

ANNEX 4 – Vacuum Units

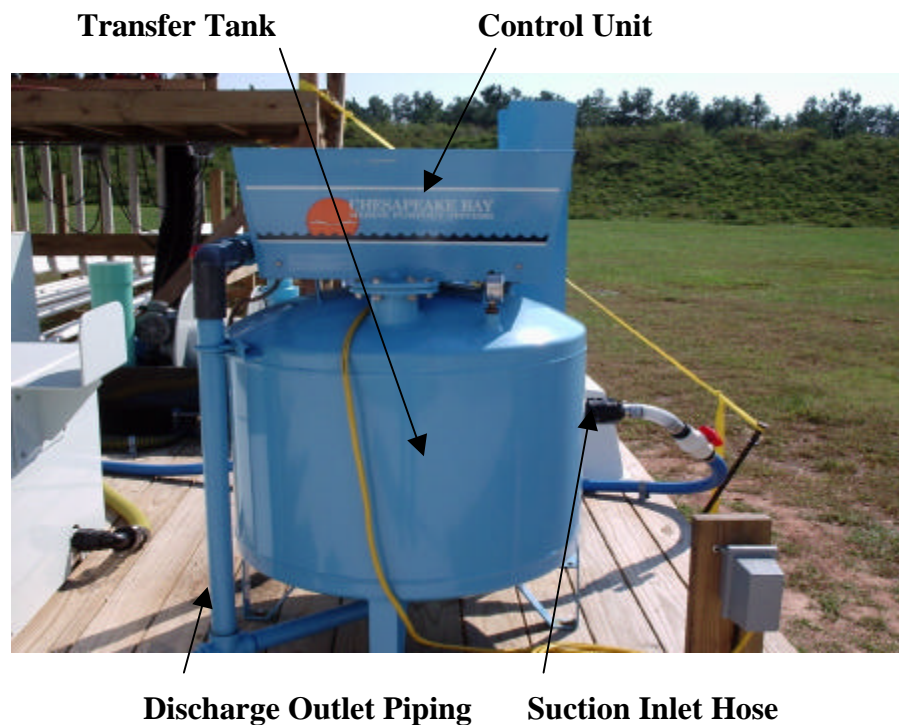
Annex 4.1 - General Information

The table below provides information on the five vacuum pump-out units evaluated in this study.

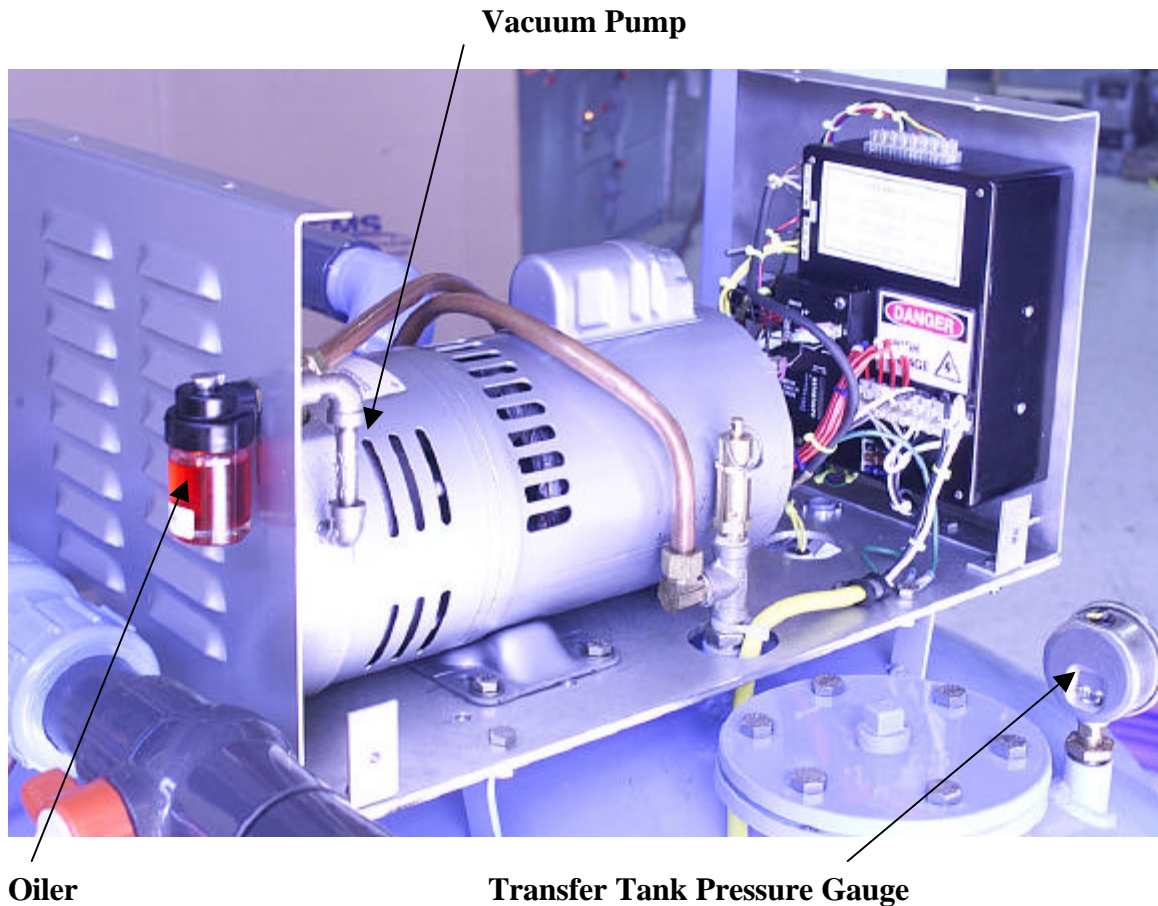
Manufacturer	Model
Chesapeake Bay Marine	CB70HD
Edson International	290-35-1HP
Keco	Vacuum 1000V-3 HP
Waubauskene	AVR60
Waubauskene	LD125

Theory of Operation – Vacuum Pump-out

The following photographs of the Chesapeake Bay Marine Model CB70HD Vacuum Pump-Out unit illustrate the typical design of a vacuum pump-out system. The transfer tank on the unit temporarily holds the media being pumped during the suction and discharge cycles of the pump-out unit. When the unit is in the suction cycle (i.e. drawing boat holding tank contents into the transfer tank), the vacuum pump inside the control unit draws a vacuum on the transfer tank. When the unit shifts to the discharge cycle (i.e. discharging transfer tank contents to a sewer system), the vacuum pump applies pressure to the transfer tank to expel the contents of the tank to the discharge piping. All five vacuum pump-out units used this same basic construction and theory of operation.



Internal View of Control Unit (Cover Removed)



Typically, solenoid-operated control valves installed in the piping that connects the vacuum pump to the transfer tank are used to direct the flow of air into and out of the tank during the suction and discharge cycles.

The vacuum pump is lubricated by an oiler that is mounted on the unit, and the oil is drawn into the pump through a connecting pipe during pump operation to lubricate the internal components. During operation of the vacuum pump, some of this oil is released into the transfer tank and piping during the discharge cycle.

In the closed loop system used for this testing program this type of oiler arrangement would have resulted in small amounts of the oil being deposited in the underground storage tank.

The lubricating oil chosen for the study was Mobil EAL® 224H Biodegradable, Virtually Nontoxic Antiwear Hydraulic Oil. This oil was selected for the study due to superior lubricating qualities and the nontoxic, biodegradable nature of the oil. Since this oil is virtually nontoxic and biodegradable, it gave the added benefit of making the life-cycle testing setup as safe as possible for the environment. Two of the vacuum pump-out manufacturers (Keco and Waubaushene Machine and Welding) specifically recommended the use of this oil for their units in their unit manuals. The other two vacuum pump-out manufacturers (Chesapeake Bay Marine and Edson International) were consulted regarding the use of this oil in their units, and both manufacturers approved the use of this oil in their pump-out units prior to life-cycle testing.

**Annex 4.2 – Manufacturer: Chesapeake Bay Marine
Model: CB70HD (Vacuum)**

Unit Photograph



Description of Pump-Out Unit

Serial Number: A03275

Construction:

- Transfer tank: 75-gallon (Normal operating capacity - 55 gallons); made of boilerplate steel.
- Control unit panels constructed of aluminum
- Powdered-coated finish on tank and control unit
- Full-flow check valves installed in suction and discharge piping
- Direct drive connection between motor and rotary vane vacuum pump

Rating of Vacuum Pump Motor: 0.75 Horsepower, 115 Volts, 11.0 Amps (as configured for testing)
Circuit breaker used in life-cycle testing set-up: 20 Amps
GFCI protection provided by a GFCI receptacle outlet

Summary of Life-Cycle Testing Performance

The Chesapeake Bay Marine Pump-Out unit operated for the full 1000 hours in the life-cycle testing set-up. During the first 38.8 hours of operation in the life-cycle testing setup, this unit exhibited problems with frequently blowing the internal fuse for the vacuum pump and tripping of the unit circuit breaker. A representative of Chesapeake Bay Marine made a site visit to troubleshoot problem with unit. When the vacuum pump was disassembled for troubleshooting, unusual deposits were found in the internals of the pump and in the air discharge manifold of the pump. After consultation with the manufacturer, it was decided that these deposits were most likely caused by the lubricating oil overheating in the vacuum pump; and the resulting break-down of the oil showed up as visible deposits on the internals of the pump and the air discharge manifold. Since the Waubaushene Model AVR60 had a similar vacuum pump produced by the same manufacturer (Gast), the air discharge manifold for the Waubaushene Model AVR60 vacuum pump was inspected to see if it contained similar deposits. No deposits were noted in the Waubaushene Model AVR60. This problem most likely showed up in the Chesapeake Bay Marine unit because the unit utilizes a very low-flow oiler for lubrication. With very small amounts of oil flowing through the vacuum pump, the oil has more time to heat up to a high temperature where it is likely to break-down. The Waubaushene Model AVR60 used an oiler with a higher oil flowrate and this unit did not experience a problem of this type. In order to address the problem with the Chesapeake Bay Marine Vacuum Pump-out unit, another vacuum pump oil (Nu-Calgon Vacuum Pump Oil) was used in this unit during the remaining 961.2 hours of operation and no further problems with the pump was noted.

Note: Because of the lengthy time required to diagnose the lubrication problem, the SOBA representative allowed the Chesapeake Bay Marine unit to be operated beyond the June 4, 2004 cut-off date. The extended operation was allowed on the condition that if the unit continued to shutdown, testing would be halted. Once the Nu-Calgon Vacuum Pump Oil was substituted, the unit continued operation without any further problem.

Summary of Repairs

After the lubrication issue on this unit was identified and resolved, no additional repairs were required on the unit during life-cycle testing.

Results of Environmental Testing

1. Corrosion Resistance: A sample of the Boilerplate Steel used in constructing the tank and steel mounting legs was subjected to the Salt-Spray Exposure described in *Section 2*. The sample was found to have inferior corrosion resistance on bare surfaces. The powder-coated painted surfaces of the sample exhibited good corrosion resistance. An additional sample of the aluminum Control Unit cover was subjected to the Salt-Spray Exposure described in *Section 2.3* and the sample was found to have superior corrosion resistance.
 2. Ultraviolet Exposure Resistance: This unit did not have any fiberglass or plastic covers, so no ultraviolet exposure testing was performed on this unit.
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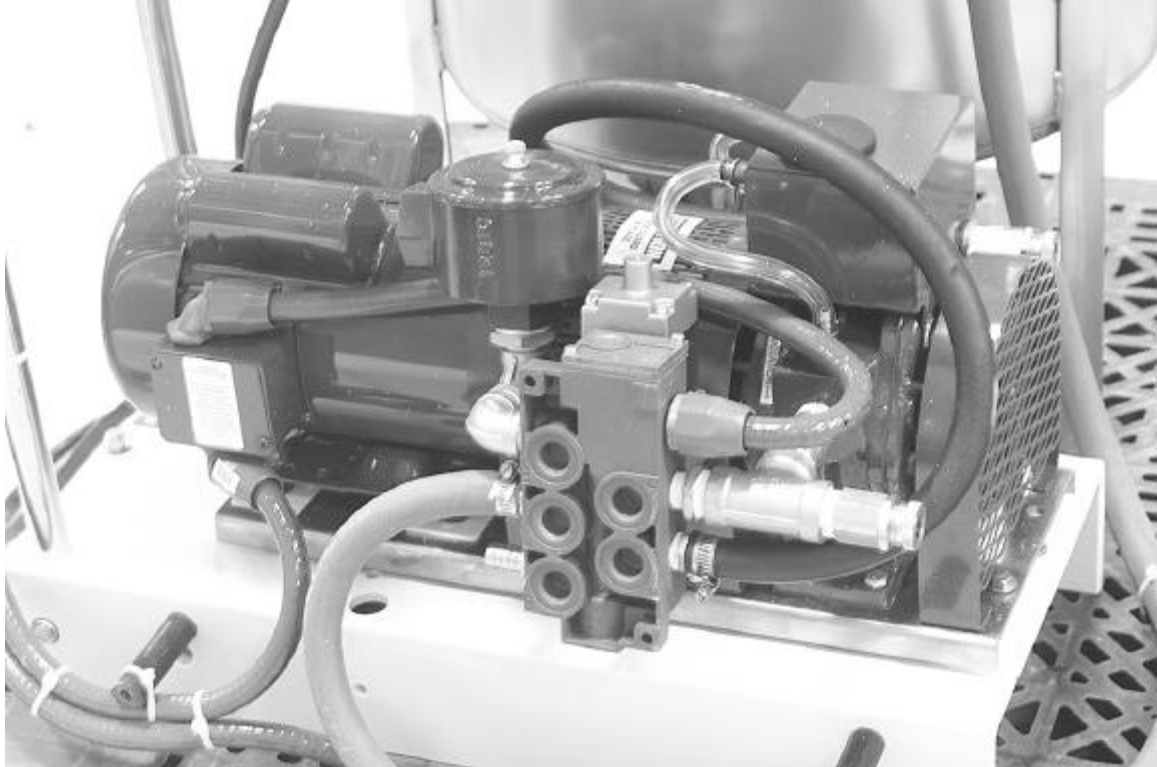
**Annex 4.3 – Manufacturer: Edson International
Model: 290-35-1HP (Vacuum)**

Unit Photographs

External View



Internal View (Cover Removed)



Description of Pump-Out Unit

Serial Number: 27795

Construction:

- Transfer tank: 35-gallon made of stainless steel.
- Molded Solid Fiberglass Enclosure
- Clear PVC check valves installed in suction and discharge piping
- Direct drive connection between motor and rotary vacuum pump

Rating of Electric Motor: 1 Horsepower, 115 Volts, 13.4 Amps (as configured for testing)

Circuit breaker used in life-cycle testing set-up: 20 Amps

GFCI protection provided by a GFCI receptacle outlet

Summary of Life-Cycle Testing Performance

The Edson International Model 290-35-1HP Vacuum Pump-out unit operated for the full 1000 hours of operation in the life-cycle testing set-up.

Summary of Repairs

No repairs were required on this unit during life-cycle testing.

Results of Environmental Testing

1. Corrosion Resistance: A sample of the Aluminum Frame was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have superior corrosion resistance.
 2. Ultraviolet Exposure Resistance: A sample of the Molded Solid Fiberglass Enclosure for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.
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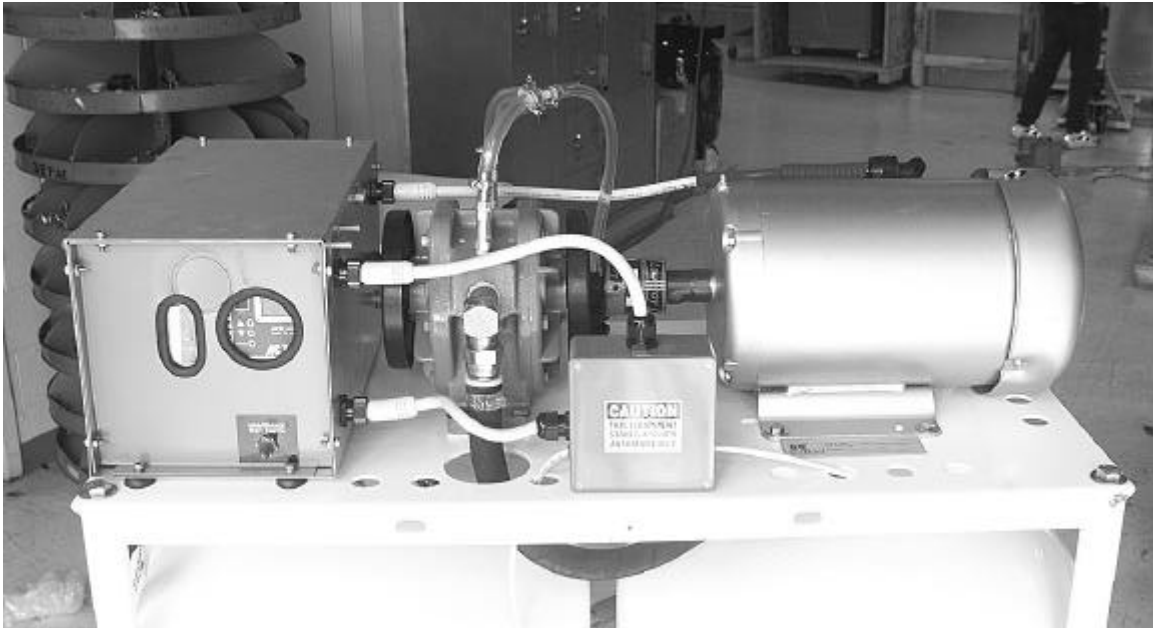
**Annex 4.4 – Manufacturer: Keco
Model: 1000V-3HP (Vacuum)**

Unit Photographs

External View



Internal View (Cover Removed)



Description of Pump-Out Unit

Serial Number: V11125

Construction:

Transfer tanks (2) - made of Polyvinyl Chloride (PVC), 36-gallon capacity (each) Normal operating volume of each tank: 25-30 gallons

Molded Solid Fiberglass Cover

Clear PVC check valves installed in suction and discharge piping

Direct drive connection between motor and rotary vacuum pump

Stainless Steel Hardware

Painted Steel Frame (zinc-based primer used for corrosion resistance)

Rating of Electric Motor: 3 Horsepower, 230 Volts, 17.0 Amps (as configured for testing)

Circuit breaker used in life-cycle testing set-up: 30 Amps

GFCI protection provided by a GFCI receptacle outlet

The theory of operation of this unit was different than the other vacuum units that were evaluated in the study, because this vacuum unit utilized a two-tank design. The other vacuum systems utilized a one-tank design, which have a distinct suction cycle (when the transfer tank is filling from the suction hose) and discharge cycle (when the transfer tank contents are being discharged). Rather than having a distinct suction and discharge cycle, this two-tank design provides continuous flow through the pump-out unit. In Keco's two-tank design, as one tank is filling, the other tank is discharging its contents into the discharge piping. In this scenario, the suction of the vacuum pump is drawing a vacuum on the one tank that is filling, while the discharge of the vacuum pump is applying pressure to the other tank that is discharging. The vacuum pump continues to draw vacuum on the tank that is filling until the tank reaches capacity, as indicated by an electronic level sensor. Once the tank that is filling has reached

capacity, the level sensor system transmits a signal to the control unit to reverse the electric motor that drives the vacuum pump. When the electric motor reverses direction, the tank that had been filling is now placed under pressure in order to discharge the contents, and the other tank is placed under vacuum and begins to fill. These cycles are repeated by the control unit to create a continuous flow of media through the pump-out unit.

Summary of Life-Cycle Testing Performance

The Keco Vacuum 1000V-3HP Pump-Out unit operated for a total of 619.8 hours in the life-cycle testing set-up, and exhibited the following failures (See *Summary of Repairs* on page 74):

1. The unit shut down two times on the F1 Fault on the control system. The F1 Fault is described in the Keco Product Guide as: “EPM Fault: The EPM is missing or damaged”. Keco was contacted and indicated that the source of the problem was most likely a loose EPM chip in the control circuit. Keco recommended reseating the EPM chip on the front panel of the control unit. For each F1 Fault, the EPM chip was reseated by hand by pressing in on the cover of the EPM chip on the front panel of the control unit. Power to the unit was cycled by opening and closing the circuit breaker for the unit, and the failure code was cleared from the control system. The unit was restarted and exhibited normal operation.
2. The unit shut down once and dashed lines were displayed on the control unit display. Keco was contacted and recommended cycling power to the unit to clear the failure code on the control system. The reason for this shutdown was not able to be determined, but it was most likely caused by a logic error in the Programmable Logic Controller (PLC). The power to the unit was cycled by opening and closing the circuit breaker for the unit, and the unit was restarted, however, it exhibited the same shutdown within a few minutes of operation. The power to the unit was cycled again by opening and closing the circuit breaker for the unit, and the unit was restarted and exhibited normal operation.
3. Both transfer tanks on the unit had to be replaced after approximately 450 hours of operation in the life-cycle testing set-up, because both tanks developed cracks on the bottom around the outer edge of the cylindrical tank. Keco was consulted regarding the failure of these tanks, and they believe that the ambient temperature during life-cycle testing probably contributed to the failure. The Keco Product Guide for the unit indicates that stainless steel tanks are strongly recommended for cold weather locations (below 45 degrees Fahrenheit). Life-cycle testing was conducted through the winter months at temperatures below 45 degrees Fahrenheit for considerable time periods during life-cycle testing. The life-cycle testing set-up was shutdown during the winter months when temperatures dropped below 32 degrees Fahrenheit to prevent freezing of the media in the piping.
4. The unit began to exhibit episodes of intermittent running after the first tank was replaced, and the problem could not be resolved by cycling power to the unit. After consulting Keco, the control unit was changed out with a spare control unit and life-cycle testing was continued. Keco performed troubleshooting on the original control unit and the problem was identified to be a defective EPM chip in the control circuit.

Life-cycle testing was concluded on this unit on June 4, 2004. Some delays were encountered in repair of the unit during life-cycle testing that were not attributed to Keco’s delivery of parts and repair instructions. Some potential run time was lost while the unit was powered off.

Summary of Repairs

Keco

Model: Vacuum 1000V – 3HP

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Troubleshoot F1 shutdown of unit	85.2	None required	N/A	N/A	0.5	<1
Troubleshoot F1 shutdown of unit	184.6	None required	N/A	N/A	0.5	<1
Troubleshoot shutdown of unit	418.8	None required	N/A	N/A	0.5	<1
Tank replacement	445.8	Tank	\$325	5	1	31 Note 1
Replace control unit	445.8	EPM Chip	\$25	0 Note 2	1	4
Tank replacement	457.2	Tank	\$325	8	1	37 Note 1

Note 1: Delays were encountered in the repair which were not due to Keco.

Note 2: Keco provided a spare control unit, so the repair parts were on-hand.

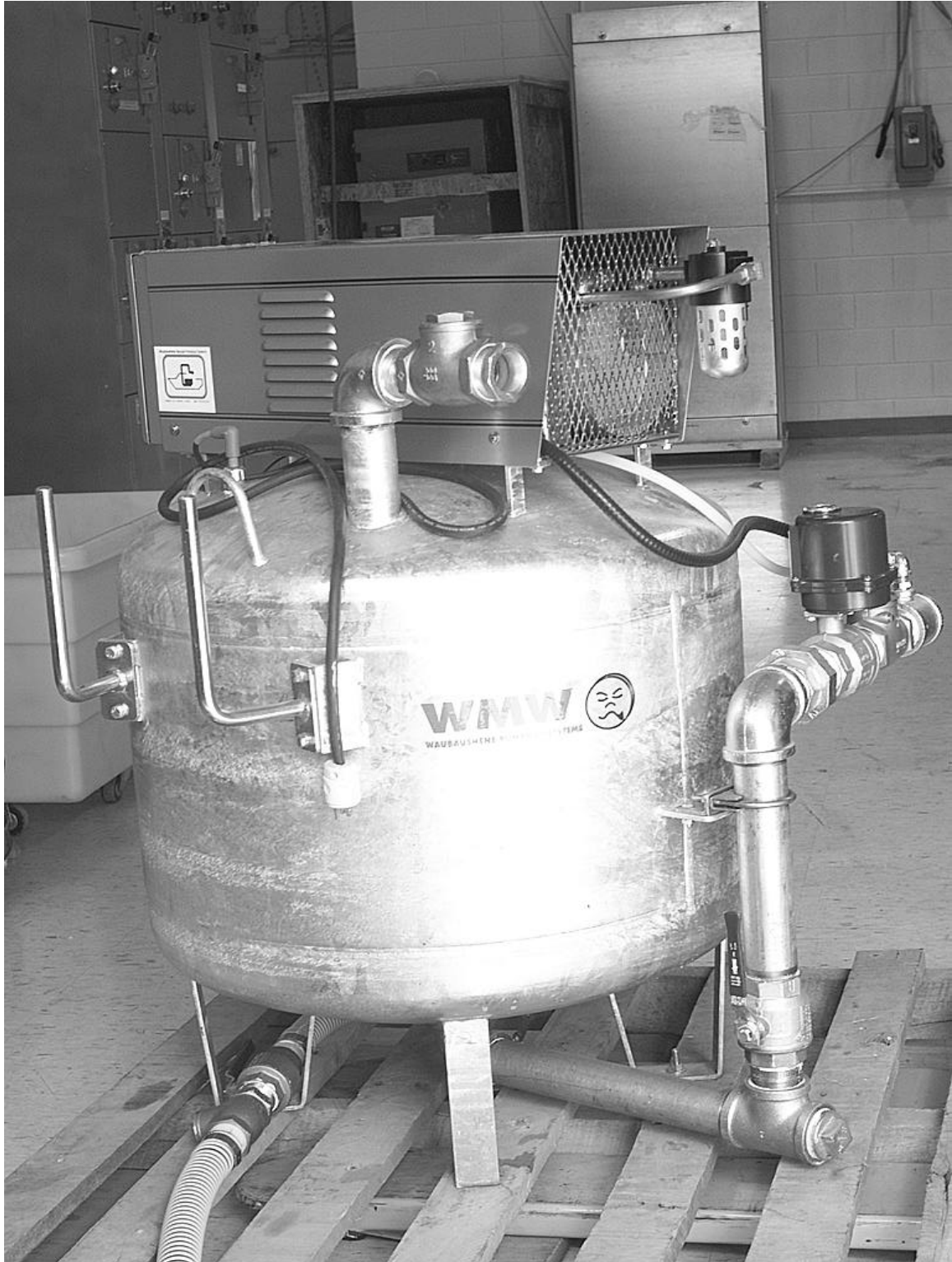
Results of Environmental Testing

1. Corrosion Resistance: A sample of the metal frame that supports the plastic tanks was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have inferior corrosion resistance. The sample displayed pronounced corrosion on bare metal surfaces of the sample. The painted surfaces of the metal sample also exhibited corrosion under the surface of the paint.
 2. Ultraviolet Exposure Resistance: A sample of the Molded Solid Fiberglass Cover for the unit was subjected to the Ultraviolet Exposure described in *Section 2.4*. The sample was found to have superior resistance to fading, cracking, and discoloration due to simulated exposure to sunlight and moisture.
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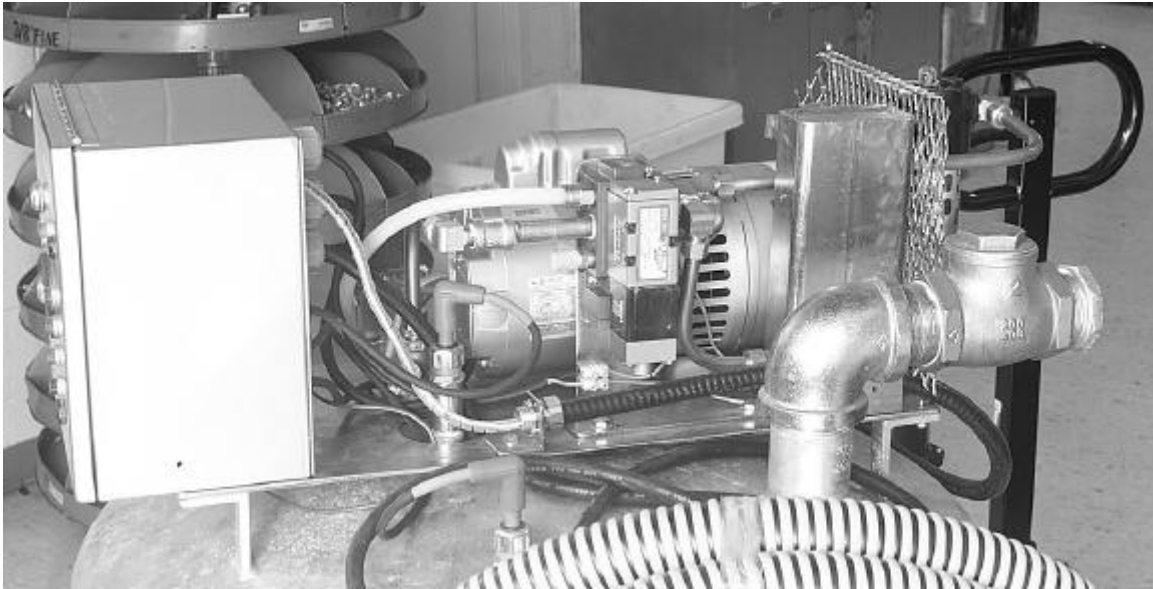
**Annex 4.5 – Manufacturer: Waubaushene Machine and Welding
Model: AVR60 (Vacuum)**

Unit Photographs

External View



Internal View of Control Unit (Cover Removed)



Description of Pump-Out Unit

Serial Number: 2854

Construction:

- Transfer tanks: 60-gallon capacity; made of stainless steel
- Direct drive connection between motor and rotary vacuum pump
- Stainless steel hardware
- Painted steel enclosure for control unit

Rating of Electric Motor: 0.75 Horsepower, 115 Volts, 11.8 Amps (as configured for testing)

Circuit breaker used in life-cycle testing set-up: 20 Amps

GFCI protection provided by a GFCI receptacle outlet

Summary of Life-Cycle Testing Performance

The Waubaushene Model AVR60 Vacuum Pump-Out unit operated for a total of 413.5 hours in the life-cycle testing set-up, and exhibited the following failures (See *Summary of Repairs* on page 77):

1. The unit was initially found with the circuit breaker tripped at 382.7 hours of operation. The unit was inspected and found to have no obvious problem, so the unit was restarted. The unit was monitored during operation and the vacuum pump was not drawing a vacuum on the transfer tank during the suction cycle. The unit was manually shifted to the discharge cycle and the vacuum pump would not produce pressure in the transfer tank. Waubaushene was consulted regarding this problem and suggested that this problem may be caused by the vanes in the rotary vacuum pump becoming stuck in place in the rotor of the pump. Waubaushene recommended opening up a port on the suction side of the vacuum pump and lubricating the pump with a lubricating oil (such as WD-40) to free up the stuck vanes. The vacuum pump was lubricated in this manner and the pump was
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restarted in the life-cycle testing set-up. The unit operated for a short time and then tripped the circuit breaker again. On several occasions, the vacuum pump was lubricated and attempts were made to restart the unit. However, the unit continued to trip the circuit breaker. After further troubleshooting of the unit, the vacuum pump was found to stop operating prior to the circuit breaker tripping. Waubaushene was consulted and suggested that the problem may be overheating of the vacuum pump and electric drive motor. The electric motor that drives the vacuum pump has a thermal overload which is designed to interrupt power to the motor when the temperature of the motor is elevated sufficiently that damage might occur to the motor. The thermal overload will reset once the motor cools off, after being shut off for some period of time. In this case, the thermal overload was resetting after the pump cooled off, but the inrush of current when the motor was still at an elevated temperature was most likely tripping the circuit breaker. Waubaushene eventually recommended changing out the circuit breaker that was used to power the unit with another breaker of the same current rating, just to make sure that the circuit breaker was not the source of the problem. The circuit breaker was changed out with a spare breaker in the electrical panel and the unit continued to trip the circuit breaker during operation.

- When the vacuum pump problem was identified on the Chesapeake Bay Marine unit, the Waubaushene Model AVR60 was inspected to determine if the clogging problem, due to the lubricating oil encountered in the Chesapeake Bay Marine Vacuum unit, might be the cause of the frequent breaker tripping on the unit. The Waubaushene Model AVR60 vacuum pump is similar to the vacuum pump used on the Chesapeake Bay Marine unit and is produced by the same manufacturer (Gast). The vacuum pump discharge piping of the Waubaushene Model AVR60 was inspected and no deposits were noted. The clogging problem that occurred in the Chesapeake Bay Marine unit was most likely due to the low oil flowrate provided by the oiler. The Waubaushene Model AVR60 is equipped with an oiler with a higher oil flowrate than the Chesapeake Bay Marine and this difference in the units, most likely, prevented a clogging problem in the Waubaushene Model AVR60.

Life-cycle testing was concluded on this unit on June 4, 2004. Some delays were encountered in repair of the unit during life-cycle testing that were not attributed to Waubaushene. The cold winter weather and the high volume of repairs required on other pump-out units in the study delayed the repairs outlined above for this unit.

Summary of Repairs

Waubaushene Machine and Welding

Model: AVR60

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Lubrication of vacuum pump	382.7	None	N/A	N/A	0.75	<1
Troubleshooting circuit breaker tripping	382.7	None	N/A	N/A	6	45 Note 1
Inspection following identification of Chesapeake Bay Marine vacuum pump clogging	413.5	None	N/A	N/A	0.75	Note 2
Tested circuit breaker – exchange with another unit	413.5	None	N/A	N/A	0.5	Note 2

Note 1: Delays were encountered in troubleshooting the unit that were not attributed to Waubaushene.

Note 2: Requested additional guidance from Waubaushene regarding possible causes of circuit breaker tripping.

Results of Environmental Testing

1. Corrosion Resistance: One sample of the stainless steel frame and one sample of the painted steel cover over the control unit were subjected to the Salt-Spray Exposure described in *Section 2.3*.

The stainless steel frame sample was found to have superior corrosion resistance. A light coating of corrosion was visible on surfaces that had been cut using a hacksaw, but the outer surfaces of the stainless steel exhibited superior corrosion resistance.

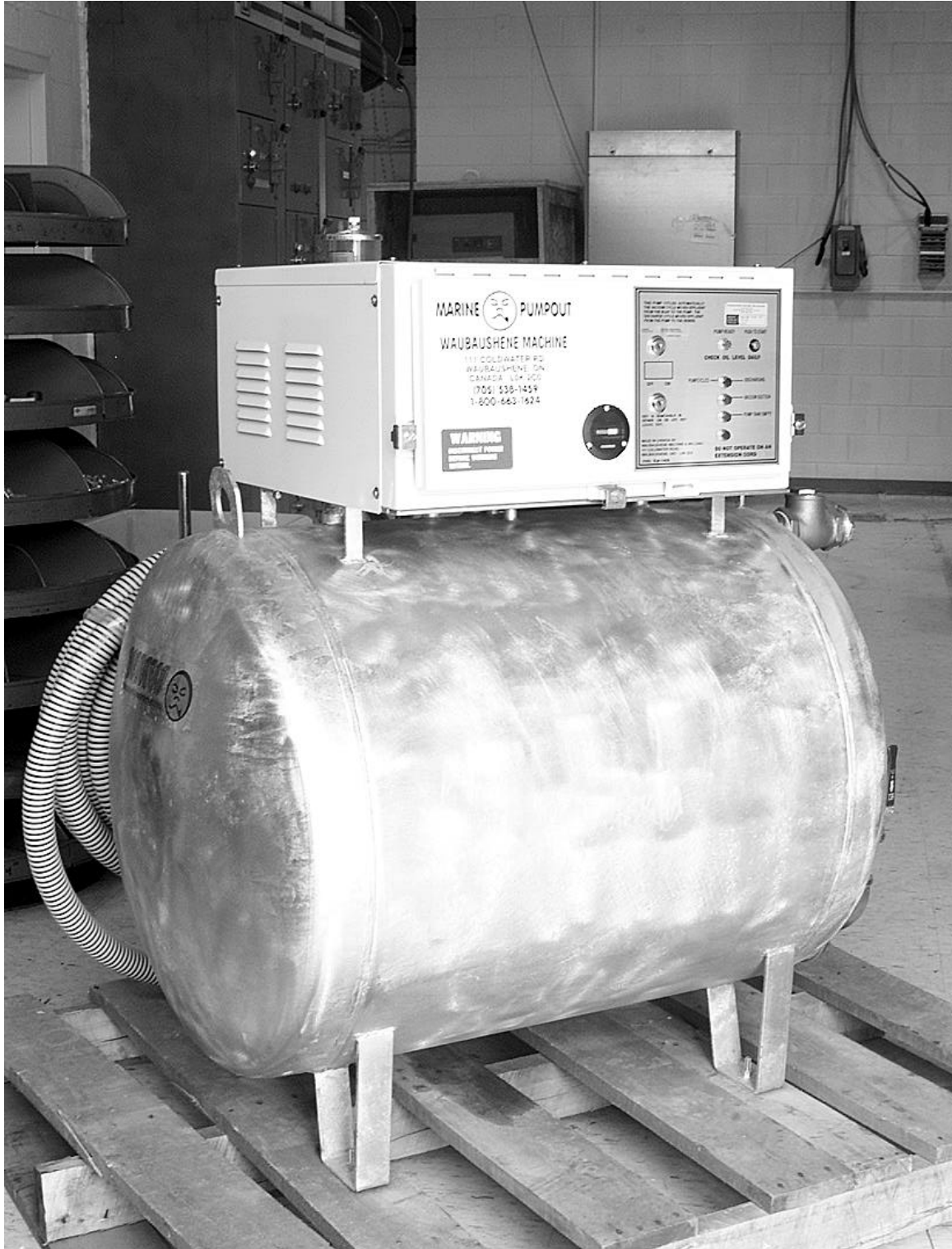
The painted steel cover sample exhibited inferior corrosion resistance. The sample displayed pronounced corrosion on bare metal surfaces of the sample. The painted surfaces of the sample also exhibited corrosion under the surface of the paint.

2. Ultraviolet Exposure Resistance: This unit did not have a fiberglass or plastic cover, so the Ultraviolet Exposure described in *Section 2.4* was not conducted on this unit.
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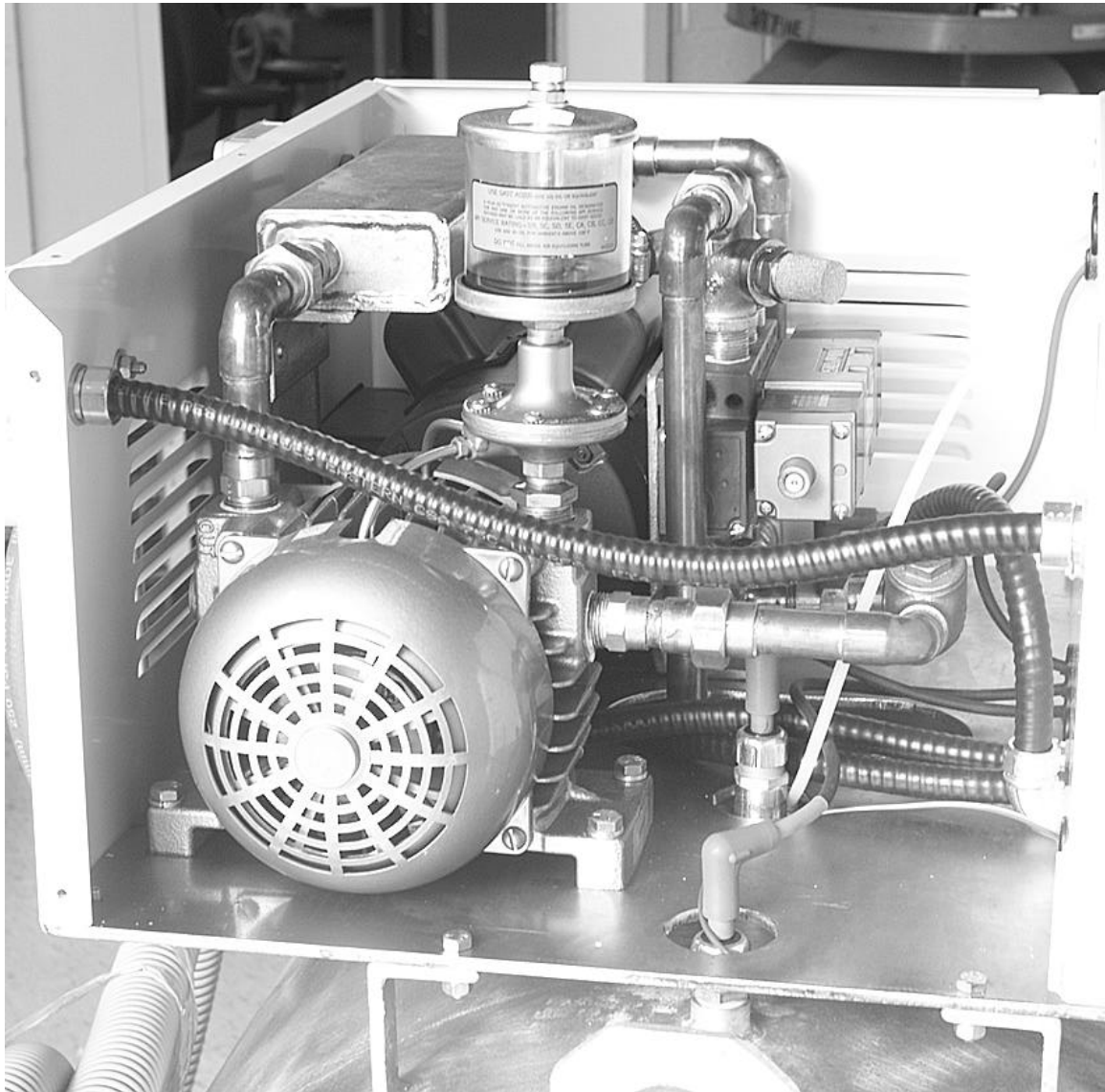
**Annex 4.6 – Manufacturer: Waubaushene Machine and Welding
Model: LD125 (Vacuum)**

Unit Photographs

External View



Internal View of Control Unit (Cover and Side Panel Removed)



Description of Pump-Out Unit

Serial Number: 2855

Construction:

- Transfer tank: 125-gallon capacity; made of stainless steel
- Direct drive connection between motor and rotary vacuum pump
- Stainless steel hardware
- Painted steel enclosure for control unit

Rating of Electric Motor: 1.5 Horsepower, 230 Volts, 9.2 Amps (as configured for testing)

Circuit breaker used in life-cycle testing set-up: 30 Amps

This unit was originally powered in the life-cycle testing set-up by a 30-Amp breaker with a Ground Fault Circuit Interrupter (GFCI). However, during initial test runs on the unit, the circuit breaker tripped several times during operation of the unit. After consultation with a UL electrical engineer, the most likely cause for these breaker trips was a phase imbalance between the line and neutral phases during operation of the unit. In order to continue with the life-cycle test program, the circuit breaker for the unit was changed out with a non-GFCI breaker. UL recommends that GFCI protection should be provided for every receptacle outlet and motor connection in every location where the environment might be wet, moist, or damp. Since this unit is used in an environment near water, and where operators of the unit could potentially be wet, the design of this unit should be evaluated and the phase imbalance that is present during operation should be eliminated, so the unit will operate with a GFCI breaker or GFCI receptacle outlet to ensure the safety of operators of the pump-out unit.

Summary of Life-Cycle Testing Performance

The Waubaushene Model LD125 Vacuum Pump-Out unit operated for a total of 220.2 hours in the life-cycle testing set-up and exhibited the failures indicated in the *Summary of Repairs* on page 82. After 72.6 hours of operation in the life-cycle testing set-up, the unit experienced a series of failures that placed the unit out of operation for an extended period of time during the study. The following sequence of events is included to describe the circumstances of this series of failures.

1. The pump was found operating with the spider coupling between the electric motor and the vacuum pump sheared out, so that the electric motor was disengaged from the vacuum pump and the motor was spinning freely. Troubleshooting revealed that the vacuum pump had filled with test media and was seized up (i.e. the pump shaft would not turn). Waubaushene was contacted regarding the problem and requested that the vacuum pump be shipped to their manufacturing facility for reconditioning.
 2. Following reconditioning, the vacuum pump was reinstalled and the unit was restarted. The vacuum pump immediately started to make noise and the unit was shutdown again. Troubleshooting revealed that test media had again entered the vacuum pump, but this time the pump did not seize up. Waubaushene was contacted and suggested that the second failure of the vacuum pump was most likely caused by a failure of the air-reverse valve. Waubaushene recommended that the fuses in the air-reserve valve solenoid circuit be checked to see if the air-reverse valve was operating properly. A fuse was found to be blown in the circuit, so Waubaushene recommended cleaning the air-reverse valve assembly and replacing the fuse that was blown in the circuit. The air reverse valve assembly was disassembled and found to have test media inside the valve assembly (i.e. small pieces of toilet paper and sponge material). In addition, the vacuum pump had to be cleaned out and lubricated following the entry of test media into the pump, which was done this time by UL personnel. The unit was repaired and restarted.
 3. The unit was found shutdown the next day with the circuit breaker tripped. Troubleshooting revealed that the unit was using very little oil out of the lubricating oil reservoir during operation. The oiler was removed and inspected for proper operation. No problems were identified with the oiler and the oiler was replaced and the unit was restarted.
 4. The next day, the unit was found with the spider coupling between the vacuum pump and the electric motor sheared out again. Troubleshooting revealed that the vacuum pump had not seized this time but the pump shaft was rather difficult to turn by hand, so the pump was lubricated with oil to allow it to turn more freely. Waubaushene was consulted and concluded that the previous repairs were most likely caused by inadequate lubrication from the oiler on the unit. Waubaushene shipped a
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- replacement oiler with a different design to modify the unit. The new oiler was installed and a new spider coupling was installed between the motor and the vacuum pump and the unit was restarted.
5. The spider coupling was found worn again the next day, this time due to the sprocket moving on the vacuum pump shaft, and allowing the spider coupling to become worn.
 6. Waubaushene was consulted regarding this failure and the decision was made to use Lock-Tite on the sprocket to keep it from moving on the vacuum pump shaft during operation.
 7. A replacement spider coupling was installed and Lock-Tite was applied to the vacuum pump shaft during reassembly to ensure that the sprocket remained fixed in place during pump operation and the unit was restarted.

After replacing the oiler with the new design and correcting the problem with the frequent failure of spider couplings, the unit operated in the life-cycle testing set-up for 128.7 hours without any additional problems being identified. Life-cycle testing was concluded on this unit on June 4, 2004. Some delays were encountered in repair of the unit during life-cycle testing that were not attributed to Waubaushene. The cold winter weather and the high volume of repairs required on other pump-out units in the study delayed the repairs outlined above for this unit.

Summary of Repairs

Waubaushene Machine and Welding

Model: LD125

Repair Required	Run Time on Unit (hours)	Repair Parts Required	Cost of repair parts	Time required to receive parts (days)	Time required to make repair (hours)	Total Time Off-Line (days)
Vacuum pump seized	72.6	None	\$210 Note 1	28 Note 1	1.5	41
Vacuum pump filled again	72.6	None	N/A	N/A	2.0	3
Fuse troubleshooting and replacement	72.6	Fuse	N/A Note 2	N/A Note 2	2.0	1
Solenoid cleaning	72.6	None	N/A	N/A	2.0	50 Note 3
Oiler inspection	72.6	None	N/A	N/A	0.5	<1
Oiler replacement with new design	72.6	Oiler	\$99	5	0.75	15
Spider gear replacement	72.6	Spider coupling	\$7.75	5	0.75	Note 4
Spider gear replacement	72.6	Spider coupling	\$7.75	0 Note 5	0.75	<1
Spider gear replacement and lock-tite of sprocket	91.5	Spider coupling	\$7.75	8	1.5	15

Note 1: Vacuum pump reconditioned by Waubaushene. "Time required to receive parts" in the table includes the repair time at the manufacturing facility and the shipping time for the vacuum pump to Canada from North Carolina for repair.

Note 2: Spare fuses were supplied with the unit.

Note 3: Delays encountered in troubleshooting the unit that were not attributed to Waubaushene. Cold winter weather and the high volume of repairs, required by other pump-out units in the study, delayed the repair of this unit.

Note 4: Repair of spider coupling was done in conjunction with the replacement of the oiler.

Note 5: Waubaushene supplied two spider couplings with the initial order, so a spare spider coupling was on-hand for repair.

Results of Environmental Testing

1. **Corrosion Resistance**: One sample of the stainless steel frame and one sample of the painted steel cover over the control unit were subjected to the Salt-Spray Exposure described in *Section 2.3*.

The stainless steel frame sample was found to have superior corrosion resistance. A light coating of corrosion was visible on surfaces that had been cut using a hacksaw, but the outer surfaces of the stainless steel exhibited superior corrosion resistance.

The painted steel cover sample exhibited inferior corrosion resistance. The sample displayed pronounced corrosion on bare metal surfaces of the sample. The painted surfaces of the sample also exhibited corrosion under the surface of the paint.

2. **Ultraviolet Exposure Resistance**: This unit did not have a fiberglass or plastic cover, so the Ultraviolet Exposure described in *Section 2.4* was not conducted on this unit.
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Annex 4.7 – Conclusions regarding Vacuum Pump-Out Units

1. The most common repairs for the vacuum units were repairs required to the vacuum pump and electric drive motor.
 2. One representative transfer tank vacuum/pressure gauge from one of the vacuum units (Waubashene Model LD125) was subjected to the Salt-Spray Exposure described in *Section 2.3*. The sample was found to have inferior corrosion resistance. The gauge sample displayed pronounced corrosion on bare metal surfaces of the sample. This gauge was typically of gauges found on the other vacuum units.
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