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Salt Survey Comparison of Pressurized vs Ambient Deck Air Intakes on JEFF (B) Hovercraft

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A survey was conducted on AALC JEFF (B) hovercraft to measure salt-spray loadings to an engine (No. 6) which was pressurized from the bag plenum as compared to the loading to an engine (No. 5) drawing ambient deck air. The average deck ambient salt loading in the small (1-50 μm) size range was 2 PPM as compared to 4 PPM in the bag plenum. An average 0.25 PPM salt in air entered No. 6. Wash water salinity indicated that the unpressurized engines had 1/10 the loading of the pressurized engine on this mission and 2/3 on more "normal" missions (without frequent periods

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20. Abstract (Continued)

of idling to change salt samplers).

Leakage bypassing the filters had been improved by a factor of 20 since early craft missions, but still dominated over inlet filter design as a source of salt loading to the unpressurized engines. Pressurization eliminated salt due to leakage, but still gave more loading of both salt and sand as compared to the unpressurized inlets.

The pattern of paint stripping by spray and sand in the lift fan volute provided graphic evidence that proper selection of the source location for lift fan pressurized air could provide much cleaner engine air. Temperature rise with pressurization was found to be lower than expected. If the pressure loss through the intake filter could also be reduced using cleaner lift fan air (permitting fewer filter elements), then the overall engine performance could be improved over previous predictions with a pressurized system. With any type of system, agglomerator or barrier type filter pads are required in order to minimize salt loading by 1-50 μm droplets, but with ambient air these pads should all be downstream of the spin tubes in order to avoid blockage by sand. Drain traps also must be designed not to plug with sand. A first roughing stage of hook vanes is needed to handle large quantities of spray (1000 PPM) in drop sizes larger than 50 μm. Final stage hook vanes were found ineffective.

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SALT SURVEY COMPARISON OF PRESSURIZED vs AMBIENT DECK AIR INTAKES ON JEFF (B) HOVERCRAFT

INTRODUCTION

In the design of the LCAC (Landing Craft Air Cushion), next generation of hovercraft, an important information item is the design of the main propulsion gas turbine air intake configuration, particularly the relative merits of taking air from the inboard deck regions vs taking air from the pressurized region beneath the deck. During April 1980, Salt Survey Measurements were conducted by NRL aboard AALC (Amphibious Assault Landing Craft) JEFF (B), to compare the salt loading in the intake air to engine No.6, which was pressurized with bag plenum air vs the loading to engine No. 5 which was drawing deck air. Additional measurements were made upstream of the No. 5 intake filters for air typical of the deck ambient environment as compared to the salt loading in the bag plenum near the point of pickup for the pressurized air being fed to No. 6 engine.

The location of the ambient deck measurements is shown at A in Figure 1. The bag plenum sampling point is at location B. The pressurized air from the bag plenum is fed through the access hatch at B and ducted through "boiler plate" duct work to a plenum at C of Figure 1 into the intake filters of No. 6 engine. Salt spray entering the intake bellmouth of engines No.6 and No. 5 are measured with Nuclepore filter probes located through a replacement blow-in door at location D of Figure 1 for No. 6 engine and location E for No. 5. (See Instrumentation, Appendix A.)

SALT SURVEY INSTRUMENTATION

The on-deck instrumentation shown in Figu[illegible] consists of a Nuclepore filter probe at the top and a Knollenberg (PMS, Particle Measuring System) electro-optical probe beneath the Nuclepore probe for real time measurements of the size distribution of salt spray particles in the size range of 1 to 50 μm diameter. All sizes of particles up to approximately 1 mm are drawn into the instrument mounted below these probes in Figure 2. This instrument is called the Salt Spray Conductivity Meter (SSCM). It includes both the small droplets and the larger quantities of water which are present in droplets larger than 50 μm. The water samples collected in the SSCM can also be brought back to the laboratory and analyzed for other constituents in the sample, particularly sand. Water collected in this manner averaged 72 parts per million of salt in air over the entire mission, implying peaks of at least 1000 parts per million during the heavy loading portions of the

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operations. This information on the salt content of the large droplets is of value in the design of hook-vane roughing stage and proper drains for the LCAC intake filtration system. However, in any consideration of filtration of the air going to the engine intakes, the only particles of consequence are those smaller than about 50 μm. These are the only particles which cause a problem in separating them from the air. They require tight mesh or barrier type filters. All of the instrumentation employed in this survey other than the SSCM was chosen to measure the particles generally between one and fifty microns diameter. These instruments indicated approximately 2 PPM (parts per million) of salt in the air on deck and 4 PPM in the bag plenum at location B in sizes smaller than 50 μm.

These instruments at "B" are shown in Figure 3. They consist of a Nuclepore probe extending vertically downward through the deck into the bag plenum space (where the value of 4 PPM was measured) and a PMS probe inserted horizontally into the elbow of the "boiler plate" duct. This latter probe malfunctioned and did not provide the data hoped for on particles sizes in this pressurized duct. A Nuclepore probe used through the blow-in door space under engine No. 6 at position D of Figure 1 and engine No. 5 at position E is shown in Figure 4. This probe is located in the air entering the engine bellmouth directly above the probe shown in Figure 4. When the engine intake plenum is operated unpressurized (as was the case of engines No. 1 to 5) leakage can occur either around the edges of the inlet filters so that salt may enter the bellmouth near its periphery, missing the instrumentation probe, or air may leak into the engine intake duct above the bellmouth in the secondary cooling air space. In either case the leakage salt will not be registered in the instrumentation probe. The probes will measure only the air passing through the intake filters, but will not be representative of the total air entering the engine. On this mission (085) the probe in No. 5 engine inlet plenum indicated an average of 0.004 PPM salt in air and that in the pressurized inlet of No. 6 engine averaged 0.25 PPM. A discussion of the effects of leakage and other aspects of these readings will follow later.

MISSION 085 OPERATIONS

The mission test plan called for obtaining one set of salt survey data in the relatively calm St. Andrews Bay, and passing into the Gulf of Mexico at Lands End. The mission then would proceed in the Gulf to Crooked Island, where it would cross the beach and pick up the Vice Chief of Naval Operations (VCNO) for a demonstration of the craft operations. After off-loading the VCNO, the mission would proceed in the Gulf to a location off Shell Island, where the craft would rendezvous with a Surface Effect Ship (SES) BH/110 for joint operations. This rendezvous was not accomplished because BH/110 was down for repairs. Interwoven throughout the mission test plan were tests for the salt survey, in which the types of operation were, in so far as possible, conducted in 15 minute increments with provision for setting down for 10 or 15 minutes after each task to permit the NRL scientists to change Nuclepore probes in order to isolate the effects of the various types of operations on the salt loading. It had been originally planned to conduct the various salt spray tests on four missions with probes located in different locations on the different missions. However, as many as possible of the types of craft manuever were integrated into this mission in case it might not be possible to continue missions on following days (as turned out to be the case). Through the exceptional efforts of the Experimental Trials Unit (ETU) most of the more important phases of the test operations were completed during a 6 1/3 hour mission, one of the longest missions accomplished to date. A summary of the operations and measurements taken during mission 085 are presented in Table I. The times shown in the first column of Table I indicate the beginning of one-minute time slices in which the Bell computer reduced their onboard instrumentation readings to engineering unit readouts for use in characterizing the various portions of the mission. The particular operation being conducted during each time-interval block of Table I started two minutes before the first time shown in each block and continued for approximately 15 minutes, ending three minutes after the second time shown in each block. The second column labeled "Task Number" identifies the the operational tasks as listed in the test plan and log for the mission. The next two columns show the wind heading and velocity in knots relative to the craft. The next two columns indicate the craft heading and speed. It had been intended to conduct each phase of the salt survey test operations at three engine speeds (N_2). For this mission the minimum and maximum N_2 values of 88 and 95 percent of maximum were chosen in order to minimize the number of tests conducted on this one mission. These values of percent of max N_2 are shown in the next column of Table I. The next three columns present the salt spray measurement data taken on deck. The first of these columns shows the parts per million of salt in air as measured by the Knollenberg (PMS) instrument. The second column shows the effective mass median diameter (MMD) of the particles being measured by this instrument in micrometers (μm). The two cases in which Nuclepore data were available from the pressurized bag plenum simultaneously with the deck are shown in the data blocks of time intervals 1030-36 and 1155-1211. In each of these cases it can be seen that the value in the bag is approximately twice that on deck. The average of the parts per million (PPM) values measured on deck was approximately 2 PPM and in the bag, 4 PPM. The mass median diameters of the particles within the 1 to 50 micron range of these instruments fall generally in the range of 12 to 40 microns. The next three columns labeled "Engine Bellmouth" present the data from the Nuclepore probes mounted under engines No. 5 and No. 6. The average for the engine No. 5 values is 0.004 PPM and that for No. 6 is 0.25. The third column shows the ratios of the readings for number 6 to those for number 5 for the various tests. In the last column is shown the type of operation being conducted under each of these tasks.

The hope of comparing two engine speeds (N_2) for each type of operation succeeded only for the case of proceeding upwind at 10 knots. In this case the data seem to say that more salt was ingested at the higher engine RPM, both in terms of the readings on deck and that ingested in No. 6 engine. Although one single reading is insufficient to draw any firm conclusions, these data, on their face, indicate that the effect of the higher engine speed is to increase the salt loading. However, this period in the testing coincided with that in which the sea states had increased to some extent, so that the effect of engine RPM (N_2) here is not conclusive. The highest loadings were found during the starboard crosswinds and the accel-decel operations. It is reasonable that the starboard crosswinds heading should provide more salt to the starboard side of the deck where this instrumentation was located. The increase in salt during acceleration and deceleration has also been documented previously. A typical example of the higher salt loadings during acceleration and deceleration compared to normal running is shown in Figure 5. Typical size distribution during acceleration and deceleration are shown in Figure 6. The ordinate indicates the cumulative PPM of salt in particles smaller than each size shown on the abscissa. For example, on the acceleration curve with a total of 10 PPM, the MMD (mass median diameter) is 32 μm, meaning that 5 PPM or half of the salt is in particles smaller than 32 μm and half is in particles larger than 32 μm. Similarly during deceleration the total is 2 PPM and MMD is 19 μm. Detailed Nuclepore data tables are presented in Appendix E and PMS data in F.

ENGINE WASH WATER SALINITY DATA

After each mission each engine is routinely water washed with a "deluge wash" of ten gallons of water flushed through in less than one minute while the engine is being rotated by the starter. At the end of this first ten gallons of deluge wash, a water sample is routinely taken from the combuster drain valve. This sample's salinity is checked by electrical conductivity to determine whether or not the residual salt in the engine is sufficiently low so that no additional washing of that engine is required. These data are tabulated for mission 085 in Table II in the third column labeled "Residual in Compressor at End Ten Gallons". For mission 085 an additional procedure was carried out whereby a sample was collected during the first ten gallon deluge wash. This procedure was designed to distribute that sample uniformly throughout the ten gallons in order to measure the amount of salt removed from the engine in this water. Approximately one half of the ten gallons of water introduced was blown out through the exhaust of each engine and the remaining portion drained rapidly from the combustor drain valve during approximately one minute. This water ejecting from the drain valve was collected during several two-second intervals spaced approximately five seconds apart throughout this wash cycle in an attempt to obtain a fairly representative sample of the first ten gallons of wash water. The salt in these samples is tabulated in the second column of Table II in terms of the PPM of salt in the water in the sample averaged over the ten gallons of water. The three entries in column two with an asterisk indicated those in which the sample was collected fairly undisturbed as compared to that from engines 2, 4, and 5 where the water was splashing off wire, pipes, etc., as it was being collected. The value of 130 PPM shown for engine No. 2 includes an estimate of the salt lost by water wash performed during the mission. For this estimation the salt was prorated according to the accumulated running time before and after the underway water wash. The total salt accumulated in each engine is best represented by the sum of that in the first ten gallons of wash water and that remaining at the end of ten gallons (column 3 of Table II). This total is shown in column 5 labeled "Total by Electrical Conductivity" of salt in the water. The last column labeled "Total by Atomic Absorption" indicates the amount of salt found by a later laboratory analysis of sodium in the samples using the method of flame spectroscopy called "atomic absorption." This method is less influenced by contamination in the sample than is the electrical conductivity method normally used. It is interesting to note that the two samples from engines No. 4 and No. 5 which showed a larger reading by atomic absorption than by electrical conductivity are also two of the samples in which the water was splashing off of the pipes and wires while being collected. This lower reading by conductivity may be explained by the fact that any contamination of a sample by hydraulic fluid and such being washed off the pipes and wires would tend to contaminate the electrodes of the electrical conductivity instrument and cause a reduced reading by the conductivity method, but not by atomic absorption.

Since the only wash water salinity data available from most missions is that such as is shown in column 3 taken at the end of the 10 gallon deluge wash, a comparison was made for mission 085 between these readings and those obtained during the first 10 gallons of water wash. The percent of the residual at the end as compared to the total engine salt is tabulated in column 4 of Table II. From this column it can be seen that the percentage varies considerably (from approximately 5 to 18%), but the average factor of approximately 11.5% can possibly be used as a rough indication of the amount of salt ingested on other missions where this is the only type of data available.

In order to determine the amount of salt in PPM of air ingested by an engine it is necessary to know not only the total weight of salt collected in the wash water but also the weight of air drawn into the engine during the mission for which the wash water sample was taken. In the note at the right-hand side of Table II the average amount of intake air is shown as 22.85 lbs per second, derived from the computer printouts of engineering units tabulated by Bell. On mission 085, because of repeated setdowns for probe change, the total operating time underway was 3 hours as compared to idle time of 3 1/3 hours. During these periods of idle the air intake to each engine was approximately 12 pounds per second. For this mission the total intake air was 190 tons per engine. For this mission the value of the ratio of PPM of salt in water to PPM in air is 5,000. Therefore, multiplying the PPM-in-water value tabulated in Table II by this factor of 5,000 provides the data needed to calculate the average PPM of salt in the air entering each engine.

COMPARISON OF PRESSURIZED VS AMBIENT INTAKE AIR

Engine Degradation and Salt Ingestion

In Table III the average ingested salt PPM in air at the engine intake as calculated from Table II is tabulated in columns 6 and 7. Since engines No. 1 - 5 (which are all unpressurized) have considerable spread in the data as shown in Table II, the average of these five engines was used wherever possible in the comparisons rather than comparing No. 6 pressurized engine to No. 5 alone. An exception to this is for the case of the Nuclepore readings in column 8 where there was no comparable data from engines 1 thru 4 and where the Nuclepore information from No. 5 is reliable for comparison to that from No. 6 engine. The ratio of salt in No. 6 to the average of Nos. 1 thru 5 indicates approximately 8 to 10X higher salt loading for the pressurized engine No. 6. It is interesting to note that for the average of all previous missions in which engine No. 6 was pressurized (shown in column 5), there was essentially no difference between the wash water salinity found in engine No. 6 as compared to the average of engines 1 to 5.

This same pattern is evident in the engine degradation data. In columns 2,3, and 4 of Table III are tabulated the engine degradation measured by the loss in the ratio between the intake pressure and discharge pressure of the compressor. In column 3 the loss rate in percent per hour is shown for mission 085 averaging the degradation over the entire 6.3-hour duration of the mission. Since approximately half of this mission was spent at idle while changing probes for the salt survey, the total air ingested in the engines was reduced to the equivalent of a 4.7-hour running time. The total degradations for the mission divided by 4.7 hours are shown in column 4. Since the degradation in No. 6 engine was probably as great or greater during the idle periods than during the running time, the 6.3-hour values probably should be used for No. 6 engine, whereas engines 1 thru 5 had little degradation during these idle periods so that the values in the 4.7-hour column should probably be used for engines 1 thru 5. On this basis, the ratio of degradation for No. 6 engine to that for No. 5 would be approximately a factor of 10 rather than the factor of 14 as shown in Table III. This ratio of ten, possibly fortuitously, is approximately equal to the ratios of the salt ingested as shown in columns 6 and 7. Engine degradation during the other missions (078-084) in which No. 6 engine was pressurized are shown in column 2 of Table III. These values indicate that for those missions in which there were not repeated setdowns for probe changes (as was the case in mission 085) the degradation in engine No. 6 was only 70% higher than that for the average of engines 1 thru 5. This small difference could well be accounted for solely by the fact that No. 6 engine with its pressurization "boiler plate" could not accomodate a second stage agglomerator filter as was used in engines 1 thru 5. See Appendix D for filter arrangements. Two possible explanations for the considerably greater degradation of No. 6 engine on mission 085 are (a) that more spray is ingested into the lift fan outboard inlet at low speeds as compared to that at higher speeds, therefore causing a greater average ingestion into the fans and to the pressurized duct of No. 6 engine on this mission; or (b) the fact that when the craft settles down in the water during idle, water floods the bag plenum where air is blowing back to the pressurization duct for No. 6 engine. During lift off, when the fan speeds are increased to raise the craft, this air velocity becomes quite high both blowing downward onto the water in the bag immediately under the lift fan and also blowing along the length of this water surface until this water has time to drain out. In Figure 7 the engine degradation for engines No. 5 and No. 6 are shown throughout mission 085. Here it can be noted that the greatest degradation in engine No. 6 occurred at approximately 1330. Referring back to Table I it should be noted that at approximately this time the ingested salt at the engine bellmouth in column 11 indicates that this is the first period in which the PPM ingested into engine No. 6 exceeded the value of 0.1 PPM which the original AVCO engine data indicated was the transition loading for considerably increased degradation of the engine.

Effects of Leakage With Unpressurized Intake

It has been found in various wind tunnel tests that what appear to be insignificant amounts of leakage bypassing a filter can cause more salt loading than the entire salt coming through the filters. An advantage of the pressurized intake system is that any leakage is out into the atmosphere rather than into the engine. As mentioned earlier, a tool for determining the amount of leakage into the engine intake is provided by locating the instrument probes near the center of the engine intake bellmouth, such that air leaked either around the periphery of the filter or into the engine intake ducting in the secondary cooling air space above the bellmouth is not sampled. Wash water, on the other hand, provides a measure of the total salt ingested into the engine during a mission, independent of whether this loading was through the filter or through leaks bypassing a filter. A comparison of these two salt loading measurements then provides a measure of leakage present for that engine. This comparison in Table III between columns 8 and 6 or 7 indicates that for the pressurized engine No. 6 the Nuclepore probe read essentially the same amount of salt loading as did the salinity of the engine wash water. The probable leakage is shown in column 9 as the difference between the Nuclepore reading and the wash water salt loading reading. For Engine No. 5 this probable leakage is 0.009-.011 ppm or a factor of 2 to 3 times more salt entering the engine by leak paths than through the filters. This implies that if no leaks had been present, engine No. 5 would have been 2 to 3 times cleaner than it was as compared to the No. 6 pressurized engine. This leakage factor of 2 to 3 is a considerable improvement over the factors found by the same method (comparison with wash water) during early missions surveyed in 1978. At that time this ratio was a factor of 30 to 50 times more leakage than salt through the filters. In other words, the leakage factor has been improved by approximately a factor of 20.

This factor of 20 improvement in leakage from 1978 to the present tests is corroborated by the same factor of 20 improvement in the engine degradation between the 1978 missions and recent ones, as shown in Figure 8. In this figure it can be seen that the original filters cause a degradation rate of approximate 2 1/2 to 3% per hour. The addition of air inlet duct sheds improved this by approximately a factor of 4. The bottom curves labeled 107/108 show approximately 0.1% per hour degradation rate. While it can be argued that this improvement is due to the improved filters in the 107/108 configuration, it should be noted that during mission 085 the port side of the craft was still using essentially the original base line type of filters on engines 2 and 4. The variation among the engines, probably from leakage, was sufficient to mask any improvement on the starboard side using configuration 107/108 as compared to the port side with the nearly basic filter configuration. This variation is apparent both in the engine wash water salinity data and in engine degradation data taken on recent missions (078-085). Whereas the forward engines 1 and 2 are expected to be generally cleaner than the aft engines, Table I' shows that on mission 085 on the starboard side the forward engines 1 and 3 were dirtier than the aft engine No. 5. Likewise, on the port side the forward engine 2 was dirtier than 4. Both port engines 2 and 4 (using essentially the original base line configuration of filters) were cleaner than the corresponding starboard engines with the improved filters 107/108. On other missions the order is sometimes similar to this and sometimes totally mixed in other patterns both in the wash water salinity and in engine degradation. This variability seems to indicate that variations in leakage among the engines is a more dominant factor in the salt loadings than is the difference between the original base line filters plus a hook-vane stage as compared to the best filter combination which has been tried so far, 107/108. The three conclusions that can be drawn with regard to leakage are (a) that the leakage present in all of the intakes may not be curable with any reasonable degree of success, particularly during variable maintenance, (b) pressurization is a simple solution to the problem of the leaks and (c) if leaks could be totally eliminated the ambient deck air would have been 5 to 8 times cleaner than the pressurized air as used in missions 078 through 085 (20X on mission 085). See Appendix D, Filter Configurations.

Bow Ramp Hinge Leakage

During previous salt survey missions it was determined that approximately half of the normal salt loadings to the engines from the ambient deck air is caused by a cloud or fog generated at the hinge of the bow ramp. Water collects at this low point and is atomized by cushion air leaking up through the hinge and through this collected water. The factor by which ambient deck air through an unpressurized intake is cleaner than the pressurized system as used on missions 078 through 085 would have been approximately doubled in favor of the unpressurized engines if the bow ramp hinge leak could have been sealed. Combining (a) this factor of 2 with (b) the factor of 2 cleaner air already found on deck and (c) the factor of 2 to 3 times cleaner which the unpressurized engine could have been without leaks around the filters, the total advantage of unpressurized deck air vs. pressurized bag air is approximately a factor of 8 advantage to the unpressurized system (if ideally sealed etc.). For a mission with many setdowns such as 085, this factor of 8 is probably increased to at least 20. In Table II column 8 it was actually a factor of 60 on mission 085.

SAND

During the entire mission 085 approximately one gram of sand was collected in the SSCM on the deck, probably mainly during the 8 minutes of run over the sand and beach areas. This amount of sand averaged over 4.7 hours would indicate 2.5 PPM of sand in the air. If we assume that it was all acquired during the 8-minute beach run this would be equivalent to 88 PPM of sand in air for that period. The sizes of this sand were found to be as follows: 98% larger than 150 μm diameter, 1.2% between 44 and 150 μm, and 0.5% smaller than 44 μm. Much of the sand at the intakes of engines No. 1 thru 5 was accumulated in the second stage agglomerator filter. Figure 9 shows a photo of this sand. It appears heaviest near the bottom, but with some distribution all the way up the face of the filter. Possibly because of the lack of this filter stage in engine No.6, sand came through sufficiently so that it was found accumulated on the blow-in door and other areas of the intake plenum downstream of the filters. The Nuclepore samplers found an average of 0.09 PPM of sand in the air to No. 5 engine and 0.23 PPM in No. 6 (2.7 times that in No. 5). In tasks No. 1 and No. 2 coming off the ramp and in St. Andrews

Bay the deck showed 4.9 times more sand than that in the bag plenum. In the design of inlet filters systems, two important factors to consider are that (a) an agglomerator or barrier type filter upstream from the spin-tubes may plug up; and (b) the filter drain system must be designed to handle large quantities of sand without clogging. The exception to these requirements may be for the case that the engine inlet air is ducted from a clean area of the lift fans to be considered below.

SALT AND SAND SEPARATION BY LIFT FANS

Considering the advantages reported here of a pressurized system in avoiding the problems of leaks bypassing the filters measured against the disadvantage of the present pressurized inlet having higher salt and sand loadings, the question naturally follows: Can a pressurized system be designed for LCAC which is also cleaner than the ambient deck air inlets? To answer this question let us consider some of the mechanisms involved in causing the high salt loadings in the present pressurized air configuration. A visualization of the fog in the present lift fan air can be seen by the trail of fog exiting from the bow thrusters. When the bow thrusters are turned such that their effluent goes down along the deck, one can visually see this cloud to be a much more dense spray than is present on the rest of the deck. On some occasions this cloud can be seen to enter the engine intakes. At these times the salt loading to the engines is greatly increased. This same air is being used to pressurize engine No. 6, with the possible exception that it takes approximately two second for the air to transit from the lift fans back through the bag to the engine, whereas the bow thruster air blowing directly down the deck takes about one second to enter on engine intake. However, any settling of the droplets in going the length of the bag plenum is still negligible for droplets smaller than 50 µm, the primary particle size range of interest in causing the problem of salt separation by the intake filters. The settling velocity for the 50µm particles during the two seconds of traverse through the length of the bag plenum is approximately 5 centimeters per second and for the one micron particles is only one-hundredth of a centimeter per second. Ten micron droplets are intermediate in settling velocity at approximately 1/2 centimeter per second. All of these settling velocities are sufficiently slow so that a negligible amount of separation is effected during the two seconds of transit time through the bag plenum.

Although some sand and debris are carried over the superstructure and enter the deck areas, (as evidenced by the sand shown on the second stage agglomerator pad of Figure 9 and debris collected at the inboard lift fan inlets as shown in Figure 10), still the largest amount of salt, sand, and debris are entrained from the outboard lift fan inlet as evidenced by the pattern of paint stripping inside the lift fan scroll volute shown in Figure 11. In this figure, the paint has been stripped clean from the outboard inlet at the left of the picture to approximately 6 inches inboard of the center line of the rotor; then the paint is still intact at the right hand side of the figure and extending beyond the photo for a total distance of approximately two feet toward the inboard or deck-side lift fan inlet. This figure graphically demonstrates how much cleaner the lift fan air would be if it could be ducted from the two feet inboard where the paint is not stripped or if all lift air were drawn from the inboard side. While it is recognized that it may be impossible on LCAC craft design to bring air from this point, it should be pointed out that on the present JEFF (B) design there is a passageway approximately 3 by 4 feet ducting this clean air from the center line of the lift fans across into the athwart ship stablizer and cushion area (from the location that should be most nearly free of salt and sand loading). A further reduction in loading could undoubtedly be achieved if the fan scrolls and rotation were reversed or the geometry could otherwise be arranged such that the engine inlet air could be ducted from a portion of the fan exhaust near the inner radius side of the scroll. Here most of the salt and sand would have been centrifuged toward the outer radius and thereby miss the duct pickup point.

If air could be ducted from such a location, it is probable that essentially all sand and large salt spray droplets would be eliminated before entering this duct and the only filtration required might be a single low pressure drop stage or a Duralife type of filter. This type of configuration would fairly closely resemble the British Hovercraft SN4 configuration except with the vertical fan shaft rotated to horizontal as in the JEFF (B).

CONCLUSIONS

AALC salt survey conclusions were developed jointly by representatives of NRL DTNSRDC, and ETU based on the conditions: (a) engine No. 6 has one less barrier (agglomerator) filter than engine No. 5; (b) leakage paths exist downstream of the filters in engine Nos. 1 thru 5 which increase salt loadings by 2X; (c) a moisture cloud from a bow ramp hinge leak produces salt loadings in the engine air intakes equivalent to 1/2 that of the total deck loading; and (d) during mission 085, JEFF (B) came off cushion many times during the 6-hour mission, thus generating considerably more spray than during the more "normal" missions 078-084. These conclusions are as follows:

1. Bag air is at least 2X dirtier than ambient air in the 1-50μ range. (4PPM vs 2PPM)

2. Engine No. 6 (pressurized) ingested 8X-20X more salt than engines 1-5.

3. Engine No. 6 compressor pressure ratio degradation is 14X higher than engine nos. 1-5.

4. During "Normal" missions 078-084, engine No. 6 compressor pressure ratio degradation was only 70% higher than engine Nos. 1-5.

5. Engine Nos. 1-5 still receive 2X more salt through downstream filter leaks than through the filters themselves.

6. Lift fan paint degradation patterns confirm that ingestion is severe on the outboard side of the volute.

7. Potentially, in the JEFF (B) configuration, unpressurized deck air would be "cleaner" than bag air by 4-8X if bow hinge leaks and downstream filter leaks could be eliminated.

8. Potentially, in the JEFF (B) configuration, pressurized air would be comparable to deck air in cleanliness only if air from the inboard side of the lift fan volute were used.

9. Increasing the number of off-cushion/on-cushion transitions increases salt ingestion into the pressurized engine more than into the unpressurized engine.

10. Engine degradation, when subjected to salt above 0.14 PPM, correlates with AVCO experimental data (TF-35 engine).

11. The pressurized engine data demonstrated that the effect of leakage downstream of the filters was eliminated.

12. Leakage downstream of the filters in an unpressurized system may be impossible to reduce below that achieved on JEFF (B) due to practical limitations on structural sealing.

13. Leakage appears to dominate over filter design, judging by the lower salt loadings in engines 2 and 4 than in Nos. 1, 3 and 5 which had the improved 107/108 filter configuration.

14. Large droplet sizes must be filtered by means of a roughing stage, such as a hook-vane filter (for particle sizes greater than 50 μm).

15. Sand ingestion is greater in engine No. 6 than in engine No. 5.

16. Ingestion of debris, such as grass, has not yet been evaluated relative to advantages of pressurized vs unpressurized engines.

17. Additional tests on JEFF (B) are required to compare engines 5 and 6 with identical filters installed in each intake. Future JEFF (B) tests by NAVSSES. concentrate on improved collection of engine wash water during first 10 gallons, possibly use one Nuclepore for entire mission in No. 5 and one in No. 6 blow-in door with identical inlet filters in No. 5 and No. 6, and normal missions w/o set-downs.

18. With a pressurized system scavenge fans can be eliminated for the spin tubes.

19. During the higher-sea-state portion of mission 085 both the NRL bag air thermometer and Bell's TT2 in #6 inlet indicated that the temperature rise from pressurization was only half of the ΔT values which have been used in previous calculations

of pressurized engine performance. Evaporation of the spray may cause this cooling. (See Appendix B.)

LCAC INLET RECOMMENDATIONS

1. Use a spray suppression device to reduce the amount of salt spray ingested into the engines.

2. Consider use of a Duralife filter as the final stage in the filter arrangement.

3. Design consideration must be given to achieving long engine life in addition to extending the time periods between required water washes.

4. Engine air intakes must be located to minimize spray/sand ingestion.

5. Lift fan air intakes must be located to minimize spray/sand ingestion; particularly if a pressurized engine air inlet is to be used with air from the plenum.

6. Filter arrangements must provide for easy removal of the various filter components to permit daily cleaning.

7. If possible, duct engine intake air from deck side of lift fan inner radius (probably low ΔP single-stage barrier or Duralife would suffice).

8. If not possible, then concentrate on sealing against leaks at intake and bow hinge and use unpressurized deck air (predict 5X cleaner on normal mission, 20X with frequent set-downs).

9. If a heavy sand environment is to be handled, hooked vane and spin tube should be installed ahead of any agglomerator in order to avoid plugging the agglomerator with sand; drains must also be designed to avoid plugging with sand.

10. The inlet design should be integrated with the design of structure and propulsion system; e.g., if lift fan rotation and scrolls were reversed from the Jeff (B), engine air ducting could more easily utilize the cleaner air available from the inner radius of the volutes.

11. Previous calculations of pressurized engine performance should be rechecked taking into account the greater density of the pressurized air if its temperature rise during the higher sea state portion of mission 085 is only half of the expected ΔT. (See Conclusion 19 and Appendix B.)

ACKNOWLEDGEMENTS

The JEFF (B) officers and crew made exceptional efforts in order to perform during mission 085 most of the salt test tasks which had been scheduled to be performed over a series of missions. Particular credit is due LT J. N. Mullican, Officer in Charge of JEFF (B). The Experimental Test Unit (ETU) staff provided support and encouragement under the leadership of Messrs. Allan Kidd and David Gerzina. All photos are courtesy of Mr. Stuart Bumgardner, ETU. The Bell Aerospace team provided excellent support in installation of the instrumentation and in engine data computation and printout -- particular thanks to Messrs. Michael Dvornak, Al Coles, Luther Cassler, and Chuck Lester. The DTNSRDC program office sponsored the salt survey; Mr. James Kordenbrock provided helpful guidance and encouragement. Messrs. Richard Weiss, Joseph Baron and Anthony DiGiovanni of NAVSSES, Philadelphia, assisted, including late at night, in installing the instrumentation, collecting the engine wash water samples, and performing the atomic absorption sodium analyses. At NRL Mr. Ron Beattie prepared the PMS instrumentation and contributed to its installation, including late at night. Mr. David Bressan developed the SSCM instrument. Mrs. Bettie Edger prepared this report for reproduction.

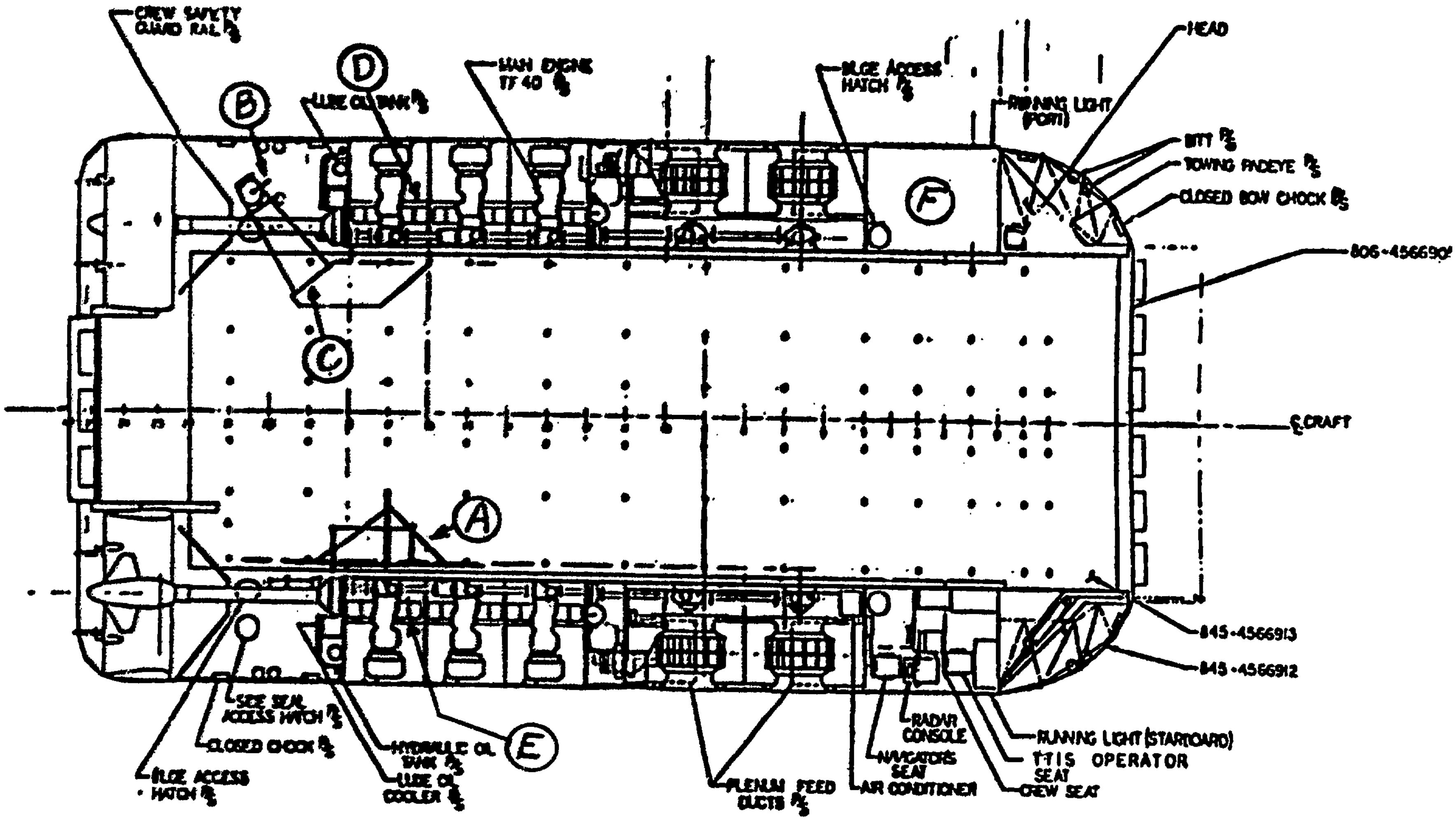


Fig. 1. Plan View Sketch of JEFF (B) Showing Salt Survey Instrument Locations: A - On-Deck Nuclepore, PMS, SSCM; B - Nuclepore and PRT Through Deck, PMS, in Pressurization Duct; C - Plenum Ducting Air to No. 6 Inlet (No Instruments); D and E - Nuclepore Probes Through Blow-in Door into Intake Plenum; F - Controls and Readouts in Port Cabin.

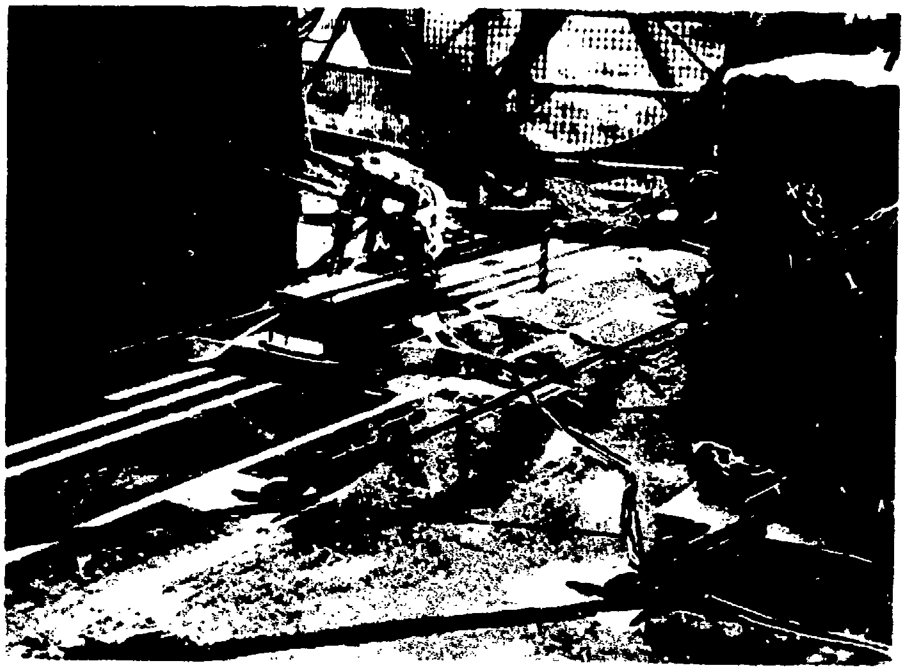


Fig. 2. Nuclepore (Top), PMS Probe on Antenna Rotor, SSCM (Left) on Deck Plate in Front of No. 5 Inlet.

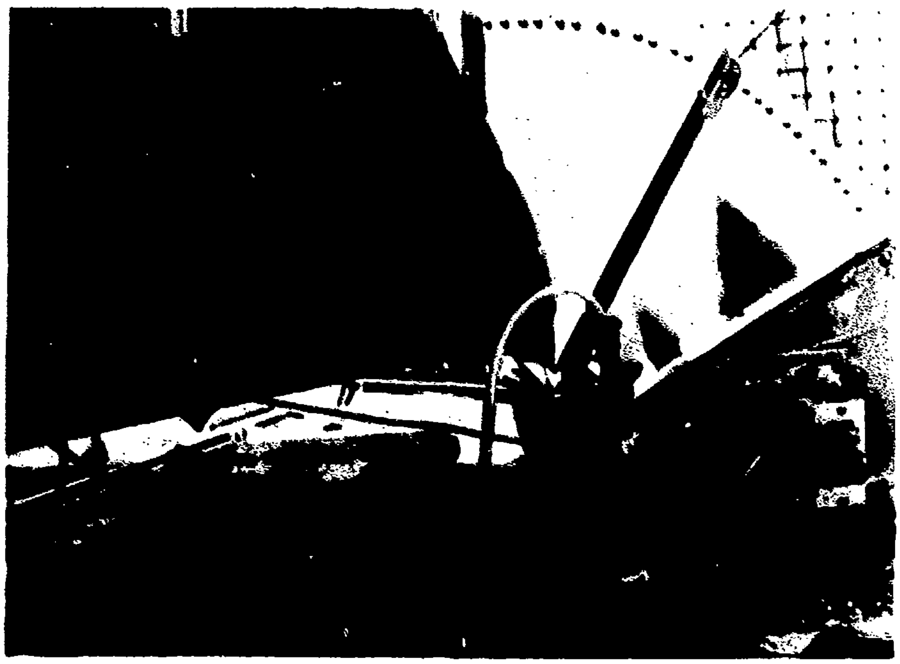


Fig. 3. Nuclepore Probe Mounted Through Deck (Lower Right of Center); PMS Probe Into Pressurization Duct (Right)

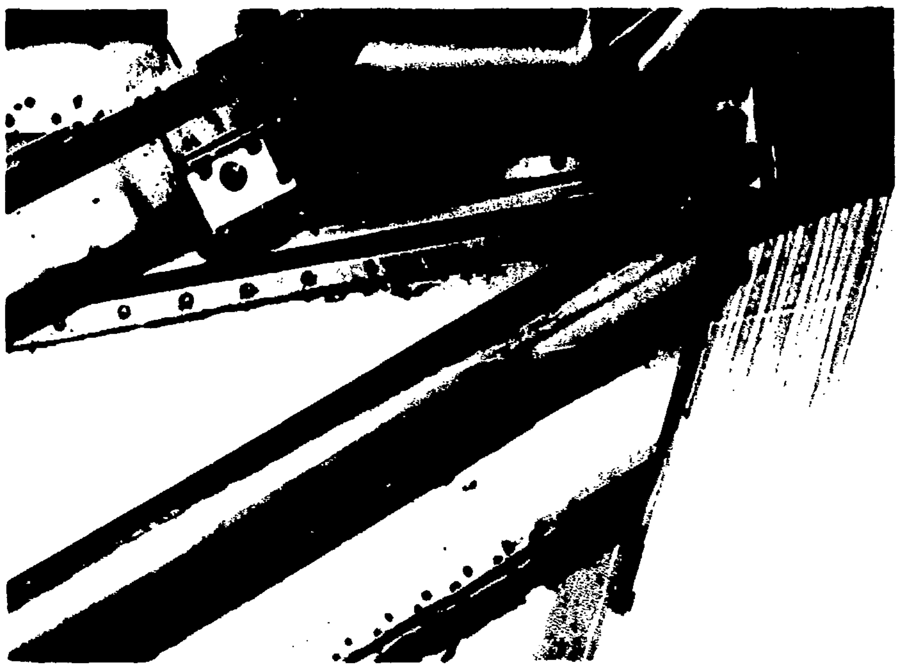


Fig. 4. Inside Intake Plenum: Nuclepore Probe (Lower Left to Center); Blow-in Door Latched Up (Upper Left); Engine Intake Bellmouth (Top Center); Last-Stage Hook Vane Filter (Right).

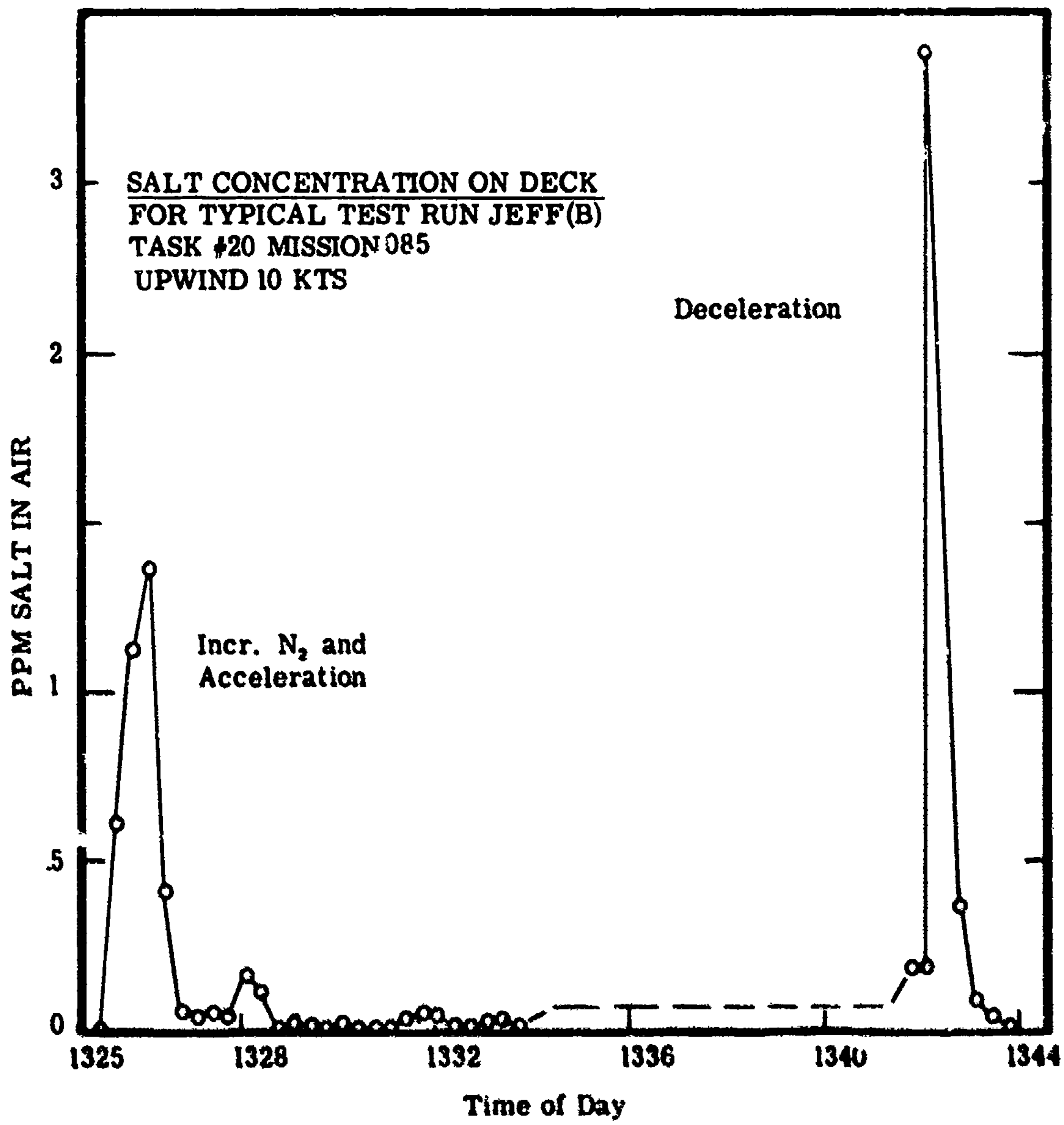


Fig. 5. Salt Loadings on Deck During Acceleration, on Cushion and Deceleration (PMS Data).

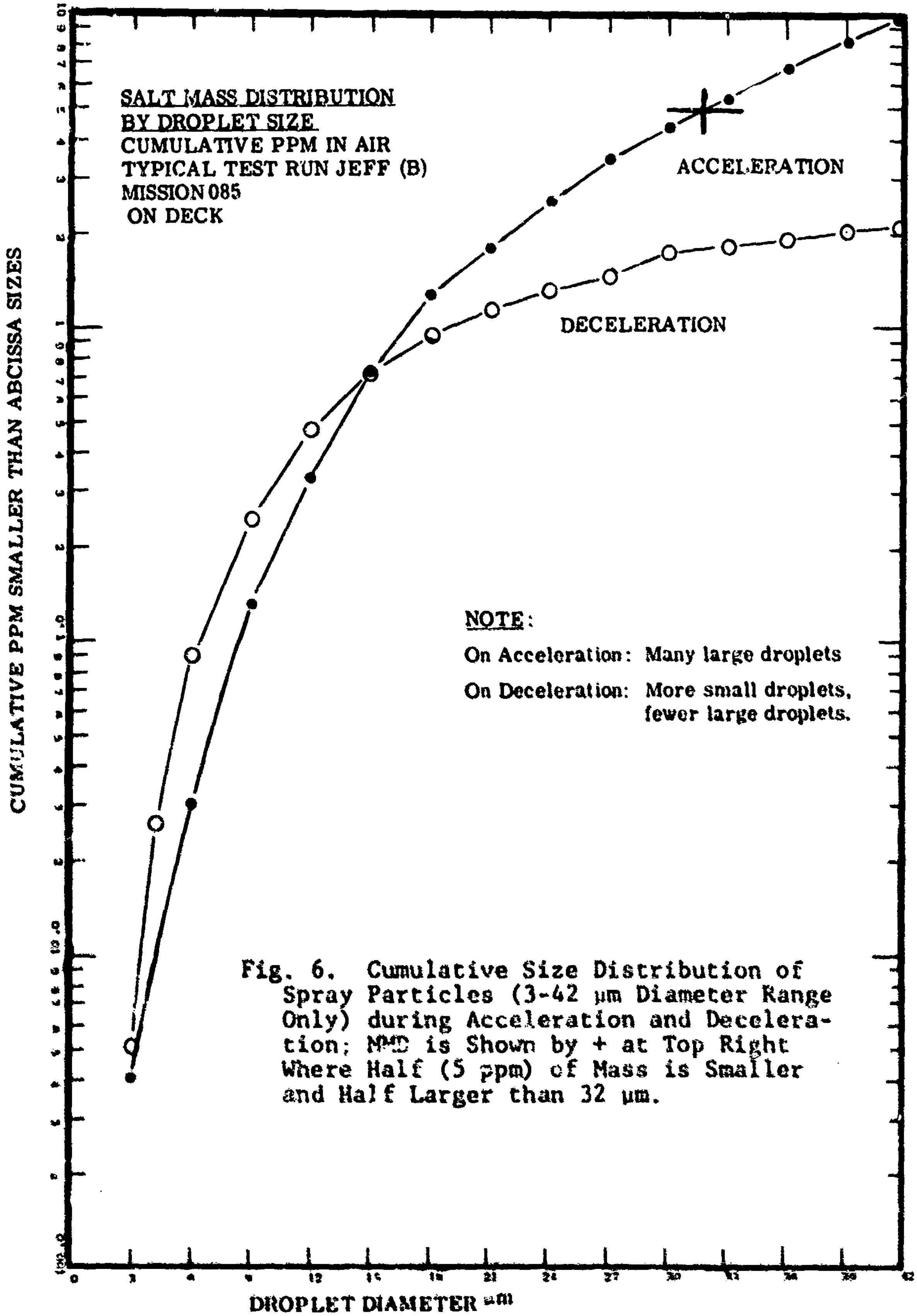


Fig. 6. Cumulative Size Distribution of Spray Particles (3-42 μm Diameter Range Only) during Acceleration and Deceleration; MMD is Shown by + at Top Right Where Half (5 ppm) of Mass is Smaller and Half Larger than 32 μm.

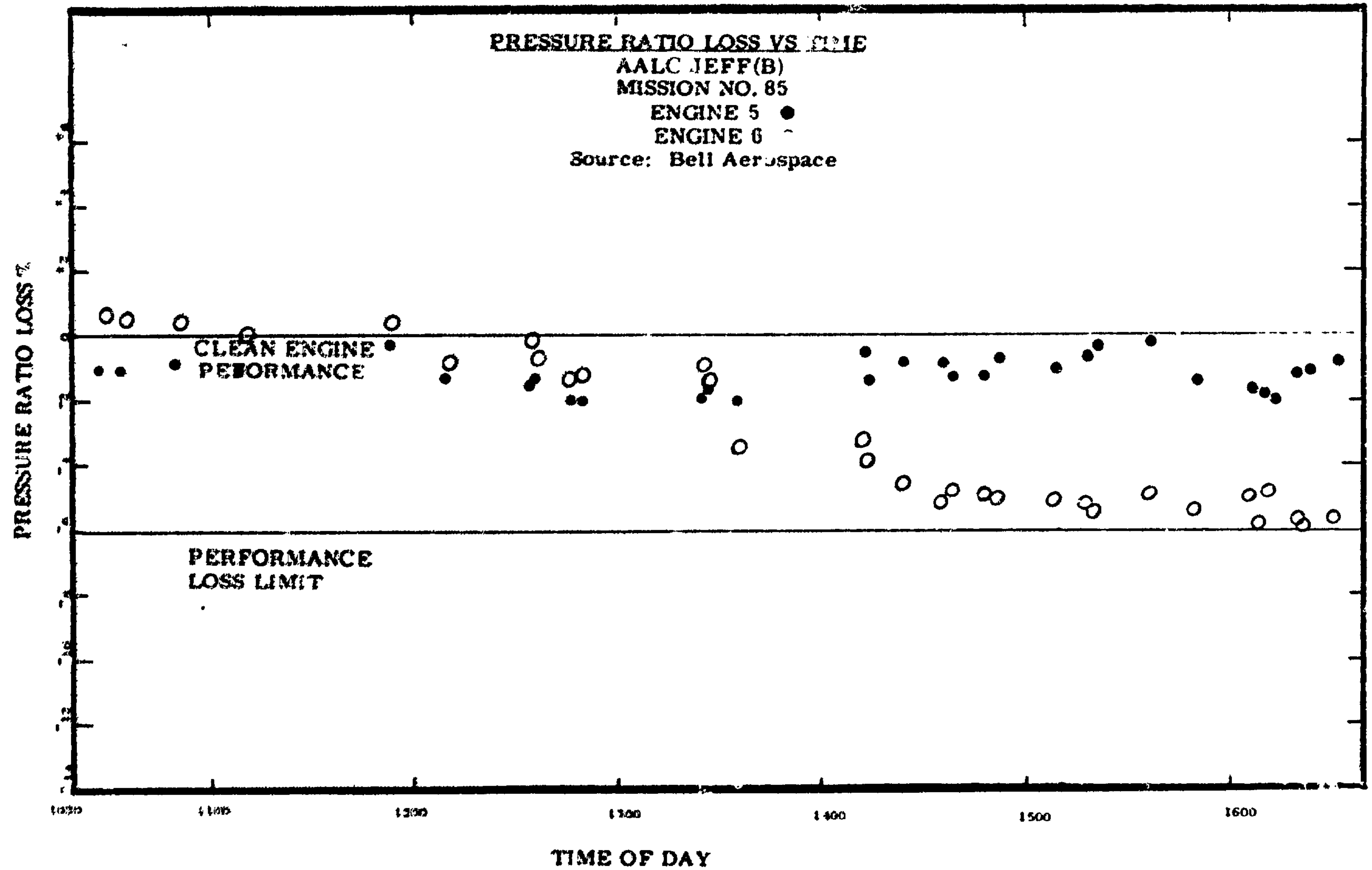
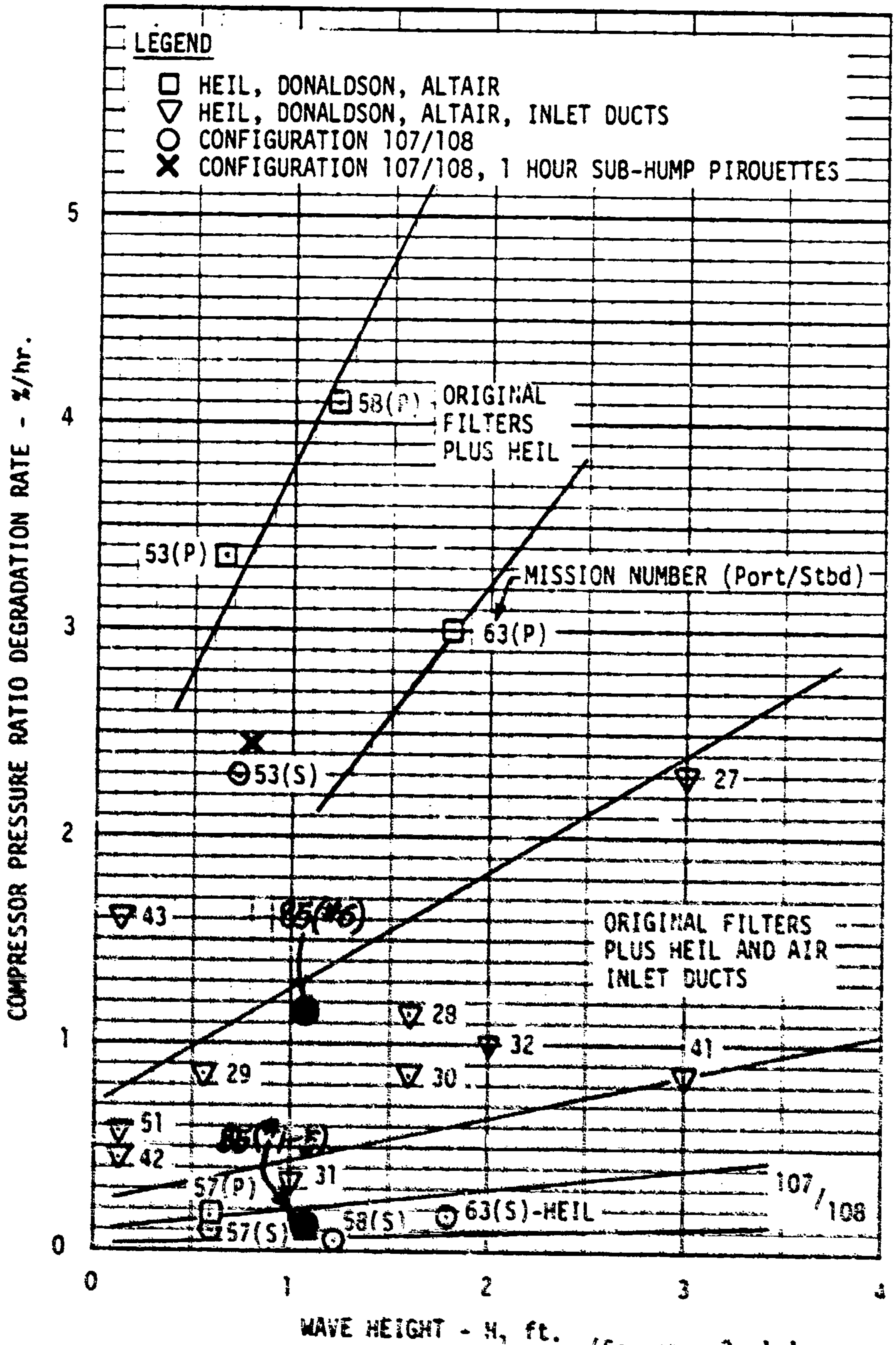


Fig. 7. Chronological Plot of Engine Nos. 5 and 6 Degradation during Mission 85. Note No. 6 Fall-off at 1337h when Salt Loading Exceeded 0.14 ppm.



(Source: Bell Aerospace)

Fig. 8. JEFF (B) History of Compressor Degradation. Engine No. 6 Pressurized vs Nos. 1-5 Unpressurized on Mission 85 Shown as Solid Circles.

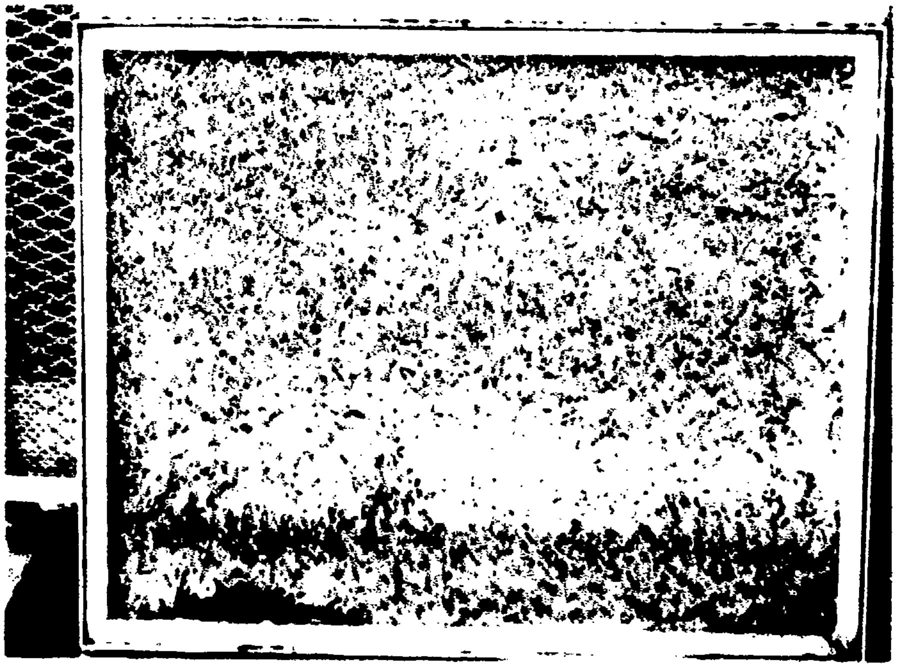


Fig. 9. Sand Nearly Plugging Agglomerator Pad Upstream of Spin Tubes After 8 Minutes of Beach Transit.

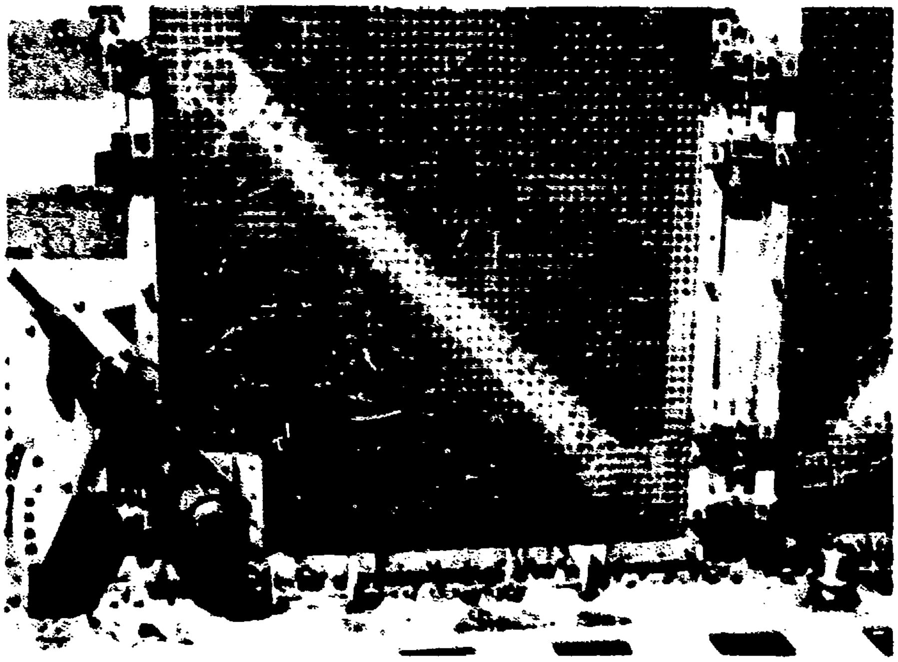


Fig. 10. Vegetation Debris Collected on Lift Fan Screens.

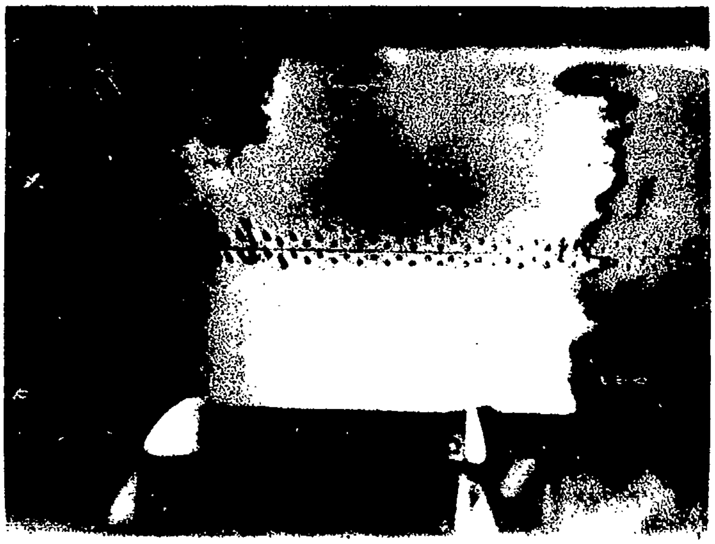


Fig. 11. Looking up into Lift Fan Scroll Volute. Paint has been Stripped Clean by Sand and Salt from Outboard Inlet at Left 6 Inches Inboard of Rotor Septum. A Possible Source of Cleaner Air for Engine Intake on LCAC is the Inboard 2 Feet Where the Paint is Still Intact (Extending Out of Photo at the Right).

TABLE I
SUMMARY MISSION 085 SALT SURVEY

Time 4/22/80	Task No.	Rel Wind Hdg°	Rel Wind Vel Kts	Craft Hdg°	Craft Speed Kts	% of Max N_2	DECK PPM (PMS) (1-50μm)	DECK MMD μm	Engine Bellmouth PPM #5	Engine Bellmouth PPM #6	Engine Bellmouth Ratio #6/#5	Operation
1030 1036	2 2	10 14	4.2 36.5	138 123	40	88 88	2.9 (Nuc) (Bag 5.3)		.0075	.11	14.4	In Bay Lands End
1052 1111	4 4	10 356	45.4 37.8	96 280	40	95 95	.8-1.8	33				In Gulf Crooked Is.
1155 1211	8 8	13 357	41 45	153 316	vary-ing	88 88	.4-1.5 .8 (Nuc)	30-33 (Bag 2.0)				Reach and Gulf
1237 1247	12 12	355 354	41.3 41.1	296 289	40	88 88	1-3	33-36	.0016	.023	14.1	Off Shell Island
1328 1337	20 20	358 355	20.1 19.5	260 260	10	88 88	.003-0.1	20-40		.04		Upwind at 10 Kts
1353	18	0	12	260	0	50	.02-.03	13-27	.0015	.29	195	Idle upwind
1413 1425	24 24	353 351	17.1 19.9	246 260	10	92 94	.02-0.2	21-36	.0009	.29	323	Upwind at 10 Kts.
1439 1448	30 30	334 327	14.4 12.1	351 351	10	94 94.5	.02-0.8	12-40	.0011			Port cross-wind at 10K
1509 1519	28 28	32 43	9.1 11.7	172 168	10	94 95	.1-10	12-40	.0063	.64	102	Stbd cross-wind at 10K
1537 1550	41 41	37 35	29.6 23.1	150 67	vary-ing	86 86.5	.2-10	20-40	.0063	.113	18	Accel-dec all Hdgs
1606 1609	43 43	8 352	13.8 10.8	263 261	0	88 88	.03-1	20-30	.0034	.48	142	Hover into 10 Kt wind
1623 1631	32 32	350 346	41.4 39.4	313 335	40	90 85	.2-2.5	30-36				Return to base 40 kts

TABLE II

ENGINE COMPARISON, SEA SALT AS MEASURED FROM WASH WATER

Engine No.	Salt/H_2O PPM Avg First 10 gal. PPM	Residual in Compressor at end 10 gal PPM	Residual in Compressor at end 10 gal %	Total by Elect Conduct. PPM	Total by Atomic Absorption PPM
1	305*	55	6.5	360	173
2	130⊗	5	5.9 ¢	135	34
3	185*	10	5.1	195	136
4	35	5	12.5	40	73
5	55	10	18.2	65	77
Avg 1-5	142	17	12	159	98
6	1135*	115	9.2	1250	1061

*Cleanest sample collections; others splashed off wires, pipes
⊗Includes 45 estimated in wash under way
¢W/O 45 estimated in wash under way

Note:
Mission 085 air intake 22.85 lbs. per sec
3 hr
12 lbs @ idle
3 1/3 hr
Each engine 190 tons air
Mission 085:
$$\frac{\text{PPM in } H_2O}{\text{PPM in Air}} = 5000$$

TABLE III

AALC COMPARISON ENGINES NO. 5 vs NO. 6

	Engine Pressure Ratio Loss Rate % per hour			Avg Ingested Salt PPM in Air				Probable Leakage	Comments
		085		As measured from Wash Water			Nuclepore		
Mission	078-084	6.3HR	4.7HR	078-084	085 El. Cond.	085 Atom Ab	085	085	
No. 6	.52	1.15	1.54		.25	.21	.25	0	Pressurized Bag Air (w/o Early Stage Barrier)
No. 5	.45	.01	.013		.013	.015	.004	.009-.011 (2X-3X)	Deck Air (with Early Stage Barrier)
AVG No. 1-5	.31	.084	.11		.032	.02			
Ratio No. 6/ No. 5							60		More vegetation debris at No. 6
Ratio No. 6/ Avg No. 1-5	1.7	14		1.01	8	10.7			

APPENDIX A

INSTRUMENTATION

(1) Nuclepore Filter Probes:

The NRL filter probe consists of a 2" O.D. tube fitted with a filter screen holder and appropriate inlet cover which permits isokinetic aerosol sampling with a properly adjusted aspiration rate. Air is drawn through the filters by vacuum pumps located in the port auxiliary cabin at F in Figure 1. The flow rates are monitored by flow meters also in the port cabin as shown in Figure A-1. The aerosol sample is collected on a 25 mm diameter Nuclepore filter having a pore size of 0.8 μm diameter. Flow rates are typically 20-30 liters per minute. Material collected on the filters was analyzed at NRL by the method of x-ray fluorencence (XRF). The chloride content was determined to yield the mass of sea salt present while the silicon content in each sample was analyzed to estimate the total amount of sand on the filter. Since sea water has a constant ratio of chloride ion to total salt, the analytical conversion is straightforward and reliable. Our XRF method for Cl has a lower detection limit of approximately 0.5 μg and the precision at the 0 to 0.5 ppm salt level is ± 10% or better. At higher salt loadings the precision drops to ± 20%. Determination of total sand is more difficult and less accurate. Using silicon, which is the most readily analyzed component in the quartz-type sand found near Panama City, estimates of sand concentrations may vary as much as 50%. The minerology (and silicon content) of beach sand can change drastically in the small size ranges so that an educated guess has to be made for an "average" factor to scale the silicon up to the total mass. The precision of the sand concentration values for each engine should be much better than ± 50% since the sizes (and thus minerology) of particles able to penetrate each inlet system should be comparable. There is no satisfactory way to calibrate the silicon content in the small-particle fraction of the bulk beach sand since particle density and shape will effect each mineral type differently. The Nuclepore filter results are listed in Appendix E.

(2) Sea Spray Conductivity Meter (SSCM):

The deck unit of the SSCM shown in Figure 2 operates by drawing a continuous stream of sample air through a series of fine mesh screens. These meshes are known to collect 98% of the wet spray and a large percentage of any dry aerosol particles present in the airstream (87% efficiency for particles greater than 5 μm diameter). When sufficient spray has been collected to wet the screens, the collected liquid drains into a small electrical conductivity measuring cell. The conductivity is continuously recorded and indicates the rate of accumulation of spray water as well as its salt content. The spray samples are also retained for later chemical analyses and separation of insoluble aerosol components such as sand and dust. The SSCM controller, which was located in the JEFF (B) port cabin, enabled manual or automatic sequencing of distilled water spray bursts into the SSCM inlet. These periodic washings of the SSCM meshes with precisely known quantities of distilled water allow measurement of the buildup of dry salt residue on the meshes, even in the absence of heavy spray events.

Based on previous JEFF (B) surveys using the SSCM, during which relatively low salt concentrations were recorded on deck, a sensitive conductivity bridge was chosen for this deployment. Unfortunately, during mission 085 several direct spray bursts which occurred soon after departure caused over-ranging in the conductivity electronics. As a result, specific correlations of salt concentrations with craft operations could not be accomplished. However, the SSCM did sample wet and dry aerosols throughout the mission so that average concentrations of sea salt and sand could be calculated. These results are also listed in Appendix E.

(3) Particle Measuring System (PMS) Axially Scattering Spectrometer Probes (ASSP):

Electrooptical probes (sometimes called Knollenberg probes) are shown in Figures 2 and 3. These probes measure the light forward scattered from an axial laser beam as each particle of salt spray or sand passes through the beam. The sizes of the electrical pulses generated by the light pulses are a function of the individual particle sizes. The pulses are sorted into 15 different size bins. These bins represent sizes of 0.3 μm to 7 μm when the instrument is operating in one range. Every few seconds the range is automatically switched to a second range where the 15 bins represent sizes of 1 to 50 μm. The 15 channels of pulses are accumulated usually for 10 seconds, then recorded on a digital tape cassette in a Hewlett-Packard 9825A computer mounted in the port auxiliary cabin. (See Figure A-2.) This computer is programmed to correct the droplet salinity for humidity and printout tables of particle size spectra PPM and mass median diameter (MMD) as presented in Appendix F.

One PMS probe was mounted in front of the engine No. 5 inlet as shown in Figure 2. In order to align this probe with the air flow along the deck and into the engine inlet, the probe was rotated about its axis by a TV antenna rotor. Proper alignment was determined from prior testing with air flow direction tufts as discussed in Appendix G.

Calculation of PPM salt in air requires information on the air flow rate through the probe. This flow was measured by a Thermal Systems Inc. (TSI) hot-wire flowmeter mounted in the probe aft of the laser beam. Cabling from this flow sensor was routed with the probe cable through the antenna rotor to an electronics box near the probe, then to the port cabin for control and data handling. This equipment is shown in Figure A-2.

(4) Temperature Measurement of Bag Air:

The NRL filter probe which was used to sample salt aerosol in the bag plenum (feeding air to #6 engine)also contained a digital platinum resistance thermometer (PRT) (Fluke Model 2180) to monitor the temperature of this bag air. The entire PRT was insulated from the stainless steel filter probe. The sensing tip was located approximately 18" below deck level. Temperatures were displayed in the port cabin and manually recorded. The entire system had been recently calibrated at NRL to $\pm$ 0.1°C using a stirred ice/water mixture.

Fig. A-1. Nuclepore Flowmeters (on Shelf) and Vacuum Pumps Below in Port Cabin.

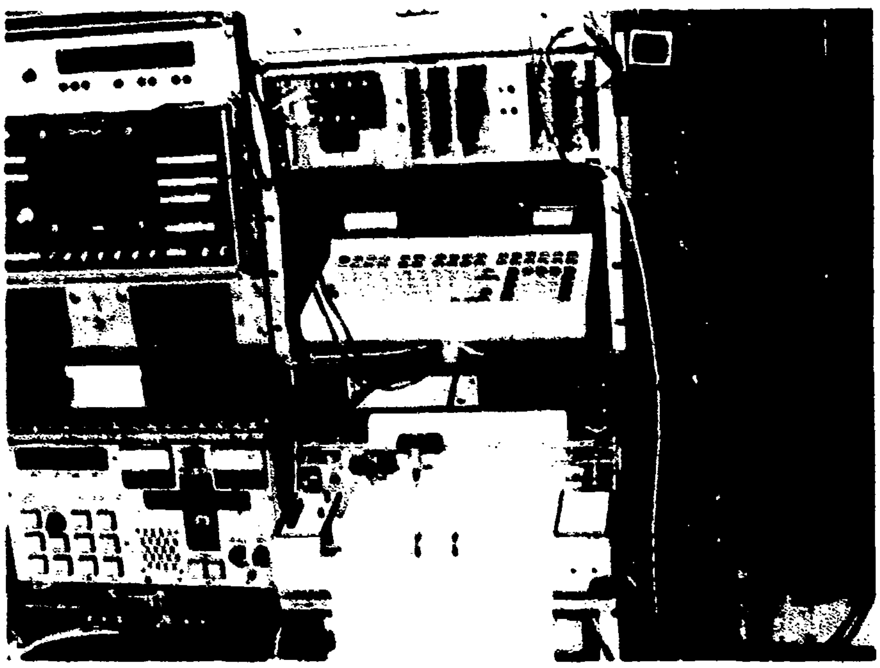


Fig. A-2. Salt Survey Readouts at Right. Computer Keyboard is Visible at Center, Analog Recorder Below.

APPENDIX B

TEMPERATURE DATA: AMBIENT IN BAG PLENUM

The NRL temperature measurements are presented in Table B-1 along with relevant data from Bell Aerospace. Bell's estimates of the temperature rise above ambient by compression through the lift fan to the bag are approximately 13-20^{o}F or 7-11^{o}C. The listed ΔT's (^{o}C in column 5) for the time slices 3, 4, 5 and 7 are close to the lower range of these estimates and are about equal to the theoretical ΔT for 140 psf pressure. However, the values of ΔT after 1337h decreased by about one-half. Comparing Bell's data for ambient temperature versus inlet bellmouth temperatures (TT2) for engine #6 also shows the same pattern (of only half as much ΔT) after 1337h as the NRL PRT data. This shift was concurrent with abrupt degradation of #6 engine as shown in Figure 7 and also the start of an ~10X increase in salt loading to #6 engine. At this time, the craft was operating in the Gulf under higher sea state conditions than the previous portion of the mission. An examination of average TT2 temperatures for engines 1-5 versus ambient does not show this shift after 1337h.

According to these measurements during the last half of the mission, computations of pressurized engine efficiencies and power output which assume a 13-20^{o}F rise will generate ΔT's which are in error by at least a factor of 2. For example, a factor of 1/2 in temperature rise as found in this case would increase the air density by approximately 1.3% out of the total 5 to 7% density increase from pressurization. The net result is that engine performance power for the pressurized case is more favorable than previous computations would indicate. Ironically, cleaner bag air would reduce this improvement.

Considering Bell's TT2 engine inlet bellmouth temperatures as listed in Table B-1, the values for engine #6 during time slices 2-9 average 12.5^{o}F (7^{o}C) warmer than the composite average temperatures from engines 1-5. This difference is expected since the air fed into engine #6 has been pressurized. However, the average TT2's for engine #6 are also 3^{o}C warmer than the NRL bag temperatures; and TT2's for engines 1-5 are approximately 2.2^{o}F warmer than the Bell ambient temperatures. For these 5 engines (non-pressurized air source), TT2 would be expected to be cooler than ambient due to evaporative cooling and possibly cooling due to expansion of air at the filters. We have no ready explanation for this discrepancy. The data should be reexamined after determining whether all of the temperature probe readings are calibrated absolutely or whether all TT2's may be reading 2-3^{o}C too high.

The engine performance calculations should be restudied to ascertain whether the apparent jump in degradation of #6 at 1337h may be partially an artifact of the method of handling the increased inlet air density by temperature decrease which occurred at that time.

TABLE B-1

TEMPERATURE MEASUREMENTS - MISSION 085

Time	Time Slice	Bag (1)	Temperature °C Ambient (2)	ΔT (1)-(2)	TT2 (3) Engine 6	TT2 (4) Eng. 1-5
0954	-	38.3	-	-	-	-
1012	-	30.3	-	-	-	-
1015	-	30.2	-	-	-	-
1017	-	30.9	-	-	-	-
1020	-	34.6	-	-	-	-
1022	(down ramp)	35.0	-	-	-	-
1027	-	31.1	-	-	-	-
1030	3	29.3	21.81	7.5	30.9	23.5
1035	4	27.2	20.94	6.3	29.6	22.7
1046	-	25.5	-	-	-	-
1052	5	26.8	20.27	6.5	29.0	21.7
1100	-	27.3	-	-	-	-
1155	7	28.7	22.66	6.0	32.4	26.3
1234	-	27.4	-	-	-	-
1305	-	23.4	-	-	-	-
1337	15	23.1	22.53	0.6	26.2	22.4
1417	-	23.7	-	-	-	-
1450	21	23.5	21.29	2.2	26.8	22.7
1523	-	24.9	-	-	-	-
1553	27	24.7	21.66	3.0	28.0	24.5
1607	28	23.6	20.59	3.0	26.4	23.4

FOOTNOTES:

(1) Temperature measured in bag air by NRL PRT.
(2) Ambient air temperature measured near control cabin by Bell.
(3) Engine inlet bellmouth temperature (TT2) for engine # 6.
(4) Average engine inlet temperatures (TT2) for engine #'s 1-5.

APPENDIX C

SALT SPRAY PARTICLE SIZE CONSIDERATIONS

Two particle size ranges are of importance in hovercraft engine air inlet design. The larger sizes between about 50 µm and 2-3 mm are mist or rain sizes. Only these large drops can be caught in rain gages or "coffee cans" as used by the British in early studies. References to 50 ppm or higher loadings usually refer to this large size range. The smaller sizes below 50 µm are invisible to the eye unless in a dense cloud or in an intense light beam. (A human hair is about 50 µm diameter.) These are the sizes of principal concern in protecting gas turbine engines from salt spray ingestion. The large size range is primarily of concern in the design of hook-vane roughing stages and drains. The 1-50 µm sizes require a barrier or agglomerator pad or Duralife type of fine filter. Spin tubes are effective in a mid- to large- size range and for dust and sand.

Instrumentation for mission 085 was chosen to look primarily at the 1-50 µm size range, the primary concern in filter design. The only instrument which looked also at the larger drops was the Sea Spray Conductivity Meter (SSCM) discussed in Appendix A(2).

The mass median diameter (MMD) of droplets listed in Appendix F do not include the mist-to-rain sizes.

Figure C-1 summarizes the MMD found by numerous investigators in the atmosphere, the Naval Air Propulsion Center, Trenton, wind tunnel, and in earlier JEFF (B) measurements.

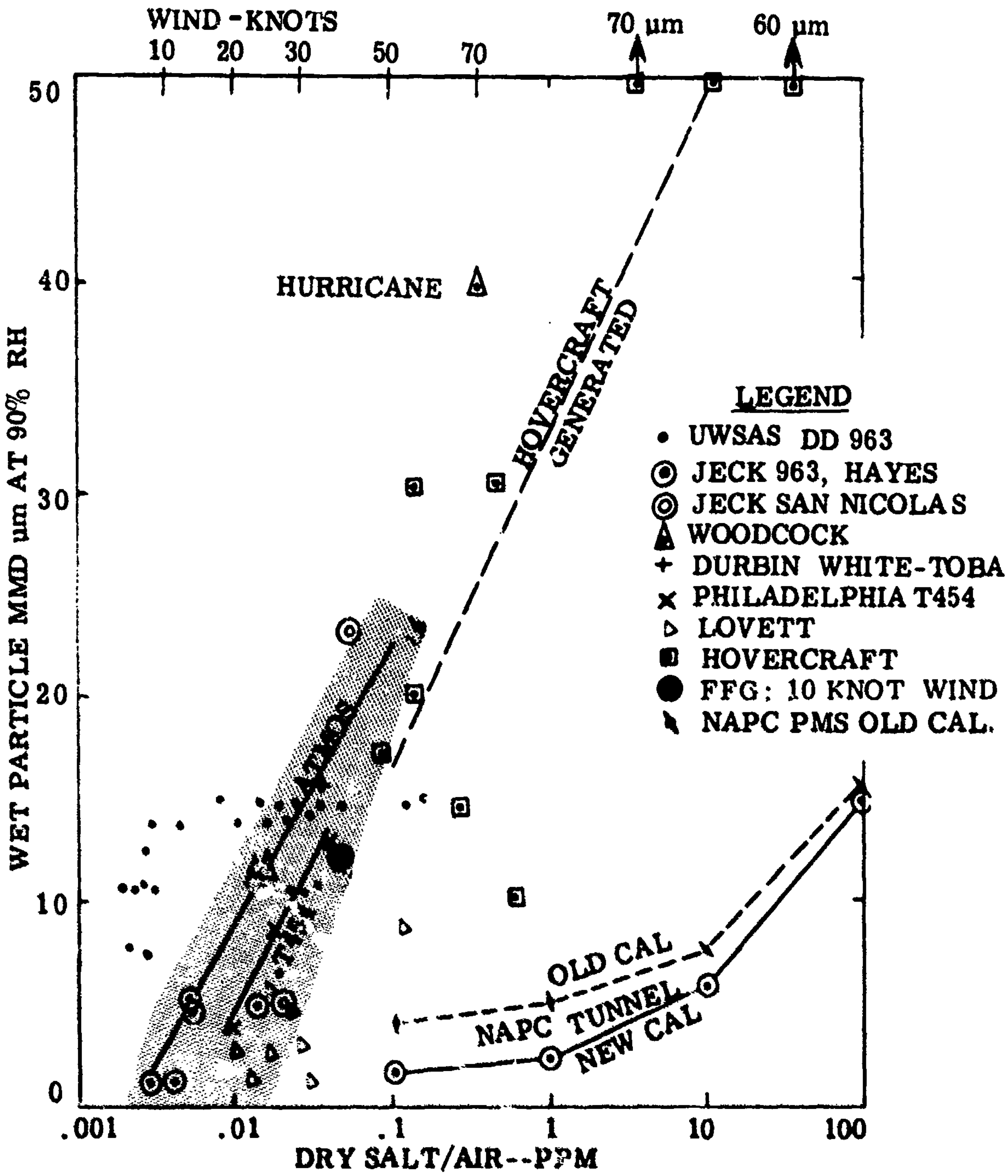


Fig. C-1. Mass Median Diameters (MMD) of Salt Particles in the Atmosphere Found by Various Investigators Plotted as a Function of PPM Present Wind Speeds Typically Producing the Various Salt PPM's are Shown at Top.

APPENDIX D

FILTER CONFIGURATIONS — MISSION 085

Engines No. 1, 3, and 5

5" Peerless Hook Vanes
Agglomerator Pad (Peerless)
Donaldson Cyclone Spin Tube
Agglomerator Pad (Peerless)
2½" Peerless Hook Vanes

Engines No. 2 and 4

5" Peerless Hook Vanes
Agglomerator Pad (Peerless)
Donaldson Cyclone Spin Tube
Altair Agglomerator Pad

Engine No. 6

5" Peerless Hook Vanes
Donaldson Cyclone Spin Tube
Agglomerator (Peerless)
2½" Peerless Hook Vanes

APPENDIX E.

1. Nuclepore Filter Sea Salt Data Mission 085 22 April 1980

PPM SALT

Time	No. 5 Engine	No. 6 Engine	Deck	Bag Plenum
1023-1032	0.0075	0.1080	2.9391	5.2866
1155-1202	—	—	0.7801	1.9817
1234-1243	0.0016	0.0225	—	—
1326-1341	—	0.0375	—	—
1353-1407	0.0015	0.2922	—	—
1414-1429	0.0009	0.2911	—	—
1436-1452	0.0011	—	—	—
1509-1523	0.0063	0.6409	—	—
1536-1552	0.0063	0.1131	—	—
1603-1613	0.0034	0.4815	—	—

2. Nuclepore Filter Sand Data Mission 085 22 April 1980

PPM SAND

Time	No. 5 Engine	No. 6 Engine	Deck	Bag Plenum
1023-1032	0.063	0.470	0.480	0.064
1155-1202	—	—	0.169	0.076
1234-1243	0.139	0.024	—	—
1326-1341	—	0.023	—	—
1353-1407	0.019	0.006	—	—
1414-1429	0.017	0.156	—	—
1436-1452	0.013	—	—	—
1509-1523	0.028	0.018	—	—
1536-1552	0.007	0.033	—	—
1603-1613	0.029	0.107	—	—

APPENDIX E (CONT'D)

3. SSCM Salt Spray Data

Time	Total Salt (mg)	Total Air (kg)	Avg PPM Salt
1017-1651	37,499	520	72

4. SSCM Sand Data

		Size Ranges (diameter)		
Time	Total Sand (gm)	>150μm	150-44μm	<44μm
1017-1651	0.9253	98.3%	1.2%	0.5%

Sand Concentration = 1.8 ppm @ 6.5 hours total operating time
(on deck) 2.5 ppm @ 4.7 hours running time
88 ppm @ 8 minutes beach operation

APPENDIX F

PMS DECK DATA COMPUTER PRINTOUTS

Detailed salt data on the deck are tabulated in this appendix for time intervals from generally a couple of minutes before to a couple of minutes after the times tabulated in Table I. The averages of PPM and MMD from the tables of this appendix are tabulated in columns 8 and 9 of Table I labeled DECK PPM (PMS) and MMD, respectively. These computer printouts list 20-second intervals of the PMS probe (ASSP) data. The automatic range switching alternates between 10 seconds on range 4 (0.3 to 7 μm) and 10 seconds on range 1 (1 to 50 μm). These two data sets are combined in the computer, using 15 size channels in each range to compute the amount of water in droplets passing through the probe during each time interval. The last column labeled "SWELL", shows the factor by which each liquid droplet diameter is divided in order to derive the amount of dry salt mass present in each droplet. This swell factor is dependent on the salinity of the water in the droplets, which in turn is dependent on the relative humidity and length of time the droplets were residing in the atmospher before passing through the instrument. In the case of hovercraft most of the spray is generated by the craft about one second before measurement and the humidity is high in this spray. Therefore the droplets over the deck are assumed to have the salinity of sea water, resulting in a swell factor of 3.5 for all of these runs.

The probe from NAPC, Trenton, was installed in the elbow of the pressurization duct to No. 6 engine as shown in Figure 3, but was found to have a dead laser which could not be replaced for these runs. Had it provided data, its swell factor would have been reduced to allow for lower humidity in the pressurized air because of adiabatic compressional heating as discussed in Appendix B.

Also required for computation of the PPM of salt in air is the velocity of the air through the probe. This value is tabulated in column 3 labeled WSPD(M/S) (Wind Speed in Meters per Second).

In columns 5 and 6 are tabulated the mass median diameters of the dry salt and the wet droplets, respectively. The DRY MMD's are used in Table I.

The fourth line of the heading indicates that the calibration curve of the NRL probe was that derived from wind tunnel tests at NAPC, Trenton. The fifth line on tasks 28-43 indicates that the NAPC probe calibration was derived from PMS probe studies previously conducted at SNI (San Nicolas Island) and verified for this probe in the NAPC wind tunnel tests.

TAPE NO.: JEFF-B PROJECT: SALT SURVEY

DATE: 22 APR 1980 TASK NO. 4, 40KT TO CROOKED I.

DATE PROCESSED: 9/15/80 USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP

TIME	RANGES	WSPD(M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL	
1049:10	4,1	23.2	0.2800	9.40	32.90	3.5	
1049:30	4,1	23.2	0.1704	8.54	29.90	3.5	
1049:50	4,1	23.2	0.3813	8.54	29.90	3.5	Bouncy ride
1050:10	4,1	23.2	0.4286	9.40	32.90	3.5	over waves
1050:30	4,1	23.2	0.3884	8.54	29.90	3.5	
1050:50	4,1	23.2	0.4949	9.40	32.90	3.5	
1051:10	4,1	23.2	1.6065	10.26	35.90	3.5	
1051:30	4,1	23.2	1.7424	9.40	32.90	3.5	
1051:50	4,1	23.2	1.3777	9.40	32.90	3.5	
1052:10	4,1	23.2	1.3161	9.40	32.90	3.5	
1052:30	4,1	23.2	1.6005	9.40	32.90	3.5	
1052:50	4,1	23.2	1.1793	9.40	32.90	3.5	
1053:10	4,1	23.2	1.6212	9.40	32.90	3.5	
1053:30	4,1	23.2	1.5449	9.40	32.90	3.5	
1053:50	4,1	23.2	0.6499	9.40	32.90	3.5	
1054:10	4,1	23.2	0.7628	9.40	32.90	3.5	
1054:30	4,1	23.2	0.9676	9.40	32.90	3.5	
1054:50	4,1	23.2	0.9434	9.40	32.90	3.5	
1059:00	4,1	23.2	0.6236	9.40	32.90	3.5	
1059:20	4,1	23.2	0.6296	10.26	35.90	3.5	
1059:40	4,1	23.2	0.7855	9.40	32.90	3.5	
1100:00	4,1	23.2	0.6851	10.26	35.90	3.5	
1100:20	4,1	23.2	1.1705	8.54	29.90	3.5	
1100:40	4,1	23.2	0.9179	9.40	32.90	3.5	
1101:00	4,1	23.2	1.2829	9.40	32.90	3.5	
1101:20	4,1	23.2	1.0073	10.26	35.90	3.5	
1101:40	4,1	23.2	0.8003	9.40	32.90	3.5	
1102:00	4,1	23.2	1.3671	9.40	32.90	3.5	
1102:20	4,1	23.2	0.7404	9.40	32.90	3.5	
1102:40	4,1	23.2	0.9182	9.40	32.90	3.5	
1103:00	4,1	23.2	1.6118	9.40	32.90	3.5	
1103:20	4,1	23.2	2.7346	9.40	32.90	3.5	Spray coming
1103:40	4,1	23.2	2.3001	9.40	32.90	3.5	over sides
1104:00	4,1	23.2	3.1215	9.40	32.90	3.5	of craft
1104:20	4,1	23.2	2.4538	9.40	32.90	3.5	onto deck.
1104:40	4,1	23.2	2.5008	9.40	32.90	3.5	
1105:00	4,1	23.2	2.5706	9.40	32.90	3.5	Turn left.
1105:20	4,1	23.2	1.9486	9.40	32.90	3.5	
1105:40	4,1	23.2	0.4651	9.40	32.90	3.5	

TAPE NO.: JEFF-B PROJECT: SALT SURVEY

DATE: 22 APR 1980 TASK NO. 4, 40KT TO CROOKED I. Contd.

DATE PROCESSED: 9/15/80 USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP

TIME	RANGES	WSPD(M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL	
1106:00	4,1	23.2	1.3141	9.40	32.90	3.5	
1106:20	4,1	23.2	0.8849	9.40	32.90	3.5	
1106:40	4,1	23.2	1.5749	9.40	32.90	3.5	
1107:00	4,1	23.2	1.9238	9.40	32.90	3.5	
1107:20	4,1	23.2	3.4141	9.40	32.90	3.5	
1107:40	4,1	23.2	0.5896	9.40	32.90	3.5	
1108:00	4,1	23.2	1.5225	10.26	35.90	3.5	
1108:20	4,1	23.2	0.8861	10.26	35.90	3.5	Start approach to beach
1110:10	4,1	19.6	2.1442	9.40	32.90	3.5	
1110:30	4,1	19.6	1.0423	9.40	32.90	3.5	
1110:50	4,1	19.6	5.9256	9.40	32.90	3.5	
1111:10	4,1	19.6	2.9264	9.40	32.90	3.5	
1111:30	4,1	19.6	1.0323	9.40	32.90	3.5	
1111:50	4,1	19.6	0.8095	8.54	29.90	3.5	
1112:10	4,1	19.6	0.8690	8.54	29.90	3.5	

TAPE NO.: JEFF-B PROJECT: SALT SURVEY

DATE: 22 APR 1980 TASK NO. 8: VCNO DEMO, GULF

DATE PROCESSED: 9/15/80 USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP

TIME	RANGES	WSPD(M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL	
1155:20	4,1	24.7	1.6113	10.26	35.90	3.5	
1155:40	4,1	24.7	0.5189	9.40	32.90	3.5	
1156:00	4,1	24.7	0.4223	9.40	32.90	3.5	
1156:20	4,1	24.7	0.3389	9.40	32.90	3.5	
1156:40	4,1	24.7	0.4643	9.40	32.90	3.5	High speed 90°
1157:00	4,1	24.7	0.3280	8.54	29.90	3.5	turn to left
1157:20	4,1	24.7	0.5253	8.54	29.90	3.5	Craft sideslip-
1157:40	4,1	24.7	0.4625	8.54	29.90	3.5	ping to left.
1158:00	4,1	24.7	1.4810	9.40	32.90	3.5	
1158:20	4,1	24.7	0.6896	9.40	32.90	3.5	
1158:40	4,1	24.7	0.2895	8.54	29.90	3.5	
1159:00	4,1	24.7	1.3813	9.40	32.90	3.5	
1159:20	4,1	24.7	1.3860	9.40	32.90	3.5	
1159:40	4,1	24.7	0.8208	8.54	29.90	3.5	
1208:10	4,1	25.0	0.6005	9.40	32.90	3.5	
1208:30	4,1	25.0	0.9633	9.40	32.90	3.5	
1208:50	4,1	25.0	0.6743	10.26	35.90	3.5	
1209:10	4,1	25.0	1.0773	9.40	32.90	3.5	
1209:30	4,1	25.0	0.7367	9.40	32.90	3.5	
1209:50	4,1	25.0	0.5034	11.11	38.90	3.5	
1210:10	4,1	25.0	0.7412	9.40	32.90	3.5	
1210:30	4,1	25.0	1.1000	9.40	32.90	3.5	High speed run.
1210:50	4,1	25.0	0.5548	9.40	32.90	3.5	
1211:10	4,1	25.0	0.9060	9.40	32.90	3.5	
1211:30	4,1	25.0	1.0937	10.26	35.90	3.5	
1211:50	4,1	25.0	1.6348	9.40	32.90	3.5	
1212:10	4,1	25.0	1.1234	9.40	32.90	3.5	
1212:30	4,1	25.0	0.8325	9.40	32.90	3.5	
1212:50	4,1	25.0	0.9860	9.40	32.90	3.5	
1213:10	4,1	25.0	0.4725	9.40	32.90	3.5	

TAPE NO.: JEFF-B   PROJECT: SALT SURVEY

DATE: 22 APR 1980   TASK NO.12: TO SHELL ISLAND

DATE PROCESSED: 9/15/80   USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP   NOTE: 40 knot run, rough ride

TIME	RANGES	WSPD (M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL
1236:20	4,1	21.3	0.7166	8.54	29.90	3.5
1236:40	4,1	21.3	1.4729	8.54	29.90	3.5
1237:00	4,1	21.3	1.4875	9.40	32.90	3.5
1237:20	4,1	21.3	1.2443	9.40	32.90	3.5
1237:40	4,1	21.3	1.1096	9.40	32.90	3.5
1238:00	4,1	21.3	0.8781	9.40	32.90	3.5
1238:20	4,1	21.3	3.1293	9.40	32.90	3.5
1238:40	4,1	21.3	1.8756	9.40	32.90	3.5
1239:00	4,1	21.3	1.0485	9.40	32.90	3.5
1239:20	4,1	21.3	1.4151	10.26	35.90	3.5
1239:40	4,1	21.3	2.0642	9.40	32.90	3.5
1240:00	4,1	21.3	1.1578	8.54	29.90	3.5
1240:20	4,1	21.3	1.4272	8.54	29.90	3.5
1240:40	4,1	21.3	1.6560	10.26	35.90	3.5
1241:00	4,1	21.3	2.6970	9.40	32.90	3.5
1241:20	4,1	21.3	1.6202	10.26	35.90	3.5
1241:40	4,1	21.3	1.2285	9.40	32.90	3.5
1242:00	4,1	21.3	1.1249	9.40	32.90	3.5
1242:20	4,1	21.3	1.8087	9.40	32.90	3.5
1243:20	4,1	21.2	1.4986	10.26	35.90	3.5
1243:40	4,1	21.2	1.2260	9.40	32.90	3.5
1244:00	4,1	21.2	1.7597	9.40	32.90	3.5
1244:20	4,1	21.2	1.0237	9.40	32.90	3.5
1244:40	4,1	21.2	1.3781	9.40	32.90	3.5
1245:00	4,1	21.2	1.5127	9.40	32.90	3.5
1245:20	4,1	21.2	0.9783	9.40	32.90	3.5
1245:40	4,1	21.2	1.9409	9.40	32.90	3.5
1246:00	4,1	21.2	1.6725	10.26	35.90	3.5
1246:20	4,1	21.2	1.9433	9.40	32.90	3.5
1246:40	4,1	21.2	1.2139	9.40	32.90	3.5
1247:00	4,1	21.2	1.2689	9.40	32.90	3.5
1247:20	4,1	21.2	2.0321	9.40	32.90	3.5
1247:40	4,1	21.2	2.2114	10.26	35.90	3.5
1248:00	4,1	21.2	1.7342	9.40	32.90	3.5
1248:20	4,1	21.2	1.3647	9.40	32.90	3.5
1248:40	4,1	21.2	1.2255	9.40	32.90	3.5
1249:00	4,1	21.2	1.2988	9.40	32.90	3.5
1249:20	4,1	21.2	2.7665	9.40	32.90	3.5

TAPE NO.: JEFF-B   PROJECT: SALT SURVEY

DATE: 22 APR 1980   TASK NO.12: TO SHELL ISLAND - Contd.

DATE PROCESSED: 9/15/80   USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP NOTE: 40 knot run, rough ride

TIME	RANGES	WSPD (M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL
1249:40	4,1	21.2	1.5141	9.40	32.90	3.5
1250:00	4,1	21.2	2.3740	9.40	32.90	3.5
1250:20	4,1	21.2	1.0722	9.40	32.90	3.5
1250:40	4,1	21.2	1.9821	9.40	32.90	3.5
1251:00	4,1	21.2	1.9131	9.40	32.90	3.5
1251:20	4,1	21.2	1.2503	9.40	32.90	3.5
1251:40	4,1	21.2	1.0536	10.26	35.90	3.5
1252:00	4,1	21.2	0.9187	9.40	32.90	3.5
1252:20	4,1	21.2	0.4854	9.40	32.90	3.5
1252:40	4,1	21.2	0.8868	9.40	32.90	3.5

TAPE NO.: JEFF-B PROJECT: SALT SURVEY

DATE: 22 APR 1980 TASK NO.20: CRAFT SPEED 10 KT UPWIND

DATE PROCESSED: 9/15/80 USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP

NOTE: Craft bounding slightly in waves. Sea state 2, occasional white caps.

TIME	RANGES	WSPD(M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL
1326:40	4,1	10.3	0.0585	7.69	26.90	3.5
1327:00	4,1	10.3	0.0509	9.40	32.90	3.5
1327:20	4,1	10.3	0.0426	8.54	29.90	3.5
1327:40	4,1	10.3	0.0410	11.11	38.90	3.5
1328:00	4,1	10.3	0.1851	8.54	29.90	3.5
1328:20	4,1	10.3	0.1369	9.40	32.90	3.5
1328:40	4,1	10.3	0.0024	3.41	11.95	3.5
1329:00	4,1	10.3	0.0235	6.86	24.00	3.5
1329:20	4,1	10.3	0.0215	8.54	29.90	3.5
1329:40	4,1	10.3	0.0036	5.17	18.10	3.5
1330:00	4,1	10.3	0.0415	8.54	29.90	3.5
1330:20	4,1	10.3	0.0094	7.69	26.90	3.5
1330:40	4,1	10.3	0.0100	7.69	26.90	3.5
1331:00	4,1	10.3	0.0029	2.54	8.90	3.5
1331:20	4,1	10.3	0.0452	8.54	29.90	3.5
1331:40	4,1	10.3	0.0567	8.54	29.90	3.5
1332:00	4,1	10.3	0.0455	11.97	41.90	3.5
1332:20	4,1	10.3	0.0117	7.69	26.90	3.5
1332:40	4,1	10.3	0.0140	8.54	29.90	3.5
1333:00	4,1	10.3	0.0407	11.97	41.90	3.5
1333:20	4,1	10.3	0.0423	6.03	21.10	3.5
1333:40	4,1	10.3	0.0074	5.17	18.10	3.5

TAPE NO.: JEFF-B   PROJECT: SALT SURVEY

DATE: 22 APR 1980   TASK NO.18: CRAFT AT IDLE FACING UPWIND

DATE PROCESSED: 9/15/80   USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP

NOTE: Some spray generated intermittently by water in the bow hinge, and may be the source of some or most of the "background" spray recorded here.

TIME	RANGES	WSPD (M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL
1350:40	4,1	6.2	0.0154	5.17	18.10	3.5
1351:00	4,1	6.2	0.0363	9.40	32.90	3.5
1351:20	4,1	6.2	0.0316	5.17	18.10	3.5
1351:40	4,1	6.2	0.0184	4.30	15.05	3.5
1352:00	4,1	6.2	0.0339	4.30	15.05	3.5
1352:20	4,1	6.2	0.0404	4.30	15.05	3.5
1352:40	4,1	6.2	0.0080	2.54	8.90	3.5
1353:00	4,1	6.2	0.0570	5.17	18.10	3.5
1355:00	4,1	6.2	0.0504	6.03	21.10	3.5
1357:00	4,1	6.2	0.0507	6.86	24.00	3.5
1359:00	4,1	6.2	0.0196	4.30	15.05	3.5
1401:00	4,1	6.2	0.0289	5.17	18.10	3.5
1403:00	4,1	6.2	0.0295	5.17	18.10	3.5
1405:00	4,1	6.2	0.0186	6.03	21.10	3.5
1407:00	4,1	6.2	0.0152	3.41	11.95	3.5

TAPE NO.: JEFF-B PROJECT: SALT SURVEY

DATE: 22 APR 1980 TASK NO.24: CRAFT SPEED 10 KT UPWIND

DATE PROCESSED: 9/15/80 USING TAPE 102, TRK1, FILE 5

POST NAPC CALIB. FOR NRL ASSP NOTE: Relatively smooth ride, craft bounding only slightly.

TIME	RANGES	WSPD(M/S)	NRL ASSP PPM	DRY MMD	WET MMD	SWELL
1416:00	4,1	9.8	0.4898	10.26	35.90	3.5
1416:20	4,1	9.8	0.1883	9.40	32.90	3.5
1416:40	4,1	9.8	0.2371	9.40	32.90	3.5
1417:00	4,1	9.8	0.1365	6.86	24.00	3.5
1417:20	4,1	9.8	0.1338	10.26	35.90	3.5
1417:40	4,1	9.8	0.2211	8.54	29.90	3.5
1418:00	4,1	9.8	0.1513	8.54	29.90	3.5
1418:20	4,1	9.8	0.2150	9.40	32.90	3.5
1418:40	4,1	9.8	0.2652	8.54	29.90	3.5
1419:00	4,1	9.8	0.1705	9.40	32.90	3.5
1419:20	4,1	9.8	0.2331	11.11	38.90	3.5
1419:40	4,1	9.8	0.1537	8.54	29.90	3.5
1420:00	4,1	9.8	0.1509	7.69	26.90	3.5
1420:20	4,1	9.8	0.0778	6.86	24.00	3.5
1420:40	4,1	9.8	0.1796	8.54	29.90	3.5
1421:00	4,1	9.8	0.1029	7.69	26.90	3.5
1421:20	4,1	9.8	0.2121	9.40	32.90	3.5
1421:40	4,1	9.8	0.1114	8.54	29.90	3.5
1422:00	4,1	9.8	0.1018	7.69	26.90	3.5
1424:00	4,1	10.3	0.0874	9.40	32.90	3.5
1424:20	4,1	10.3	0.0894	7.69	26.90	3.5
1424:40	4,1	10.3	0.0657	9.40	32.90	3.5
1425:00	4,1	10.3	0.0747	11.11	38.90	3.5
1425:20	4,1	10.3	0.1290	10.26	35.90	3.5
1425:40	4,1	10.3	0.1119	9.40	32.90	3.5
1426:00	4,1	10.3	0.0937	7.69	26.90	3.5
1426:20	4,1	10.3	0.1374	10.26	35.90	3.5
1426:40	4,1	10.3	0.1113	9.40	32.90	3.5
1427:00	4,1	10.3	0.0566	6.03	21.10	3.5
1427:20	4,1	10.3	0.0501	6.03	21.10	3.5
1427:40	4,1	10.3	0.0861	9.40	32.90	3.5
1428:00	4,1	10.3	0.0372	6.86	24.00	3.5
1428:20	4,1	10.3	0.1013	9.40	32.90	3.5
1428:40	4,1	10.3	0.0118	5.17	18.10	3.5
1429:00	4,1	10.3	0.0988	7.69	26.90	3.5
1429:20	4,1	10.3	0.1091	8.54	29.90	3.5
1429:40	4,1	10.3	0.0982	8.54	29.90	3.5
1430:00	4,1	10.3	0.0547	11.97	41.90	3.5

APPENDIX G

PREMISSION TUFT TESTS OF AIR FLOW

The instrumentation mount shown in Figure 2 was designed to provide flexibility in adjusting the compound angle for straightest possible air flow through the Nuclepore and PMS probes at a location near the center of the aft inlet screen of No. 5 turbine.

The optimum angle for a range of craft operations was determined by installing two vertical rows of tufts and recording their angles during various speeds and wind directions on mission 084. These tufts are shown in Figure G-1. One row was located to include the inlet to the SSCM 18 inches inboard of the forward inlet screen of No. 5 engine and the second row, the inlet to the Nuclepore and PMS probes, 7 inches inboard of the aft inlet screen.

At hover the tuft angles were erratically variable at all craft headings to the wind. Therefore the hover tasks were omitted from the mission 085 high priority tasks.

Underway the tuft angles were generally 5^{o} outboard aft and 5^{o} downward aft. The instrument mount was then modified to permit this compound angle for mission 085.

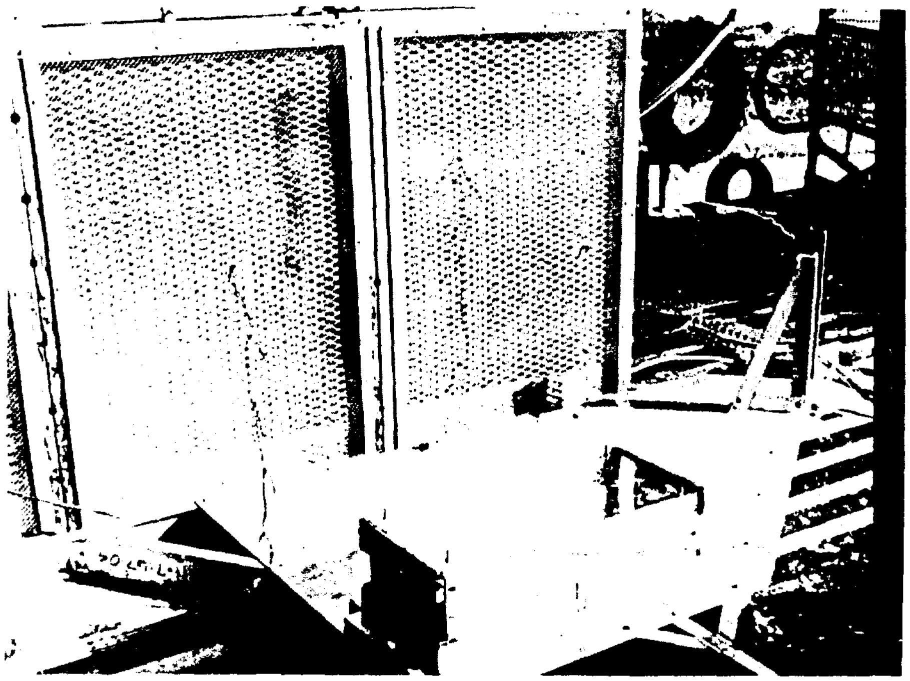


Fig. G-1. Tufts Mounted in Front of No. 5 Inlet Screens for Checking Angles of Air Flow.