SIMULATED SERVICE RIG BUILD, UPGRADE AND TESTING

INTERIM REPORT
TFLRF No. 486

by
Kevin Shannon

U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, TX

for
Eric Sattler
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan

Contract No. W56HZV-15-C-0030 (WD010)

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Approved by:

Gary B. Bessee

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EXECUTIVE SUMMARY

The objective of this effort was to build two new ASTM D2570 Simulated Service Corrosion rigs and upgrade the three currently existing rigs at SwRI with modern data acquisition, instrumentation, and controls. These improvements facilitate real-time monitoring and both manual and automated regulation of temperature, flow rate, and pressure parameters while under testing. Automatic shutdown functions were built into the rig design to minimize down time and preserve coolant containment in the event of an upset. The updated equipment provides a more reliable platform for the evaluation of coolants which closely simulates performance in the field.

Initially, all design, fabrication, and assembly work was focused toward the production of a single prototype rig. Official rig blueprints not available in the published ASTM D2570 test method were purchased from ASTM to guide the creation of the prototype and ensure adherence to design principles. Where allowable, modern materials and instrumentation were substituted for the original parts. Instead of welded tube steel used in the existing rigs, the frame of the prototype was constructed from extruded aluminum sections that were bolted together. New cast iron reservoirs with machined flanges were ordered from a mechanical design firm. A new, real-time flow measurement system was created to replace the limited one-time flow control procedure previously performed during test setup. The new approach utilizes a sensitive, calibrated pressure transducer coupled to a venturi tube flow meter made to withstand heat and coolant chemistries. All analog gauges throughout the rig were upgraded to digital readouts on process controllers, which are hard-wired to the heaters, the variable frequency drive governing flow control, and system pressure.

A shakedown test following standard ASTM D2570 methodology was then conducted on the prototype rig using a candidate coolant specified by TARDEC. The results of the test, which consist primarily of corrosion weight loss values for replicates of six different metallic coupon specimens, were transmitted to TARDEC technical personnel for review. TARDEC representatives then approved the construction of the second ASTM D2570 rig. Effort then moved toward procurement of materials and assembly of the remaining four rigs with the goal of completion on September 30th, 2017.

FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period 3/28/2016 to 9/30/2017 under Contract No. W56HZV-15-C-0030. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Eric Sattler (RDTA-SIE-ES-FPT) served as the TARDEC contracting officer's technical representative. Zackery Schroeder and Bridget Dwornick of TARDEC served as project technical monitors.

The author would like to acknowledge the contribution of the TFLRF technical support staff along with the administrative and report-processing support provided by the TFLRF administrative staff.

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1.0 INTRODUCTION

In response to the WD010 request for proposal, SwRI designed and constructed a total of five new/upgraded test rigs in accordance with ASTM D2570 *"Standard Test Method for Simulated Service Corrosion Testing of Engine Coolants"*. Initially a prototype rig was built and tested with a known candidate coolant. The results from this test were shared with TARDEC technical personnel, who approved project continuation for the assembly of the remaining four rigs. Where possible, modifications were implemented to the original SwRI test rig design to make the new rigs more serviceable, safe, and reliable and also ergonomically compatible to the operator, while still holding true to the technical equipment blueprints issued by ASTM.

2.0 ORIGINAL SWRI ASTM D2570 RIGS

2.1 KNOWN ISSUES WITH ASTM D2570 RIG OPERATION—PUMP FAILURE

Laboratory testing has shown that the 1,064 hour standard ASTM D2570 test is frequently interrupted by pump failure, usually tied to wear and eventually improper function of the bearings. These failures are symptomatic to the varying quality of the part itself and not due to user error or environment. The pump failures are widely known and understood to be unavoidable, having been experienced by producers and testing laboratories across the industry, including SwRI. Extended, modified ASTM D2570 tests which can run up to 2.5 times as long as a standard test are subject to numerous pump failures during the course of the test. The interruption caused by a pump failure necessitates manual draining of all test fluid from the rig, removal of the failed pump (which is bolted in place), and installation of a new replacement pump along with gasket sealing material as required. The labor involved with this task can take an experienced technician half a day to complete under optimal conditions. Since the system is operated under pressure, complicating the stoppage of the test itself is the frequent loss of coolant containment. As such, significant test fluid spillage through the weep holes often accompanies pump failure. Cleanup can take as long as pump replacement, meaning a full day of operation can be lost, perhaps longer depending on time of discovery.

The coolant pump mandated by the ASTM D2570 test method is a GM part number 14033483 aluminum matching front end cover paired to GM part number 14033526 aluminum back cover. The OEM pump was standard issue on a number of vehicles produced by General Motors during the 1980s such as the Buick Skylark, Chevrolet Citation and Citation II, and Pontiac Firebird, among others. OEM production of the pump has been discontinued. However, the ASTM D2570 method does not allow substitution of the pump for a modern analog, leaving the testing laboratory with aftermarket sources as the only options for these crucial components. Experimentation with various suppliers and manufacturers has proven to be unproductive, as a significant percentage of defective/short-lifetime pumps have been received from all vendors that SwRI has identified.

2.2 KNOWN ISSUES WITH ASTM D2570 RIG OPERATION—FLOW CONTROL

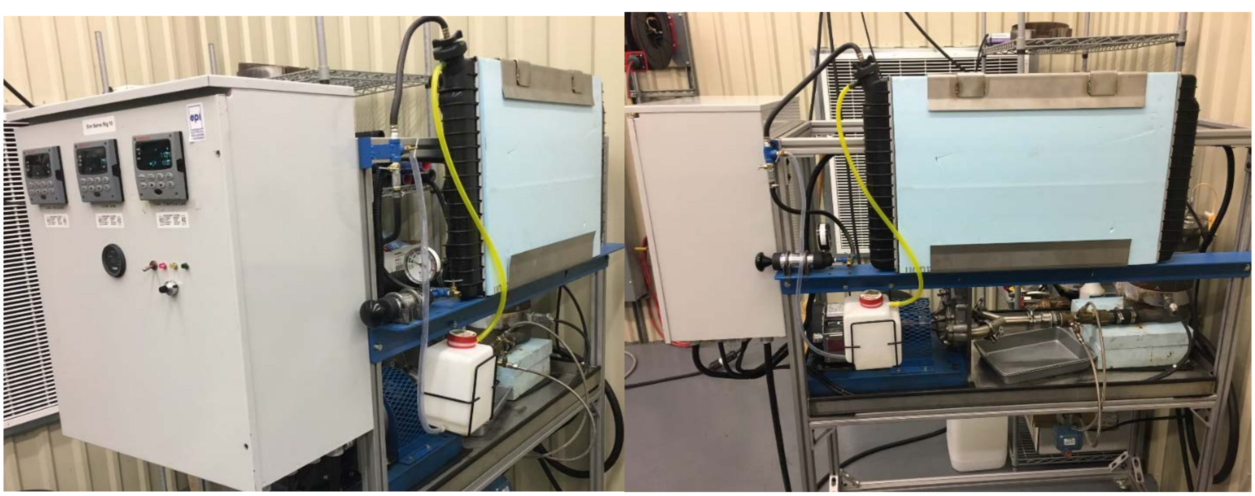
Additionally, coolant flow rate for the system flow loop of the ASTM D2570 rig was set initially at the start of the test and then left unmeasured, in the hopes that the liquid flow would be constant if all system parameters were fixed throughout the 1,064 hour test. The ASTM D2570 procedure, as currently written, instructs the operator to establish coolant flow rate through a flow measurement device (such as a turbine flow meter) plumbed between two pressure gauges. Since flow meters of many types are subject to long-term damage caused by coolant cavitation effects, the procedure directs the operator to shut down the rig, remove the flow measurement device from the system after the set point has been achieved and splice the plumbing together with a variable-flow restriction valve. As long as the same pressure drop is maintained across this adjustable restriction valve manipulated by the operator, flow is assumed to be unchanged from that determined during initial setup.

3.0 IMPROVEMENTS TO EXISTING RIGS THROUGH INNOVATIVE DESIGN

3.1 GOAL--TO REDUCE STRAIN ON PUMP BEARINGS

The opportunity existed to improve on the operation of the ASTM D2570 rig through subtle design changes as seen in Figure 1. Upon evaluation of pump failures by SwRI personnel, it was postulated that the cross-axial load imposed by the motor belt could contribute to the wear on the pump bearings over the lengthy and continuous test durations required by the test, which are not representative of normal, intermittent vehicle operation. Since the ASTM D2570 test method did not specify a particular motor configuration, the decision was made to substitute the belt-driven motor in the original rig with a shaft-driven motor. It was believed that this setup would relieve strain on the bearings since the motor drive is in line with the axis of rotation on the pump impeller.

Belts stretch and loosen over time, leading to losses in efficiency and added vibration. Another benefit afforded by the shift to a shaft-driven motor is lessened vibration and a sliding motor mount that simplifies serviceability.



Oblique View (Top) **Side View (Bottom**

Figure 1. Prototype ASTM D2570 Rig

3.1.1 Shaft-Driven Motor and Pump

Just as with the belt-driven motor on the older rig, a variable frequency drive (VFD) was paired with the shaft-driven motor to govern rotational speed and thereby maintain coolant flow rate at the intended set point of 23 gallons per minute (+/- 1 gallon/minute). See Figure 2.

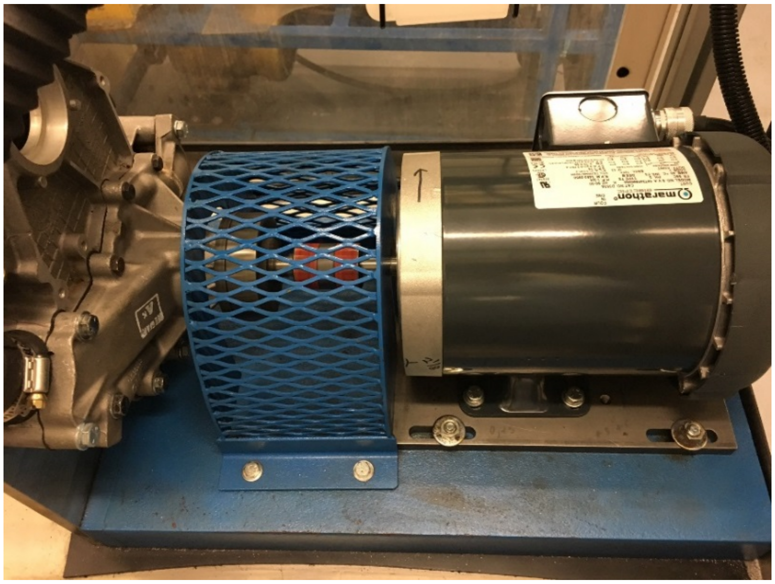


Figure 2. Close-up of Shaft-Driven Motor Coupled to Coolant Pump

3.2 GOAL—REAL-TIME FLOW MEASUREMENT AND CONTROL

A venturi-style bronze coolant flow meter intended for harsh chemical and heat applications was plumbed into the coolant flow loop. This flow meter was connected to a calibrated pressure transducer with signal outs to a digital process controller as seen in Figure 3. The flow meter was optimized for the flow range of 23 gallons/per minute (+/- 1 gallon/minute) specified in the ASTM D2570 method.

Figure 3. Pump Connection to Calibrated Flow Meter

3.3 MATERIALS OF CONSTRUCTION

Wherever possible, plumbing sections were upgraded from heater hose to stainless steel sanitary tubing and fittings with leak-tight cam-lock style connections. The mounting bracket for the radiator was modified so that it could be enclosed with insulation, helping to conserve system heat. A new mounting plate was developed and tapped to mate with the timing cover. The entire frame was rebuilt using a lightweight but strong extruded aluminum strut. A stainless steel containment tray was installed underneath the coolant flow loop to collect any coolant leakage that might occur. Appropriate machine guarding was placed around the shaft-driven motor and coupling to the coolant pump.

3.4 INSTRUMENTATION AND PROCESS CONTROL

All analog measurement devices were upgraded to modern digital versions as shown in Figure 4. In addition to the flow meter and pressure transducer combination mentioned above, thermocouples for the heaters and a system pressure transmitter were installed. These were configured to dedicated Honeywell process controllers for each critical system parameter: coolant flow rate, system temperature, and system pressure. These process controllers provided a visual readout of the parameter of concern to the user as well as automated regulation of the band heaters and variable frequency drive for the electric motor. Operational and emergency shutdown tolerances were programmed into the controllers. Data was recorded by the operator and optional signal outs from these process controllers allowed integration with familiar software platforms such as Prism® or LabView to give unified oversight of all connected test rigs to the laboratory staff.

Figure 4. Front of Rig Showing Instrument Panel

4.0 EVALUATION

4.1 SHAKEDOWN RUN ON PROTOTYPE

Once the prototype was completed, a shakedown run of standard 1,064 hours duration was conducted using green Fleet Charge EG 50/50 coolant, as specified by TARDEC technical personnel.

4.2 TEST RESULTS

At the conclusion of the 1,064 hour ASTM D2570 test, the three bundles of six different metal coupons were carefully cleaned as per method by an SwRI technician and weighed as shown in Table 1. The post-test solution was also analyzed.

Table 1: Test Results

Test	ASTM Method	Units	SwRI Sample ID CL15-7564 Results
(NOTE: as per the method, weight loss is reported as a positive value)			
Simulated Service Corrosion	D2570		
Copper 1		mg	19
Copper 2		mg	25
Copper 3		mg	21
Copper Avg		mg	22
Solder 1		mg	17
Solder 2		mg	25
Solder 3		mg	19
Solder Avg		mg	20
Brass 1		mg	17
Brass 2		mg	15
Brass 3		mg	15
Brass Avg		mg	16
Steel 1		mg	0
Steel 2		mg	0
Steel 3		mg	0
Steel Avg		mg	0
Cast Iron 1		mg	0
Cast Iron 2		mg	-1
Cast Iron 3		mg	-1
Cast Iron Avg		mg	-1
Cast Aluminum 1		mg	1
Cast Aluminum 2		mg	0
Cast Aluminum 3		mg	0
Cast Aluminum Avg		mg	0
New Freeze Point		°F	-17
New pH		--	9.1
New Reserve Alkalinity		ml HCl	1.8
New Color		--	Green
New Precipitate		--	None
New Clarity		--	Translucent
Used Freeze Point		°F	-17
Used pH		--	8.8
Used Reserve Alkalinity		ml HCl	2
Used Color		--	Green
Used Precipitate		--	None
Used Clarity		--	Translucent

4.3 REVIEW AND VALIDATION

TARDEC staff reviewed the data above and authorized SwRI to proceed with the production of the remaining four ASTM D2570 rigs following the design of the prototype.

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 OBSERVATIONS

Despite the change from a belt-driven motor to a shaft-driven one, the coolant pumps have nonetheless still been observed to fail on the new prototype rig with essentially the same frequency as that seen on the older rigs. The quality of these pumps received within a single ordered batch from the same vendor can vary drastically, so it is probably unrealistic to expect that any rig design improvement will noticeably prolong the life of these coolant pumps and resolve this issue. Even so, the streamlined layout of the new motor and pump coupling has eliminated vibration and rotating motion hazards characteristic of a belt and pulley arrangement, culminating in a quieter, more efficient, and safer unit. With the motor itself being mounted to a sliding plate, ease of pump removal and replacement is more straightforward for the operator.

For the first time, the operator is able to see a more complete picture of the ASTM D2570 rig under test, and therefore able to see problems maintaining test conditions that were heretofore unknown to exist. Previously, flow was set at the commencement of the test and then never known during the test or at the test conclusion. Pressure, temperature, and coolant flow are all closely interconnected. A rise or decrease in one parameter has a clear impact on the function of the components (heater, variable frequency drive) used to maintain the other parameters. As such, a learning curve has been undertaken by SwRI personnel in order to determine how to tune the process controllers and appropriately curtail system output to stay within specified operational limits. This staff education into coolant rig behavior is ongoing.

5.2 Conclusion

The effort to create five new and modern ASTM D2570 rigs has been successful. Shortcomings inherent to the older rigs have been addressed, making for the potential for improved system control and performance. Instrumentation has been upgraded from analog to digital electronic versions. Aside from the original cast iron coolant reservoirs which are being repurposed, all of the new rigs are made of new and superior materials.

5.3 Recommendations

Further testing should be conducted to determine rig temperature, pressure, and flow optimization. Eventually the goal will be to unify all of the rigs under a single software platform with full data acquisition and system control. More data is needed to discover whether incidents of pump failure diminish with the shaft-driven motor.

6.0 REFERENCES

ASTM Designation: D2570 – 16, *“Standard Test Method for Simulated Service Corrosion Testing of Engine Coolants”*

ASTM Designation: Adjunct D2570r, *“Casting Blueprints for Iron Reservoir”*