TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: March 24, 2006 To: March 30, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI received Work Assignment 1-5 from EPA which will fund the continuation of the saltwater catalyst durability project. A work plan will be submitted within 15 days of receipt of the assignment. This is the first weekly report for WA 1-5.

A conference was held in San Antonio between SwRI, EPA, CARB and Mercury Marine. The discussions centered on Mercury's concerns about the direction of the project. EPA and CARB agreed to include a metal substrate catalyst in the new catalyzed manifold designs. EPA and CARB agreed to include Mercury in the design process. Mercury Marine agreed to make engineers available for discussions and critical analysis of the designs before beginning manifold fabrication.

We received the new 304 stainless steel thermostat housings. 304 Stainless is being used because the thermostats are made of this material and the anode in this coupled system is the cast-iron manifold. The machined channels in the housings to hold the O-ring seals were not finished with a smooth surface, and they were returned for refinishing.

Projected Activity:

A meeting at SwRI with Mercury Marine and EPA will be held on April 3. SwRI will setup a video conference to include CARB personnel.

Continue operations with the Maxum boat, and continue redesigning the Malibu and SeaRay exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: March 31, 2006 To: April 6, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

A conference was held in San Antonio between SwRI, EPA, and Mercury Marine, with CARB on video conference. The discussions centered on exhaust system design, and methods to preclude corrosion of the exhaust system and metal substrate catalysts. The new exhaust system design is attached to this report.

The coolant passage walls in the fabricated exhaust system are welded to their end flanges, and the inner tubing is welded first, followed by the outer tubing. Therefore, the weld bead is along the inside of the coolant passage for the inner tubing, and along the outside of the coolant passage for the outer tubing. Mercury's material scientist noted that since only one side of the joints at the end of the coolant passage tubes are welded, the non-welded side of the joint has a crevice which could be a starting point for corrosion. Mercury recommended contacting a few sealant manufacturers to choose a sealant for the crevices at the joints within the exhaust system coolant passage. SwRI will put thermocouples on the coolant passage walls of the SeaRay catalysts in the test cell in order to measure peak temperatures during engine operation to inform sealant manufacturers.

In order to further reduce the chance of corrosion, it was agreed that freshwater cooling systems would be added to the 5.7L V8 engines if they could be fit into the boats. Mercury agreed to provide freshwater cooling systems for the SeaRay and Malibu boats. SwRI will ascertain if a freshwater cooling system can be used on the Malibu.

Projected Activity:

Continue operations with the Maxum boat, and begin fabrication of the SeaRay and Malibu exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: April 7, 2006 To: April 13, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI tested the SeaRay engine after placing internal thermocouples on the catalysts' cooling passage walls. Temperatures were measured 1) on the internal wall of the exhaust just ahead of the catalyst, 2) on the other side of the same wall in the coolant passage, and 3) about 2 inches from the front face of the catalyst on the coolant passage wall. Attached is a summary of the temperature measurement findings.

After contacting sealant manufactures to choose an anti-corrosion sealant for the new exhaust system coolant passages, SwRI chose a sealant for the internal welds of the exhaust system. To wit, Permabond HL126 which forms an Acrylic bond and seal. It is a low viscosity, wickable liquid that will fill crevices through capillary action and then set anaerobically. It has very good temperature resistance up to 125C in the presence of glycol, and is expected to have good resistance to saltwater. Attached is the HL126 technical data sheet. We have ordered HL126 to seal the new exhaust manifolds and catalyst coolant passages.

We received the closed-loop engine cooling systems from Mercury. One of the seawater pump actuator housings was damaged, but this system cannot be used for the Malibu as it does not have a Mercury sea pump. SwRI will study the installation instructions to see what can, or needs to be modified to fit to the Malibu's engine.

SwRI requested a one-week extension of the due date for submittal of the work plan for WA 1-5, and received approval from EPA.

Projected Activity:

Prepare the work plan for WA 1-5 and submit it to EPA by April 14.

Continue operations with the Maxum boat, and continue fabrication of the SeaRay and Malibu exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: April 14, 2006 To: April 20, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The work plan for WA 1-5 was submitted to EPA on April 14.

We received Permabond HL126 wicking-grade sealant to cover the crevices left in the fabricated exhaust manifolds. We plan to seal the new water-jacketed exhaust systems and the Maxum's existing water jacket with HL126.

Permabond was contacted and they recommended washing out the Maxum's water jacket with de-ionized water before applying the sealer. We plan to travel to the Texas coast and perform the following maintenance and upgrades to the Maxum engine:

- Change engine oil and filter
- Flush exhaust system with tap water, and then de-ionized water
- Seal the fabricated stainless steel with Permabond HL126
- Remove and replace the original aluminum thermostat housing on the exhaust manifold with the new stainless steel housing

Projected Activity:

Travel to the Texas coast to inspect the Maxum boat, and update the Maxum's engine. Continue operations with the Maxum boat, and continue fabrication of the SeaRay and Malibu exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: April 21, 2006 To: April 27, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI traveled to the Texas coast and brought the Maxum boat back to San Antonio. We did not want to begin work on the boat at the coast and find out that the maintenance and upgrades could not be completed because we lacked the necessary tools.

The Maxum's exhaust system was removed from the engine at SwRI and inspected. The catalysts appeared to be in good shape. They were still tightly mounted in their canisters, and had no evidence of saltwater on them. However, we found evidence of small leaks in the stainless steel near weld locations in the catalyst canisters and in both exhaust connections from the catalysts to the bullhorn.

Figures 1 though 5 show the left converter and the outlet section to the bullhorn, and Figures 6 through 10 show the right side exhaust system. There is no evidence of stains or salt residue to indicate that saltwater has collected within the exhaust system. However, Figures 1 and 2 show where precipitate has formed along the weld of the catalyst canister's inlet. Figures 3 and 4 show precipitates at the outlet of the catalyst canister, and show that the Monel (70% nickel, 30 % copper) wire mesh seal around the end of the catalyst substrate is starting to fray away. In addition, the Monel has become extremely fragile. A slight touch to the Monel is enough to break it off, and it turns to a dust-like consistency with only a little pressure. SwRI will subject the Monel to microscopic and elemental analyses to find the cause of the metal degradation.

Figures 5 and 10 are photos of the interior of the left and right bullhorn connections from the catalyst, and both show rust spots along the weld between the two tubing sections. Because the steel is already pitted, these exhaust sections will have to be re-fabricated and then sealed. Figure 7 also shows some precipitate at the weld line between the flange and the catalyst's can.

Projected Activity:

SwRI will contact the ceramic catalyst supplier regarding the Monel seal and research other seal material options. SwRI will analyze the Monel seals on the Maxum's catalysts. We will finish engine maintenance and updates to the Maxum boat's exhaust, and continue fabrication of the SeaRay and Malibu exhaust systems.

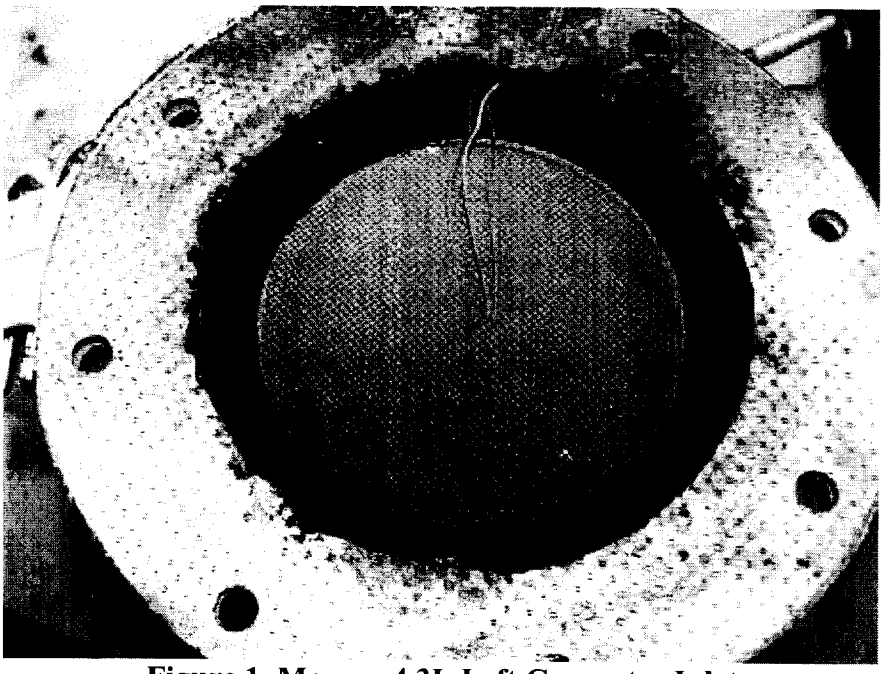


Figure 1. Maxum 4.3L Left Converter Inlet

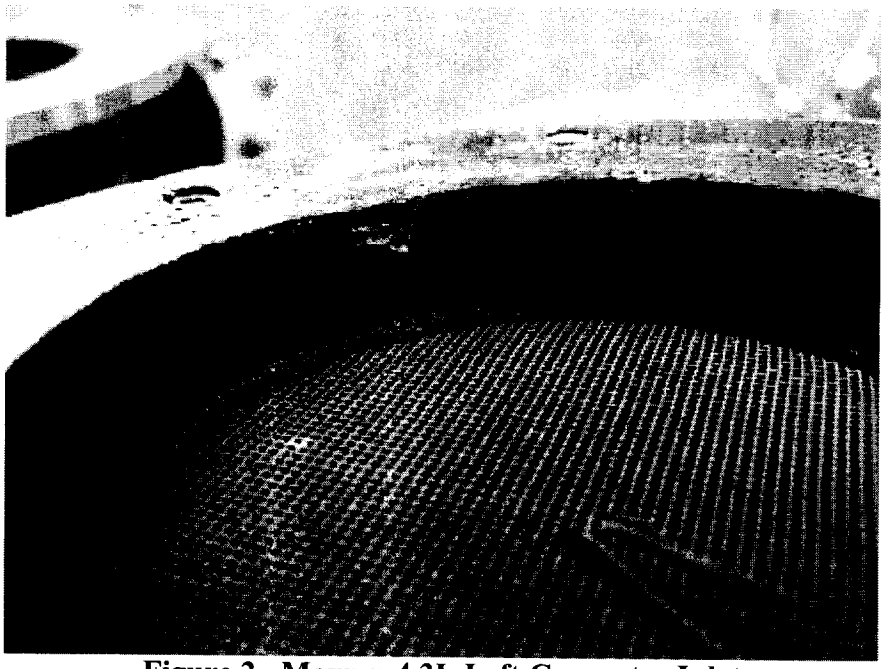


Figure 2. Maxum 4.3L Left Converter Inlet

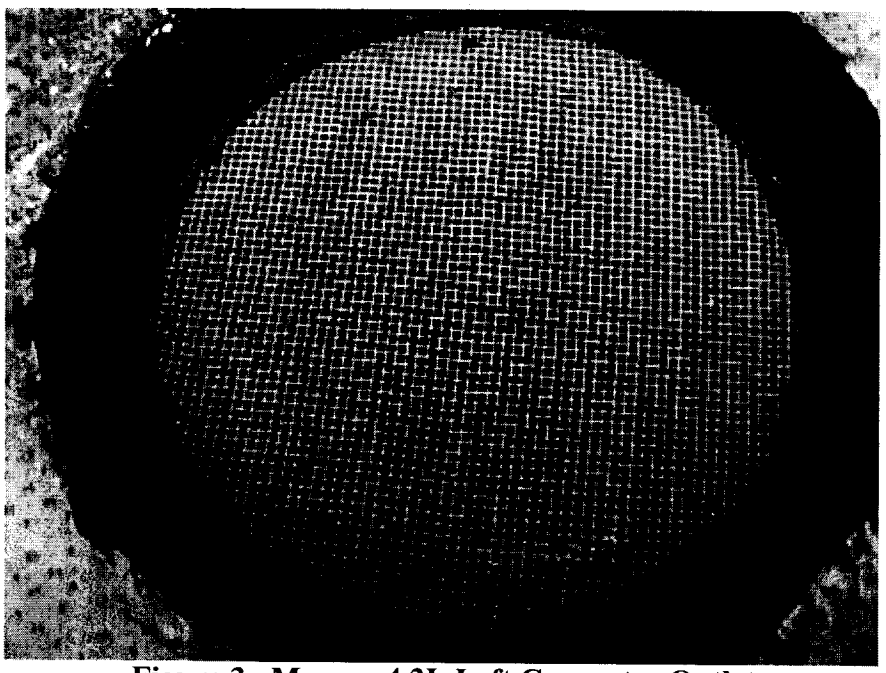


Figure 3. Maxum 4.3L Left Converter Outlet

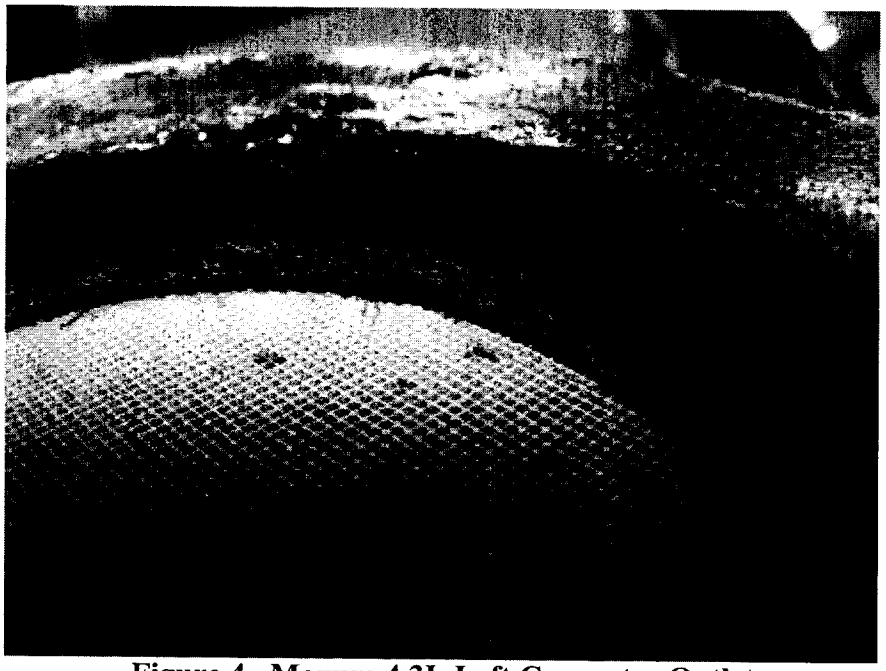


Figure 4. Maxum 4.3L Left Converter Outlet

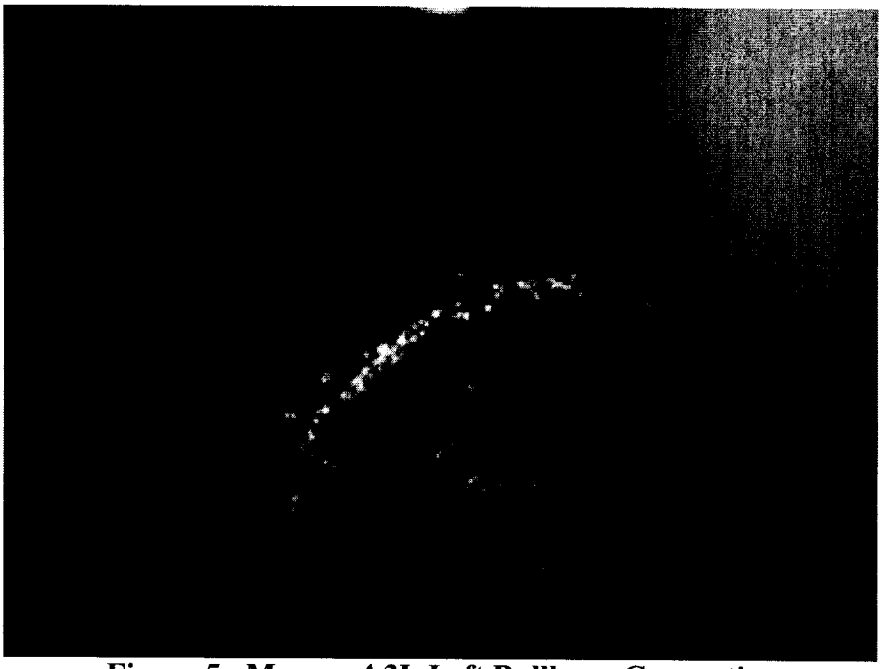


Figure 5. Maxum 4.3L Left Bullhorn Connection

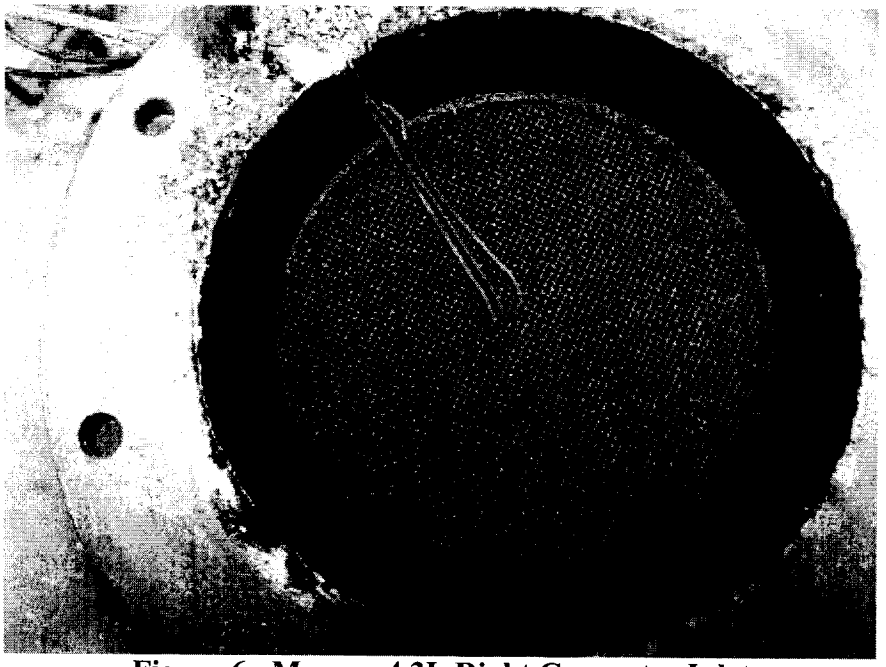


Figure 6. Maxum 4.3L Right Converter Inlet

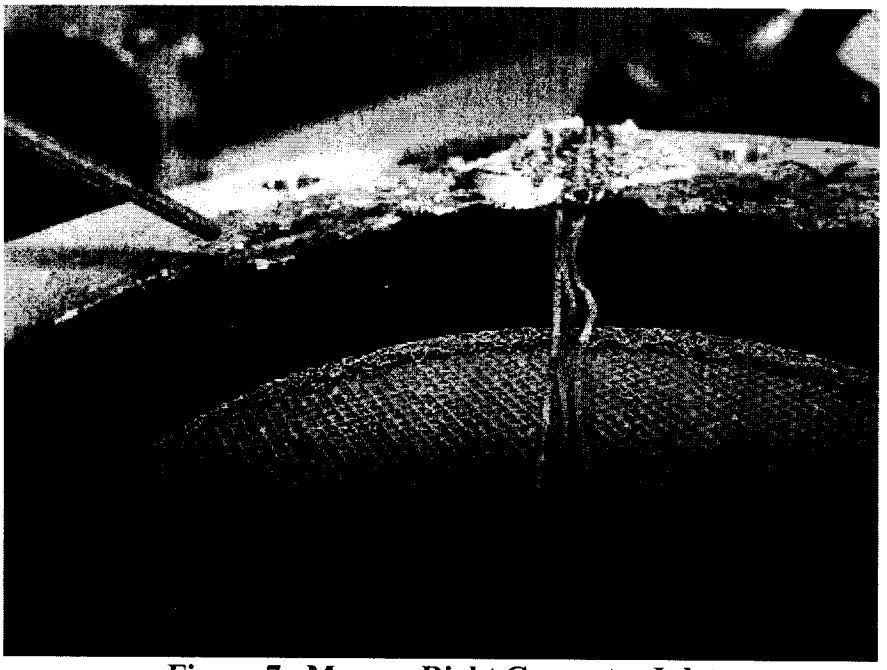


Figure 7. Maxum Right Converter Inlet

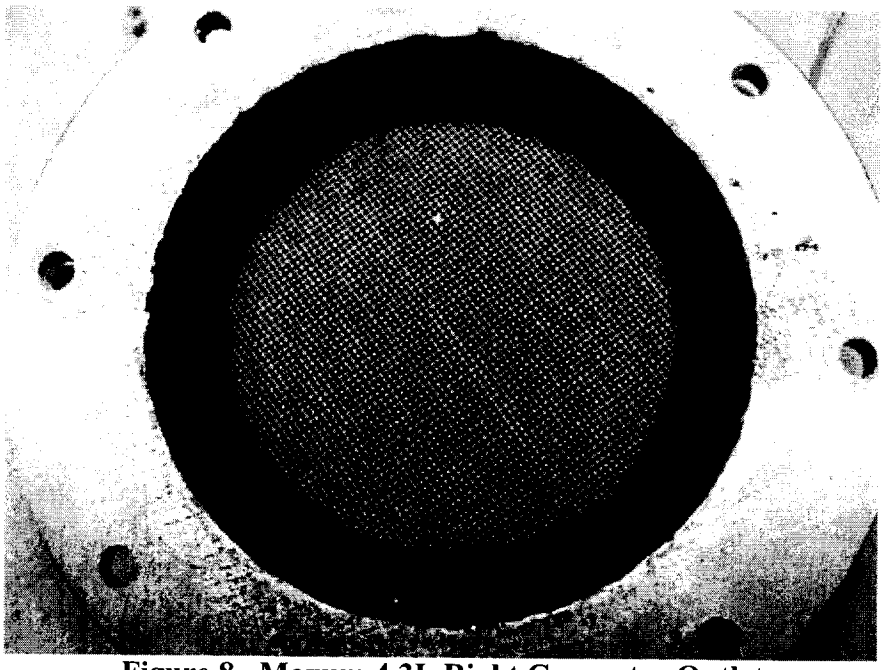


Figure 8. Maxum 4.3L Right Converter Outlet

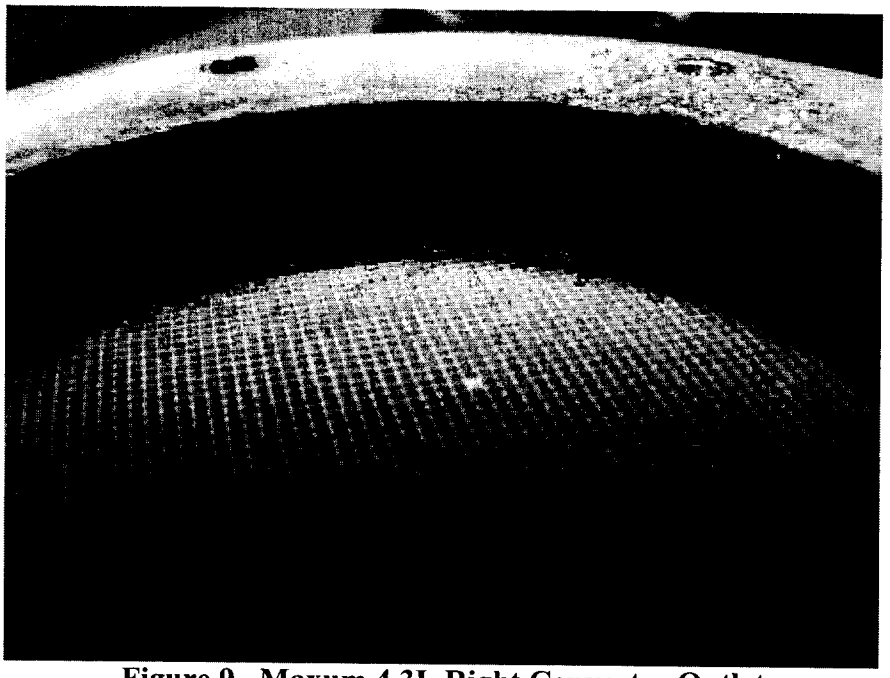


Figure 9. Maxum 4.3L Right Converter Outlet

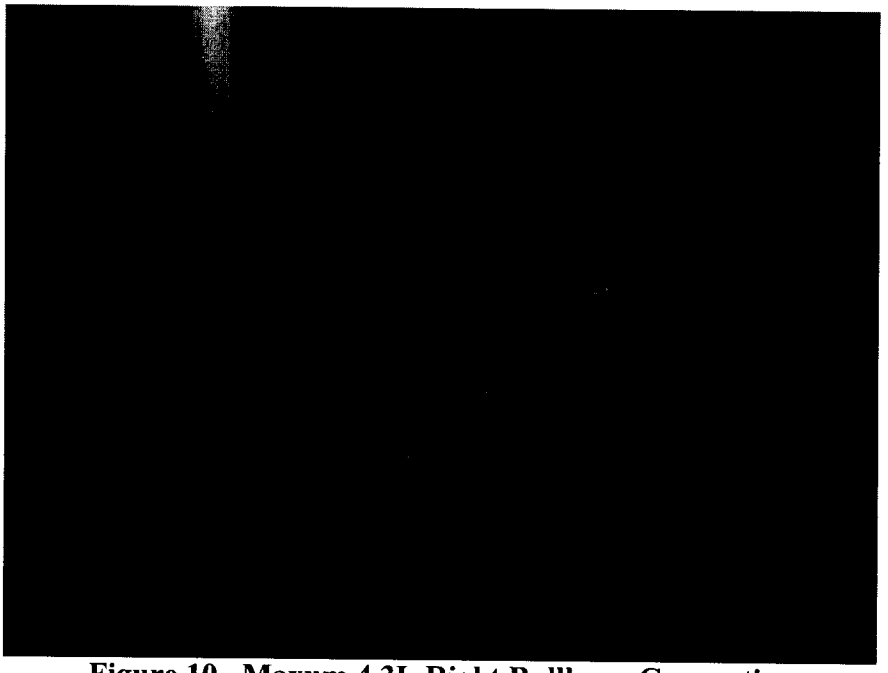


Figure 10. Maxum 4.3L Right Bullhorn Connection

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: April 28, 2006 To: May 4, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI is continuing fabrication of the SeaRay 220's re-designed exhaust system. Once it is completed it will be solution annealed into a temperature range wherein elements or compounds which precipitated at or near the welds will dissolve back into the alloy. Then by quickly cooling the metal the elements will remain in solution at room temperature. The treatment reduces the number of locations on the part where corrosion can begin. The treatment also relieves any residual stresses from welding. We plan to solution anneal all of the re-fabricated exhaust systems as they are completed. Once the parts are annealed we will seal the coolant passages within each part with Permabond HL 126.

We have also begun a failure analysis of the Monel seals in the Maxum's catalyst canisters. SwRI has contacted the catalyst manufacturer and is discussing the seals with other catalyst experts and is inquiring into other seal materials.

Once the SeaRay 220's exhaust system is fabricated, the corroded outlets in the Maxum exhaust system will be rebuilt with 316 stainless steel.

Projected Activity:

SwRI will continue fabrication of the SeaRay, Malibu, and Maxum exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: May 12, 2006 To: May 18, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

We received the heat treated exhaust parts for the SeaRay 220 and began installing them on the engine in the test cell. The valve over on the right side of the engine had to be modified to move the engine oil cap. The new exhaust design placed the right catalyst's flange just above the cap. The fresh-water closed-loop cooling system from Mercury will was also installed on the engine.

The new exhaust outlets for the Maxum's 4.3L engine were completed and sent out to be solution annealed. We began cutting apart the Maxum's catalyst canisters in order to re-fabricate their water jackets and flanges. Re-fabrication had to be done because there was evidence of corrosion near the flange welds on the original parts. The new canisters' cooling passages will be sealed with Permabond HL 126 to reduce the chance of corrosion.

Projected Activity:

SwRI will emission test the SeaRay engine with new catalysts and exhaust system. SwRI will continue fabrication of the Malibu, and Maxum exhaust systems.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: May 19, 2006 To: May 25, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The SeaRay 220 5.7L V8 engine was run for six hours to degreen the new metal substrate catalysts. We then baseline emission tested the SeaRay's engine. A summary of the emissions results are shown below:

TABLE 1. SEARAY 220 ENGINE BASELINE EMISSION TEST RESULTS AFTER REDESIGN OF EXHAUST SYSTEM

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	11.4	27.8	2.63	30.4	3828
2	0.14	15.3	5.00	8.01	13.0	356
3	0.15	8.10	2.94	2.11	5.04	162
4	0.25	4.83	2.83	0.35	3.2	126
5	0.40	0	11.0	0.00	11.0	37.3
SUM	1.00	39.6	49.6	13.1	62.7	4509
			HC (g/kW-hr)	NOx (g/kW-hr)	HC+NOx (g/kw-hr)	CO (g/kW-hr)
Brake-Specific Emissions			1.25	0.33	1.58	114

The SeaRay engine was removed from the test cell in order to re-install it in the boat. However, re-installation was delayed due to the following:

- The bilge pump automatic level switch was inoperative and was replaced.
- The bilge pump was seized and was replaced.
- The dashboard's circuit board had overheated and burned the circuit for the bilge pump, and a wire jumper was soldered in place around the burned portion of the board.
- Due to the numerous removals and replacements of the engine, the motor mount holes in the boat had become loose. The motor mounts were relocated and new holes had to be drilled. The old holes were filled and sealed with epoxy.
- The bullhorn in the boat was not in the same location as the bullhorn in the test cell. Subsequently, when the engine was mounted in the boat the exhaust outlets on both sides did not line up with the bullhorn. The exhaust pipes were swiveled about the catalyst flanges until they aligned with the bullhorn, and new bolt holes were drilled into the flanges.

The new exhaust outlets for the Maxum's 4.3L engine were returned after being solution annealed. They have been mounted onto the engine along with the Maxum's re-flanged catalyst canisters. The new canisters' cooling passages were sealed with Permabond HL 126 to reduce the chance of corrosion.

Photographs of new exhaust system parts for the SeaRay and Maxum engines are shown below. Figures 1 and 2 show the re-fabricated 316L stainless steel catalyst outlets for the Maxum engine, and the saltwater demister installed within the exhaust pipe. These parts were solution annealed and then sealed internally with Permabond HL 126. Figures 3 and 4 contrast the original freshwater exhaust system for the SeaRay engine with the new saltwater design. Figure 4 also shows the closed-loop cooling system installed on the top front of the engine. Figures 5, 6, 7, and 8 show the 316L stainless steel exhaust connections which are mounted after the catalyst of the SeaRay 220 engine. Figure 7 shows how the outer tube of the riser had to be cut and welded in order to match the radius of the inner exhaust tube. Figure 8 shows the smooth inner exhaust tube which only has welds at the flanges on both ends to reduce the number of potential corrosion formation sites in the steel.

Projected Activity:

Representatives of Mercury Marine and the EPA Work Assignment Manager plan to visit SwRI next week to inspect the re-designed and re-fabricated exhaust systems on the Maxum and SeaRay engines.

SwRI will continue fabrication of the Malibu's exhaust system.

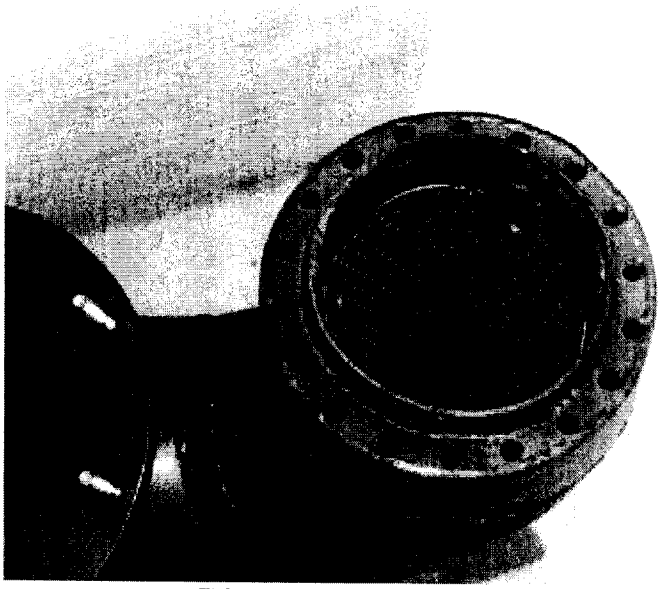


FIGURE 1. MAXUM EXHAUST RISER

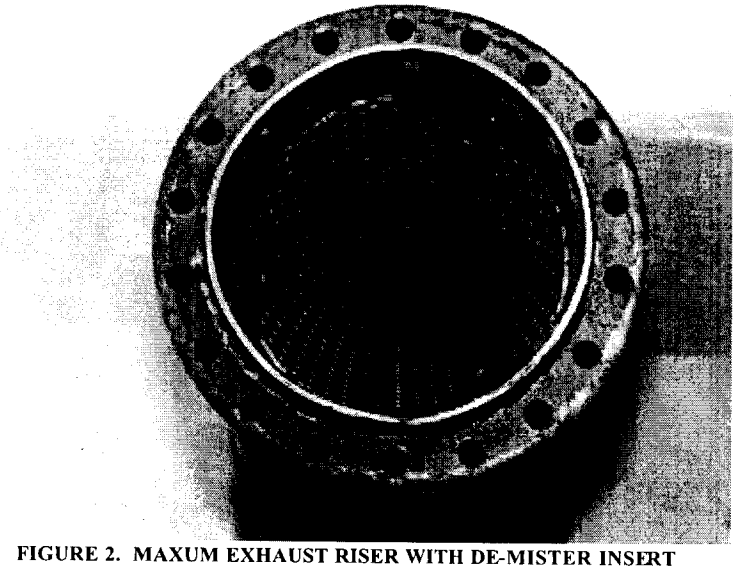


FIGURE 2. MAXUM EXHAUST RISER WITH DE-MISTER INSERT

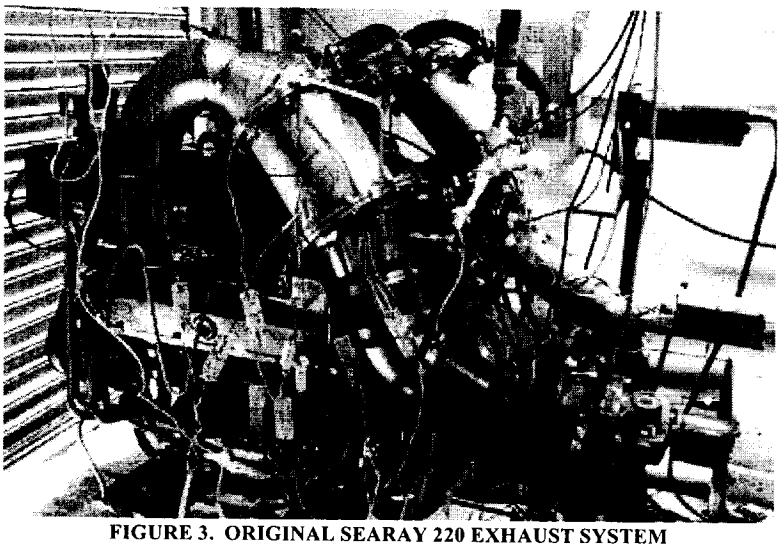


FIGURE 3. ORIGINAL SEARAY 220 EXHAUST SYSTEM

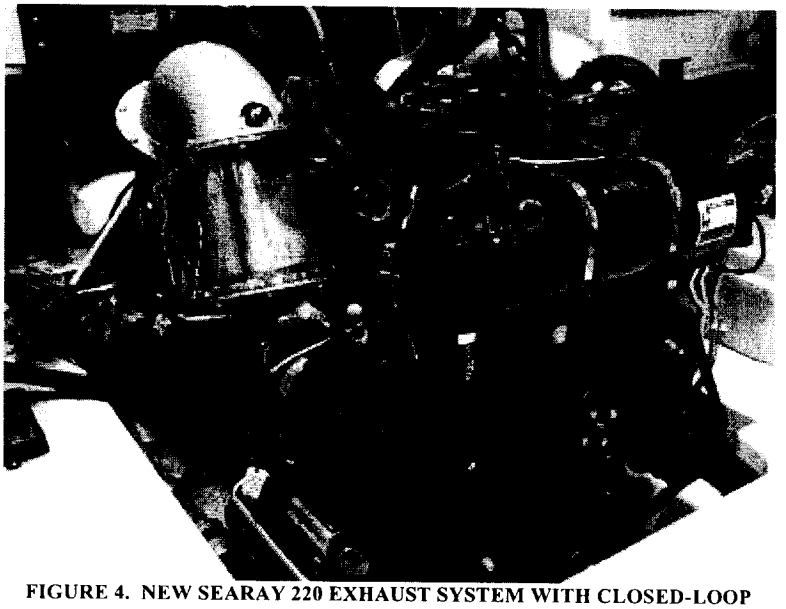


FIGURE 4. NEW SEARAY 220 EXHAUST SYSTEM WITH CLOSED-LOOP FRESHWATER HEAT EXCHANGER

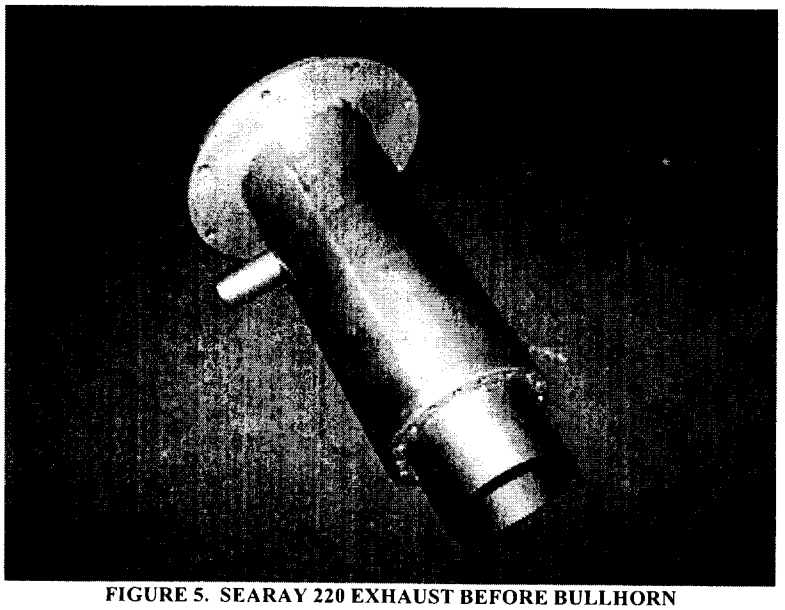


FIGURE 5. SEARAY 220 EXHAUST BEFORE BULLHORN

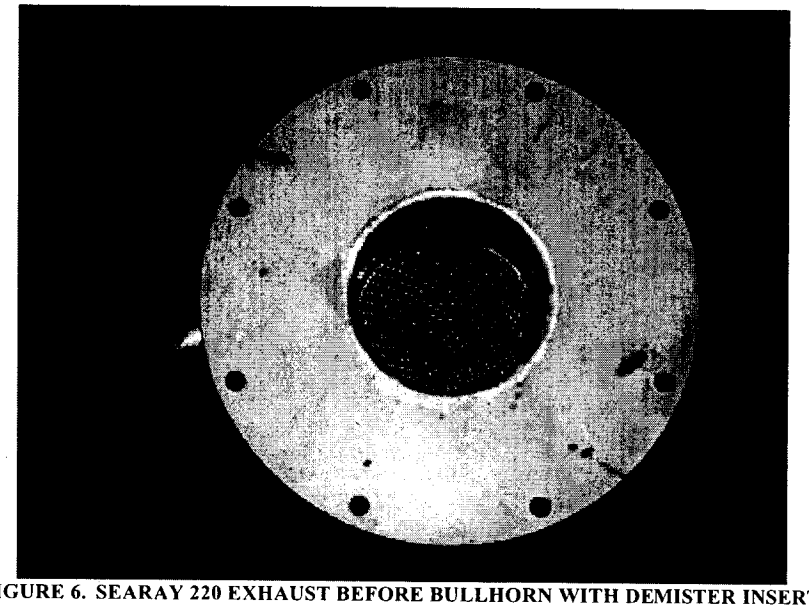


FIGURE 6. SEARAY 220 EXHAUST BEFORE BULLHORN WITH DEMISTER INSERT

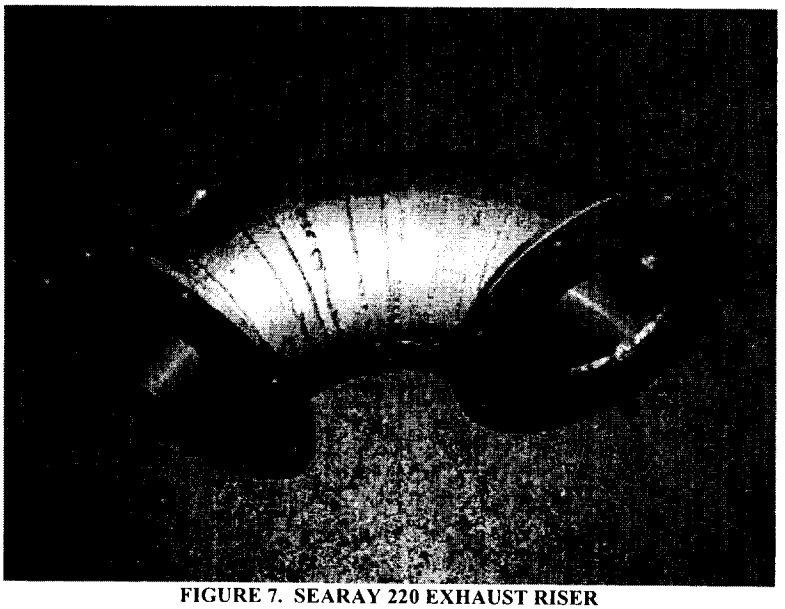


FIGURE 7. SEARAY 220 EXHAUST RISER

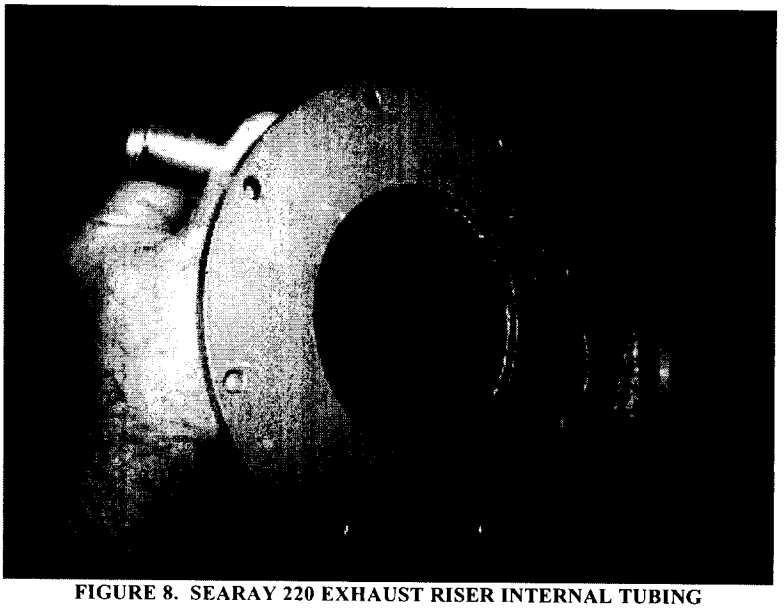


FIGURE 8. SEARAY 220 EXHAUST RISER INTERNAL TUBING

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: May 26, 2006 To: May 31, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Representatives of Mercury Marine and the EPA Work Assignment Manager visited SwRI to inspect the re-designed and re-fabricated exhaust systems on the Maxum and SeaRay engines. All present went to Medina Lake with the Maxum boat in order to observe the freshwater checkout of engine operation and the data acquisition system.

Mercury's representatives stated that the redesigned exhaust systems incorporated all of the items discussed during earlier consultations, and that no more design changes needed to be incorporated.

Projected Activity:

SwRI will continue fabrication of the Malibu's exhaust system. We will complete installation of the SeaRay's engine and deliver the Maxum and SeaRay 220 back to the Texas coast for durability operation.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: June 1, 2006 To: June 8, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI completed fabrication of the Malibu's exhaust system. It was sent out to be solution annealed.

The Maxum boat was delivered to the Texas Parks and Wildlife in Rockport, Texas. Freshwater checkout of the SeaRay boat was performed.

Projected Activity:

SwRI will deliver the SeaRay boat to Corpus Christi, Texas. We will remove the Malibu engine from the boat and install it in the test cell for baseline emissions testing.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: June 9, 2006 To: June 15, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The Malibu's exhaust system was returned to SwRI after heat treatment. SwRI began installation of the Malibu's engine and new exhaust system into the test cell.

The SeaRay boat was delivered to the Texas Parks and Wildlife in Corpus Christi, Texas.

SwRI received approval of the Work Plan submitted for Work Assignment 1-5.

Projected Activity:

SwRI will complete installation of the Malibu's engine in the test cell and perform baseline emissions testing.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: June 16, 2006 To: June 22, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI completed installation of the Malibu's engine and new exhaust system into the test cell. Emission testing of the Malibu engine was planned but delayed due to emission analyzer problems.

Projected Activity:

SwRI will perform baseline emissions testing of the Malibu engine and reinstall the engine in the boat.

SwRI will transport emission analyzer bench, calibration gases, and sampling equipment to the facility leased at the coast. SwRI will perform on-water emissions tests of the Maxum and SeaRay boats at the coast.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: June 23, 2006 To: June 29, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

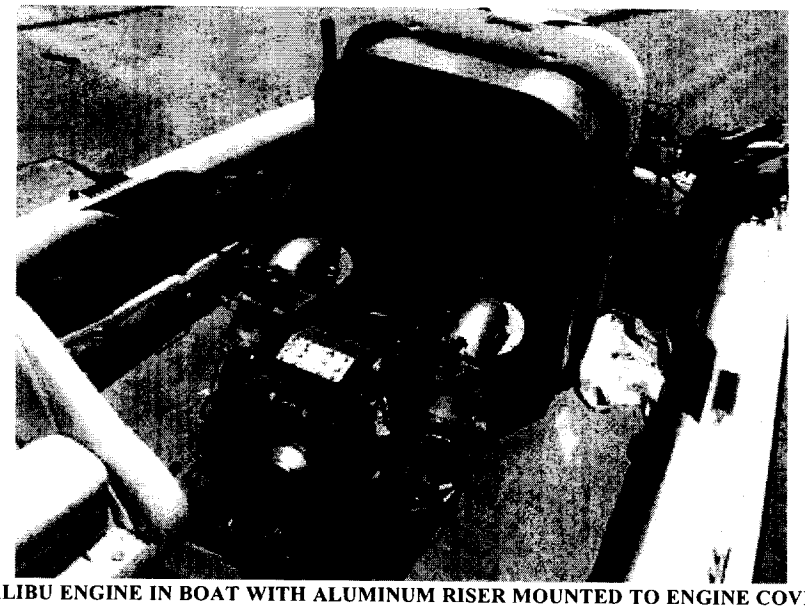
Past Progress:

SwRI completed emission testing of the Malibu engine and installed it in the boat. The new exhaust system increased the overall height of the engine by 7 inches. A riser of aluminum sheet was bent into the shape of the engine cover's base and mounted to it. The original hinges on the cover were then mounted to the aluminum riser. A photograph of the Malibu's engine cover is shown below.

SwRI transported a purpose–built emission analyzer bench, calibration gases, and sampling equipment to the facility leased at the coast. SwRI performed on-water emissions tests of the Maxum and SeaRay boats at the coast.

Projected Activity:

SwRI will check engine operation on freshwater and return the Malibu boat to operation at Port Lavaca, Texas.



MALIBU ENGINE IN BOAT WITH ALUMINUM RISER MOUNTED TO ENGINE COVER

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: June 30, 2006 To: July 6, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The Malibu boat was moved to Port Lavaca and put back into durability operation with Texas Parks and Wildlife.

Projected Activity:

Continue durability operations with all boats along the Texas coast.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: July 7, 2006 To: July 13, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI received a call from Corpus Christi telling us that SeaRay boat had overheated after a long trip to Port Aransas and back. Before the run, Texas Parks and Wildlife (TPWD) checked water level in reservoir, it was dry, and so they added coolant to the 'cool' level. They then drove to Port Aransas, into the gulf, and back to Corpus Christi. Coming back, while nearing the loading ramp, the over-temperature warning horn came on.

The TPWD warden stated that he shut the engine down at the dock, put the trailer into the water on the ramp, then restarted the engine and drove the boat onto the trailer. He also stated that the engine restarted without any problem but it seemed to lack power. After putting the boat onto the trailer they checked and found the coolant reservoir was full. The next morning they found that the reservoir was empty.

SwRI downloaded information from the data acquisition system which confirmed that the engine had overheated. We went to Corpus Christi and brought the boat back to diagnose the problem. We found two plugs with significant condensation. We pressurized the coolant system and found leaks at the exhaust manifold outlet gaskets by putting a borescope into the EGO sensor hole. When we disassembled the risers and catalysts from the engine we found that the leaks appeared to follow the machining marks left on the manifold when it was finished. We will remove the manifolds and have them machined to a smoother finish and reassemble the exhaust system.

The sea pump and intercooler were disassembled to search for indication that the engine ingested something which would block seawater flow. Only a small seashell was found in the intercooler. Engine coolant tends to leave deposits when it dries, but no deposits were seen on the catalysts or on the exhaust walls before the catalysts.

Projected Activity:

Resurface the SeaRay exhaust manifold outlets, and reassemble the SeaRay engine exhaust system. Pressure check the coolant system, and check engine compression in each cylinder. Run the boat in freshwater and look for leaks at the manifold gasket. Continue durability operations with the Maxum and Malibu boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: July 14, 2006 To: July 20, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI received a call from the Port Lavaca Texas Parks and Wildlife stating that the Malibu boat's starter had failed. We went to Port Lavaca to replace that starter and found that the exhaust manifold had leaked water into at least three cylinders on the left bank of the engine and hydraulically locked the engine. The Malibu boat was brought back to San Antonio for repairs.

The leak was found at the outlet of the manifold where a ½" plate and gasket is used to block the coolant transfer ports around the exhaust outlet. We decided that simply resurfacing the exhaust manifolds would not preclude another leak from forming, because this had already been done to the Malibu manifolds. SwRI is exploring other methods to seal the coolant passages around the exhaust outlet.

Shown below are the baseline exhaust emissions data from the Malibu, Maxum, and SeaRay boats collected in the laboratory before starting durability operations. The Malibu and SeaRay engines were baselined twice because the first set of exhaust system had leaks which corroded the catalysts and their canisters.

TABLE 1. MAXUM 4.3L V6 ENGINE BASELINE EMISSION TEST RESULTS

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	9.0	37.6	3.61	41.2	3304
2	0.14	12.1	6.1	15.05	21.1	483
3	0.15	6.28	2.81	3.5	6.3	194
4	0.25	3.78	4.52	0.40	4.9	160
5	0.40	0	14.8	0.01	14.8	93
SUM	1.00	31.1	65.8	22.6	88	4234
			HC (g/kW-hr)	**NOx (g/kW-hr)**	**HC+NOx (g/kW-hr)**	**CO (g/kW-hr)**
Brake-Specific Emissions			2.12	0.73	2.84	136

TABLE 2. SEARAY 5.7L V8 ENGINE BASELINE 1 EMISSION TEST RESULTS

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	11.8	44.9	7.94	52.8	3688
2	0.14	15.7	8.3	16.3	24.6	558
3	0.15	8.15	4.59	2.6	7.2	208
4	0.25	5.01	4.46	2.15	6.6	85.7
5	0.40	0	18.2	0.02	18.2	37
SUM	1.00	40.7	80.5	29.0	109	4577
			HC (g/kW-hr)	**NOx (g/kW-hr)**	**HC+NOx (g/kW-hr)**	**CO (g/kW-hr)**
Brake-Specific Emissions			1.98	0.71	2.69	113

TABLE 3. SEARAY 5.7L V8 ENGINE BASELINE 2 EMISSION TEST RESULTS

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	11.4	27.8	2.63	30.4	3828
2	0.14	15.3	5.00	8.01	13.0	356
3	0.15	8.10	2.94	2.11	5.04	162
4	0.25	4.83	2.83	0.35	3.2	126
5	0.40	0	11.0	0.00	11.0	37.3
SUM	1.00	39.6	49.6	13.1	62.7	4509
			HC (g/kW-hr)	**NOx (g/kW-hr)**	**HC+NOx (g/kW-hr)**	**CO (g/kW-hr)**
Brake-Specific Emissions			1.25	0.33	1.58	114

TABLE 4. MALIBU 5.7L V8 ENGINE BASELINE 1 EMISSION TEST RESULTS

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	11.7	40.5	1.93	42.4	3352
2	0.14	15.6	9.0	4.59	13.6	231
3	0.15	8.06	3.92	28.6	32.5	90
4	0.25	4.96	5.82	10.3	16.1	59.5
5	0.40	0	12.3	0.06	12.3	11
SUM	1.00	40.3	71.4	45.4	117	3742
			HC (g/kW-hr)	**NOx (g/kW-hr)**	**HC+NOx (g/kW-hr)**	**CO (g/kW-hr)**
Brake-Specific Emissions			1.77	1.13	2.90	92.9

TABLE 5. MALIBU 5.7L V8 ENGINE BASELINE 2 EMISSION TEST RESULTS

MARINE MODE	Weight Factor	Weighted Power, kw	HC (g/hr)	NOx (g/hr)	HC+NOx (g/hr)	CO (g/hr)
1	0.06	11.6	11.5	0.91	12.4	3703
2	0.14	15.6	3.4	2.36	5.7	372
3	0.15	8.09	1.48	0.1	1.5	120
4	0.25	4.87	1.12	12.31	13.4	69.2
5	0.40	0	2.8	0.00	2.8	19
SUM	1.00	40.1	20.3	15.6	36	4283
			HC (g/kW-hr)	**NOx (g/kW-hr)**	**HC+NOx (g/kW-hr)**	**CO (g/kW-hr)**
Brake-Specific Emissions			0.50	0.39	0.89	106.7

Projected Activity:

Decide how to proceed with the Malibu and SeaRay exhaust manifold leaks.
Continue durability operations with the Maxum boat.
Report the on-water emissions data for the Maxum and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: July 21, 2006 To: July 27, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The Malibu engine that had hydro-locked due to coolant leaks in the manifold was pulled from the boat and partially disassembled. The left cylinder bank's connecting rods were removed from the boat and new ones were ordered.

The manifold outlets on the Malibu and SeaRay boats that were leaking coolant into the exhaust were discussed internally. One idea was to fill the coolant passages with lead, seal the flange with a metal plate, and place the manifold in an oven to melt the lead (at 620F) and seal the passages. It was decided that there was a good chance that the lead would re-melt if the engine lost coolant and overheated for any reason.

We then contacted Mercury Marine to discuss how to seal the coolant passages. Their material scientist suggested that we attempt to fill the coolant passages with nickel welding rod, which we will do during the next reporting period.

Projected Activity:

Continue durability operations with the Maxum boat.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: July 28, 2006 To: August 3, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Based on input from Mercury Marine, we attempted to fill in the coolant passages at the exhaust manifold flanges with nickel welding rod material. A used manifold from the freshwater catalyst development program was used for practice. Before welding on them, the manifolds were placed in an oven and heated to 320°F to reduce the temperature gradient around the welds. After welding, the manifolds were placed in sand in order to slow the cooling process. However, the stresses produced by welding onto the cast iron manifold cracked the manifold during cooling.

We then decided to try silicon-bronze welding rod to fill the coolant passages because less energy is needed for welding them and thus the heat load on the manifold would be reduced. Small pieces of steel were cut and fit into the coolant passages to partially block the passage and create an initial bridge for the welding material to span. Using silicon-bronze rod, the cast-iron manifolds did not crack during cooling.

We re-examined the SeaRay's manifolds which had lost coolant and overheated. We find small cracks in the manifolds which probably formed when they overheated. A new pair of manifolds was ordered and machined to accept the thermostat housing. The coolant passages in the new manifolds were filled in using silicon-bronze welding rod. Once cooled the built-up welding material at the manifold flanges was ground smooth with a surfacing grinder. Compressed air was used to leak check the welding material and we found a few pinhole leaks. We used Permabond sealer to stop the leaks in the manifolds.

The new connecting rods for the hydro-locked Malibu engine were delivered and the engine was rebuilt. We began the process of filling its exhaust manifolds' coolant passages with welding rod material.

Figure 1 shows a manifold flange that had its coolant passages filled with silicon-bronze welding rod.

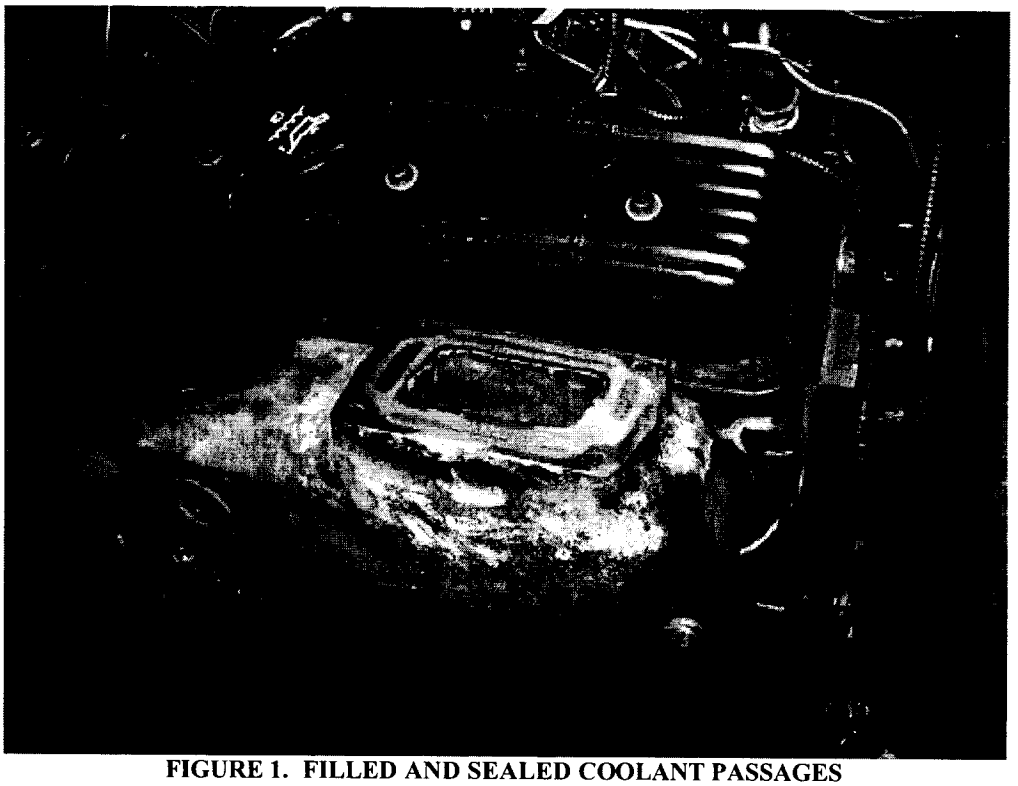


FIGURE 1. FILLED AND SEALED COOLANT PASSAGES AT 5.7L V8 MANIFOLD FLANGE

Projected Activity:

Continue durability operations with the Maxum boat.
Complete rebuilding the Malibu and SeaRay boat engines.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: August 4, 2006 To: August 10, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

We completed rebuilding the SeaRay and Malibu engine exhaust system in the boats. The Malibu boat was fresh water tested at Medina Lake. We did not experience any problems during testing and a check with a borescope did not show any internal leaks at the flange.

The SeaRay boat was then connected to a water hose for a quick check out of the engine before taking it to Medina Lake for freshwater testing. During the check out the engine temperature continued to rise until the over-temperature warning horn went off. After cool down and inspection we found that some of the Permabond sealant that was used to seal the exhaust manifolds had clogged the intercooler. The sealant usually forms a thin coating on the surface and in voids on whatever it wets, but, it appears that some of the sealant pooled and hardened within crannies in the manifolds and then cracked away when the engine started.

Projected Activity:

Continue durability operations with the Maxum boat.
Return the Malibu boat to Port Lavaca and continue durability operations.
Replace the intercooler on the SeaRay boat and retest it on freshwater.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: August 11, 2006 To: August 17, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The Malibu boat was returned to durability operations at Port Lavaca.

We replaced the intercooler on the SeaRay engine and took the boat to Medina Lake for freshwater testing. During high speed operations on the water the engine ran cool but when we settled the boat down to idle the engine temperature continued to rise until the over-temperature warning horn went off. After cool down we opened the coolant cap and added coolant. Thereafter, the engine did not experience any over temperature periods.

Projected Activity:

Continue durability operations with the Maxum and Malibu boats.
Return the SeaRay boat to Corpus Christi and continue durability operations.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: August 18, 2006 To: August 24, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The SeaRay boat was returned to durability operations at Corpus Christi.

Projected Activity:

Continue durability operations with the Maxum, Malibu and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: August 25, 2006 To: August 31, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

We received a call from Texas Parks and Wildlife in Port Lavaca informing us that the Malibu boat had bent its propeller while operating in shallow water. They will remove the propeller and have it straightened locally.

Projected Activity:

Continue durability operations with the Maxum and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: September 1, 2006 To: September 7, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Texas Parks and Wildlife in Port Lavaca is waiting for the Malibu boat's bent propeller to be straightened.

Projected Activity:

Continue durability operations with the Maxum and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: September 8, 2006 To: September 14, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Texas Parks and Wildlife in Port Lavaca put the re-straightened propeller back onto the Malibu boat and put the boat back into durability operation.

Projected Activity:

Continue durability operations with the Maxum, Malibu, and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: September 15, 2006 To: September 21, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Continued durability operations with the Maxum, Malibu, and SeaRay boats.

Projected Activity:

Continue durability operations with the Maxum, Malibu, and SeaRay boats.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: September 22, 2006 To: September 28, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

Continued durability operations with the Maxum, Malibu, and SeaRay boats. We received a call from the TPWD informing us that the SeaRay boat had started to overheat on a trip back from the gulf. They had to shut the engine off twice, let it cool down, and then continue their trip back to the dock.

Projected Activity:

Continue durability operations with the Maxum and Malibu boats. Travel to Corpus Christi and check the SeaRay boat for the cause of its overheating, and travel to Port Lavaca and perform on-water emission testing.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: September 29, 2006 To: October 5, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

SwRI traveled to the Texas coast and inspected the overheated SeaRay boat in Corpus Christi. The coolant level in the engine was found to be below the bottom of the intercooler. We could not inspect the interior of the exhaust system because the ports into the exhaust system were inaccessible. The boat will be returned to San Antonio to remove the rear seats, inspect the exhaust system, and decide on the next course of action.

SwRI then traveled to Port Lavaca and the Malibu boat was emission tested using the portable dilution system and bag cart stored in Rockport.

Projected Activity:

Continue durability operations with the Maxum and Malibu boats. Check the SeaRay boat for coolant leaks in the exhaust, and decide on the next course of action.

TO: Mike Samulski, EPA-AA

FROM: Jim Carroll, Southwest Research Institute

SUBJECT: Weekly Progress Report for Work Assignment 1-5, EPA Contract EP-C-05-018

Period From: October 6, 2006 To: October 12, 2006

PERCENTAGE OF WORK COMPLETED:

Task or Item	Level of Effort, %	Hours	Target Completion Date
[redacted]			

Past Progress:

The SeaRay boat engine covers were partially dismantled to gain access to exhaust ports for inspection. The inside surfaces of the exhaust systems were completely dry from the exhaust ports past the catalysts. There was no sign of leakage from the exhaust manifold flanges. It is our opinion that the reasons that the engine overheated are two-fold and interconnected.

First, there are three high spots in the closed-loop cooling system, namely, the coolant filler and pressure-relief cap above the intercooler, and the two exhaust risers past the catalysts on each bank of the engine. Any vapors within the coolant system will rise to the high spots and remain there unless pushed out by liquid during high speed operation. During an overheat period, higher system pressure will push coolant and vapors past the pressure cap on the intercooler and into the overflow tank. While the system is cooling down, the reduced pressure in the coolant system draws coolant from the overflow tank back into the intercooler. But, there is no escape or return path for the vapors in the exhaust risers and they tend to trap more and more vapor each time the system overheats.

Second, the two exhaust risers after the catalyst are thin-walled and are exposed to very hot exhaust gases. During a shutdown, or slow down after a run, the coolant flow is stopped or reduced and the coolant probably boils in the riser. Boiling the coolant increases the pressure in the system and pushes coolant and vapors past the cap into the overflow tank. Vapors that escape to the atmosphere reduce the volume of liquid available to be drawn back into the system. After a few boiling cycles, the overflow tank will be empty.

A number of changes to the coolant system design could reduce or stop the overheating problem and we will continue to explore options. However, if the engine continues to overheat after revising the coolant system, then we will have to remove the intercooler and go back to an open-loop cooling system.

Projected Activity:

Continue durability operations with the Maxum and Malibu boats. Implement and test changes to the SeaRay engine coolant system.