, Manual Close off, Manual Open off, and temperature to a mid-normal level. Ensure the actuator simulator is not fully opened and the Open Limit is not activated by the simulator. Enable power.

Set the Manual Close signal to active state. Ensure that the Close Actuator signal is activated by the Digital Controller. Continue providing Interruptor pulses with the simulator until the Close Limit is activated by the simulator. Ensure the Open Actuator signal is still active. Disable the Manual Open signal.

Repeat the same test for both the Oil and the Coolant System.

Test time: 30 seconds (oil) + 30 seconds (coolant) = 60 seconds

4 Appendix A

4.1 Component Costs

The following equipment will need to be sourced or purchased for this test:

- A test PC, including monitor and keyboard
- 12 USB-controlled relays
- A DAQ system with at least 4 general purpose inputs that can be connected to the test PC
- Connectors, wiring, pins, and misc. parts for custom-made cables to attach the test PC to the Digital Controller
- Heat gun to warm PCB sensor above normal operating range

4.2 Hardware Engineering Costs

The following additional time estimates are provided to run the test:

- 1 day – relay, DAQ, and major component selection and ordering
- 1 day – system wiring diagrams and description
- 0.5 days – parts ordering for connectors, pins, wire, etc.
- 2 days – wiring of the custom cables between the test PC, relays, DAQ, and Digital Controller
- 0.5 days – test and bringup of system along with SW resource to handoff system
- TOTAL: 5 days of effort (additional calendar to account for shipping)

4.3 SW Engineering Costs

About 2.5 weeks – requires setup of test PC, implementing test framework (robot/Jenkins?), implementing test suites for each of the tests in the test matrix, including expected pass/fail conditions, and debugging of any issues with tests.

Another 1 week for any debugging efforts shared between test creator and the engineer that wrote the software for the Digital Controller, plus any time to investigate firmware failures and update Digital Controller firmware as needed.

3.5 weeks total

4.4 Time Estimates for Test Completion

Adding up all the test time in the test procedures section, an automated test suite can complete in approximately 120 minutes.

Operator intervention is required to configure the test cables for oil or coolant, and then again to review the results of the testing. The operator will have to setup prior to running the test

suite, then after 60 minutes will have to re-configure the cabling to switch from Oil to Coolant based tests.

Additionally, 2 tests require operator intervention (manually triggering a watchdog failure, and manually overheating the PCB) and will be run outside of the automated test flow. A budget of 5 minutes for these tests should be sufficient.