WSRC-TR-2000-00296

TANK 19F PITBULL™ EDUCTOR EVALUATION (U)

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E. Saldivar, High Level Waste Division, Customer	9/19/00 Date

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TEMPORARY DELEGATION OF AUTHORITY

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Title: Level 3 Manager

I hereby delegate authority to Daniel B. Burns on 9/1/00 through 9/17/00.

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EXECUTIVE SUMMARY

At the request of the High Level Waste Division of the Westinghouse Savannah River Company, the Experimental Thermal Fluids Group of the Savannah River Technology Center performed three tests from August 1 to August 7, 2000 on the VACCON 750 Eductor. This eductor is part of the PITBULL™ pump, which will be used to remove the waste heel from Tank 19F in the process of closing that tank.

These eductor tests were performed in response to a safety analysis carried out by the Westinghouse Safety Management Solutions Company that raised concerns of the eductor's response to defined off-normal pump operations. Two abnormal conditions for the operation of the PITBULL™ pump would be if waste entered the 36-foot high vacuum line of the eductor and, either it is raised to the maximum vacuum level possible or it is ejected through the eductor while the pump is being pressurized. Both scenarios could lead to complications during waste transfer that can be avoided or properly addressed by knowing how eductor will perform under these conditions.

The first test determined the deadhead vacuum level for the VACCON 750 eductor. There is an adjustment on the eductor diffuser to set the vacuum strength. That adjustment can be turned three times, but it was received from High Level Waste preset at 1.5 turns. This setting was not changed nor verified. With the eductor exhausting to the atmosphere, the test supplied air pressure from 10 psig to 112 psig. However, during the tank transfer the intent is to supply the eductor with air at 80 psig. The results were:

• 15 ft.WC ±1 ft.WC deadhead vacuum at an air supply pressure of 80 psig
• 22 ft.WC ±1 ft.WC deadhead vacuum at an air supply pressure of 112 psig

The second and third tests were to determine the amount of waste that could be atomized after being ejected through the eductor. Even though the entire pump will be contained within the waste tank, the eductor will be near the top of the tank. The concern is that these small droplets of waste could reach the HEPA filter and cause damage. Both atomization tests ejected water (approximately 1 gallon) through the eductor at a height of 10 feet above an 8-foot x 8-foot plastic tarp. The eductor was held vertically downwards and it exhausted to the atmosphere. Water that was not retained by the tarp from the spray was assumed to be atomized and carried away by the ventilation. The first atomization test ejected water by vacuum alone with air pressure supplied to the eductor at higher than the one to be used in the field, i.e., 80 psig. The second test ejected water by a vacuum, and also by a positive pressure applied to the vacuum line at a pressure higher than the one to be used in the field, i.e., 80 psig. The results were:

• 95% ±3% of water was retained when ejected by a vacuum created with an air supply pressure of 112 psig; therefore 5% is assumed to be atomized.

• 88% ±3% of water was retained when ejected by a vacuum created with an air supply pressure of 112 psig and while the vacuum line was pressurized to 107 psig; therefore 12% is assumed to be atomized.

ACKNOWLEDGMENTS

I would like to thank the Experimental Thermal Fluids Group personnel for assisting me in carrying out this task professionally and on time. Special thanks go to Michael Armstrong for constructing test rig, to Michael, Andy Forman, and Jimmy Mills for running the experiment, to Jimmy, Vernon Bush, and Gean Bridgmon for their assistance with the Measuring and Testing Equipment, and to Hector Guerrero for helping with video equipment. Discussions with and insights from Tim Steeper, Zafar Qureshi, and John Steimke enabled the experiment proceed along the right track Thanks to Susan Hatcher for making sure everything was done safely. Thanks to Dan Burns, Al Siddell and Tom Nance from Site Remote Systems for bringing this work to our attention. A final thanks to our customer from the High Level Waste Division, especially Eloy Saldivar, Stephen A. Smith, and Phil Davis for having faith in the Experimental Thermal Fluids Group to perform this needed task. The work was funded by the U. S. Department of Energy under Contract DE-AC09-96SR18500.

NOMENCLATURE

ETF	Experimental Thermal Fluids Group
ft.WC	Feet of Water (Column)
gpm	Gallons Per Minute
HLW	High Level Waste Division of WSRC
M&TE	Measurement and Testing Equipment
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
psig	pounds per square inch gauge pressure
psia	pounds per square inch absolute pressure
SRTC	Savannah River Technology Center
SRS	Savannah River Site
SV	Vacuum-line Shutoff Valve
TFL	Thermal Fluids Laboratory
WSMS	Westinghouse Safety Management Solutions Company
WSRC	Westinghouse Savannah River Company
VE	VACCON 750 Eductor

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1.0 INTRODUCTION

Part of the effort by the Westinghouse Savannah River Company (WSRC) to close Tank 19F in F Area at the Savannah River Site (SRS) is the removal of the waste in that tank. In the process of emptying Tank 19F, the waste heel needs to be removed. The High Level Waste Division (HLW) of WSRC, which will close the tank, procured a PITBULL™ pump, manufactured by the Chicago Industrial Pump Company, to remove the heel. This pump is designed to handle slurries and sludge but because the pump will have to operate remotely inside the tank it was tested at the Pacific Northwest National Laboratory in 1998 (1). The test determined the pump design to be robust and showed that it can transfer approximately 10 gallons of waste every 10 to 20 seconds (60 to 30 gpm) during normal operation until the waste level goes below 2 inches.

The subject of this report only deals with a small portion of the PITBULL™ pump system. That is, the task was to look at some accident scenarios involving the pump eductor (2,3,4,5). The eductor is only used during the initial pump cycle to pull waste into the pump housing, subsequently the waste is pushed out of the tank and then the cycle repeats. A detailed explanation of the overall pump operation or its design can be found in other sources (1) and will not be given here. However, some general operational details will be described to understand what was needed and what was done for this task. Salient features of the pump are shown in Fig.1.

During a safety analysis performed by the Westinghouse Safety Management Solutions Company (WSMS), several issues were raised concerning the operation of the pump under possible accident scenarios. The work discussed in this report concerns two of those issues. They are:

1. What is the maximum vacuum produced by the pump eductor under a deadhead condition?
2. What amount of liquid would be atomized by the eductor in the event liquid accidentally passed through the air eductor?

The first issue would occur if the pump bubbler did not send a signal to close the vacuum line shutoff valve, resulting in waste entering the vacuum line. The vacuum could lift the waste to the maximum vacuum level that the eductor can produce. However, waste could not reach the eductor by vacuum alone because the eductor will be located approximately 36 feet above the bottom of the tank (Fig. 1) which is 35.5 feet above the waste, if the heel were 6 inches in height, as expected (1). Since a perfect vacuum is only about 33.6 feet of water (and lower for the more dense waste), the waste will stop rising before it reached the eductor. However, there were other concerns dealing with waste volatilization at low pressures, so it was important to know the maximum vacuum level attainable. This concern was addressed by measuring the deadhead vacuum for a range of air supply pressures stipulated by HLW.

The second issue would occur if the vacuum-line shutoff valve, which needs to be pressurized with air to close, somehow remained open when the pump begins to push the waste out of the tank with pressurized air. In this situation, the waste could conceivably be pushed through the eductor. Further, since the air supply to the eductor is continuous, by design, then the vacuum would accelerate the passing of waste. The eductor itself is not expected to be damaged by the waste, since it is specifically designed to handle slurries and sludges. This is the reason why the air supply goes to the side of the eductor (Fig. 1) and the vacuum line is connected at the top; the vacuum flow path is straight through the eductor, which allows very large particles to pass. However, while the entire pump will be contained within the waste tank during the transfer, the eductor will be close to the top. The safety concern is with the spraying of waste into the tank atmosphere.

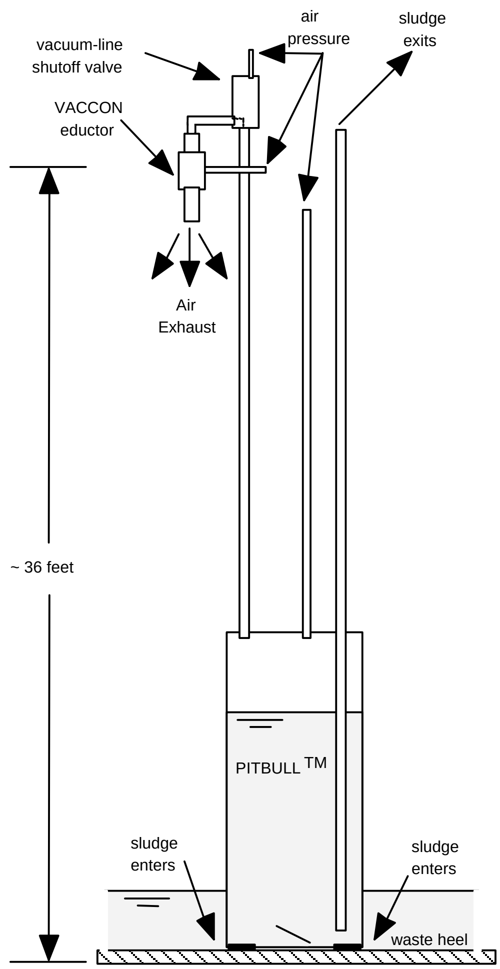

Figure 1. Sketch of some parts of the PITBULL™ pump

While the eductor will be facing down, to the bottom of the tank, it will be located so close to the tank top that a highly atomized mist of waste may be carried to the HEPA filter and cause several problems. In an attempt to quantify the amount of waste that would be atomized, and have the potential of being carried to the filter, a test was done to inject water, at 40°C, through the eductor directly into the atmosphere. Ten feet under the exhaust of the eductor was located a 8-foot x 8-foot square tarp. Any water that was not caught and retained by the tarp would be assumed lost to the atmosphere; that is, the liquid waste that could potentially enter the tank HEPA filter. This test was assumed to give conservative results because:

1. The actual pump would be supplied with 80 psig air to run the eductor and the pump (it will be less at the pump itself because of losses). The test would be run at better than 100 psig, thus there would be more energy to atomize the liquid in the laboratory test than in the tank.
2. In the test, the water at 40°C would be spraying out of the eductor exhaust into the laboratory environment at less than saturated conditions. That is, in the laboratory environment the warm water droplets could readily evaporate, which would cause more liquid loss than in the tank. In the tank the vapor space is expected to be at a saturated state, which will cause waste droplets to remain liquid and fall to the bottom of the tank.
3. The vapor space in the tank will be stagnant because of the large, basically empty, tank; therefore there will be very little vapor movement to carry any atomized waste to the HEPA. The laboratory environment has a continual movement of air, which will tend to carry away very small particulates of water from the eductor.

This baseline task began with the issuance of a Task Technical Request (4), which was followed by the approval of a Task Technical and Quality Assurance Plan (6) and the assigning of a task notebook (7). Because of the urgency of the overall tank closure effort, unqualified experimental results were transmitted at the end of each day of testing (8,9,10) to aid in planning. However, those data were qualified within two weeks of the experiment (11). This report further qualifies those data by giving a more detailed explanation on how they were obtained.

2.0 EXPERIMENTAL SETUP & TEST PROCEDURES

As stated above, there were three basic tests done for this task: A deadhead test, an atomization test with only vacuum used to drawn liquid through the eductor, and an atomization test with both vacuum and positive pressure used to force liquid through the eductor. The test setup for each is explained below and a summary of how each test was run is given. The work instructions that were followed can be found in Appendix C.

2.1 Instrumentation and Measurement Uncertainty

There were six instruments used to do this task. A summary of the instruments and their uncertainties are listed below:

Measurement	M&TE No.	Range	Uncertainty (95% Confidence)
Eductor Air Pressure	TR-3411	0 to 120 psig	0.5 psi
Vacuum-line Pressure	TR-3538	0 to 120 psig	0.6 psi
Vacuum	3-2549	0 to 22 psia	0.006 psi

Temperature	TR-1140	0 to 100°C	2.2°C
Weight	TR-3547	0 to 25 lbs	0.024 lb
Weight	TR-30075	0 to 200 lbs	0.022 lb

The three pressure sensing gauges were calibrated before the tests began and after they were completed. The type J thermocouple did not have a formal calibration. Instead, it was checked before and after testing, at three temperatures, to see if it measured within the NIST-stated measurement uncertainty for all type J thermocouples, i.e., ±2.2°C. The two weight scales are on a formal calibration cycle; they are recalibrated every 12 months. No special calibration was done on those scales for this task. The measurement uncertainties listed above are the result of the calibrations done and those data can be found in Appendix B.

2.2 Test Setup of the Deadhead Test

2.2.1 *Test Setup of the First Deadhead Test*

Figure 2 shows the VACCON 750 Eductor (VE) connected to the Vacuum-line Shutoff Valve (SV). During the PITBULL™ pump operation, the eductor air supply runs continuously. When vacuum is needed, the SV is opened to begin filling the pump with waste. Under a deadhead condition, no air will flow through the vacuum line. The deadhead test setup was comprised of the eductor being connected to an air supply and a vacuum gauge was connected to the SV inlet. To measure the air supply pressure, a pressure transducer was connected to the inlet of the eductor. As the air supply pressure is increased, the vacuum produced increases. During this test, the SV was left in the open position at all times, which is accomplished by not pressurizing the SV.

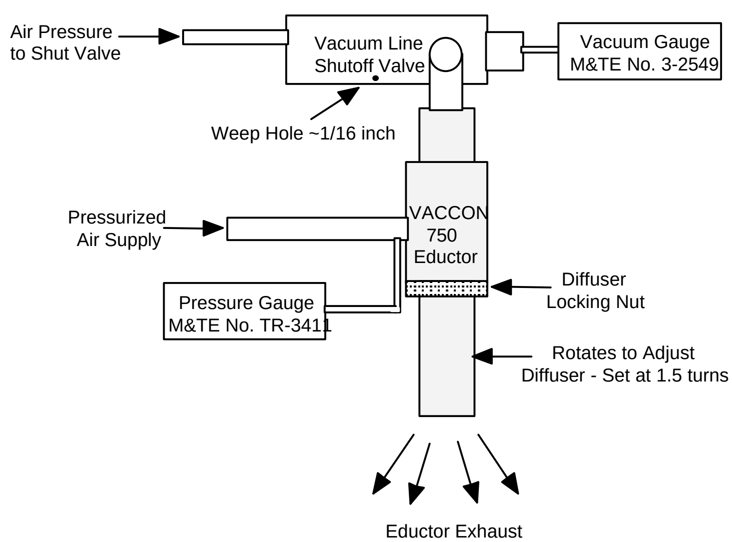

Figure 2. VACCON 750 Eductor and the Vacuum-line Shutoff Valve: Deadhead Test

2.2.1.1 First Test Procedure Summary

The steps used to do this test are listed in Appendix C, section C1, but in general, the air supply pressure was increased in 10 psi increments starting with 10 psig until the maximum available pressure was attained. At each increment, the pressure and deadhead vacuum were recorded. After the maximum pressure was reached, the test runs were repeated while decreasing the pressure from the maximum to 10 psig. There was a concern that the weep hole, shown in Fig. 2, would allow air to enter the vacuum line and thus reduce the deadhead vacuum level; therefore, the complete test was repeated again with the weep hole closed. Another controlled variable is the diffuser adjustment. As shown in Fig. 2 the bottom part of the eductor can rotate to set the diffuser from 0 to 3 turns, which changes the vacuum level. The as-received setting of the diffuser from HLW was not changed nor verified (it was stated to be set at 1.5 turns). However, the body of the eductor was marked to make sure the diffuser setting was not changed during this task.

2.2.2 Test Setup of the Second Deadhead Test

After all testing was complete, i.e., deadhead and both atomization tests, the eductor was checked once more to determine if its deadhead operating characteristics remained unchanged. The initial deadhead test was performed with both the VE and the SV connected because that is how the pump will operate in the field, Figs.1 and 2. This follow-up test also used both pieces of equipment together. However, without testing the eductor alone, it would be difficult to compare its operation to vendor data. So another deadhead test was done on just the eductor. Figure 3 show the setup without using the shutoff valve.

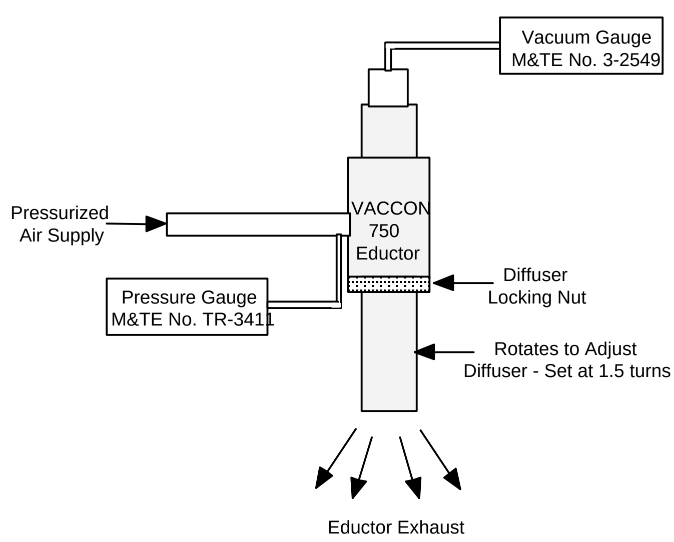

Figure 3. VACCON 750 Eductor without the Vacuum-line Shutoff Valve.

2.2.2.1 Second Test Procedure Summary

The steps for this recheck were similar to that used for the first test, in fact, the same work instruction shown in Appendix C, section C1 was used. However, the number of data points was less. The desire was to just verify the first test.

2.3 Test Setup of the Atomization Test Without Pressurizing the Vacuum Line

In a middle bay of the Experimental Thermal Fluids Laboratory (building 786-A), a simple structure was constructed to do this test. Figure 4 (repeated here from Appendix C for convenience) shows a sketch of the setup. The open structure was such that the end of the eductor was held 10 feet above a plastic tarp to catch water as it was sprayed. The eductor was connected to the vacuum-line shutoff valve, which was connected to a tube that held water ready for spraying. That tube was connected to a water heater and pump that allowed the water to circulate and heat up. A portion of that tube was to model the actual vacuum tube and it was approximately 40 feet long and connected directly to the inlet of the shutoff valve. That portion of the tube had a 1-inch diameter with a 0.065-inch wall thickness (i.e., inside diameter of 0.87 inch). This 1-inch length of tube was used to hold a fixed amount of heated water that discharged through the eductor when vacuum was created. The valves in the tube, shown in Fig. 4, allowed the pump and the lower part of the tube to be disconnected when a test was to begin. All the valves and instruments were operated manually.

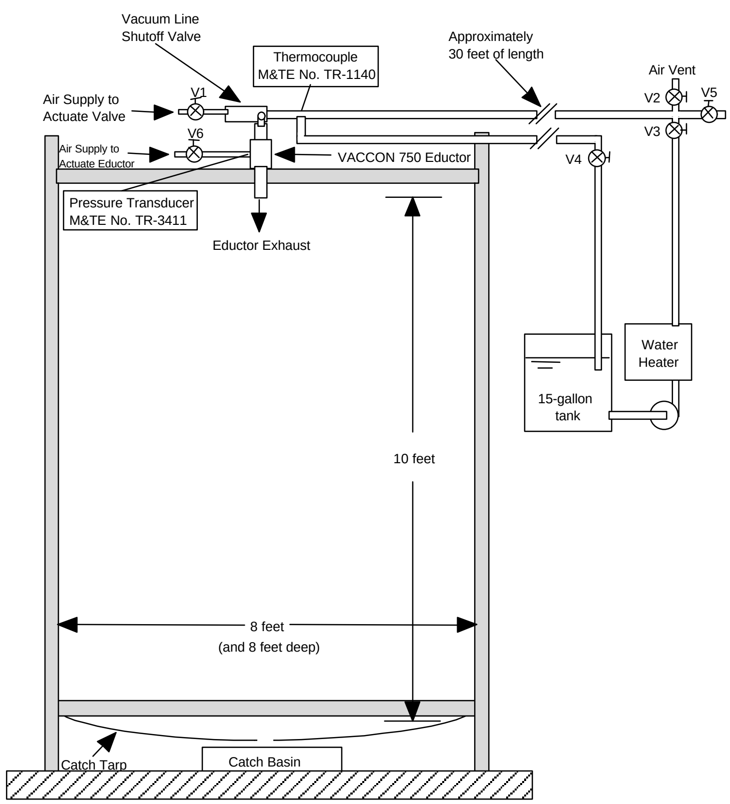

Figure 4. Atomization Test Without Pressurizing the Vacuum Line

2.3.1 *Test Procedure Summ*ary

The steps used to do this test are listed in Appendix C, Section C2, but in general two specific actions were done:

1. Quantifying the liquid charge to be sent through the eductor.
2. Determining the liquid captured on the 8 foot x 8 foot tarp.

The same procedure was used for both actions except that for action 1, a container was placed on the exhaust of the eductor to capture all the liquid. However, a lower air supply pressure on the eductor was used in order not to create an unsafe condition with the collection container connected to a high pressure source.

The procedure was to close the vacuum-line shut off valve and then to circulate water through the vacuum tube until it reached approximately 39°C. At that point valves were closed to isolate the water in the 1-inch tube and the tube's end was opened to the atmosphere with a 1-inch ball valve. The pressure to the air supply was set (between 15 and 20 psig for action 1 and at the maximum building pressure (~110 psig) for action 2) and then the shut off valve was opened to allow the water to be sucked through the eductor. The collected water was weighed. Each action was done several times to perfect the method of operation, which was then followed by enough runs to obtain reproducible results.

2.4 Test Setup of the Atomization Test With Pressurizing the Vacuum Line

The setup used in section 2.3 was the same for this test. However, there were some small changes and Fig. 5 (repeated here from Appendix C for convenience) shows a sketch of the setup. For this test, the eductor was not connected to the vacuum-line shutoff valve. During a low pressure shakedown test, water came out of the weep hole, see Fig. 2, and therefore there was a concern that high-pressure water could damage the valve. The customer allowed the valve to be replaced by a ball valve so that the test could continue. A 1-inch ball valve was used which would present less resistance to the water flow than the shutoff valve; therefore it would be a more conservative test. Another change was in the direction of the water flow through the vacuum line. Since the water flow was stopped just before the test began, the direction of water flow would not have any effect on the test. However, it did have a significant effect on quantifying the fixed volume of water to be discharged through the eductor. The problem was that the vacuum line needed to be pressurized, which meant that the line remained closed to the atmosphere at all times. Being closed, the line was more difficult to purge any trapped air. By changing the direction of the water flow, it was easier to purge the line of air and therefore the measurement of the fixed quantity of water in the line became stable.

2.4.1 *Test Procedure Summary*

The steps used to do this test are listed in Appendix C, Section C3, but in general two specific actions were done, as in Section 2.3.1:

1. To quantify the liquid charge to be sent through the eductor.
2. To determine liquid captured on the 8 foot x 8 foot tarp.

Once again , the same procedure was used for both actions except that for action 1, a container was placed on the exhaust of the eductor to capture all the liquid. Because of the container, a lower air supply pressure on the eductor was used to avoid an unsafe condition with the collection container connected to the high pressurized source.

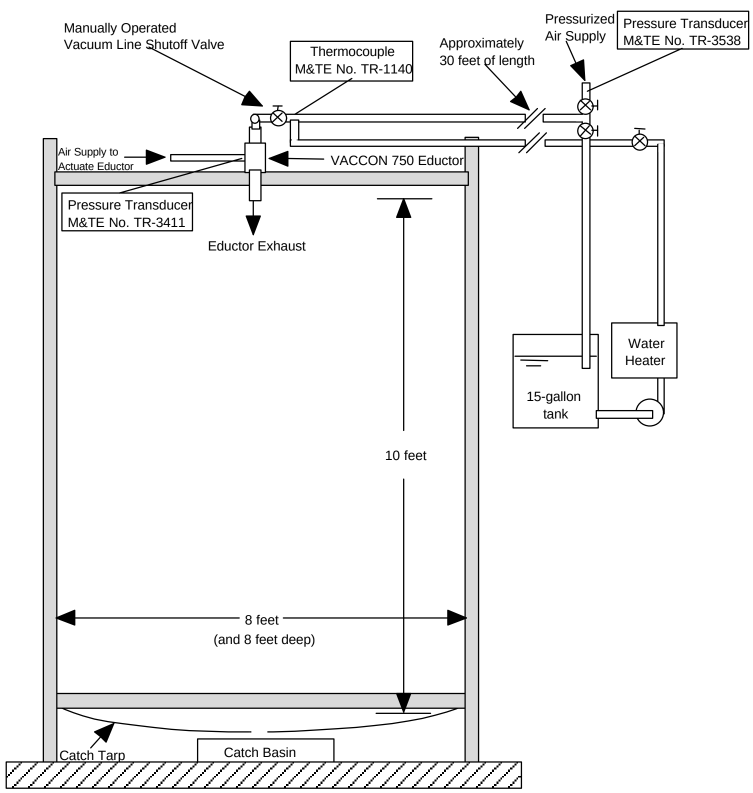

Figure 5. Atomization Test With Pressurizing the Vacuum Line

The procedure was to close the manually controlled vacuum-line ball valve and then to circulate water through the vacuum tube until it reached approximately 39°C. At that point, valves were closed to isolate the water in the 1-inch tube and the tube's end was pressurized with air (at approximately 20 psig for action 1 and at the maximum building pressure (~110 psig) for action 2). The pressure to the air supply to the eductor was set (at approximately 20 psig for action 1 and at.the maximum building pressure (~110 psig) for action 2) and then the vacuum-line ball valve was opened to allow the water to be sucked and pushed through the eductor. The collected water was weighed. Each action was done several times to perfect the method of operation, which was then followed by enough runs to obtain reproducible results.

3.0 DISCUSSION OF RESULTS

The complete set of tabulated data for all the tests can be found in Appendix A. In this section only highlights of the data are shown to illustrate the important aspects of the tests.

3.1 Deadhead Test

Before this test began, the equipment, the VACCON eductor (VE) and vacuum-line shutoff valve (SV) unit, was checked for leaks, since any leak would reduce the vacuum level. Figure 6 shows how the VE and the SV were arranged to do this test. The air supply to create the vacuum enters the hole on the side of the VE (seen on the large diameter portion of the eductor which is lying on its side) and the air exhausts from the large opening at the bottom (shown in the foreground of the eductor). The vacuum line enters the top of the eductor and the SV is seen connected to the top of the eductor in Fig. 6. The large fitting on one side of the SV is where the vacuum line of the pump is connected (shown at the top of Fig. 6) and the small fitting on the other side of the SV is to connect an air line. The SV is closed with positive air pressure applied through the small fitting.

Figure 6. VACCON 750 Eductor (horizontal) connected to the vacuum-line shutoff

To check for leaks, the two open ports in the VE were plugged and the vacuum port of the SV was pressurized with air. Initially, the equipment did not hold any pressure because air was exiting the weep hole on the side of the SV (see the small hole near the midpoint on the SV in Fig. 6). That hole was also closed off and then no leaks were found in any of the fittings. However, somewhere in either the VE or the SV there was a slow leak. Since the intention was to test the equipment in the “as found” condition, nothing was done to determine the location of leak. (Note, when the fittings were tightened the top portion of the eductor came loose, Fig. 7. This needs to be kept tight at all times.)

To do the deadhead test the VE was held in the vertical position and the vacuum gauge was connected directly to the vacuum port of the SV (Fig. 7). The vacuum gauge was read manually and since the air pressure fluctuated slightly the test was repeated to obtain enough data to determine the measurement uncertainty due to that fluctuation. See Figs. A1.1 to A1.4 in Appendix A.

Figure 7. VACCON 750 Eductor (bottom) connected to the vacuum-line shutoff

Because air came out the weep hole during the leak test, there was a concern that air could be drawn into this small hole during vacuum operation, which would reduce the vacuum level. After two tests were done with the weep hole open, it was closed, and the tests were repeated to determine if air did enter. Figure 8 shows the complete set of data to include the test runs with the weep hole closed. In Appendix A, every data point is listed, therefore those with the weep hole open and closed can be distinguished but as can be seen in Fig. 8 there was no effect from closing the hole. This means that during vacuum operation, no air leaks into the weep hole. As another check, the hole was repeatedly opened and closed during a stable deadhead test, but the vacuum level was never affected. It appears that the seal within the SV acts like a check valve, which allows air to leak out when the vacuum system is pressurized but none to leak in when the system contains a vacuum.

There are two features of the data in Fig. 8, which need explaining. The first is the fact that the vacuum level increased almost linearly to the highest air supply pressure used, 112 psig. That is, the data did not show a plateau, after which further increases in air supply pressure would have no effect. This plateau must exist since the air flow through the eductor will eventually become choked, which limits the mass of air that can flow. Higher pressures would be needed to find that limiting vacuum level. However, since HLW will be supplying the eductor with air at approximately 80 psig, the data in Fig. 8 are sufficient.

The second feature is the magnitude of the vacuum level. At an air supply pressure of 80 psig, Fig. 8 indicates a vacuum level of approximately 13 ft.WC. Initially, it seemed low when comparing to the vendor's published data. VACCON indicates a deadhead vacuum level of approximately 28 ft. WC at an air supply pressure of 80 psig. The reason for the discrepancy is not known but the are two possibilities:

1. There was a leak in either the eductor or shutoff valve.
2. The diffuser setting was different than for the vendor's data.

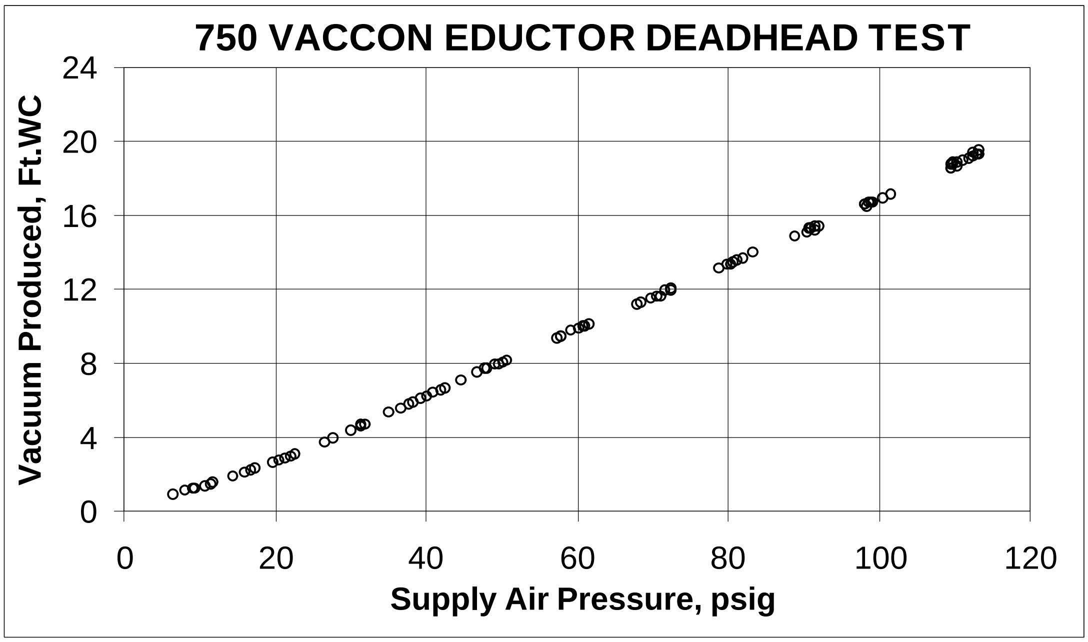

Figure 8. Deadhead test with the vacuum-line shutoff valve connected

To investigate the first possibility, the eductor was checked after the two atomization tests were complete (those tests are explained below). Besides trying to find out why the vacuum level differed from the vendors data, it was necessary to check if the equipment still functioned as received from HLW. During the atomization tests a considerable amount of water was forced through both the SV and the VE which could have an unknown effect on their performance. In fact, during the last atomization test water actually exited the weep hole for a short time. This subsequent test began with the VE and SV connected together, as they were originally tested, but then another test was done with just the VE, in order to isolate the leak. The top data set, the filled circles, in Fig. 9 is the result of that post-test check. The data from Fig. 8, the open circles, are included in Fig. 9 for comparison. The top data set contains the results from the tests with and without the SV. There appears to be no distinction among the data, which implies that there was no leak, at least during this follow-up test. If either piece of equipment had a leak then the deadhead vacuum level would have been different, and they were not; that is, all the data follow the same line. Appendix A, Figs. A1.4 and A1.5, contains all the data and both sets are listed separately, but Fig. 9 shows both sets as filled circles to emphasize their similarity. However, there does appear to be a significant difference between the pre- and post-atomization test data. The post-test data are approximately 13% higher, except below 10 psig air supply pressure. It is believed that before the atomization tests there may have been debris within the SV, which allowed a small leak. This is assumed because during the leak check the VE-SV combination did have a leak somewhere which was not pursued, as already explained.

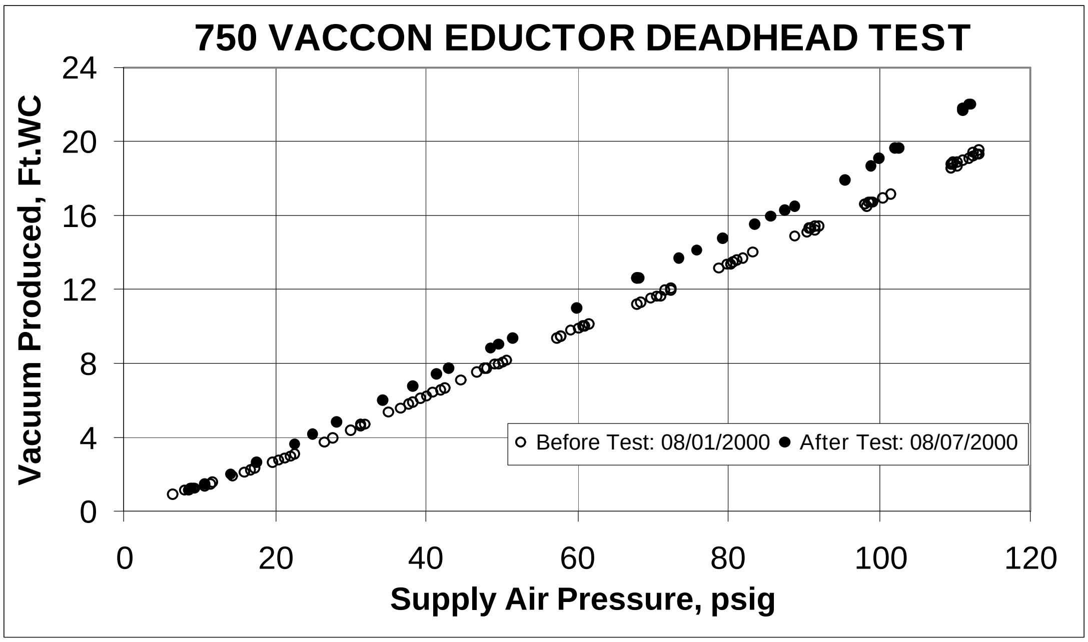

Figure 9. Deadhead test data before and after the atomization tests

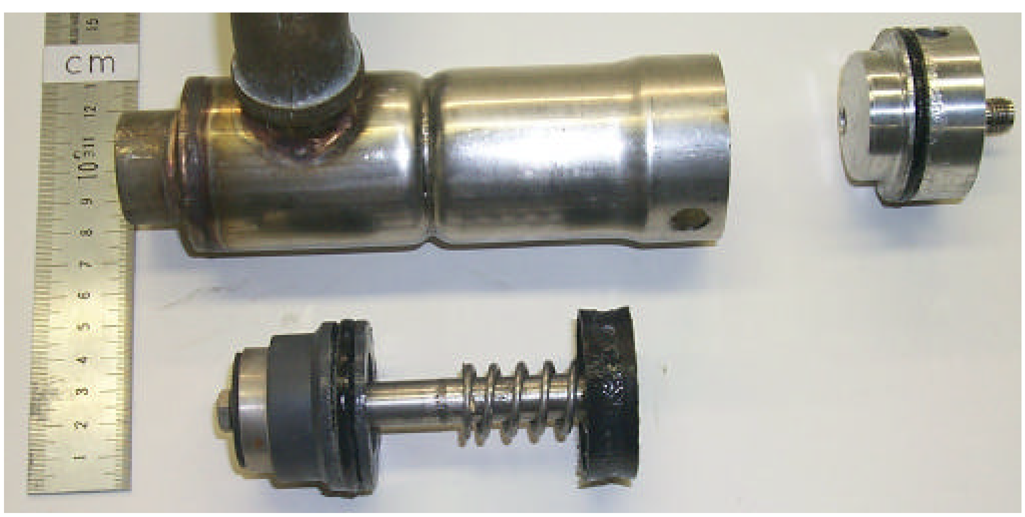

Figure 10. Vacuum-line shutoff valve with its internal removed

Figure 11. Vacuum-line shutoff valve with its internal removed and the eductor

When the SV was inspected before any testing was done, there seemed to be debris around the large rubber seal, which is within the SV when the cap was removed. That seal is shown on the right side of the SV spring assembly, at the bottom of Fig. 10 and the top of the seal is shown on the left side of Fig. 11. (Before the tests, the spring assembly was not removed and the inspection was limited to just looking into the top of the SV when the top of the SV was removed.) From the two figures, the large rubber seal still showed some signs of debris after the tests, even though water was forced through the valve to the point that it was exiting the weep hole. That water probably cleaned up some of the debris and as a result, the valve was no longer leaking, which can be implied from the deadhead data being the same with and without using the shutoff valve. Concerning the two curves in Fig. 9, note that the top curve should be used to determine deadhead vacuum of the eductor because it was the last one obtained, after the eductor was subjected to the water test. However, when taking the measurement uncertainty into account due to the fluctuating air supply pressure, the two curves only differ significantly above an air supply pressure of 100 psig. The level of fluctuation of both data sets was determined (Appendix A) and a 95% confidence level interval was place on each data point, as shown in Fig. 12.

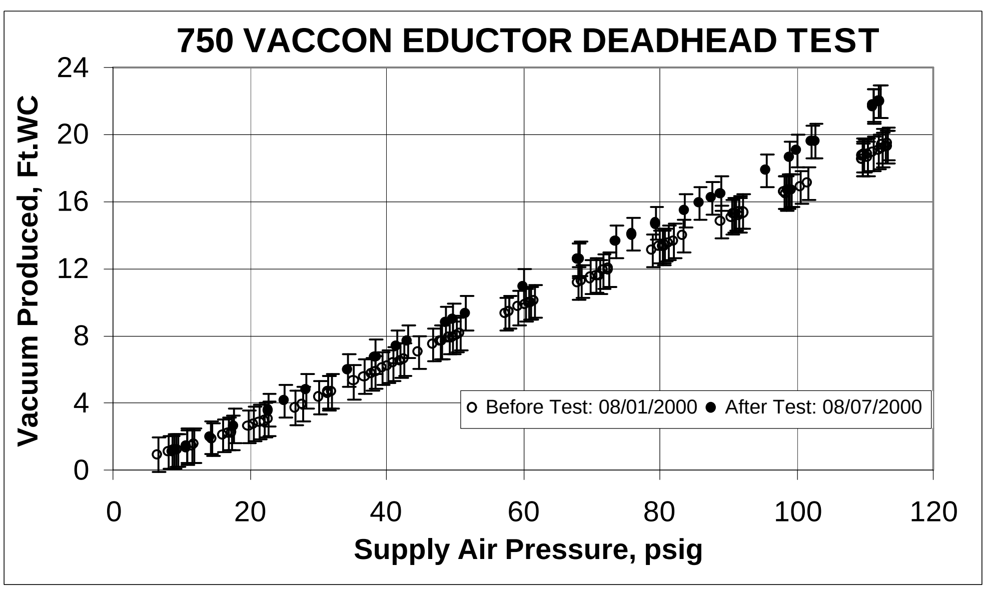

Figure 12. Deadhead test data with measurement uncertainty included

The second possibility that could have caused the magnitude of the deadhead vacuum level to differ from the vendor's data is a different diffuser setting. This seems to be the strongest reason because the diffuser setting does have a large effect on the vacuum level. Unfortunately, that difference in magnitude cannot be quantified because this task did not include a test to show the deadhead vacuum level versus the diffuser setting. The eductor was received with the diffuser already set (stated to be 1.5 turns) and HLW requested not to change that setting. The eductor was marked so that the setting would not be changed but the actual setting was not verified.

The vendor data do not include the diffuser setting and several conversations with the vendor led to more questions than answers. While the effect of the diffuser setting on the deadhead vacuum level is not know, the effect of the diffuser setting is known with a vacuum air flow when the PITBULL™ pump is operated under normal conditions. During the PNNL test (1) of the pump system, the effect of diffuser setting was evaluated to optimize the eductor. Figure 13 shows that turning the diffuser from 0.5 turns (from closed) to 2 turns, the flowing vacuum level almost doubles from 6 to 10 feet of water. While these data cannot be extrapolated to determine the deadhead vacuum levels at different diffuser settings, they do show that, qualitatively, the setting does cause a significant effect. It is assumed that the deadhead vacuum level is more sensitive to the diffuser setting when there is no vacuum air flow. Without a vacuum air flow there should be less energy lost due to flow friction, allowing the vacuum level to be more sensitive to the diffuser setting. This is similar to when the vacuum level becomes higher when the vacuum flow is stopped. If this is true then the change in dead vacuum level versus the diffuser setting is larger than shown in Fig. 13. However, without doing a deadhead vacuum-level versus diffuser test, the difference between the experimental data to that of vendor cannot be resolved.

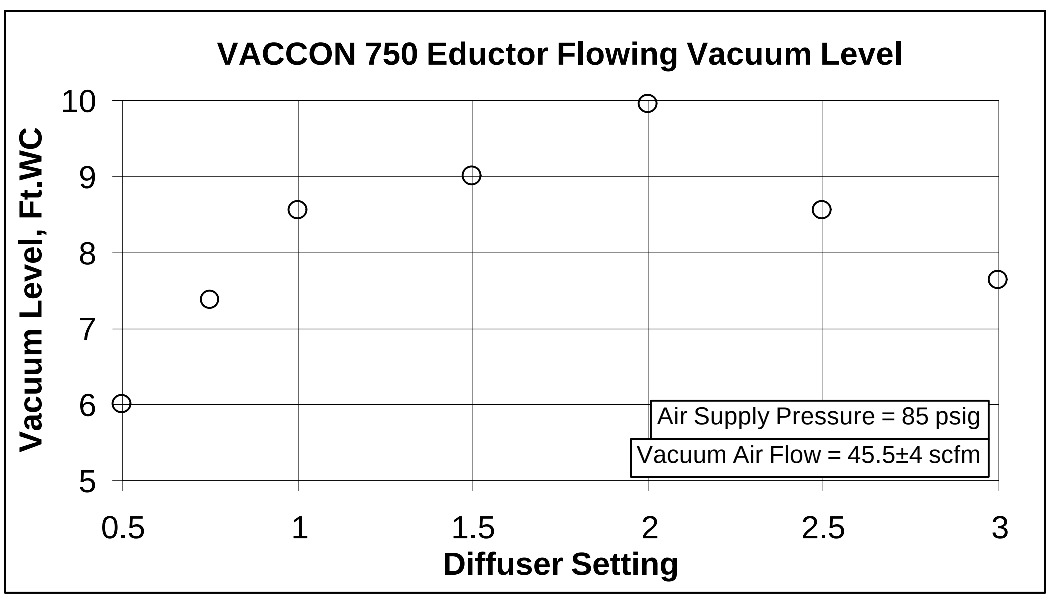

Figure 13. VACCON 750 flowing vacuum level versus the diffuser setting

3.2 Atomization Test: Vacuum Only

Two days after the deadhead test was complete the first of two atomization tests began. In this test, the amount of water which was caught by an 8-foot x 8-foot plastic tarp located 10 feet below the downwardly facing eductor was quantified. Figure 4 shows how the equipment was arranged during this test. All the test data can be found in Appendix A, Section A2, along with the measurement uncertainty.

The test was to simply allow the eductor, supplied with air at more than 80 psig, to draw a fixed quantity of water such that it sprayed out its exhaust. This modeled the accident scenario where waste is drawn from the pump, up the vacuum line, and then ejected into the tank atmosphere, 35 feet above the waste level. The water, which was collected on the plastic tarp, is assumed to be the amount of waste that will return to the waste heel and the rest is assumed to be the amount that could potentially be carried to the HEPA filter.

To obtain a measure of how much water sprays onto the plastic tarp, first, the total amount of water that is sent through the eductor must be known. That quantity of water was determined by placing a container on the end of the eductor to capture all the water that came out. However, since the exhaust of the eductor was completely contained, only a low air supply pressure could be used, i.e.,~20 psig. Six test runs were done until the method was perfected. Then, two more test runs were done to quantify the fixed water mass in the vacuum line. The results of the two tests showed two water masses to be within 0.5% of each other, i.e., 10.260 lbs and 10.255 lbs. The difference was acceptable, so the final fixed mass was set at 10.26 lbs, see Fig. A2.1 in Appendix A.

The method to do the actual test was very similar to that used to quantify the fixed mass of water that was drawn through the eductor, except for the air supply pressure. The air supply pressure to be used was to be that which produced the maximum deadhead vacuum. From Fig. 12, the strongest vacuum occurred at the maximum attainable laboratory pressure, ~112 psig, as measured at the air supply entrance to the air eductor. After the water was circulated in the vacuum-line loop, until its temperature reached approximately 39°C, the vacuum line was opened to the atmosphere and the air supply pressure was increased to the laboratory maximum. The test run was made by opening the vacuum-line shutoff valve, which was done by relieving the air pressure to that valve. The time the water took to empty through the eductor was on the order of 30 seconds. Six test runs were made, but only the last three are considered valid to quantify the water caught by the plastic tarp, because during the first three test runs the building air conditioner was on. The air conditioner was located directly in front of test rig and it created such a strong wind that it skewed the water jet and literally blew the spray of water into a large arc, causing a lot of the water to miss the tarp. The strong air not only caused the captured mass to be much lower, but the mass was not repeatable. The results of those initial three tests showed the captured mass to be between 79% and 85%. Subsequently, the air conditioner was turned off and the tests were repeated. This time the water sprayed out the exhaust of the eductor uniformly. The air movement in the laboratory, while not quantified, was still considerably more than what would be expected in Tank 19F. Figure 14 shows one frame from a video tape that was take of the tests.

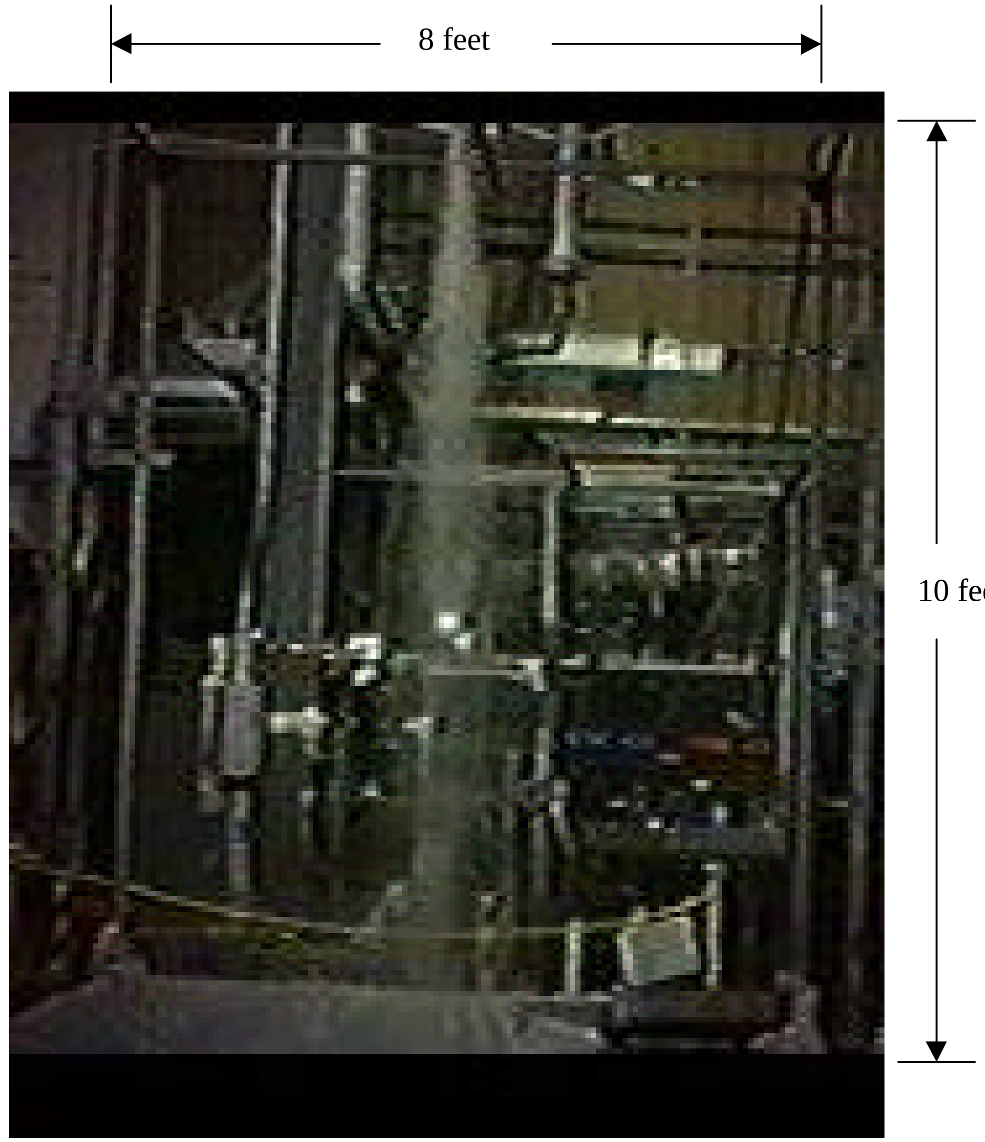

Figure 14. First atomization test with the vacuum line open to the atmosphere

The loud (about 100 dB at 7 feet from the eductor) jet of water widened from the 1-inch exhaust of the eductor to approximately 2 feet at its base. It was completely contained within the 8-foot x 8-foot tarp area, so whatever water was lost was either by small droplets being sheared away from the plume, very small particles evaporating in the relatively dry laboratory environment, or water droplets bouncing off the tarp. On the day and time of the test (08/03/2000, between 16:00 and 17:00 hours) the SRS Weather Center measured the outside relative humidity to be approximately 65%. The relative humidity inside the laboratory building had to be lower, due to the air conditioning; it was only turned off for a short time. After three test runs the test was stopped because the results were very repeatable. Figure 15 shows the results, and indicates that on the average, 95% of the water sprayed from the eductor was recovered. This implies that an accident, which causes the waste to be drawn through the eductor, would result in at least 95% of that waste to return to the bottom of the tank.

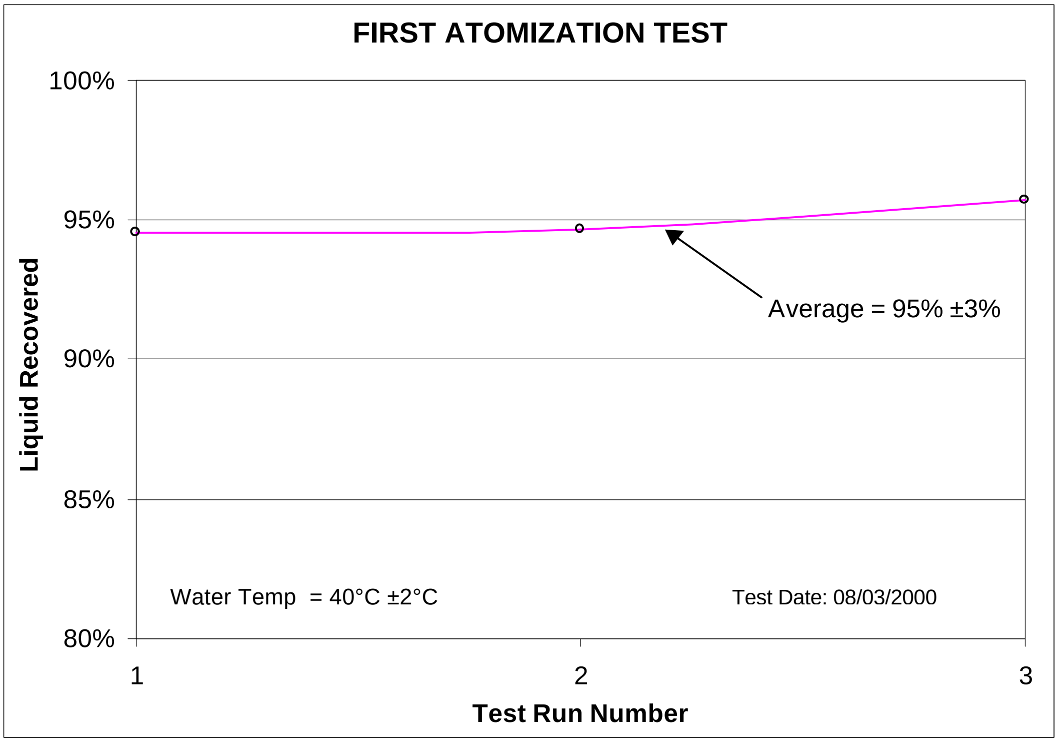

Figure 15. First atomization test with the vacuum line open to the atmosphere

This amount of liquid retention is considered a conservative estimate because of:

1. The wet environment of the waste tank.

The laboratory environment was relatively dry, <65% relative humidity, as compared to the tank, which is assumed to be saturated. The dry environment will allow small liquid particles to evaporate and thus less liquid is recovered.

2. The stagnant air of the waste tank.

Even with the air conditioner turned off, the air movement in the laboratory was significantly greater than in the closed waste tank. Except for the waste heel, the tank will be empty. With an internal volume of approximately 1 million gallons, the vapor space in the tank will be stagnant since the ventilation flow rate is only approximately 500 scfm (~4,000 gpm).

3. The waste tank is very large

In Tank 19F, the PITBULL™ pump eductor will be located approximately 35 feet above a waste surface area of approximately 4,000 square feet (assuming a tank diameter of 70 feet). The laboratory test had the eductor located 10 feet above a 64-square-foot surface. For a linear extrapolation, this laboratory surface would be equivalent to a 224-square-foot surface if the eductor were located at a height of 35 feet. Moreover, Fig. 14 shows that the width of the jet of water was contained well within the 8-foot square surface; it appears to be no more than 2 to 3 feet in diameter at the base. Any waste ejected from the eductor in the fashion done in this experiment will be returned to the waste heel.

4. Air supply pressure will be less during the actual waste heel removal.

During the heel removal from the tank, the intention is to have an 80-psig air source at the tank top to operate the pump. For this test the air was supplied at 112 psig as measured at the entrance of the eductor air supply port, see Fig. 2. This means that a higher vacuum was created to draw the liquid through the eductor than what could occur in the waste tank. This higher vacuum leads to a larger velocity liquid stream, causing more shear in the exiting liquid plume; therefore there would be more atomization losses to the surrounding atmosphere. Further, if the waste tank does supply the pump with 80 psig at the tank top, then the actual air supply pressure will be less at the eductor due to the pressure drop from the air header to the eductor. That pressure drop may be on the order of 15 psi, which make the results herein even more conservative.

5. The eductor in actual use will have to drawn liquid from a vertical vacuum line

The actual pump system will have a vertically oriented vacuum line from the pump body to the eductor, see Fig. 1, and most of that line is located below the exhaust of the eductor. For this task, the vacuum line was horizontal and above the exhaust of the eductor, see Figs. 4 and 5. This means that for this test the eductor did not have to use energy to accelerate the liquid against gravity. The energy not wasted in lifting the liquid goes into moving the liquid faster than it would experience in the field under the same motive air supply pressure. The faster moving liquid for this test is then subjected to more shear when exiting the eductor, causing more atomization and more losses than in the field.

3.3 Atomization Test: Vacuum and Positive Pressure

Following the atomization test, with the vacuum line open to atmospheric pressure, another atomization test was done where the vacuum line was pressurized. Like the preceding test, this test quantified the amount of water was caught by an 8-foot x 8-foot plastic tarp located 10 feet below the downwardly facing eductor. Figure 5 shows how the equipment was arranged. All the test data can be found in Appendix A, Section A3, along with the measurement uncertainty.

This test also allowed the eductor to draw a fixed quantity of water such that it sprayed out its exhaust, but this time the vacuum line was to be pressurized. This new test modeled not only the accident scenario where waste is drawn from the pump (up the vacuum line, and then is ejected into the tank atmosphere, 35 feet above the waste level), but also the situation where the pump begins to pressurize the waste, which would push waste through the eductor. As in the first atomization test, the water which is collected on the plastic tarp is assumed to be the amount of waste that will return to the waste heel and the rest is assumed to be the amount that could potentially be carried to the HEPA filter.

The first step for this test was to quantify, once again, the mass of water that would be ejected from the eductor. While the experimental setup was basically the same, as was used for the first atomization test, it differed in being a closed system and the method of ejecting the water was different. Those differences could possibly change the fixed amount of water. The system had to be closed because the vacuum line needed to be pressurized instead of simply opened to the atmosphere. The fixed quantity of water was to be both drawn through the eductor by a vacuum and simultaneously pushed through with a pressure higher than would be used in the field to push waste out of the pump, i.e., 80 psig. Initially, seven test runs were done until the method was perfected. A container was placed on the end of the eductor to capture all the water that came out. However, since the exhaust of the eductor was completely contained, only low air pressure was supplied to the eductor, i.e.,~20 psig, and the same pressure was used to pressurized the vacuum line. During those seven runs, the fixed mass of water varied by as much as 20%. This was unacceptable. The problem was the trapped air in the closed system. To help remove the air from the system, the flow direction of the vacuum-line flow loop was changed (compare Fig. 5 to Fig. 4) and an air pocket near the eductor was removed prior to each run. With those changes, the variability in the data was significantly reduced. Subsequently, three more test runs were done to quantify the fixed water mass in the vacuum line. The results of that those tests showed three water masses to be with 0.6% of each other, i.e., 10.735 lbs, 10.795, and 10.795 lbs. This variability was acceptable, so the final fixed mass was set at 10.78 lbs, see Fig. A3.1 in Appendix A.

Besides the direction of the water flow in the vacuum-line, another change was the removal of the vacuum-line shutoff valve (SV) from the test setup. Upon doing the first 20-psig test, water exited the weep hole in the SV. That hole can be seen in Figs. 2, 6, and 7. The water from that hole could have been included in the overall test results, but a larger concern was damage to the SV from the higher pressure, i.e., >100 psig, to be used in the atomization test. The vendor, the Chicago Industrial Pump Company, stated that the SV is a robust design and made for fast and easy replacement. However, it was probable that the central shaft seal in the SV could be damaged. Figure 10 shows the internals of the SV and the shaft seal is the smallest one on the left hand side of the spring assemble. To avoid possible seal damage, HLW consented to have the SV removed from the test setup and replaced with a 1-inch ball valve. When opened, the ball valve would present less of a flow restriction than the SV. Less flow restriction would allow the water to exit the eductor faster and make the test even more conservative because of the stronger shear field.

The method to do the actual test was very similar to that used to quantify the fixed mass of water drawn through the eductor, except for the air pressure. The air pressure to be used was to be that which produced the maximum deadhead vacuum. From Fig. 12, the strongest vacuum occurred at the maximum attainable laboratory pressure, i.e., ~112 psig, as measured at the air supply entrance to the air eductor. Likewise, the vacuum line would be pressurize to the maximum pressure that the laboratory could produce.

After the water was circulated in the vacuum-line loop until its temperature reached approximately 39°C, the vacuum line was isolated from the loop and pressurized to approximately 107 psig, the laboratory maximum. Then, the air supply to the eductor was turned on and pressurized to the laboratory maximum. The test run was made by shutting off the laboratory air conditioner and opening the manually controlled 1-inch ball valve that contained the warm water. The time the water took to empty through the eductor was on the order of 5 to 10 seconds. Six test runs were made to quantify the water caught by the plastic tarp. The results were very repeatable and the water jet was very stable and thin. Figure 16 shows the results of those tests, along with those of the first atomization test to compare the difference in liquid recovery.

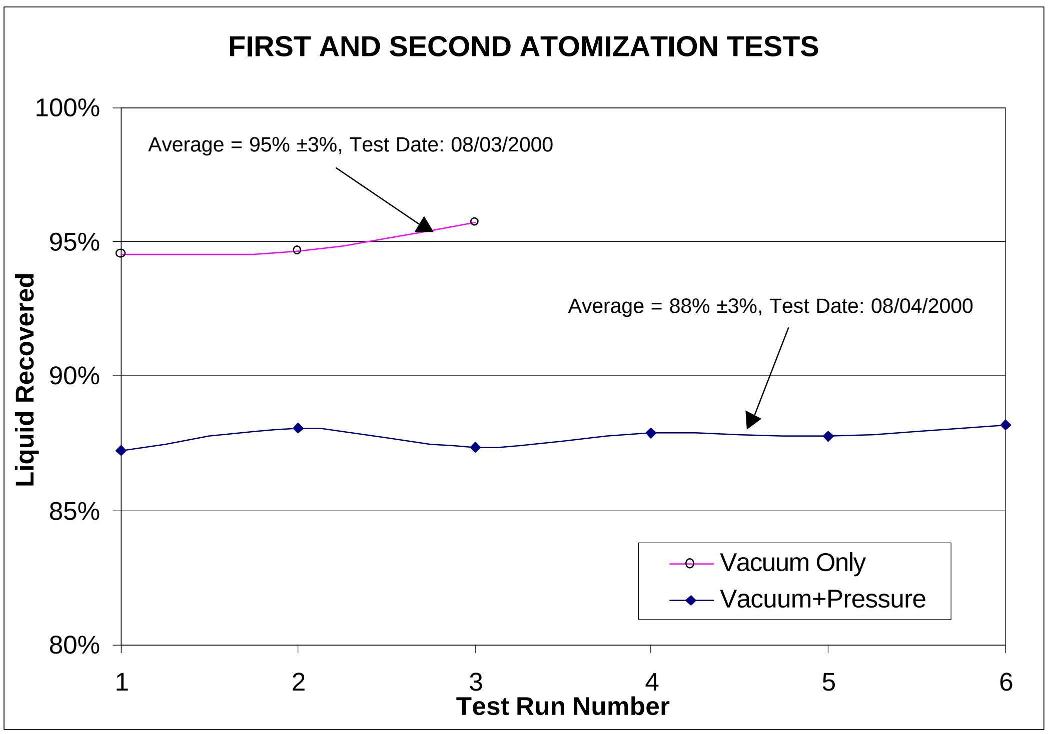

Figure 16. Second atomization test with the vacuum line pressurized (first test data are also included for comparison of the difference in liquid retention)

Similar to the preceding test, Fig. 17 shows that the jet of water widened from the 1-inch exhaust of the eductor to approximately 2 feet at its base. However, even though the fixed amount of water in both tests was nearly the same, about 1 ¼ gallon, the water stream exited much faster, 10 seconds instead of 30, and it was more opaque (from having more water); compare Fig. 17 to Fig. 14. Even though the jet was more energetic than the vacuum-only jet, it was still completely contained within the 8-foot x 8-foot tarp.

Whatever water was lost could only be from small droplets being sheared away from the plume, from very small particles evaporating in the relatively dry laboratory environment, or from water particles bouncing off the tarp. Of course, the higher energy water jet meant higher velocities which means that more of the water would shear from the plume causing less water to be retained. The test was stopped after the sixth run because the results were very repeatable, as seen in Fig. 16. The average water retention was measured to be 88% and the results fluctuated approximately ±2%. This implies that an accident, which causes the waste to be drawn and pushed through the eductor, would result in at least 88% of that waste to return to the bottom of the tank. This liquid retention is considered a conservative estimate of the waste that will return to the heel for the same five reasons listed in the preceding section, i.e., Section 3.2.

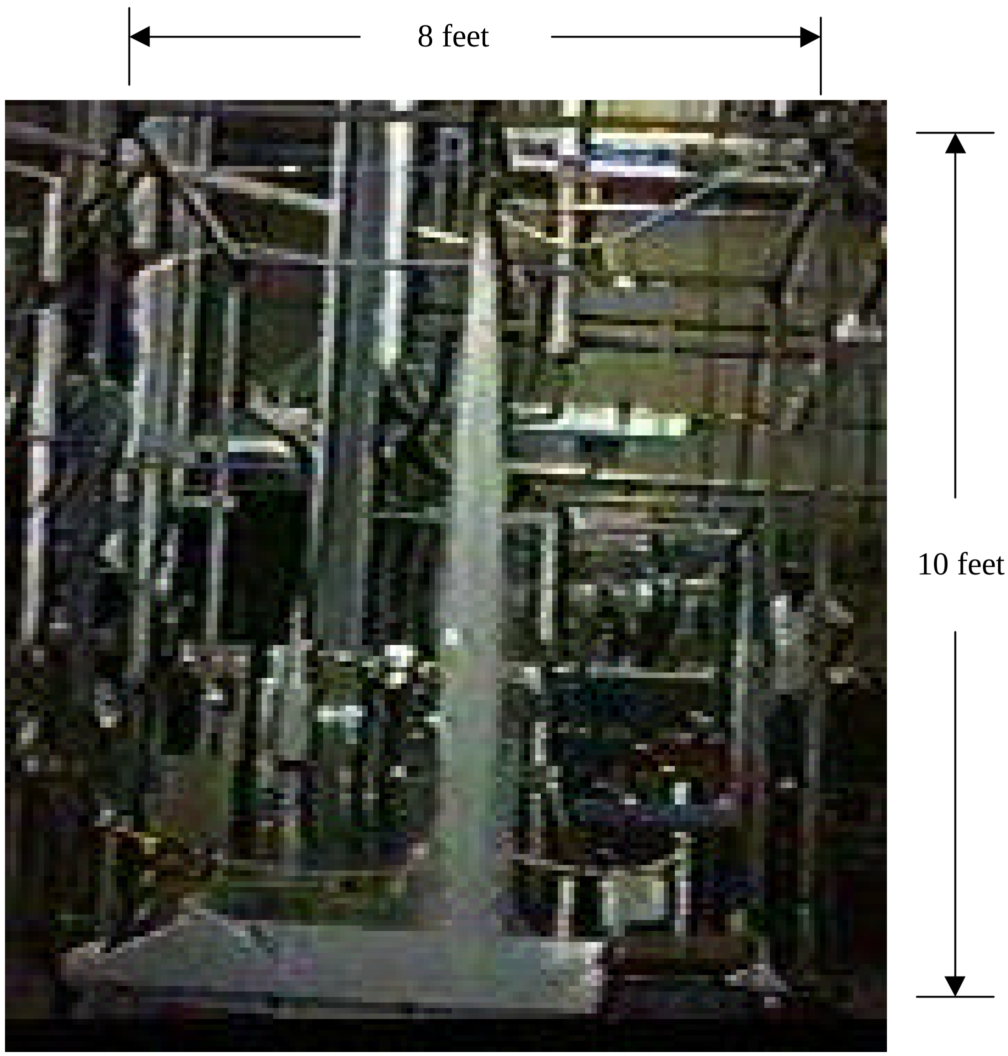

Figure 17. Second atomization test with water drawn and pushed through the vacuum line

4.0 CONCLUSIONS

For the PITBULL™ eductor at the “as-received” diffuser setting, the following conclusions can be made:

4.1 The deadhead vacuum level of the eductor is:
15 ft. WC ±1 ft.WC at an air supply pressure of 80 psig
22 ft. WC ±1 ft.WC at an air supply pressure of 112 psig

4.2 The percentage of liquid that is not lost when drawn through the eductor which exhausts directly to the atmosphere is:
95% ±3% at an air supply pressure of 112 psig (5% is assumed atomized)

4.3 The percentage of liquid that is not lost when drawn through the eductor, while the vacuum line is pressurized, which exhausts directly to the atmosphere is:
88% ±3% at an air supply pressure of 112 psig and the vacuum line is pressurized to 107 psig (12% is assumed atomized)

5.0 RECOMMENDATIONS

5.1 When installing the eductor make sure that the vacuum side of the eductor is tightly screwed into its main body. That is, from Fig. 7, the eductor appears to be made of two cylinders with the large diameter cylinder in the center. Actually the top small cylinder can be removed from the central fatter body because it is simply screwed into the body with pipe threads. Those two pieces should be tightened together to prevent air leaks. (The bottom small cylinder is designed to rotate to change the diffuser setting and it is tightened with a locking nut, visible in Figs. 2 and 7.)

5.2 Do not change the diffuser setting. The position of the diffuser was set before this task began. That position was not checked nor changed. It was marked on the eductor to make sure it was not moved. However, changing the diffuser setting will affect the results of this task and may affect the conclusions.

6.0 REFERENCES

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APPENDIX A

EXPERIMENTAL DATA

AND

MEASUREMENT UNCERTAINY

A1. Deadhead Vacuum Test

[Note: HLW indicated that the diffuser setting on the VACCON 750 eductor was 1.5 turns and that it should not be changed. This setting was not verified nor modified. A mark was made on the body of the eductor to maintain the position of the diffuser.]

The following data were taken on 08/01/2000 and 08/07/2000 in the Experimental Thermal Fluids Laboratory at an ambient temperature of 21°C (Measured by TR-1140).

Measurement and Testing Equipment Used (see Appendix B):

Measurement	M&TE No.	Range	Uncertainty (95% Confidence)
Eductor Air Pressure	TR-3411	0 to 120 psig	0.5 psi
Vacuum	3-2549	0 to 22 psia	0.006 psi
Temperature	TR-1140	0 to 100°C	2.2°C

The following six figures (A1.1 to A1.6) show data to determine the deadhead vacuum for the VACCON 750 eductor under different conditions. Testing was done on two separate days: 08/01/2000 and 08/07/2000. On the first day of testing the data set from 10 to 112 psig air supply pressure was done twice for each condition. There were two conditions: weep hole open and closed. There is a weep hole in the vacuum-line shutoff valve (Figs 2 and 6) and air exited that hole when positive pressure air was applied during shakedown, to determine if any leaks existed. There was a concern that the weep hole would also allow air to be sucked into the vacuum line, which could reduce the deadhead vacuum level. This testing resulted in four tables of data (A1.1 to A1.4) and the data show that the weep hole did not allow air to enter the vacuum line. The second day of testing was done after both atomization tests were complete. The second test was done to show that the eductor/shutoff valve setup performed as it did on 08/01/2000, before returning it to High Level Waste. Further, the eductor was checked without the shutoff valve to determine if that valve had any leak that would reduce the deadhead vacuum level since the data obtained on 08/01/2000 did not meet vendor-published data. Those data are in the two tables shown in Figs. A1.5 and A1.6. All data are included in Fig. 9.

Measurement Uncertainty

The uncertainty is as listed above for each instrument. The uncertainty of the reported absolute vacuum is that of the vacuum gauge, M&TE No. 3-2549, which is 0.006 psi. However the reported vacuum in feet of water is relative to atmospheric pressure. This value is obtained by subtracting the absolute vacuum from atmospheric pressure. The uncertainty of this relative vacuum will be taken as twice that of the absolute value, i.e., 2x(±0.006 psi) = ±0.012 psi (or ±0.03 ft.WC). However, since the regulated air supply pressure fluctuated, a curve fit of the data was done to quantify the scatter around the curve. Both sets of data were fairly linear between 20 psig and 100 psig of air supply pressure. By applying a best fit least-square analysis, the uncertainty due to the fluctuation around a straight line between those pressures is ±0.63 ft.WC for the data obtained on 08/01/2000 and 0.91 ft.WC for the data obtained on 08/07/2000. These uncertainties are for a confidence level of 95%. For this task the data uncertainty will be set at ±1 ft.WC.

	8/1/2000	Started 14:15	Atm. = 14.5803 psia	
	*********************Weep Hole Open*********************			
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	5.21	9.15	14.07	1.18
2	6.62	19.82	13.46	2.58
3	8.16	31.47	12.6	4.57
4	9.32	40.25	11.91	6.16
5	10.59	49.86	11.15	7.91
6	12.09	61.20	10.28	9.92
7	13.42	71.26	9.58	11.53
8	14.65	80.57	8.83	13.26
9	16.12	91.69	8	15.18
10	17.32	100.77	7.28	16.84
11	18.48	109.54	6.56	18.50
12	19	113.48	6.24	19.24
13	18.81	112.04	6.35	18.98
14	18.6	110.45	6.54	18.55
15	17.1	99.10	7.37	16.63
16	16.06	91.24	7.99	15.20
17	14.43	78.91	8.9	13.10
18	13.5	71.87	9.44	11.86
19	11.86	59.46	10.38	9.69
20	10.2	46.90	11.35	7.45
21	9.22	39.49	11.95	6.07
22	8.17	31.55	12.56	4.66
23	6.3	17.40	13.61	2.24
24	5.08	8.17	14.12	1.06
	Ended at 14:45			

Figure A1.1. Deadhead vacuum data of the VACCON 750 eductor with the vacuum-line shutoff valve weep hole open and the diffuser set to 1.5 turns – first data set.

	8/1/2000	Started at 15:50	Atm. = 14.5743 psia	
	**********************	Weep Hole Open	********************	
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	5.92	14.53	13.78	1.83
2	7	22.70	13.25	3.05
3	8.65	35.18	12.3	5.25
4	9.56	42.06	11.75	6.51
5	10.52	49.33	11.16	7.88
6	12.15	61.66	10.21	10.07
7	13.61	72.70	9.39	11.96
8	14.84	82.01	8.65	13.67
9	16.01	90.86	7.98	15.21
10	16.99	98.27	7.41	16.53
11	18.54	110.00	6.46	18.72
12	18.99	113.40	6.13	19.48
13	18.54	110.00	6.44	18.76
14	16.99	98.27	7.4	16.55
15	16.13	91.77	7.91	15.37
16	14.57	79.96	8.82	13.27
17	13.08	68.69	9.69	11.27
18	11.6	57.50	10.54	9.31
19	10.36	48.12	11.26	7.64
20	8.99	37.75	12.1	5.71
21	7.98	30.11	12.69	4.35
22	6.83	21.41	13.34	2.85
23	5.53	11.58	13.96	1.42
	Ended at 16:00			

Figure A1.2. Deadhead vacuum data of the VACCON 750 eductor with the vacuum-line shutoff valve weep hole open and the diffuser set to 1.5 turns – second data set

	8/1/2000	Started 15:20	Atm. = 14.5676 psia	
	********************Weep Hole Closed********************			
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	4.87	6.58	14.18	0.89
2	6.24	16.95	13.63	2.16
3	8.16	31.47	12.57	4.61
4	9.41	40.93	11.82	6.34
5	10.74	50.99	11.03	8.16
6	12.07	61.05	10.25	9.96
7	13.25	69.98	9.58	11.50
8	14.64	80.49	8.79	13.33
9	15.76	88.97	8.15	14.80
10	17.03	98.57	7.43	16.46
11	18.48	109.54	6.54	18.52
12	18.96	113.18	6.22	19.26
13	18.89	112.65	6.29	19.09
14	18.72	111.36	6.38	18.89
15	17.43	101.60	7.17	17.06
16	15.97	90.56	8.04	15.06
17	14.68	80.80	8.75	13.42
18	13	68.09	9.74	11.14
19	11.67	58.03	10.48	9.43
20	10.64	50.23	11.08	8.04
21	9.62	42.52	11.71	6.59
22	7.52	26.63	12.96	3.71
23	6.14	16.19	13.68	2.05
24	5.25	9.46	14.06	1.17
	Ended at 15:30			

Figure A1.3. Deadhead vacuum data of the VACCON 750 eductor with the vacuum-line shutoff valve weep hole closed and the diffuser set to 1.5 turns – first data set.

	8/1/2000	Started 15:35	Atm. = 14.5676 psia	
	*********************Weep Hole Closed*******************			
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	5.58	11.95	13.93	1.47
2	6.74	20.73	13.38	2.74
3	7.68	27.84	12.86	3.94
4	8.86	36.77	12.16	5.55
5	9.92	44.79	11.52	7.03
6	11.68	58.10	10.48	9.43
7	13.58	72.47	9.4	11.92
8	15.04	83.52	8.53	13.93
9	16.18	92.14	7.89	15.40
10	17.12	99.26	7.35	16.65
11	18.49	109.62	6.44	18.75
12	18.87	112.49	6.19	19.32
13	18.59	110.38	6.41	18.82
14	17.06	98.80	7.37	16.60
15	16.05	91.16	7.96	15.24
16	14.76	81.40	8.69	13.56
17	13.36	70.81	9.54	11.60
18	12	60.52	10.3	9.84
19	10.35	48.04	11.26	7.63
20	9.08	38.43	12.03	5.85
21	8.24	32.08	12.54	4.68
22	6.93	22.17	13.28	2.97
23	5.45	10.97	13.99	1.33
	Ended at 15:45			

Figure A1.4. Deadhead vacuum data of the VACCON 750 eductor with the vacuum-line shutoff valve weep hole closed and the diffuser set to 1.5 turns – second data set.

	8/7/2000	Started 10:25	Atm. = 14.6179 psia	
	********************No Air Valve****************			T = 21°C
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	7.75	28.37	12.57	4.73
2	9.08	38.43	11.69	6.76
3	10.84	51.75	10.57	9.34
4	13	68.09	9.2	12.50
5	14.49	79.36	8.25	14.69
6	15.78	89.12	7.48	16.47
7	17.11	99.18	6.55	18.61
8	17.6	102.89	6.12	19.60
9	18.7	111.21	5.23	21.66
10	18.85	112.34	5.1	21.96
11	15.08	83.82	7.91	15.47
12	13.74	73.69	8.71	13.63
13	9.71	43.20	11.3	7.66
14	5.2	9.08	14.12	1.15
	Ended at 10:35	Atmospheric = 14.6197 psia		
		T = 21°C		

Figure A1.5. Deadhead vacuum data of the VACCON 750 eductor with NO vacuum-line shutoff valve and the diffuser set to 1.5 turns.

	8/7/2000	Started 14:08	Atm. = 14.6008 psia	
	********************With Air Valve*************			T = 21°C
Run	Applied Pressure mA	Applied Pressure psig	Vacuum psia	Vacuum ft H2O
1	5.45	10.97	13.97	1.45
2	7.32	25.12	12.83	4.08
3	8.54	34.35	12.03	5.93
4	9.5	41.61	11.42	7.33
5	10.43	48.64	10.82	8.72
6	11.96	60.22	9.85	10.96
7	13	68.09	9.17	12.52
8	14.04	75.95	8.51	14.05
9	15.36	85.94	7.71	15.89
10	16.63	95.55	6.86	17.85
11	17.52	102.28	6.11	19.58
12	18.7	111.21	5.17	21.75
13	18.8	111.97	5.08	21.96
14	17.25	100.24	6.34	19.05
15	15.6	87.76	7.56	16.24
16	13.05	68.47	9.14	12.59
17	10.6	49.93	10.71	8.97
18	7	22.70	13.06	3.55
19	6.35	17.78	13.46	2.63
20	5.88	14.22	13.75	1.96
21	5.16	8.78	14.12	1.11
	Ended at 14:25	Atmospheric = 14.5984 psia		
		T = 20°C		

Figure A1.6. Deadhead vacuum data of the VACCON 750 eductor with the vacuum-line shutoff valve and the diffuser set to 1.5 turns.

A2. Atomization of Water Sucked through the Vacuum Line

[Note: HLW indicated that the diffuser setting of the VACCON 750 eductor was 1.5 turns and should not be changed. This setting was not verified nor modified. A mark was made on the body of the eductor to maintain the position of the diffuser.]

The following data were taken on 08/03/2000 in the Experimental Thermal Fluids Laboratory at an ambient temperature of 21°C (Measured by TR-1140).

All runs were done with the vacuum line open to the atmosphere.

Figure A2.1 is comprised of three tables: The top table shows the data to quantify the fixed volume of water in the vacuum line, the middle table shows the data to quantify the water not lost through atomization, and the bottom table quantifies water which remained on the collection surfaces. Fig. 15 shows the overall results.

Measurement Uncertainty

Measurement and Testing Equipment Used (see Appendix B):

Measurement	M&TE No.	Range	Uncertainty (95% Confidence)
Eductor Air Pressure	TR-3411	0 to 120 psig	0.5 psi
Temperature	TR-1140	0 to 100°C	2.2°C
Weight	TR-3547	0 to 25 lbs	0.024 lb
Weight	TR-30075	0 to 200 lbs	0.022 lb

<u>Starting Water Volume</u>

The uncertainty of the fixed volume of water in the vacuum line is:

10.258 lbs ±(2x0.0035 lb + 2x0.022 lb.) = **10.26 ±0.06 lbs** **(A2.1)**

Notes:
1. Two standard deviations were used for the measurement data for a 95% confidence level.
2. Two masses of water were subtracted to obtain the captured mass.

Captured Water Volume

The uncertainty of the captured volume of water from the eductor is:

9.74 lbs ±(2x0.07 lb + 2x0.022 lb. + 2x0.024) = **9.74 ±0.23 lbs** **(A2.2)**

Notes:

1. Two standard deviations were used for the measurement data for a 95% confidence level.
2. Two masses of water were subtracted to obtain the captured mass and two masses were subtracted to obtain the water retained on the capture tarp.

Percentage of Water Recovered

The uncertainty of the water recovered is based on the two quantities determined above, i.e., A2.1 and A2.2. Since they are divided the law of propagation of errors* can be used:

$95.0\% \pm\{95.0\%\text{x}[(0.05/10.26)^2+(0.23/9.74)^2]^{1/2}\} = 95.0\% \pm\{95\%\text{x}0.0243\}$ = **95% ±3%**

*Reference: Mandel, John, "The Statistical Analysis of Experimental Data," Dover Publ., 1984, section 4.7, pp. 72-75.

Atomization Test Run with only Vacuum Applied to the Vacuum Line

Done on: 8/3/2000

Started 14:42

Valid Cal Run No.	Air Eductor Applied Pressure mA	Air Eductor Applied Pressure psig	Water* Temp. °C	Container Tare lbs	Captured Water lbs.	Net Water Weight lbs.
1	6.30	17.5	39	4.265	14.53	10.260
2	6.73	20.7	39	4.265	14.52	10.255
Pres Chg	6.85	21.6				
Ended 15:10 (estimated)					Average	10.258
					Std Dev	0.0035

*The water mass uncertainty due to the temperature uncertainty is insignificant. The stated Type J thermocouple uncertainty of 2.2°C leads to an uncertainty in the water volume due to volume change in the stainless steelpipes to less than ±0.25 gram (±0.0005 lb.).

Started 16:15 (estimated)

Test Run No.	Air Eductor Applied Pressure mA	Air Eductor Applied Pressure psig	Water Temp. °C	Container Tare lbs	Captured Water lbs.	Net Water Weight lbs.	Water + Tarp lbs.	Total Water Recovered fraction
1	18.90	112.6		34.46	43.86	9.40	9.70	0.946
Pres Chg	18.70	111.1						
2	18.87	112.3		43.86	53.27	9.41	9.71	0.947
Pres Chg	18.98	113.2	40					
3	18.63	110.5		53.27	62.79	9.52	9.82	0.957
Pres Chg	18.90	112.6	40					
Averages		112.0				9.44	9.74	0.950
Std Dev		1.0	40			0.07	0.07	0.006

Ended 16:45

Water recovered from the wet tarp and bucket

	Tarp	Bucket*	
Dry Weight (lbs)	2.25	1.275	Total Extra Water
Wet Weight (lbs)	2.55	1.280	Collected (lbs.)
Collected Mass (lbs)	0.30	0.005	0.30

* This value is within the uncertainty of balance TR-3547 (±0.03 lb) and therefore it is not included.

Figure A2.1. Tabulated data from Task Notebook on the First Atomization Test

(Note: Pres Chg lines in the table indicate how the pressure changed while the test was running. These changes were not noted in the second atomization test because they were not significant, as seen above.)

A3 Atomization of Water Sucked and Pushed through the Vacuum Line

[Note: HLW indicated that the diffuser setting of the VACCON 750 eductor was 1.5 turns and should not be changed. This setting was not verified nor modified. A mark was made on the body of the eductor to maintain the position of the diffuser.]

The following data were taken on 08/05/2000 in the Experimental Thermal Fluids Laboratory at an ambient temperature of 21°C (Measured by TR-1140).

Figure A3.1 is comprised of three tables: The top table shows the data to quantify fixed volume of water in the vacuum line, the middle table shows the test data to quantify the water not lost through atomization, and the bottom table quantifies water which remained on the collection surfaces. The bottom curve in Fig. 16 shows the overall data for this test.

Measurement Uncertainty

Measurement and Testing Equipment Used (see Appendix B):

Measurement	M&TE No.	Range .	Uncertainty (95% Confidence)
Eductor Air Pressure	TR-3411	0 to 120 psig	0.5 psi
Vacuum-line Pressure	TR-3538	0 to 120 psig	0.6 psi
Temperature	TR-1140	0 to 100°C	2.2°C
Weight	TR-3547	0 to 25 lbs	0.024 lb
Weight	TR-30075	0 to 200 lbs	0.022 lb

Starting Water Volume

The uncertainty of the fixed volume of water in the vacuum line is:

10.78 lbs ±(2x0.03 lb + 2x0.024 lb.) = **10.78 ±0.16 lbs** **(A3.1)**

Notes:
1. Two standard deviations were used for the measurement data for a 95% confidence level.
2. Two masses of water were subtracted to obtain the captured mass.

Captured Water Volume

The uncertainty of the captured volume of water from the eductor is:

9.46 lbs ±(2x0.04 lb + 2x0.022 lb. + 2x0.024) = **9.46 ±0.18 lbs** **(A3.2)**

Notes:
1. Two standard deviations were used for the measurement data for a 95% confidence level.
2. Two masses of water were subtracted to obtain the captured mass and two masses are subtracted to obtain the water retained on the capture tarp.

Percentage of Water Recovered

The uncertainty of the water recovered is based on the two quantities determined above, i.e., A3.1 and A3.2. Since they are divided the law of propagation of errors* can be used:

$87.7\% \pm\{87.7\%x[(0.16/10.78)^2+(0.18/9.46)^2]^{1/2}\}= 87.7\% \pm\{87.7\%x0.0241\}$ = **88% ±3%**

*Reference: Mandel, John, "The Statistical Analysis of Experimental Data," Dover Publ., 1984, section 4.7, pp. 72-75.

Atomization Test with both Vacuum and Positive Pressure Applied to the Vacuum Line

Done on: 8/5/2000

Started 16:00

Valid Cal Run No.	****************Applied Air Pressure to the: Air Eductor mA	Air Eductor psig	Vacuum Line mA	************ Vacuum Line psig	Water* Temp. °C	Container Tare lbs	Captured Water lbs.	Net Water Weight lbs.
1	7.07	23.3	7.07	23.3	40	0	10.735	10.735
2	7.10	23.5	7.03	23.0	40	0	10.795	10.795
3	6.92	22.2	7.03	23.0	40	0	10.795	10.795
Ended 16:20							Average	10.78
							Std Dev	0.03

*The water mass uncertainty due to the temperature uncertainty is insignificant. The stated Type J thermocouple uncertainty of 2.2°C leads to an uncertainty in the water volume due to volume change in the stainless steel pipes to less than ±0.25 gram (±0.0005 lb.)

Started 16:40

Test Run No.	****************Applied Air Pressure to the: Air Eductor mA	Air Eductor psig	Vacuum Line mA	************ Vacuum Line psig	Water* Temp. °C	Container Tare lbs	Captured Water lbs.	Net Water Weight lbs.	Water + Tarp lbs.	Total Water Recovered fraction
1	18.94	112.9	18.27	107.8	40	0	9.06	9.06	9.40	0.872
2	18.95	112.9	18.20	107.3	40	9.06	18.21	9.15	9.49	0.881
3	18.75	111.4	18.13	106.8	40	18.21	27.28	9.07	9.41	0.873
4	18.75	111.4	18.20	107.3	40	27.28	36.41	9.13	9.47	0.879
5	18.90	112.6	18.15	106.9	40	36.41	45.53	9.12	9.46	0.878
6	18.68	110.9	18.10	106.5	41	45.53	54.69	9.16	9.50	0.882
Averages		112.0		107.1				9.12	9.46	0.877
Std Dev		0.9		0.5				0.04	0.04	0.004

Ended 17:30

Water recovered from the wet tarp and bucket

	Tarp (lbs)	Catch Basin (lbs)	
Dry Weight (lbs)	2.265	13.315	Total Extra Water
Wet Weight (lbs)	2.540	13.380	Collected (lbs)
Collected Mass (lbs)	0.275	0.065	0.340

Figure A3.1. Tabulated data from Task Notebook on the Second Atomization Test

APPENDIX B

MEASUREMENT AND TESTING EQUIPMENT

AND

CALIBRATION DATA

There were six instruments used to do this task. A summary of the instruments and their uncertainties are listed below:

Measurement	M&TE No.	Range .	Uncertainty (95% Confidence)
Eductor Air Pressure	TR-3411	0 to 120 psig	0.5 psi
Vacuum-line Pressure	TR-3538	0 to 120 psig	0.6 psi
Vacuum	3-2549	0 to 22 psia	0.006 psi
Temperature	TR-1140	0 to 100°C	2.2°C
Weight	TR-3547	0 to 25 lbs	0.024 lb
Weight	TR-30075	0 to 200 lbs	0.022 lb

The following six pages show the calibration data for each instrument. Only the final page of the calibration package is shown. The complete package on each can be found in the Engineered Equipment & Systems Department Document Control job folder No. 22 789 located in Building 730-A or in the task notebook(7). Further, most of the instruments were calibrated before and after this task. The exceptions are the weight scales (TR-3547 and TR-30075) which are on a fixed recalibration schedule. For the remaining four instruments the listed measurement uncertainties are the result of both the pre- and post-calibrations.

UNCERTAINTY ANALYSIS **TR-03411**
REF. WSRC-TR-91-106, REV. 0 cal. date: 08/08/2000
Post-Calibration

Calibration Data

Nominal Pressure (psig)	Applied Pressure (psig)	Gage Reading (mADC)	Curve Fit (mADC)	Error (mADC)	Error (psig)
0.00	0.00	3.98	3.98	0.004	0.03
21.00	21.00	6.77	6.77	-0.003	-0.02
41.00	41.00	9.42	9.42	-0.003	-0.03
61.00	61.00	12.06	12.07	0.007	0.05
81.00	81.00	14.71	14.72	0.006	0.05
101.00	100.00	17.36	17.23	-0.126	-0.95
121.00	121.00	20.00	20.02	0.016	0.12
0.00	0.00	3.98	3.98	0.004	0.03
21.00	21.00	6.77	6.77	-0.003	-0.02
41.00	41.00	9.42	9.42	-0.003	-0.03
61.00	61.00	12.06	12.07	0.007	0.05
81.00	81.00	14.71	14.72	0.006	0.05
101.00	101.00	17.36	17.37	0.006	0.05
121.00	121.00	20.00	20.02	0.016	0.12
0.00	0.00	3.98	3.98	0.004	0.03
21.00	21.00	6.77	6.77	-0.003	-0.02
41.00	41.00	9.42	9.42	-0.003	-0.03
61.00	61.00	12.06	12.07	0.007	0.05
81.00	81.00	14.71	14.72	0.006	0.05
101.00	101.00	17.36	17.37	0.006	0.05
121.00	121.00	20.00	20.02	0.016	0.12
0.00	0.00	3.98	3.98	0.004	0.03
21.00	21.00	6.77	6.77	-0.003	-0.02
41.00	41.00	9.42	9.42	-0.003	-0.03
61.00	61.00	12.06	12.07	0.007	0.05
81.00	81.00	14.71	14.72	0.006	0.05
101.00	101.00	17.36	17.37	0.006	0.05
121.00	121.00	20.00	20.02	0.016	0.12

Standard Uncertainties: Multimeter: +/- (0.04 % RDG + 0.0001 mADC)
Dead Weight Tester: +/- 0.1 psi

Statistical Info:

a	b	n	T	Xbar psig	Sxx psig ^{2}	SEE mADC ^{2}	MSE mADC ^{2}
3.9843	0.1325	24.00	2.07	60.82	45204.11	0.0176	0.0008

Calculated Uncertainties: / Total Uncertainty

σ_C psig	σ_E psig	σ_F psig	σ_T psig
0.12	0.47	0.10	**0.49**

Pre/post Calibration Combined Uncertainty

Figure B1. Transducer used to measure the air supply pressure to the eductor

UNCERTAINTY ANALYSIS **TR-03538**
REF. WSRC-TR-91-106, REV. 0 cal. date: 08/08/2000
Post-Calibration

Calibration Data

Nominal Pressure (psig)	Applied Pressure (psig)	Gage Reading (mADC)	Curve Fit (mADC)	Error (mADC)	Error (psig)
0.00	0.00	4.00	4.01	0.012	0.09
21.00	21.00	6.79	6.78	-0.006	-0.04
41.00	41.00	9.43	9.42	-0.005	-0.04
61.00	61.00	12.07	12.07	-0.005	-0.04
81.00	81.00	14.70	14.71	0.005	0.04
101.00	100.00	17.33	17.21	-0.116	-0.88
121.00	121.00	19.97	19.99	0.016	0.12
0.00	0.00	4.00	4.01	0.012	0.09
21.00	21.00	6.79	6.78	-0.006	-0.04
41.00	41.00	9.43	9.42	-0.005	-0.04
61.00	61.00	12.07	12.07	-0.005	-0.04
81.00	81.00	14.70	14.71	0.005	0.04
101.00	101.00	17.33	17.35	0.016	0.12
121.00	121.00	19.97	19.99	0.016	0.12
0.00	0.00	4.00	4.01	0.012	0.09
21.00	21.00	6.79	6.78	-0.006	-0.04
41.00	41.00	9.43	9.42	-0.005	-0.04
61.00	61.00	12.07	12.07	-0.005	-0.04
81.00	81.00	14.70	14.71	0.005	0.04
101.00	101.00	17.33	17.35	0.016	0.12
121.00	121.00	19.97	19.99	0.016	0.12
0.00	0.00	4.00	4.01	0.012	0.09
21.00	21.00	6.79	6.78	-0.006	-0.04
41.00	41.00	9.43	9.42	-0.005	-0.04
61.00	61.00	12.07	12.07	-0.005	-0.04
81.00	81.00	14.70	14.71	0.005	0.04
101.00	101.00	17.33	17.35	0.016	0.12
121.00	121.00	19.97	19.99	0.016	0.12

Standard Uncertainties: Multimeter: +/- (0.04 % RDG + 0.0001 mADC)
Dead Weight Tester: +/- 0.1 psi

Statistical Info:

a	b	n	T	Xbar psig	Sxx $psig^2$	SEE $mADC^2$	MSE $mADC^2$
4.0120	0.1320	24.00	2.07	60.82	45204.11	0.0163	0.0007

Calculated Uncertainties: Total Uncertainty

σ_C psig	σ_E psig	σ_F psig	σ_T psig
0.12	0.45	0.22	**0.52**

Pre/post Calibration Combined Uncertainty

Figure B2. Transducer used to measure the air pressure applied to the vacuum line

UNCERTAINTY ANALYSIS **M&TE No. 3-2549**
REF. WSRC-TR-91-106, REV. 0 cal. date: 08/08/2000
Post-Calibration

Calibration Data

Nominal Pressure (psia)	Applied Pressure (psia)	Gage Reading (psia)	Curve Fit (psia)	Error (psia)
0.00	0.00000	0.00106	-0.0009	-0.0019
5.00	4.99968	4.99718	4.9991	0.0019
10.00	9.99387	9.99330	9.9936	0.0003
BP	14.61100	14.61400	14.6110	-0.0030
15.00	14.98882	14.98780	14.9888	0.0010
20.00	20.00952	20.00740	20.0098	0.0024
22.00	22.04545	22.04710	22.0458	-0.0013
22.00	22.04379	22.04530	22.0442	-0.0011
20.00	19.99664	19.99950	19.9969	-0.0026
15.00	14.98868	14.98760	14.9887	0.0011
BP	14.59900	14.59600	14.5990	0.0030
10.00	9.99359	9.99288	9.9933	0.0004
5.00	4.99860	4.99626	4.9980	0.0018
0.00	0.00000	0.00110	-0.0009	-0.0020

Standard Uncertainties: App Pres: +/- (0.01 % RDG)

[Note: Used Paroscientific Readout Serial No. 49641 Model 710 to indicate pressure]

Statistical Info:

a	b	n	T	Xbar psia	Sxx $psia^2$	SEE $psia^2$	MSE $psia^2$
-0.000856	1.000057	14.00	2.18	12.38	753.42	0.000050	0.000004

Calculated Uncertainties: Total Uncertainty

σ_C psia	σ_E psia	σ_F psia	σ_T psia
0.0022	0.0050	0.0003	**0.0055**

Pre/post Calibration Combined Uncertainty

Figure B3. Transducer used to measure the deadhead vacuum level

This type J thermocouple was not specially calibrated to a measurement tolerance better than the NIST published uncertainty for all type J thermocouples of ±2.2°C. Only a check was done before and after this task to make sure that the thermocouple was reading within that stated tolerance.

Temperature Check of Thermocouple TR-1140

Pre-test check date: 07/31/2000

Standard*	Thermocouple Response**
0°C	1°C
21.1°C	21.0°C
100°C	99°C

Post-test check date: 08/09/2000

Standard*	Thermocouple Response**
0°C	1°C
23.6°C	23.5°C
100°C	99°C

*Standards: Mixed house-water ice bath for the freezing point
Boiling house-water for the 100°C point
Thermometer*** TR-3226 for the mid-range point

**A type J readout box TR-2729 was used to read temperature directly.

***Thermometer TR-3226 has a range of 15°C to 40°C and a calibrated uncertainty

Figure B4. Type J thermocouple used to measure the ambient air and the vacuum line water temperature

UNCERTAINTY ANALYSIS **M&TE No. TR-3547**
REF. WSRC-TR-91-106, REV. 0 cal. date: 02/17/2000

Calibration Data

Nominal Loading (lbm)	Applied Loading (lbm)	Gage Reading (lbm)	Curve Fit (lbm)	Error (lbm)
0.000	0.000	0.000	-0.003	-0.003
1.000	1.000	1.000	0.996	-0.004
5.000	5.000	4.990	4.991	0.001
10.000	10.000	9.980	9.984	0.004
15.000	15.000	14.970	14.977	0.007
20.000	20.000	19.965	19.971	0.006
25.000	25.000	24.955	24.964	0.009
25.000	25.000	24.995	24.964	-0.031
20.000	20.000	19.965	19.971	0.006
15.000	15.000	14.970	14.977	0.007
10.000	10.000	9.980	9.984	0.004
5.000	5.000	4.990	4.991	0.001
1.000	1.000	1.000	0.996	-0.004
0.000	0.000	0.000	-0.003	-0.003

Standard Uncertainties: App Loading: +/- (0.0005 lbm)

Statistical Info:

a	b	n	T	Xbar lbm	Sxx lbm^2	SEE lbm^2	MSE lbm^2
-0.002910	0.998689	14.00	2.09	10.86	1101.71	0.001292	0.000108

Calculated Uncertainties: Total Uncertainty

σ_C lbm	σ_E lbm	σ_F lbm	σ_T lbm
0.0005	0.0243	0.0000	0.0244

Figure B5. Weight balance used to measure all weight under 25 lbs.

UNCERTAINTY ANALYSIS **M&TE No. TR-30075-1**
REF. WSRC-TR-91-106, REV. 0 cal. date: 07/06/2000

Calibration Data

Nominal Loading (lbm)	Applied Loading (lbm)	Gage Reading (lbm)	Curve Fit (lbm)	Error (lbm)
0.00	0.00	0.00	0.00	0.00
40.00	40.00	40.00	40.00	0.00
80.00	80.00	80.00	80.00	0.00
120.00	120.00	120.00	120.00	0.00
160.00	160.00	160.00	160.00	0.00
200.00	200.00	200.00	200.00	0.00
200.00	200.00	200.00	200.00	0.00
160.00	160.00	160.01	160.00	-0.01
120.00	120.00	119.99	120.00	0.01
80.00	80.00	80.00	80.00	0.00
40.00	40.00	40.00	40.00	0.00
0.00	0.00	0.00	0.00	0.00
50.00	50.00	49.99	50.00	0.01
50.00	50.00	49.98	50.00	0.02
50.00	50.00	50.00	50.00	0.00
50.00	50.00	50.02	50.00	-0.02

Standard Uncertainties: App Loading: +/- (0.005 lbm)
[NIST Class F Weights]

Statistical Info:

a	b	n	T	Xbar Ibm	Sxx Ibm^2	SEE Ibm^2	MSE Ibm^2
-0.001693	1.000012	16.00	2.145	87.50	63500.00	0.001084	0.000077

Calculated Uncertainties: Total Uncertainty

σ_C	σ_E	σ_F	σ_T
Ibm	Ibm	Ibm	Ibm
0.005	0.021	0.000	0.022

Figure B6. Weight balance used to measure weights over 25 lbs

APPENDIX C

WORK INSTRUCTIONS

This appendix contains the steps followed to carry out the three tests of this task. They are repeated here for convenience and more detail can be found in the task notebook (7)

C.1. Work Instruction Number 1

This test is done to comply with Task Technical and Quality Assurance Plan No. EES-22789-TTP/QAP, 08/01/2000. Work will be carried out in the Experimental Thermal Fluids Laboratory, Bldg. 786-A

Written by_________signed __________________ Date__08/01/2000__
Mark R. Duignan, Task Leader

Reviewed by_______signed__________________ Date__08/01/2000__
John L. Steimke

VACCON 750 Eductor Deadhead Vacuum Evaluation

1. Note all data in task notebook.
2. Turn on all electrical equipment ½ hour before the test.
3. Open dP air meter to measure zero reading.
4. Close dP air meter to read air supply pressure.
5. Note air pressure should be applied to the c. Open position.
6. Note the atmospheric pressure with the vacuum meter.
7. Put on hearing protection.
8. Put up barriers to prevent unprotected personnel into test area during the test.
9. Turn on the air supply to the eductor and set the pressure to the first setting in the test matrix.
10. Record the air supply pressure and the vacuum level/
11. Carry out the test for all setting in the test matrix, with increasing air pressure.
12. Repeat step 11 for decreasing air pressure.
13. Repeat steps 11 and 12.
14. Turn off the air supply and then cover up the vacuum-line shutoff valve weep hole with tape.
15. Repeat steps 9 through 13.
16. Turn off the air supply and remove the personnel barriers.
17. End of Test

Test Matrix

Run	Air Supply Pressure	Multimeter Setting (TR-03411)
1	10 psig	5.32 mA
2	20 psig	6.64 mA
3	30 psig	7.97 mA
4	40 psig	9.29 mA
5	50 psig	10.61 mA
6	60 psig	11.93 mA
7	70 psig	13.25 mA
8	80 psig	14.57 mA
9	90 psig	15.90 mA
10	100 psig	17.22 mA
11	110 psig	18.54 mA
12	120 psig (if possible)	19.86 mA (Highest Calibrated Value)
	130 psig	21.18 mA

C2. Work Instruction Number 2

This test is done to comply with Task Technical and Quality Assurance Plan No. EES-22789-TTP/QAP, 08/01/2000. Work will be carried out in the Experimental Thermal Fluids Laboratory, Bldg. 786-A

______________signed__________________ Date__08/03/2000__
Mark R. Duignan, Task Leader

______________signed__________________ Date__08/03/2000__
John L. Steimke, Technical Reviewer

Test 2: VACCON 750 Eductor Evaluation for aerosol production with unpressurized water in the vacuum line.

[Refer to the Figure C1 on the last page for the test setup.]

I. Determine water volume in vacuum line

1. Note all data in task notebook.
2. Turn on all electrical equipment ½ hour before the test.
3. Have ready a container that can hold at least 2 gallons of water and measure the weight of the container. Note the number of the scale in the task notebook. The container will be placed immediately under the exhaust of the eductor to capture about 1 gallon of water.
4. Note the zero indication of the dP air supply pressure meter.
5. Close the air vacuum-line shutoff valve, V1, with ~80 psig air. (The reading off the pressure regulator is fine. Just note the value in the notebook.)
6. Fill the water reservoir with approximately 15 gallons of process water.
7. Begin circulating process water through the eductor vacuum line by closing the 1-inch vent valve, V2, opening the two water-line valves, V3 & V4, and turn on the water pump.
8. Note the water temperature when it becomes stable.
9. Turn on the water heater and allow the water to reach 101°F±2°F, then maintain that temperature for 15 minutes.
10. Place the weighed container under the eductor to capture the water.
11. As fast a safely possible: close the two in-line water valves, V3 & V4, shut off the water pump, open the vent valve, V2, then relieve the air pressure (turn V1 to the vent position) to the vacuum-line shutoff valve to allow it to open.
12. Allow the container to fill with water and note if the temperature changes during the draining.
13. After the water has stopped filling the container, apply just enough air pressure (by opening valve V5) to the vacuum line to allow the remaining water in the line to be pushed through the eductor. Closing the line vent, V2, may help.
14. Measure the weight of the liquid.

15. Repeat steps 7 through 14 five (5) times to get an average value of the loop water volume.

At this point the task leader will determine if steps 7 through 14 need further repeating.

II. Determine aerosol loss

16. Have ready a container that can hold at least twelve times the volume of the loop volume determined in step 15. Measure the dry weight of the container and note the scale used.
17. Set up a video camera to film the test.
18. Cut a piece of plastic that will serve as a catch tarp under the eductor. The plastic needs to cover the 8x8 floor space and up to the lower set horizontal UNISTRUT members of the test superstructure. Cut a hole in the middle of the tarp and place a container under the hole. (This container should be able to hold at least 2 gallons of water. Measure its dry weight.)
19. Measure the dry weight of the tarp and make a note of the scale used.
20. Install the plastic under the eductor.
21. Put up barriers to prohibit unprotected personnel from entering the 85 dB test area.
22. Close the air vacuum-line shutoff valve with ~80 psig air. (The reading off the pressure regulator is fine. Just note the value in the notebook.)
23. Begin circulating process water through the eductor vacuum line by closing the 1-inch vent valve, V2, opening the two water-line valves, V3 & V4, and turn on the water pump.
24. Turn on the water heater and allow the water to reach 101°F±2°F, then maintain that temperature for 15 minutes. Make a note of the temperature.
25. Open the air supply to the eductor to the maximum stable line pressure. Make a note of pressure. Open the air valve, V6, to full.
26. For the first test put on a face shield in case the water spray is directed towards someone's face. The first test will determine if future use of a face shield is necessary. Laboratory coats are not necessary but may help in preventing personnel clothes from getting wet.
27. One person needs to be ready to monitor the air supply pressure to the eductor during the test.
28. One person needs to be ready to observe the water as it sprays to the tarp and make notes on its behavior, i.e., direction, form, etc.
29. All personnel in the test area must put on hearing protection.
30. Turn on the video camera.
31. As fast a safely possible: close the two in-line water valves, V3 & V4, shut off the water pump, open the vent valve, V2, then relieve the air pressure (turn V1 to the vent position)to the vacuum-line shutoff valve to allow it to open.
32. After the water flow has stopped close the vacuum-line shutoff valve with ~80 psig air, V1.
33. Shut off the air supply to the eductor.
34. Empty the container under the tarp into the large container obtained in step 16.
35. Repeat steps 23 to 34 ten times.
36. Measure the weight of the water in the large container obtained in step 16.

37. Measure the empty, wet, weight of the container used to catch the water after each run.
38. Measure the weight of tarp and remaining water.
39. Turn off the air supplies, remove the personnel barriers, turn off the water heater, turn off the water pump, and close all valves.
40. End of Test.

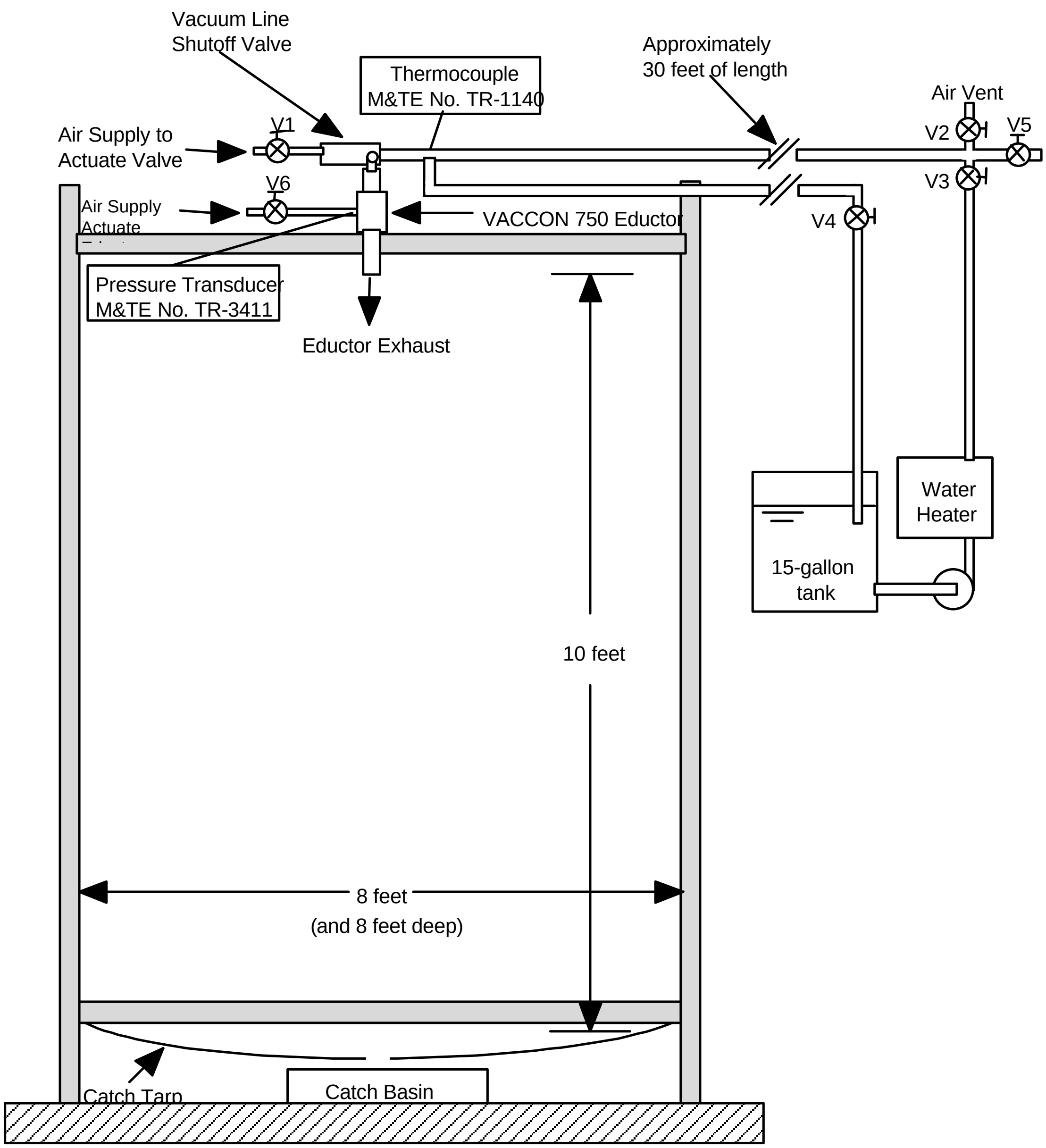

Figure C1. Setup for the PITBULL eductor water aerosol test without positive pressure

C3. Work Instruction Number 3

This test is done to comply with Task Technical and Quality Assurance Plan No. EES-22789-TTP/QAP, 08/01/2000. Work will be carried out in the Experimental Thermal Fluids Laboratory, Bldg. 786-A

_________________signed_______________ Date__08/04/2000__
Mark R. Duignan, Task Leader

_________________signed_______________ Date__08/04/2000__
John L. Steimke, Technical Reviewer

Test 2: VACCON 750 EductorEvaluation for aerosol production with pressurized water in the vacuum line.

[Refer to the Figure C2 on the last page for the test setup.]

(Note: The valves numbers are not listed in Figure C2 because while the valves were basically the same as shown in Fig. C1 the circulation of the water by the pump was reversed while doing the shakedown test. This change helped to remove the air from the system, which stabilized the fixed volume of water in the vacuum line. However, work instruction No. 3 was written for the original valve arrangement and therefore Figure C1 should be referred to when reading this instruction.)

I. Determine water volume in vacuum line

1. Note all data in task notebook.
2. Turn on all electrical equipment ½ hour before the test.
3. Have ready a container that can hold at least 2 gallons of water and measure the weight of the container. Note the number of the scale in the task notebook. The container will be placed immediately under the exhaust of the eductor to capture about 1 gallon of water.
4. Note the zero indication of the dP air supply pressure meter.
5. Close the vacuum-line shutoff valve, V1, with ~80 psig air. (The reading off the pressure regulator is fine. Just note the value in the notebook.)
6. Fill the water reservoir with approximately 15 gallons of process water.
7. Begin circulating process water through the eductor vacuum line by closing the 1-inch vent valve, V2, opening the two water-line valves, V3 & V4, and turn on the water pump.
8. Note the water temperature when it becomes stable.
9. Turn on the water heater and allow the water to reach 39°C±1°C, then maintain that temperature for 15 minutes. (Shorter times may be requested by the task leader.)
10. Place the weighed container under the eductor to capture the water.
11. As fast a possible, close the two in-line water valves, V3 & V4, shut off the water pump, and pressurize the vacuum line, by opening valve V5, to a pressure determined by the task leader.

12. Turn on the air pressure to the eductor, V6, to a level determined by the task leader.
13. Relieve the air pressure (turn V1 to the vent position)to the vacuum-line shutoff valve to allow it to open.
14. Allow the container to fill with water and note if the temperature changes during the draining.
15. Shut off the air supply to the eductor, V6, and to the vacuum line, V5.
16. Measure the weight of the liquid.
17. Steps 7 through 16 may be repeat as per the task leader.

II. Determine aerosol loss

18. Have ready a container that can hold at least twelve times the volume of the loop volume determined in step 16. Measure the dry weight of the container and note the scale used.
19. Set up a video camera to film the test.
20. Cut a piece of plastic that will serve as a catch tarp under the eductor. The plastic needs to cover the 8x8 floor space and up to the lower set horizontal UNISTRUT members of the test superstructure. Cut a hole in the middle of the tarp and place a container under the hole. (This container should be able to hold at least 2 gallons of water. Measure its dry weight.)
21. Measure the initial weight of the tarp and make a note of the scale used.
22. Install the plastic under the eductor.
23. Put up barriers to prohibit unprotected personnel from entering the 85 dB test area.
24. Close the vacuum-line shutoff valve with ~80 psig air. (The reading off the pressure regulator is fine. Just note the value in the notebook.)
25. Begin circulating process water through the eductor vacuum line by closing the 1-inch vent valve, V2, opening the two water-line valves, V3 & V4, and turn on the water pump.
26. Turn on the water heater and allow the water to reach 39°C±1°C, then maintain that temperature for 15 minutes. (Shorter times may be requested by the task leader.) Make a note of the temperature.
27. Open the air supply to the eductor to the maximum stable line pressure. Make a note of pressure. Open the air valve, V6, to full.
28. For the first test put on a face shield in case the water spray is directed towards someone's face. The first test will determine if future use of a face shield is necessary. Laboratory coats are not necessary but may help in preventing personnel clothes from getting wet.
29. One person needs to be ready to monitor the air supply pressure to the eductor during the test.
30. One person needs to be ready to observe the water as it sprays to the tarp and make notes on its behavior, i.e., direction, form, etc.
31. All personnel in the test area must put on hearing protection.
32. Turn on the video camera.
33. As fast a safely possible: close the two in-line water valves, V3 & V4, shut off the water pump, and pressurize the vacuum line by opening valve V5 to the maximum line pressure.

34. Relieve the air pressure (turn V1 to the vent position) to the vacuum-line shutoff valve to allow it to open.
35. After the water flow has stopped close the vacuum-line shutoff valve with ~80 psig air, V1.
36. Shut off the air supply to the eductor, V6, and to the vacuum line, V5.
37. Empty the container under the tarp into the large container obtained in step 18.
38. Repeat steps 25 to 37 per task leader request.
39. Measure the weight of the water in the large container obtained in step 18.
40. Measure the empty, wet, weight of the container used to catch the water.
41. Measure the weight of tarp and remaining water.
42. Turn off the air supplies, remove the personnel barriers, turn off the water heater, turn off the water pump, and close all valves.
43. End of Test.

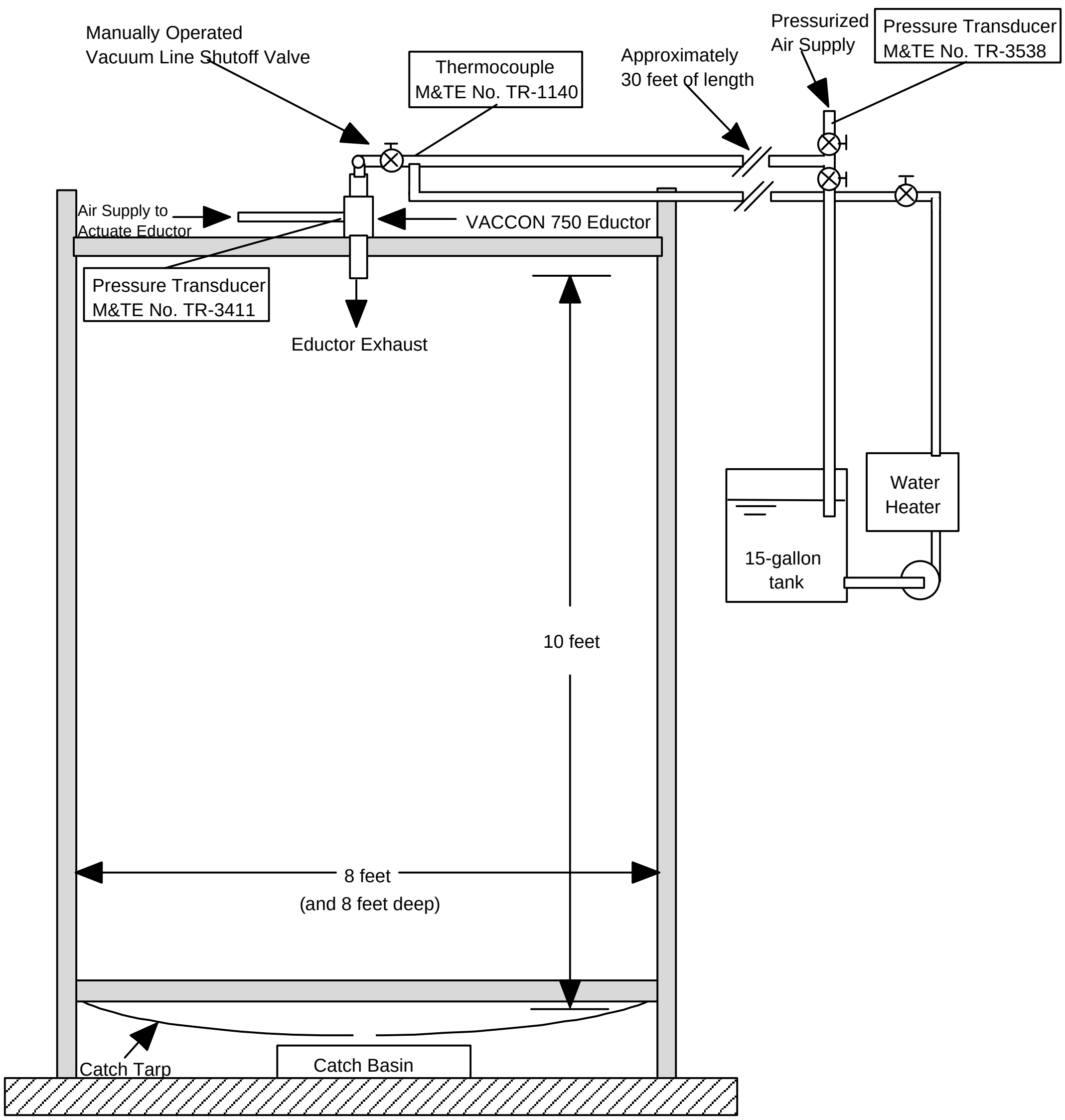

Figure C2. Setup for the PITBULL eductor water aerosol test without positive pressure

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