NMC
Committed to Nuclear Excellence

Monticello Nuclear Generating Plant
Operated by Nuclear Management Company, LLC

May 14, 2002

10 CFR Part 50,
Section 50.90

US Nuclear Regulatory Commission
Document Control Desk
Washington DC, 20555-0001

MONTICELLO NUCLEAR GENERATING PLANT
Docket No. 50-263 License No. DPR-22

Supplemental License Amendment Request and Response to Request for Additional Information Regarding License Amendment Request for Revision to Standby Diesel Generators Technical Specifications and Surveillance Requirements (TAC No. MB3042)

Reference 1: Nuclear Management Company, LLC Submittal of License Amendment Request for Monticello Nuclear Generating Plant Regarding Diesel Generators, dated September 27, 2001.

Reference 2: Nuclear Regulatory Commission Request for Additional Information Related to License Amendment Request, dated April 12, 2002.

Reference 1 proposed Technical Specifications changes to Appendix A of Operating License DPR-22, for the Monticello Nuclear Generating Plant. The purpose of the License Amendment Request was to revise the Monticello Technical Specifications (TS) to revise the diesel fuel supply volume required for Diesel Generator operability, clarify existing wording, add a TS Limiting Conditions for Operations (LCO) and Surveillance Requirements (SR) regarding Diesel Generator air receivers, delete a current TS SR concerning Diesel Generator starting air compressors, and repaginate, restructure and renumber the TS LCOs and SRs for applicability and administrative purposes.

Reference 2 requested Nuclear Management Company to provide additional information in support of the license amendment request submitted by Reference 1.

Exhibit A provides Nuclear Management Company, LLC (NMC) response to the NRC's request for additional information for the previously submitted License Amendment Request. Exhibit B provides a schematic diagram of a typical set of starting air receivers for a diesel generator, a Monticello Calculation/Analysis for Minimum Allowable Fuel Oil Storage Tank Level and Addendum 1 to the Calculation/Analysis and a drawing of the Monticello Diesel Fuel Oil Storage Tank. Exhibit C provides new marked-up Monticello Technical Specification pages. Exhibit D provides new retyped Monticello Technical Specification pages.

A001

These changes provide additional clarifications to the Monticello TS change request submitted by Reference 1, and as such, the Determination of No Significant Hazards Consideration and Environmental Assessment submitted by the original letter dated September 27, 2001, are also applicable to this supplemental submittal.

Nuclear Management Company, LLC requests a period of up to 60 days following receipt of this license amendment to implement the changes.

If you have any questions regarding this response to Request for Additional Information and Supplemental License Amendment Request please contact Doug Neve, Licensing Manager, at (763) 295-1353.

Jeffrey S. Forbes
Site Vice President
Monticello Nuclear Generating Plant

Subscribed to and sworn before me this 14 day of May, 2002

Kathryn I Kleine
Notary

KATHRYN I. KLEINE
NOTARY PUBLIC - MINNESOTA
My Comm. Exp. Jan. 31, 2005

Attachments: Exhibit A – Response to Request for Additional Information and Supplemental License Amendment Request regarding the Monticello Technical Specifications

Exhibit B - Schematic of Diesel Generator Starting Air System, a Monticello Calculation/Analysis for Minimum Allowable Fuel Oil Storage Tank Level and Addendum 1 to the Calculation/Analysis and a drawing of the Monticello Diesel Fuel Oil Storage Tank

Exhibit C - Revised Monticello Technical Specifications Page Marked up With Additional Proposed Changes

Exhibit D - Revised Monticello Technical Specifications Page

cc: Regional Administrator-III, NRC
NRR Project Manager, NRC
Sr. Resident Inspector, NRC
Minnesota Department of Commerce
J. Silberg, Esq

Supplemental License Amendment Request and Response to Request for Additional Information Regarding License Amendment Request for Revision to Standby Diesel Generators Technical Specifications and Surveillance Requirements

Background

By letter dated September 27, 2001 Nuclear Management Company, LLC (NMC) submitted a request for a change to Appendix A, Technical Specifications, of Operating License DPR-22 for the Monticello Nuclear Generating Plant. The submittal proposed to revise the diesel generator Technical Specifications (TS) to revise the minimum volume of fuel oil required for diesel generator (DG) operability, add a TS Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) regarding DG starting air receivers, delete a current TS SR regarding DG starting air compressors, and repaginate, restructure, and renumber the TS LCO's and SR's for applicability and administrative purposes.

The addition of a TS LCO and corresponding SR regarding the DG starting air receivers was determined to be a logical change to propose since the current TS SR regarding starting air compressors has no direct impact on DG operability and does not meet the minimum requirements, specified in 10 CFR 50.36(c)(2)(ii), for inclusion in the TS. The Monticello plant staff also wanted to take advantage of the robust design of the DG starting air receivers to provide more flexibility for the operation of the DG.

As stated in the Monticello Updated Safety Analysis Report (USAR), Section 8.4.1.2, "Power to start each diesel generator is derived from two independent air starting systems. Each consists of a pair of compressed air driven motors, an air dryer, strainer, air line lubricator, and related storage tanks. This provides 100% redundancy for each unit's air starting system. Starting at nominal pressure (200 psig), each of these systems has adequate capacity to start five times without recharging." A schematic diagram of a starting air system is attached in Exhibit B.

The above statement is correct for the design basis of the starting air systems for the DGs, however, the automatic start logic for each DG provides for a total of three automatic start attempts from its two associated starting air receivers before manual operator action would be required. The automatic start logic first attempts to start the DG from the selected (primary) starting air receiver. If the DG fails to start, the automatic logic will select both starting air receivers for the second attempt to start the DG. If the DG again fails to start, the automatic logic will then attempt to start the DG by selecting the non-selected (secondary) starting air receiver for the third attempt to start the DG. If the DG fails to start on the third attempt then manual operator action is required for any additional attempts to start the DG. With manual operation there is still sufficient air pressure to attempt a minimum of one additional start of the DG from each starting air receiver.

The Monticello USAR states that starting at a nominal pressure of 200 psig each starting air receiver has the capability of starting its associated DG a minimum of five times. During normal operation each starting air receiver's air compressor cycles on when the pressure in the receiver drops to 175 psig and recharges the starting air receiver to an approximate pressure of 200 psig. With a pressure ≥ 165 psig each starting air receiver has sufficient air pressure to start its associated DG a minimum of 3 times.

Specific NRC questions and corresponding NMC responses are as follows:

NRC Question:

1. The proposed new technical specification (TS) 3.9.B.3.c Limiting Condition for Operation (LCO) for standby diesel generators states:

   c. "When a diesel generator is required to be operable, maintain air pressure for both associated air starting receivers ≥ 165 psig.

      1) When a diesel generator starting air receiver pressure < 165 psig, restore starting air receiver pressure to ≥ 165 psig within 7 days, or declare the associated diesel generator inoperable.

      2) With both diesel generator starting air receivers pressure < 165 psig, immediately declare the associated diesel generator inoperable."

   Standard technical specification (STS)[1] Section LCO 3.8.3.E requires that when one or more diesel generators with starting air receiver pressure <225 psig and > 125 psig, restore (with completion time of 48 hours) the starting air receiver pressure to ≥225 psig.

   STS LCO in Section B 3.8.3 states: "The starting air system is required to have a minimum capacity for five successive diesel generator start attempts without recharging the air start receivers."

   The technical rationale for the additional requirement is that the change is consistent with NUREG-1433, General Electric Plants, BWR/4, STS. The LCO completion time of 7 days for the proposed TS versus the completion time of 48 hours as specified in the STS is based upon the more robust design (i.e., two redundant air starting systems versus the single air starting system assumed in the applicable STS LCO). However, the proposed TS specifies the minimum air starting pressure rather than the nominal air starting pressure cited in the bases of the STS. Similarly, the associated STS Surveillance Requirement (SR) criteria is based on the nominal air pressure parameter necessary for the minimum number of engine start cycles without recharging the air receiver. Please provide a technical justification for using an off-normal or marginal parameter setting for the proposed LCO and SR instead of the nominal air starting pressure value (i.e., 200 psig).

---

1 NUREG-1433, "Standard Technical Specifications (STS) for General Electric Plants, BWR/4" Revision 2.

NMC Response:

The rationale for this off-normal parameter for the Technical Specification (TS) Limiting Condition for Operation (LCO) is acceptable because of the operation of the robust starting air receiver system for the Monticello DG. The starting air receiver pressures cited in the Standard Technical Specifications (STS) are plant specific values as denoted by brackets. As discussed above, for Monticello, the minimum pressure of 165 psig for each starting air receiver provides enough air to perform a minimum of at least three (3) starts of the associated DG from each starting air receiver for a total of at least six starts. Additionally, this TS change added a TS LCO and SR for the Diesel Generator (DG) starting air receivers and relocated the existing SR for the air compressors to plant procedures. This repagination, renumbering and rewording provides a TS that more closely models the TS of NUREG-1433, General Electric Plants, BWR/4, Standard Technical Specifications.

Due to the robust nature and redundant capabilities of the starting air system for each of the DG at Monticello, NMC has determined that the previously proposed LCO and actions for the proposed TS should be changed. Therefore, proposed TS 3.9.B.3.c is being reworded to state:

c. "When a diesel generator is required to be operable, maintain air pressure for both associated air starting receivers $\geq$ 165 psig.

1) With one diesel generator starting air receiver pressure < 165 psig, restore both starting air receivers pressure to $\geq$ 165 psig within 7 days, or declare the associated diesel generator inoperable.

2) With both diesel generator starting air receivers pressure < 165 psig but $\geq$ 125 psig, restore both starting air receivers pressure to $\geq$ 165 psig within 48 hours, or declare the associated diesel generator inoperable.

3) With both diesel generator starting air receivers pressure < 125 psig, immediately declare the associated diesel generator inoperable."

This rewording of the LCO is acceptable because it is based upon the more robust design of the starting air system for Monticello (i.e., two redundant air starting systems versus the single air starting system assumed in the applicable STS LCO). The starting air receivers pressure is acceptable because:

c. With both starting air receivers at a pressure ≥ 165 psig there is sufficient air pressure to start the associated DG a minimum of six (6) times. This is acceptable because startup test data shows that each starting air receiver can provide sufficient air pressure for a minimum of three (3) DG starts when starting at a pressure ≥ 165 psig. This more than satisfies the five (5) start design requirement of the DG.

1) Test data shows that with one starting air receiver pressure ≥ 165 psig and the other starting air receiver ≤ 165 psig there is sufficient air pressure to start the associated DG a minimum of three (3) times. The seven (7) days to restore the starting air receiver pressure to ≥ 165 psig is acceptable because the combined air pressure, of the two starting air receivers, provides for a minimum of three (3) starts for the associated diesel generator, either of which provides a high level of assurance that the DG will start.

2) With both starting air receivers pressure < 165 psig but ≥ 125 psig there is sufficient air pressure to start the associated DG a minimum of two (2) times. This is acceptable because as long as each starting air receiver has a pressure ≥ 125 psig, there is adequate capacity for at least one start attempt of the DG from each starting air receiver. The 48 hours to restore one of the starting air receivers to ≥ 165 psig and entering the TS LCO 3.9.B.3.c.1, or restoring both starting air receivers to ≥ 165 psig within 48 hours is acceptable based on the remaining air start capacity, the fact that most DG starts are accomplished on the first attempt, and the low probability of an event during this brief period.

3) With both starting air receivers pressure < 125 psig there may not be sufficient air pressure to start the associated DG. Although, startup test data has demonstrated that the DG would probably start from an air pressure of < 125 psig, NMC cannot ensure a reliable start below this pressure.

The proposed revised TS provides high assurance that the DG will be available and provides adequate actions and allowances for instances in which full air start capability is not available. Additionally, the proposed revised TS adds operating flexibility without diminishing the starting air receivers capability, which more than satisfies the requirement from STS B 3.8.3 for each DG to have an air start system with adequate capacity for five successive start attempts on the DG without recharging the air start receiver(s).

Similarly, the associated STS Surveillance Requirement (SR) criteria is based on the nominal air pressure parameter necessary for the minimum number of engine start cycles without recharging the air receiver (i.e., one air start receiver for each Diesel Generator). Whereas, the proposed Monticello SR criteria is based on providing sufficient air pressure in each redundant air receiver (i.e., two air start receivers for each Diesel Generator), such that the combined pressure will provide adequate capacity for more than five successive start attempts on the DG without recharging the air start receivers.

A schematic diagram of the Emergency Diesel Generator starting air receivers is attached in Exhibit B.

NRC Question

2. Please address the potential common-cause failure modes which may be possible given that one diesel generator starting air receiver pressure is less than the minimum pressure requirement (i.e., 165 psig) under the proposed LCO TS 3.9.B.3.c and identify any independent means which will verify that the remaining air receiver has sufficient capacity to provide enough air pressure for a minimum of two emergency diesel generator (EDG) starts.

NMC Response:

The starting air receivers for each Diesel Generator at Monticello are independent and redundant, but not diverse in that each receiver has like components. The starting air receivers are cross-connected by a manual valve, but there are no active air system failures which could effect both starting air receivers. The like components, similar to other like components in the plant, may create a potential for common-cause failures. Upon failure or degradation of one starting air system, operations personnel will monitor the pressure of the redundant starting air receiver on a once per shift basis. The failure of a starting air receiver component will be reviewed, by plant personnel, to determine the root cause of the failure. This review will include the potential for a common-cause failure, of like components, for the other starting air receivers. The remaining starting air receiver will have sufficient pressure for a minimum of three (3) diesel generator starts, from 165 psig, as demonstrated by the Bechtel start-up test data.

During the start-up test the diesel generator was given a series of starts using only one air start receiver at a time. The air pressure in the air start receiver was built up to the automatic shut-off pressure of the compressor control switch. A start signal was given with the fuel held off, preventing the diesel generator from firing, and allowing the air start receiver motors to crank a full four seconds. This assured the maximum demand on the air start system. Based on this test data, it was demonstrated that, starting at a pressure less than 165 psig, each starting air receiver could start the associated Diesel Generator a minimum of three (3) times.

NRC Question

3. Provide detailed calculations to demonstrate that the fuel oil stored in the underground fuel oil storage tank will be sufficient to support the operation of one EDG for 7 days following a loss-of-coolant accident (LOCA). Information should include:

   a. The methodology[2] and assumptions used to calculate the fuel oil consumption rates.

   b. The minimum usable volume of the underground fuel oil storage tank, information should include the assumptions (e.g. instrumentation errors, vortex formation, etc.) used in the calculations and the tank design in detail (including drawings).

---

2 Calculations based on the assumption that the diesel generator operates continuously for 7 days at its rated capacity or calculations based on the time-dependent loads of the diesel generator.

NMC Response:

A drawing of the Monticello underground fuel oil storage tank and the detailed calculations that demonstrate that the fuel oil stored in the underground fuel oil storage tank is sufficient to support the operation of one EDG for 7 days following a LOCA are attached in Exhibit B. The Calculation/Analysis for Minimum Allowable Fuel Oil Storage Tank Level and Addendum 1 to the Calculation/Analysis provides the information requested. Addendum 1 to Calculation/Analysis concludes that to address vortexing concerns, a non-conservative suction source for the Diesel Oil Transfer Pump, and to provide additional margin to the calculated value of minimum required fuel oil, the amount of fuel oil contained in the underground fuel oil storage tank should be maintained at 38,300 gallons.

The Calculation/Analysis for Minimum Allowable Fuel Oil Storage Tank Level and addendum 1 to the Calculation/Analysis is being provided to the NRC on a one-time basis and any revisions to the Calculation/Analysis in the future will not be provided unless required by 10 CFR 50.59.

NRC Question

4. If the calculations for the EDG fuel oil consumption rates and inventory required are based on the time-dependent loads, the following information should be provided:

a. Tables or curves to show the EDG loadings and their corresponding fuel oil consumption rates and inventories as a function of time following the design bases accident.

b. Discussion of the provision established in plant procedures for shedding[3] the loads following a LOCA, and

c. State whether the proposed minimum EDG fuel oil required to be stored in the underground storage tank includes a 10% margin as recommended in American National Standards Institute N195-1076.

---

3 Information provided should clearly indicate which loads will be shed, following a LOCA, and at what times they will be shed.

NMC Response:

Since the calculations for the EDG fuel oil consumption rates and inventory required are not based on the time-dependent loads this question is not applicable to the Monticello Nuclear Generating Plant.

NRC Question

5. With regard to the licensees' application requests for removing/relocating existing plant Technical Specifications (TS) sections and Surveillance Requirements (SR) sections, the staff's position is that existing TS sections and SR sections that fall within or satisfy any of the four criteria described in 10 CFR 50.36 (c) (2) (ii) must be retained in the TS, while those TS sections and SR sections that do not fall within or satisfy these criteria may be relocated to other licensee's administratively controlled documents, such as plant Technical Requirements Manuals (TRMs). Please indicate the administratively controlled documents to which the current TS 4.9.B.3.b will be relocated and discuss how the air compressors will be maintained for readiness.

NMC Response:

As stated in the submittal dated September 27, 2001 current TS 4.9.B.3.b should be deleted because this surveillance requirement does not assure the operability of the EDGs will be maintained, nor that the LCO will be met. Testing the air compressors on a monthly basis does not demonstrate operability of the associated Diesel Generator (DG). Operability of the DG is demonstrated by maintaining sufficient air pressure for the DG to automatically start on an automatic start signal.

The deletion of this TS SR is acceptable because it does not meet the regulatory requirements of 10 CFR 50.36(c)(2)(ii) for inclusion into the TS. The air compressors are not part of the primary success path and do not provide a safety function or actuation to mitigate a design basis accident or transient that either assumes the failure of or presents a challenge to the integrity of a fission product barrier. Nor has this equipment been shown, either through operating experience or probabilistic risk assessment, to be significant to the public health and safety.

The requirements of current TS SR 4.9.B.3.b will be maintained in Monticello plant procedures, and the Preventive Maintenance Program. The air compressors will continue to be tested to ensure that they can support the function of maintaining the minimum air pressure in the starting air receivers. Any future changes to these requirements will be controlled by the regulations and requirements of 10 CFR 50.59.

Supplemental License Amendment Request and Response to Request for Additional Information Regarding License Amendment Request for Revision to Standby Diesel Generators Technical Specifications and Surveillance Requirements

MONTICELL NUCLEAR GENERATING PLANT

This Exhibit contains the following documents provided in support of the information contained in Exhibit A:

DG Air Starting System Schematic Diagram

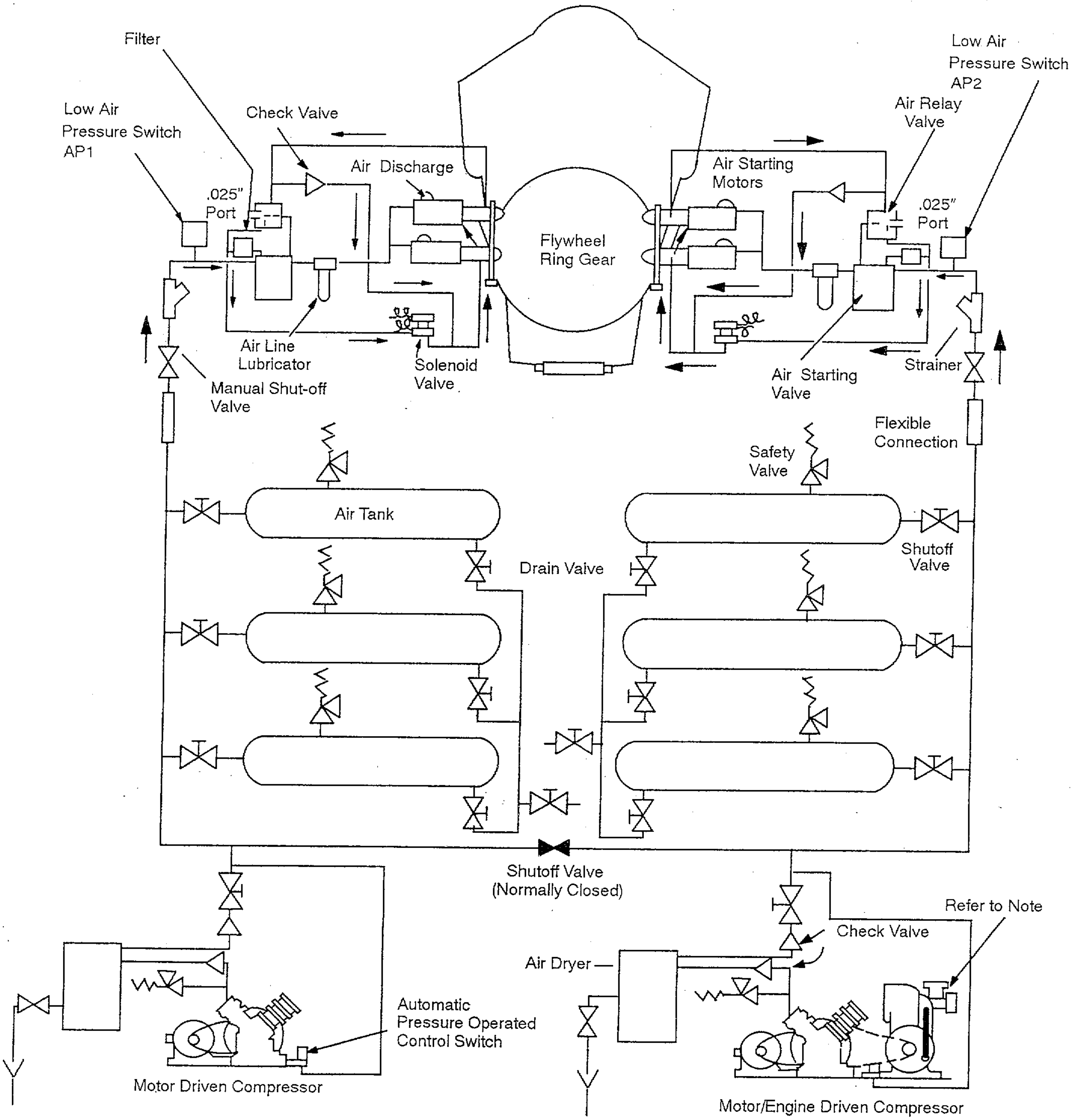
Calculation / Analysis – Minimum Allowable Fuel Oil Storage Tank Level

Calculation / Analysis, Addendum 1 – Minimum Allowable Fuel Oil Storage Tank Level

Drawing for Monticello Underground Fuel Oil Storage Tank

FIGURE 1

TYPICAL AIR STARTING SYSTEM SCHEMATIC DIAGRAM



NOTE: To drive compressor with engine, belt must be manually changed over.

b.9.8-06-6

CALCULATION/ANALYSIS CONTROL FORM

D1211039

CALCULATION/ANALYSIS #: CA-90-023

TITLE/PURPOSE: Minimum Allowable Fuel Oil Storage Tank level

ASSIGNED PERSONNEL (Names & Titles)

Approval: Anne Ward

Preparation: Larry Heath Sr. Prod Eng.

Verification: Mark Hinrichs

Verification: N/A

REFERENCES/FILING

File		Description/Location
X	1.	B.G.E. Results File
	2.	
	3.	
X		Calculation/Analysis file.

VERIFICATION METHOD(S)

Review X Alternate Calculation ___ Test ___ Other ___

Explanation:

COMPLETION (Signatures)

Prepared by:	[signature]	Date:	11/21/90
Verified by:	M. A. Hinrichs	Date:	11/28/90
Verified by:	N/A	Date:	—
Approved by:	Anne Ward	Date:	12-4-90

WP/djj

4/16

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

PURPOSE:

To calculate the minimum allowable level in the Monticello Nuclear Generating Plant Fuel Oil Storage Tank (T-44). In addition, emergency diesel fuel consumption and Fuel Oil Day Tank (T-45A and T-45B) minimum level will be checked.

METHODOLOGY:

American National Standard ANSI N-195-1976/ANS 59.51, Fuel Oil Systems for Standby Diesel Generators, states in section 5.4 "A conservative alternative to calculating the total fuel storage based on time-dependent loads is to calculate the storage capacity by assuming that the diesel operates continuously for seven days at its rated capacity. The conservative calculation is recommended." The bases of Technical Specification 3.9.B.3.c also refer to this requirement. Therefore:

1. Fuel Consumption per hour will be determined.
2. Fuel Consumption in seven days will be determined.
3. Minimum required Fuel Oil Storage Tank Level will be determined. This will include accounting for fuel below minimum tank suction level, uncertainties in tank level measurement, and uncertainties in tank size.
4. Day Tank Level will be evaluated to ensure 8 hours of operation are available from it, as described in the USAR Section 8.4.1.1.

ACCEPTANCE CRITERIA:

1. Fuel Consumption in seven days is within Fuel Oil Storage Tank capacity.
2. Fuel Consumption in 8 hours is within Fuel Oil Day Tank/ Fuel Oil Base Tank capacity.

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

INPUTS:

1. Specification for General Motors Model 999 System Generating Plant, GM Specification No. 7500, April 1967.

2. EMD Operating Cost Factors Excerpt (attached)

3. Bureau of Standards, Miscellaneous Publication No. 97, Thermal Properties of Petroleum Products, April 28, 1933. (excerpt attached)

4. MPS-49, Monticello Fuel Oil Specification

5. Drawing NX-8431-5, 60,000 Gal U. G. Oil Tank

6. Conversion factor, 1 cubic foot = 7.4805 gallons

7. MACHINE DESIGN Tech Briefs "Liquid Level in Tanks" by T. V. Seshadri (attached)

8. Drawing NX-8431-29, 1500 Gal Diesel Day Tank

ASSUMPTIONS:

1. The Heat Rate of the 999-20 configuration emergency generator at 2500 KW is 10,800 BTU/ KWH.

2. The T-44 tank level instrument is accurate within 1/2 inch.

3. The T-44 tank dimensions are accurate enough to give tank volume within 1%.

4. The heads on T-45A and T-45B may be approximated by one foot high ellipsoids.

5. T-45A and T-45B tank volumes are accurate to within 2% of total tank volume.

6. The temperature effects on the fuel oil volume and consumption are negligible for purposes of this calculation. This is because:
   a. The tank is buried with the centerline 10 feet underground. At this depth the temperature changes will be minimal from summer to winter, and any changes will be gradual as the surrounding earth must also change temperature. Therefore there will not be sudden changes in volume due to thermal contraction which might cause us to go below the specified minimum level.
   b. Before being used the fuel is brought first to the day tank, then the base tank. Therefore the fuel will be at the temperature of the diesel building before being used, so the temperature will be controlled at 60-104 F. The heat value of the fuel will then be approximately equal from summer to winter.

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

ANALYSIS:

1. Fuel Oil Consumption at full load

The fuel oil consumption at full load and the most limiting case of fuel specific gravity will be determined.

Input 1 states at 4/4 load, 999-20 fuel consumption is 205 gallons per hour. This input uses a full load of 2850 KW throughout. The API gravity of the fuel used to get this requirement is not stated, although it can be assumed to be the standard API for fuel consumption ratings.

Input 2 states, for a MP-45 generator (20-645E4 Engine) fuel consumption at 2500 KW is 186 gph at 30 API, 184 at 28 API and Heat Rate is 10550 BTU/KWH. It also states that 28 API fuel is standard for expression of fuel consumption.

We have a 20-645E4 engine coupled to an A20-C2 generator in a 999-20 configuration, with a maximum normal load of 2500 KW. While this is similar to the above configurations, it is not exactly the same. To determine a nominal fuel consumption, a heat rate will be estimated conservatively for our configuration, and this used to calculate fuel consumption at the most limiting API gravity.

Heat Rate of 999-20, based on input 1.
From input 3, High Heat Value of 28 API fuel = 143,100 BTU/gal

$$\frac{205 \text{ gal/hr} \times 143100 \text{ BTU/gal}}{2850 \text{ KW}} = 10,293 \frac{\text{BTU}}{\text{KWH}}$$

This is reasonable compared to the MP-45 values of Input 2.

For conservatism, a heat rate of 10,800 BTU/KWH will be used. This is picked to allow for the engine to be operating off its maximum efficiency point. The actual value is from the MP-45 data at 1875 KW, off the engine maximum efficiency but still highly loaded.

From Input 3, it can be seen that the lowest BTU per gallon for diesel fuel occurs at the higher API gravity. The Monticello Fuel Oil Specification , Input 4, allows fuel oil to a maximum API gravity of 38. From Input 1, the High Heat Value (BTU/gal) for 38 API oil is 137,000 BTU/gal.

$$2500 \text{ KW} \times 10,800 \frac{\text{BTU}}{\text{KWH}} \times \frac{\text{gal}}{137,000 \text{ BTU}} = 197 \text{ gal/hr}$$

This is acceptably close to observed fuel consumption to be believed as a conservative but realistic value.

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

2. Fuel Consumption in Seven Days at Full Load

In seven days at 197 Gallons per hour:

Fuel Used = 197 gal/hr × 24 hr/day × 7 days = 33096 gallons

3. Minimum Required Fuel Oil Storage Tank Level

The Fuel Oil Storage Tank is a cylinder, 13 ft. in diameter and 60 ft. long. It has 3/8 inch walls and a flat head on each end that extends slightly beyond the 60ft. See input 4, drawing NX-8431-5, for details. The drawing is unclear as to whether 13 ft. is inside or outside diameter, and does not give detailed dimensions of the head area.

For conservatism, it will be assumed that the 13 ft. is an outside diameter and that the head extends no further than the exact 60 ft. mark. This conservatively excludes a possible volume of possibly about 100 gallons, depending where on the heads the 60 feet is measured to. This conservatism will be used to compensate for internal piping and instruments in the tank, which are not otherwise accounted for and will not be further addressed.

Then Total Volume is: Inner Diameter = 13 ft × 12 in/ft − 2(3/8 in) = 155.25 in

$$V = \pi \frac{d^2}{4} h = \pi \frac{\left(\frac{155.25}{12}\right)^2 ft^2}{4} \times 60\ ft = 7887.5\ ft^3$$

$$V_{Tot} = 7887.5\ ft^3 \times 7.4805\ gal/ft^3 = 59002.8 \simeq 59000\ gal$$

In the Fuel Oil Storage Tank, the pumps have two suction points, 4 inches and 6 inches above the tank bottom respectively. Valves external to the tank allow either pump to take a suction from either valve. Therefore, unusable fuel will be all that below 4 inches from the bottom of the tank. Using the following formula from input 7:

$$p = 1 + \frac{2(2\alpha - 1)\sqrt{\alpha(1-\alpha)}}{\pi} - \frac{\cos^{-1}(2\alpha - 1)}{\pi}$$

p = ratio of liquid volume to total volume

α = ratio of liquid height to total height

The Fuel Below 4 inches is then:

$$\alpha = \frac{4}{155.25} = 0.02576$$

$$p = 0.006966$$

$$V = p\, V_{Tot} = (0.006966)(59000\ gal) = 411\ gal$$

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

The tank level instrument is assumed to be accurate to +/- 0.5 inches level in the tank. The maximum volume error introduced by 1/2 inch level error will be 1/2 inch around the tank centerline, from 6 ft. 5.5 inches to 6 ft. 6.5 inches.

Using the above formula, at 6 ft. 5.5 inches:

$$\alpha = \frac{6(12)+5.5}{155.25} = 0.4992$$

$$\rho = 0.49897$$

$$V = \rho V_{Tot} = 29439 \text{ gallons}$$

At 6 ft. 6.5 inches:

$$\alpha = \frac{6(12)+6.5}{155.25} = 0.5056$$

$$\rho = 0.50718$$

$$V = \rho V_{tot} = 29923 \text{ gallons}$$

Instrument Error Maximum = difference in above two volumes

$$\text{Inst Error} = (29923 - 29439) \text{ gal}$$

$$= 484 \text{ gallons}$$

The tank is assumed to be sized so that the calculated volume is accurate within 1%.

$$\text{Volume error} = 0.01 (59000 \text{ gal}) = 590 \text{ gallons}$$

These errors may be combined as follows:

$$\text{Total error} = \sqrt{(\text{Volume error})^2 + (\text{Inst. error})^2}$$

$$= \sqrt{(590)^2 + (484)^2}$$

$$= 763 \text{ gal}$$

Fuel required = Fuel Consumption + Unusable fuel + Total Error

$$\text{Fuel required} = 33096 \text{ gal} + 411 \text{ gal} + 763 \text{ gal}$$

$$= 34270 \text{ gal}$$

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

The tank level is measured in height above the bottom, not gallons. Therefore, for operator use the corresponding tank height for the above volume must be found.

At 7 ft. 4 inches

$$\alpha = \frac{7(12)+4}{155.25} = 0.5668$$

$$\rho = 0.5848$$

$$V = \rho V_{Tot} = 34505 \text{ gal}$$

At 7 ft. 3 inches

$$\alpha = \frac{7(12)+3}{155.25} = 0.5604$$

$$\rho = 0.5767$$

$$V = \rho V_{Tot} = 34025 \text{ gal}$$

For operator convenience, the level will be specified to the nearest inch above minimum volume, or 7 ft. 4 inches in this case.

4. Day Tank Level Evaluation

The USAR, Section 8.4.1.1 states each EDG also has a separate 8 hour supply of fuel. At 197 gal/hr., this will require:

$$8 \text{ hrs} \times 197 \text{ gal/hr} = 1576 \text{ gal}$$

By Drawing NX-8431-29, Input 8, tanks T-45A and T-45B are 7 ft long, 6 ft diameter cylinders with heads on each end extending out 1 ft. Six feet is the outer diameter, with 3/16 inch walls, so this corrected diameter will be used for further calculations. The heads will be assumed to be ellipsoids with a height of 1 foot and other axes equal at the radius of the central cylinder of the tank. To find the total volume of these tanks, first the volume of the cylinder will be found, then the volume of the heads will be found, and the results added to give total volume.

Inner Diameter of the tank:

$$I.D. = (6 \text{ ft} \times 12 \text{ in/ft}) - 2(3/16 \text{ in}) = 71.625 \text{ in}$$

For the cylinder:

$$V = \frac{\pi d^2}{4} h$$

$$V_{cyl} = \frac{\pi \left(\frac{71.625}{12}\right)^2}{4} \times 7 \text{ ft}^3 = 195.86 \text{ ft}^3$$

$$V_{cyl} = 195.86 \text{ ft}^3 \times 7.4805 \frac{\text{gal}}{\text{ft}^3} = 1465 \text{ gal}$$

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

For the ellipsoidal heads, we have two equal half ellipsoids, one on each end, so the volume of the total ellipsoid will be used for volume calculations.: For one axis, $r = 1$ ft

For the other two axes, $r = \frac{I.D.}{2} = 35.8125$ in

$V_{ends} = \frac{4}{3}\pi abc = \frac{4}{3}\pi\left(\frac{35.8125}{12}\right)\left(\frac{35.8125}{12}\right)(1)\ ft^3 = 37.3\ ft^3$

$V_{ends} = 37.3\ ft^3 \times 7.4805\ gal/ft^3 = 279\ gal$

Then the total volume is:

$V_{TOT} = V_{cyl} + V_{ends} = 1465 + 279 = 1744\ gal$

The fuel pump suction is 6 inches above the bottom of the day tank, so the bottom 6 inches is unusable. Using the formulas from Input 7 again, the volume below 6 inches is as follows.

For the cylinder: $\alpha = \frac{6}{71.625} = 0.08377$

$$p = 1 + \frac{2(2\alpha-1)\sqrt{\alpha(1-\alpha)}}{\pi} - \frac{\cos^{-1}(2\alpha-1)}{\pi}$$

$p = 0.0401$

$V = p\,V_{cyl} = (0.0401)(1465) = 58.8 \approx 59\ gal$

For the heads:

$p_2 = \alpha^2(3-2\alpha)$

$p_2 = 0.0199$

$V = p_2\,V_{ends} = (0.0199)(279) = 5.5\ gal$

Total:

$V_{6''} = 59 + 5.5 = 64.5\ gal$

The tank overflow is a 3 inch pipe centered 4 inches below the top of the tank. Therefore, overflow starts 5.5 inches below the top of the tank.

$$\alpha = \frac{71.625-5.5}{71.625} = \frac{66.125}{71.625} = 0.9232$$

For cylindrical section

$p = 0.9647$

$V = p\,V_{cyl} = (0.9647)(1465) = 1413\ gal$

For ends

$p_2 = 0.9832$

$V = p_2\,V_{ends} = (0.9832)(279) = 274\ gal$

$V_{OF} = 1413 + 274 = 1687\ gal$

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

The usable volume is that below the overflow but above the minimum suction:

$$V_{us} = V_{OF} - V_{6''} = 1687 - 64.5 = 1622.5 \text{ gallons}$$

This tank is assumed to have calculated volumes accurate to within 2% of full volume. This is less accurate than the Fuel Oil Storage Tank because there were more assumptions used in this calculation.

$$V_{2\%} = (0.02)(1744 \text{ gal}) = 35 \text{ gal}$$

$$V_{tank} = V_{us} - V_{2\%} = 1622.5 - 35 = 1587.5 \text{ gallons}$$

By the previous calculation, 1576 gallons are required for 8 hours of diesel operation. Therefore, we have adequate capacity.

By ANSI N195-1976/ ANS 59.51, Section 3, the definition of integral tank is "A fuel oil tank furnished by the diesel generator manufacturer and mounted on the engine. Its capacity may be included in establishing the available day tank capacity as set forth in section 6.1." The installed diesel generator base tank meets this definition and could be used to expand the day tank capacity, if needed. By NX-9216-7, the base tank is a 550 gallon tank. The normal level switch function to maintain level 300 to 480 gallons, with a backup switch to start at 190 gallons. The installed design is conservative because it meets the requirements without considering this additional tank, which is then available for reserve.

CONCLUSIONS:

1. The Emergency Diesel Generator Fuel Consumption at 2500 KW, with the most conservative allowable API gravity is 197 gallons per hour.

2. The minimum required level in the Fuel Oil Storage Tank (T-44) is 7 feet 4 inches or 34600 gallons.

3. The Fuel Oil Day Tanks (T-45A and T-45B) have sufficient capacity to supply the engine for 8 hours of full load operation.

ATTACHMENTS:

1. EMD Operating Cost Factors Excerpt
2. Excerpt from Bureau of Standards Miscellaneous Publication No. 97, Thermal Properties of Petroleum Products, April 28, 1933.
3. MACHINE DESIGN Tech Brief, "Liquid Level in Tanks" by T.V. Shesadri
4. CALCULATION/ANALYSIS VERIFICATION CHECKLIST

REFERENCES:

None

OPERATING COST FACTORS

EMD

SECTION 5

FUEL OIL CONSUMPTION (Per Engine - Net at Plant Bus)

Fuel consumption and heat rates for the Model MP45 and the MP40 are shown in the table below. This data was obtained from tests utilizing 30° A.P.I. gravity fuel oil.* The table also indicates expected fuel consumption based on the standard fuel (28° A.P.I. gravity) used for expression of fuel consumption. The heat rates are expressed as BTU/KWH net at the bus.

MP45 (20-645E4 Engine)

60 Cycle - 900 RPM

Rating and Load	Heat Rate (BTU/KWH) Higher Heating Value	Heat Rate (BTU/KWH) Lower Heating Value	Approximate Consumption per Hour U.S. Gal. 30° A.P.I.	U.S. Gal. 28° A.P.I.	Imp. Gal. 30° A.P.I.	Imp. Gal. 28° A.P.I.	Liters 30° A.P.I.	Liters 28° A.P.I.
Peaking								
2750 KW	10,600	9,960	206	20[illegible]	172	170	780	773
Base Load								
2500 KW	10,550	9,915	186	184	155	154	704	698
1875 KW	10,800	10,150	143	142	119	118	541	536
1250 KW	12,050	11,325	106	105	88	87	401	397

50 Cycle - 750 RPM

Rating and Load	Heat Rate (BTU/KWH) Higher Heating Value	Heat Rate (BTU/KWH) Lower Heating Value	Approximate Consumption per Hour U.S. Gal. 30° A.P.I.	U.S. Gal. 28° A.P.I.	Imp. Gal. 30° A.P.I.	Imp. Gal. 28° A.P.I.	Liters 30° A.P.I.	Liters 28° A.P.I.
Peaking								
2300 KW	10,400	9,775	169	167	141	140	640	634
Base Load								
2100 KW	10,350	9,725	154	153	128	127	583	578
1575 KW	10,650	10,010	118	117	98	97	447	443
1050 KW	11,420	10,730	85	84	71	70	322	319

* 0.876 specific gravity - 19,420 BTU per pound higher heating value.

Calculation CA-90-023
Attachment 2,
Page 1 of 1

TABLE 4-4

High and Low Heat Values of Some Typical Diesel Fuel Oils*

Gravity, deg API	Sp. Gravity, at 60 F	Weight Fuel, lb/gallon	High Heat Value Btu/lb	High Heat Value Btu/gallon	Low Heat Value Btu/lb	Low Heat Value Btu/gallon
44	0.8063	6.713	19,860	133,500	18,600	125,000
42	0.8155	6.790	19,810	134,700	18,560	126,200
40	0.8251	6.870	19,750	135,800	18,510	127,300
38	0.8348	6.951	19,680	137,000	18,460	128,500
36	0.8448	7.034	19,620	138,200	18,410	129,700
34	0.8550	7.119	19,560	139,400	18,360	130,900
32	0.8654	7.206	19,490	140,600	18,310	132,100
30	0.8762	7.296	19,420	141,800	18,250	133,300
28	0.8871	7.387	19,350	143,100	18,190	134,600
26	0.8984	7.481	19,270	144,300	18,130	135,800
24	0.9100	7.578	19,190	145,600	18,070	137,100
22	0.9218	7.676	19,110	146,800	18,000	138,300
20	0.9340	7.778	19,020	148,100	17,930	139,600
18	0.9465	7.882	18,930	149,400	17,860	140,900
16	0.9593	7.989	18,840	150,700	17,790	142,300
14	0.9725	8.099	18,740	152,000	17,710	143,600
12	0.9861	8.212	18,640	153,300	17,620	144,900
10	1.000	8.328	18,540	154,600	17,540	146,200

Note: It should be understood that heating values for a given gravity of fuel oil may vary somewhat from those shown in the above table.
*Bureau of Standards, Miscellaneous Publication No. 97: Thermal Properties of Petroleum Products, April 28, 1933.

fuels. In liquid fuels, the low heat value is about 6% below the high heat value. In most gaseous fuels the difference is approximately 10%. Assume that the thermal efficiency of a liquid-fuel engine is compared to that of a gas engine where the total heat supplied per bhp hr (HHV) was the same in both engines. Thermal efficiency of the liquid-fuel engine might be, for example, 30% while the gas engine would be 10% better and show 33% thermal efficiency by using the LHV of the fuel.

CALCULATED HEAT VALUE An approximation of high heat value (HHV) of liquid fuels can be calculated from the empirical formulas below:*

HHV = 18,640 + 40 (API gr — 10), Btu per lb
for light fuel oil
HHV = 18,440 + 40 (API gr — 10), Btu per lb
for kerosene
HHV = 17,645 + 54 (API gr), Btu per lb
for heavy, cracked fuel oil,**

Approximate values of both HHV and LHV are shown in Table 4-4 in relation to API gravity of fuel oil. Heat value of most fuel oils, neglecting the heavy oils like Bunker C, is between 19,000 and 19,750 Btu per lb (HHV).

For natural gas, heat value varies with its source. Most of them will fall in the range of 970 to 1130 (HHV), and 880 to 1020 (LHV) Btu per cu ft at 60°F.

FUEL REQUIREMENTS OF DIESEL ENGINES Wide variations in the design of diesel engines make it difficult to set up specifications to serve as an accurate guide for determining the acceptable characteristics of fuel oil. There is a definite influence on fuel requirements of such factors as: engine size and speed; type of combustion chamber (open, pre-combustion, or air cell); degree of turbulence in the combustion chamber; and type of injection system (pressure, and size and number of holes in the nozzle).

In general, lower engine speed, larger cylinder size, finer fuel spray, and more air turbulence will each tend to cause the engine to be less critical to the fuel it receives, or more capable of using lower grades of fuel oils.

Operating conditions are also very important factors in selection of the correct grade of fuel oil. Good operation under variable speed and/or load conditions, or with low ambient air or engine temperature, requires higher cetane fuel, with lower distillation range, and lower percentage of sulfur. There is greater tolerance with respect to these characteristics when the same engine is operated under high, continuous load at constant speed, with high coolant temperature, or with high ambient air temperature.

Fuel requirements for various operating conditions are pointed out in the fuel specifications for Detroit Diesel engines in Table 4-5. Table 4-6 shows also some representative fuel specifications for other high-speed engines.

Specifications for one open combustion-chamber truck diesel require a minimum of 45 cetane, and an allowable maximum of 0.5% sulfur, with 2-D fuel preferred over 1-D. In this engine, 1-D fuel is too volatile and gives poor economy and performance, but can be used. Straight-run distillate fuel oil is recommended rather than cracked blends.

Fuel economy, or miles per gallon, is affected by the weight, or API gravity, of diesel fuel. Within the range of 32 to 40 deg API gravity, a lower number indicating a heavier fuel will provide more power and increased miles per gallon. Conversely, a higher number that identifies lighter fuel will result in lower power and decreased miles per gallon. Some trucking organizations feel that if the fuel has a 40 cetane number minimum, an API gravity of 36 maximum is desirable.

For each API gravity number above 36, engine dynamometer tests indicate approximately 1% lower power and road tests indicate approximately 2% lower mileage. The difference between 32 and 40 API gravity can make a difference of 15% in fuel costs.

*Journal of the American Chemical Society, Vol. 30, No. 10 (Oct., 1908), p. 1626
**Fucuyer, Moerell, and Esser, "Relationship between Calorific Values and Other Characteristics of Residual Fuel Oil," Industrial and Engineering Chemistry, Vol. 21 (1929), p. 911

11

Calculation CH-[illegible]
Attachment 3
page 1 of 1

The die selected by GM for testing was modified for warm forming by locating electric resistance cartridges in the individual die inserts. This method was used because the die was not adaptable to a circulating fluid system, the method frequently used to heat plastic molding dies. Approximately 20 h were required to reach the 250°C forming temperature. Heating time could be reduced, however, by insulating the upper part of the die and the lower part of the punch from their supporting structures. A circulating-oil heating system with passages running through the die components would also increase heating efficiency.

LIQUID LEVEL IN TANKS

T. V. SESHADRI
Principal Engineer
Systems
Fruehauf Corp.
Detroit, Mich.

THE height of liquid in a storage tank often must be known to determine the effects of sloshing or center-of-gravity shifts. The relationship between height and volume for flat-ended cylindrical and elliptical tanks was presented in the May 8, 1980, issue as

$$p = 1 + \frac{2(2\alpha-1)\sqrt{\alpha(1-\alpha)}}{\pi} - \frac{\cos^{-1}(2\alpha-1)}{\pi}$$

where p = ratio of liquid volume to total volume, and α = ratio of liquid height to total height. But many tanks have hemispherical or ellipsoidal ends, and the relationship is more complex.

For spherical and ellipsoidal tanks, the relationship between proportional liquid volume p_2 and height is

$$p_2 = \alpha^2(3 - 2\alpha)$$

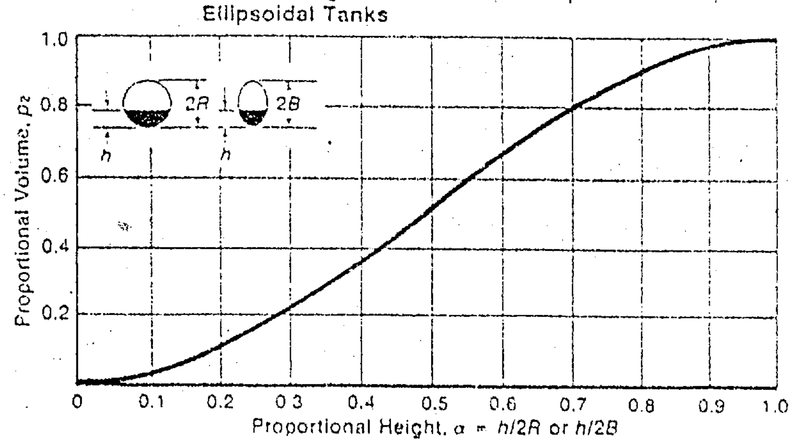
This equation is plotted in the first graph.

For cylindrical tanks with hemispherical ends, the relationship is

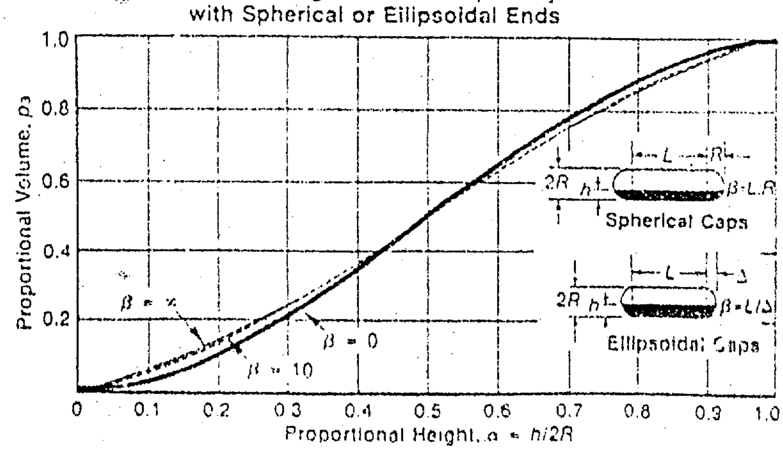
$$p_3 = \frac{3p\beta + 4p_2}{3\beta + 4}$$

where $\beta = L/R$, L = length of cylindrical section, and R = radius of spherical section. This relationship is the same for cylindrical tanks with ellipsoidal ends, except that $\beta = L/\Delta$, where Δ = length of ellipsoidal section. The equation is plotted in the second graph for various values of β.

1 — Volume/Height Relationship for Spherical and Ellipsoidal Tanks



2 — Volume Height Relationship for Cylindrical Tanks with Spherical or Ellipsoidal Ends



12

COMMENTS (CONTINUED)

2. A MORE QUANTITATIVE EVALUATION OF THE EFFECT OF TEMPERATURE CHANGES ON REQUIRED VOLUME SHOULD BE PROVIDED.

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL

Temperature Effects

Based on review comment number 2, temperature effects will be addressed to further justify assumption 6.

1. Temperature effects in Fuel Oil Storage Tank (T-44)

Per the attached excerpt from "Perrys Chemical Engineer Handbook", Sixth Edtion, for API 38 oil:

$$\frac{\Delta V}{V} \text{ per } ^\circ F = 0.00050$$

At about 34,500 gallons in T-44:

$$\Delta V/_{^\circ F} = (0.00050)(34{,}500 \text{ gal}) = 17.25 \text{ gal}/_{^\circ F}$$

The available margin in T-44 is the difference between the required 7 ft 4in minimum level and the actual fuel required in T-44 to run for seven days, 34,270 gallons per this calculation.

$$\text{Margin} = 34{,}500 \text{ gal} - 34{,}270 \text{ gal} = 230 \text{ gal}$$

This margin would allow for the following temperature change:

$$\Delta T = \frac{230 \text{ gal}}{17.25 \text{ gal}/_{^\circ F}} = 13.33 ^\circ F \simeq 13 ^\circ F$$

Based on conversations with local EPA officials on site and others from the local area, this is an unrealistically high temperature change for the contents of a buried tank.

2. Temperature Effects in Day Tank (T-45A/B)

Applying a similar approach to that above, at 1687 gallons in T-45A/B:

$$\Delta V/_{^\circ F} = (0.00050)(1687) \text{ gal}/_{^\circ F} = 0.8435 \text{ gal}/_{^\circ F}$$

Assuming the maximum design change in temperature in the diesel building:

$$\Delta T = 104 \, F - 60 \, F = 44 ^\circ F$$

$$\Delta V = (44 ^\circ F)(0.8435 \text{ gal}/_{^\circ F}) = 37 \text{ gal}$$

In the day tank, margin is:

$$\text{margin} = (1587.5 - 1576) \text{ gal} = 11.5 \text{ gal}$$

However, the fuel oil base tank on each engine is more than adequate to supply the additional 26 gallons required.

Based on the above simplified calculation of temperature effects, the decision to not further consider temperature effects on the fuel oil requirements is acceptable.

Calculation [illegible]-013
Attachment 5
Page 2 of 2

TABLE 9-9 ASTM D 396-Note 79: Detailed Requirement for Fuel Oils*

Grade of fuel oil	Flash point, °C (°F)	Pour point, °C (°F)	Water and sediment, volume %	Carbon residue on 10% bottoms, %	Ash, weight %	Distillation temperatures, °C (°F) 10% point	90% point	
	Min.	Max.	Max.	Max.	Max.	Max.	Min.	Max.
No. 1: a distillate oil intended for vaporizing pot-type burners and other burners requiring this grade of fuel	38 (100)	−18[C] (0)	0.05	0.15		215 (420)		288 (550)
No. 2: a distillate oil for general-purpose heating for use in burners not requiring No. 1 fuel oil	38 (100)	−6[C] (20)	0.05	0.35			282[C] (540)	338 (640)
No. 4: preheating not usually required for handling or burning	55 (130)	−6[C] (20)	0.50		0.10			
No. 5 (light): preheating may be required, depending on climate and equipment	55 (130)		1.00		0.10			
No. 5 (heavy): preheating may be required for burning and, in cold climates, for handling	55 (130)		1.00		0.10			
No. 6: preheating required for burning and handling	60 (140)	[G]	2.00[E]					

Universal a[illegible] (100°[illegible])
Min.
(32.6)
(45)
(>125)
(>300)
(>900)

*Reprinted, with permission, from the *Annual Book of Standards*.

[A] It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

[B] In countries outside the United States other sulfur limits may apply.

[C] Lower or higher pour points may be specified whenever required by conditions of storage or use. When a pour point less than −18°C (0°F) is specified, the minimum viscosity for grade No. 2 shall be 1.7 cSt (31.5 SUS) and the minimum 90% point shall be waived.

[D] Viscosity values in parentheses are for information only and not necessarily limiting.

[E] The amount of water by distillation plus the sediment by extraction shall not exceed 2.00%. The amount of sediment by extraction shall not exceed 0.50%. A deduction in quantity shall be made for all water and sediment in excess of 1.0%.

[F] Where low-sulfur fuel oil is required, fuel oil falling in the viscosity range of a lower numbered grade down to and including No. 4 may be supplied by agreement between purchaser and supplier. The viscosity range of the initial shipment shall be identified, and advance notice shall be required when changing from one viscosity range to another. This notice shall be in sufficient time to permit the user to make the necessary adjustments.

[G] Where low-sulfur fuel oil is required, Grade 6 fuel oil will be classified as low pour +15°C (60°F) max, or high pour (no max.). Low-pour fuel oil should be used unless all tanks and lines are heated.

Thermal expansion of petroleum fuels can be estimated as volume change per unit volume per degree:

Density		Volume change/unit volume	
kg/dm³, 15°C	API gravity	Coefficient/°F	Coefficient/°C
>0.9660	Below 14.9	0.00035	0.00063
−0.8499	15.0– 34.9	0.00040	0.00072
−0.7754	35.0– 50.9	0.00050	0.00090
−0.7239	51.0– 63.9	0.00060	0.00108
−0.6724	64.0– 78.9	0.00070	0.00126
−0.6419	79.0– 88.9	0.00080	0.00144
−0.6277	89.0– 93.9	0.00085	0.00153
−0.6112	94.0–100.0	0.00090	0.00162

ASTM-IP Petroleum Measurement Tables (ASTM D 1250 IP 200) are used for volume corrections in commercial transactions.

Specific heat capacity of petroleum liquids between 0 and 205°C (32 and 400°F) having a relative density of 0.75 to 0.96 at 15°C can be calculated within 2 to 4 percent of the experimental values from the following equations:

$$c = (1.685 + 0.0039 \times {}^\circ\mathrm{C})/s \qquad (9\text{-}11)$$

$$c' = (0.388 + 0.00045 \times {}^\circ\mathrm{F})/s \qquad (9\text{-}12)$$

where c = heat capacity, kJ/(kg·°C)
c' = heat capacity, Btu/(lb·°F)
s = relative density at 15°C (specific gravity, 60/60°F)

Specific heat varies with temperature, and an arithmetic average of the specific heats at the initial and final temperatures can be used for calculations related to the heating or cooling of oil.

Table 9-10. Typical Ultimate Analyses of Petroleum Fuels

Composition, %	No. 1 fuel oil (41.5°A.P.I.)	No. 2 fuel oil (33°A.P.I.)	No. 4 fuel oil (23.2°A.P.I.)	Low sulfur, No. 6 F.O. (12.6°A.P.I.)	High sulfur, No. 6 (15.5°A.P.I.)
Carbon	86.4	87.3	86.47	87.26	84.67
Hydrogen	13.6	12.6	11.65	10.49	11.02
Oxygen	0.01	0.04	0.27	0.64	0.38
Nitrogen	0.003	0.006	0.24	0.28	0.18
Sulfur	0.09	0.22	1.35	0.84	3.97
Ash	<0.01	<0.01	0.02	0.04	0.02
C/H Ratio	6.35	6.93	7.42	8.31	7.62

NOTE: The C/H ratio is a weight ratio.

The ther[illegible] in Fig. 9-6[illegible] fin wax in [illegible] for temper[illegible] Fuel syst[illegible] for No. 6 f[illegible] 49°C (90 t[illegible] 93°C (165 [illegible] zation. No. [illegible] electric hea[illegible] ditions, leng[illegible] relief arran[illegible] lines when [illegible] can expand[illegible] Fuel-pump[illegible] lates throug[illegible] fuel system[illegible] systems).

Commer[illegible] multiples of units used [illegible] ally involve

MJCØ1494

MONTICELLO NUCLEAR GENERATING PLANT		3494
TITLE:	CALCULATION COVER SHEET L0608004	Revision 5
		Page 1 of 1

CALCULATION COVER SHEET

Title *Minimum Allowable Fuel Oil Storage Tank Level*

CA- 90 - 023 Add. 1

Vendor No.

Associated Reference

Assigned Personnel

Name (Print)	Signature	Title	Initials
Robert D. Olson	Robert D. Olson	*Spec. Engr.*	RDO
Michael J. Morris	Michael J. Morris	*Sr. Prod. Engr.*	MJM
Stephen A. Engelke	SA Engelke	*Supt. E&I Eng.*	SAE

Record of Issues

Rev	Description	Total No. of Sheets	Last Sheet No.	Preparer	Verifier	Verifier	Approval	Approval Date
0	*Final Issue*	~~7~~8 MJM 4-24-00	Sh. 1 Att 6	RDO	MJM		SAE	5-1-00

☐ Vendor Verification/Approval in Document

Verification Method(s)

☒ Review ☒ Alternate Calculation ☐ Test ☐ Other

References/Filing Locations

1.

2.

Associated Subjects/Component -

3087 (DOCUMENT CHANGE, HOLD AND COMMENT FORM) incorporated:				
FOR ADMINISTRATIVE USE ONLY	Resp Supv: GSE-NGS	Assoc Ref: AWI-05.01.25	SR: N	Freq: 0 yrs
	ARMS: 3494	Doc Type: 3042	Admin initials:	Date:

APPROVED (Signatures available in Master File)

1/78

25

MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL CA-90-023 Add. 1

A. PURPOSE

The purpose of this addendum is to revise calculation CA-90-023 for minimum Diesel Fuel Oil Storage Tank (T-44) level by evaluating whether additional stored fuel is required to address vortexing concerns and the use of the normal lineup suction point for the Diesel Oil Transfer Pump (P-11). These additional requirements may result in a change to Technical Specification 3.9.B.3.c requiring additional fuel to be stored in tank T-44 to meet the minimum 7 day supply for 1 EDG at full load (2500 kW).

In addition, the day tank / base tank combination fuel storage capacity will be reevaluated to ensure that a minimum fuel capacity for 8 hours of full load (2500 kW) operation of an EDG remains available with day tank vortexing concerns being addressed. This 8 hour capacity requirement is discussed in Ref. 8.

B. METHODOLOGY

Critical submergence determines the amount of fluid required above an intake such that air entraining vortexing of the fluid is unlikely to occur. Critical submergence of the fuel oil pump suctions for T-44 and the day tanks will be determined in accordance with the guidance contained in Input 2. These calculated critical submergence values will then be amended by information extracted from Input 3 to account for the differences between water, the basis for the critical submergence calculation, and fuel oil. The amended values of critical submergence will then be combined with the unusable fuel volumes contained below the fuel pump suction points, the required quantity of fuel for consumption by the EDG at full load (2500 kW), and the quantities for level instrument and tank volume inaccuracies. These values were previously determined in the CA-90-023 and will be reused in this addendum to establish the revised minimum allowable fuel oil storage levels. These revised minimum levels may result in additional stored fuel being required to avoid vortexing at the suctions of the fuel pumps while maintaining the required volume of fuel oil available for consumption. The unusable volume in tank T-44 will also be revised based on a more conservative suction point within the tank.

C. ACCEPTANCE CRITERIA

1. Diesel Oil Storage Tank (T-44) capacity remains sufficient to hold the revised 7 day supply of fuel for 1 EDG at full load (2500 kW) with spare capacity for an additional 16,000 gallons of fuel, approximately 2 tanker loads, while maintaining the level below the nominal tank T-44 HI Level alarm point. This ensures adequate tank capacity for fuel additions and transfers without violating the revised 7 day supply requirement or causing nuisance alarms during fuel oil inventory control activities.

2. The capacities of the Day Tank / Base Tank combinations remain sufficient to hold the revised 8 hour supply of fuel for the respective EDG at full load (2500 kW).

D. INPUTS

1. Calculation CA-90-023, MINIMUM ALLOWABLE FUEL OIL STORAGE TANK LEVEL.

2. Water Power, Article titled: Vortices at Intakes in Conventional Sumps, March 1972.

3. Alden Research Laboratories, Inc. Report 277-97/M295F, Simulated Vortex Formation Testing of a #2 Diesel Fuel Oil Storage Tank.

4. MACHINE DESIGN Tech Brief, "Liquid Level in Tanks" by T. V. Seshadri, Fruehauf Corp.

5. Regulatory Guide 1.82, "Water Sources for Long Term Recirculation Cooling Following a Loss of Coolant Accident."(Nov. 1985).

6. Nominal Diesel Oil Transfer Pump flow rate is 25 gpm. The flow rate to be used in this calculation is 26 gpm based on 1997 and 1998 trending data from EDG System Tests 0187-01 and 0187-02.

7. Fuel Transfer Pump flow rate to be used is 10 gpm per reference 7.

8. Conversion factor: 0.1337 ft^3/gallon.

9. Conversion factor: 12 inches / foot

10. Conversion factor: 60 seconds / minute

E. ASSUMPTIONS

#2 fuel oil behaves substantially the same as a mix of #1 and #2 fuel oil in terms of flow characteristics. Therefore, the method of arriving at the critical submergence for Monticello's fuel oil mix of #1 and #2 fuel oil from the calculation for critical submergence in water, the data from the Alden Research Labs report, and the determination of a 20 percent addition for the differences between fuel oil and water, as discussed in section F.2, is conservative.

The foot valve / strainer combinations at the bottom of suction piping in tank T-44 provide no vortex suppressing function and intake levels are at the level of the installed 3 inch sleeve which are 4 and 6 inches from the bottom of the tank per Ref. 2.

Diesel Oil Transfer Pump (P-11) suction remains lined up to the suction source located 6 inches from the bottom of tank T-44, it's normal suction scurce (Ref. 1,2,11, 12, 13).

The 1 inch suction pipe in the day tanks is assumed to be schedule 80, carbon steel with an inside diameter of .957 inches.

The primary fuel transfer pump flow rate of 10 gpm is adequate to ensure only one of the fuel transfer pumps is operating to maintain base tank level, (i.e. 10 gpm = 600 gph > 197 gph burn rate).

F. ANALYSIS

1. Critical Submergence Formula

A literature search was conducted to establish the correct inputs to the calculation of minimum suction submergence to prevent vortexing. Input 2, the Water Power article, provides two equations relating the Submergence Froude Number, a function of pipe geometry and fluid velocity, to the critical submergence required to prevent vortexing in water. One of the equations is applicable to situations in which vortex suppression devices are present. The other equation, which provides a more conservative result in terms of critical submergence, is applicable to situations where no vortex suppression devices are present. The EDG day tanks have open pipe intakes with no vortex suppression devices present and it has been assumed that the foot valve / strainer combinations on the Tank T-44 suctions provide no vortex suppression. Therefore, the more conservative formula, which is applicable to situations without vortex suppression devices, will be used throughout this calculation as follows:

s/d ≥ 1 + Submergence Froude number

*and Submergence Froude number = v / √(g*d)*

where s = the fluid depth above the pipe centerline (ft)
d = the inside diameter of the suction pipe (ft)
v = the pipe inlet velocity (ft/sec)
g = acceleration due to gravity (32.2 ft/sec^2)

Rewriting the equation to solve for submergence, s, yields:

*s ≥ d * (1 + Submergence Froude number)*

or s ≥ d +v√(d/g)*

2. Critical Submergence for Variable Fluid Properties.

A literature search was conducted to determine if the variable fluid properties of fuel oil and water, and their impact on vortex formation, had been studied. Input 3, the Alden Research Labs report, was located and a copy was requested and obtained from Northeast Utilities. This report contains data which indicates that there are significant differences in the formation of vortexes between #2 fuel oil and water under a given set of circumstances.

Data points were extracted from this report and a 2nd order curve fit was performed using Microsoft Excel to determine the effects of vortexing across a range of flows. The resultant data, summarized in Attachment 3, indicates that the difference in critical submergence to prevent vortexing between fuel and water increases with flow under a given set of . nditions. At a flow rate of 30 gpm, the critical submergence to prevent vortexing in #2 fuel oil was determined to approach 115% of that required to prevent vortexing in water under the same conditions.

Using the above data as a basis, a 20 percent addition to the critical submergence calculated for water will be used in the remainder of this calculation to determine the critical submergence required for a blend of #1 and #2 fuel oil as utilized at Monticello.

3. Tank T-44 Application of Critical Submergence Formula

In tank T-44, the Diesel Oil Transfer Pump (P-11) withdrawal flow rate of 26 gpm is converted to a velocity, v, as follows:

$$v = \text{Volumetric Flow} / \text{Area}$$

Calculate Volumetric Flow

$$\text{Volumetric Flow} = 26\ gal/min * 0.1337\ ft^3/gal * 1\ min / 60\ sec = 0.058\ ft^3/sec$$

The suction piping is 1.5 inch, schedule 80, carbon steel with an inside diameter of 1.50 inches per Ref. 1, 4, and 5. The area of the pipe is calculated as follows:

$$\text{Area} = \pi * d^2/4 = \pi * (1.5\ in / 12\ in/ft)^2 / 4$$

$$\text{Area} = 0.012\ ft^2$$

Solving for velocity, v, in tank T-44 yields:

$$v = \text{Volumetric Flow} / \text{Area}$$

$$v = 0.058\ ft^3/sec / 0.012\ ft^2 = 4.8\ ft/sec$$

Solve for submergence, s, in tank T-44 as follows:

$$s \geq d + v * \sqrt{(d/g)}$$

$$s \geq (1.5\ in / 12\ in/ft) + 4.8\ ft/sec * \sqrt{((1.5\ in / 12\ in/ft) / (32.2 ft/sec^2))}$$

$$s \geq 0.42\ ft * 12\ in/ft = 5.0\ in$$

6

25

The result is that if the fluid were water, a minimum submergence of 5 inches would be required to prevent vortexing. This value must be further amended, as described in section 2 above, to account for the differences between water and fuel oil as follows:

$$s \geq 5.0 \text{ inches } H_20 * 1.2 \text{ inches Fuel Oil / inch } H_20$$

$$s \geq 6.0 \text{ inches Fuel Oil}$$

A minimum submergence of 6 inches will be used to address vortexing concerns in tank T-44.

4. Determination of Tank T-44 Minimum Level

The Diesel Oil Transfer Pump suction is normally lined up to a suction source which is located 6 inches from the bottom of the tank. The original calculation assumed that this suction would be swapped over to an alternate suction located 4 inches from the bottom of the tank. This is considered non-conservative and the normal suction, located 6 inches from the bottom, will be considered as being in use for further calculation in this addendum.

Using the suction located 6 inches from the tank bottom, the bottom 6 inches of fuel is unusable, this was previously considered to be the bottom 4 inches as described in the previous paragraph. Furthermore, due to minimum submergence considerations detailed in Section 3, the fuel between 6 and 12 inches from the bottom is considered unusable. From Ref. 6, the fuel contained below 12 inches in tank T-44 is 2102 gallons.

From the original calculation, Minimum Fuel Required is calculated as follows:

Min Fuel Req'd = Fuel Consumed + Unusable Fuel + Total Error

Substituting the new Unusable Fuel volume determined above yields:

Min Fuel Req'd = 33,096 + 2102 + 763 gallons

Min Fuel Req'd = 35,961 gallons

Conversions from tank level in inches to the nearest gallon are contained in Ref. 6. The currently specified minimum level in T-44 is 88 inches or 34,505 gallons. A revised T-44 level of 91 inches would provide a capacity of 35,940 gallons of fuel which is inadequate. A revised T-44 level of 92 inches provides a capacity of 36,416 inches which is adequate and provides a margin of 455 gallons.

For convenience, a new minimum level of 8 feet (96 inches) or 38,307 gallons is recommended. This level would provide a margin of approximately 2350 gallons, or approximately 12 hours of EDG operation at full load (2500 kW), over the calculated minimum stored fuel requirement.

This level is acceptable as the tank has ample capacity for an additional 2 tanker loads of fuel, approximately 16,000 gallons, allowing room for fuel additions and transfers without violating the revised minimum level or causing nuisance HI Level alarms during these activities.

5. Day Tank Application of Critical Submergence Formula

In the Day Tanks, the Fuel Oil Transfer Pump withdrawal flow rate of 10 gpm is converted to a velocity, v, as follows:

$$Volumetric\ Flow = 10\ gal/min * .1337\ ft^3/gal * 1\ min / 60\ sec$$

$$Volumetric\ Flow = 0.0223\ ft^3/sec$$

The suction piping is 1 inch, and has been assumed to be schedule 80, carbon steel with an inside diameter of 0.957 inches per Ref. 1, 4, and 5. The area of the pipe is calculated as follows:

$$Area = \pi * d^2/4 = \pi * (0.957\ in / 12\ in/ft)^2/4 = 0.005 ft^2$$

The solution for velocity, *v*, in the day tanks is:

$$v = Volumetric\ Flow / Area$$

$$v = 0.0223\ ft^3/sec / 0.005\ ft^2 = 4.46\ ft/sec$$

Solve for submergence, *s*, in the day tanks as follows:

$$s \geq d + v * \sqrt{(d/g)}$$

8

$$s \geq (0.957\ in / 12\ in/ft) + 4.46\ ft/sec * \sqrt{((0.957\ in / 12\ in/ft) / (32.2\ ft/sec^2))}$$

$$s \geq 0.302\ ft * 12\ in/ft = 3.6\ in$$

The result is that if the fluid were water, a minimum submergence of 3.6 inches would be required to prevent vortexing. This value must be further amended, as described in Section 2 above, to account for the differences between water and fuel oil as follows:

$$s \geq 3.6 \text{ inches } H_20 * 1.2 \text{ inches Fuel Oil / inch } H_20$$

$$s \geq 4.3 \text{ inches Fuel Oil}$$

A minimum submergence of 4.5 inches will be used to address vortexing concerns in the day tanks.

6. Confirmation of Day Tank / Base Tank Combination Capacity

The Fuel Oil Transfer Pumps draw their suction from a source which is located 6 inches from the bottom of the day tanks (Ref. 3). Using these suction points, the bottom 6 inches of fuel is unusable. Due to minimum submergence considerations detailed in Section 5, the fuel between 6 and 10.5 inches from the bottom of the tanks will be considered unusable. In addition to the unusable fuel in the bottom of the tank, the volume contained in the tank above the bottom of the overflow, which is located 5.5 inches from the top, is not capable of holding fuel.

The tank capacities were determined as follows in the CA-90-023:

Tank Diameter = 71.625 inches
Volume of cylindrical portion of tank = 1465 gal
Volume of ellipsoidal portion of tank = 279 gal
Total tank volume = 1744 gal
Overflow Unusable Volume = 57 gallons
Tank Volume Error (2%) = 35 gallons

To find the total amount of unusable fuel in the bottom of the tank, the ratio of each portion below the 10.5 inch level must be calculated in accordance with Input 4 as follows:

Find α, the ratio of Tank Level to Tank Diameter

α = *Tank Level / Tank Diameter*

$\alpha = 10.5 \text{ in} / 71.625 \text{ in}$

$\alpha = 0.147$

Find the ratio, ρ, of unusable fuel to total volume in the cylindrical portion of the tanks. Note that trigonometric functions are in radians rather than degrees.

$\rho = 1 + (2*(2\alpha-1)\sqrt{(\alpha(1-\alpha))}) / \pi - \cos^{-1}(2\alpha-1)/\pi$

$\rho = 1 + (2*(2*(0.147)-1)\sqrt{(0.147*(1-0.147))})/\pi$
$- \cos^{-1}(2*0.147-1)/\pi$

$\rho = 1 - 0.159 - 0.75$

$\rho = 0.091$

Unusable fuel, UF_1, in the bottom of the cylindrical portion of the tanks is as follows:

UF_1 = Cylindrical volume * ρ

UF_1 = 1465 gallons * 0.091 = 133.3 gallons

Find the ratio, $\rho 2$, of unusable fuel to total volume in the ellipsoidal portion of the tanks.

$\rho 2 = \alpha^2*(3-2\alpha)$

$\rho 2 = (0.147)^2 * (3 - 2 * 0.147)$

$\rho 2 = 0.059$

Unusable fuel, UF_2, in the bottom of the ellipsoidal portion of the tanks is as follows:

$$UF_2 = \text{Ellipsoidal volume} * \rho 2$$

$$UF_2 = 279 \text{ gallons} * 0.059 = 16.5 \text{ gallons}$$

Total Unusable fuel, UF_T, in the bottom of the tank is as follows:

$$UF_T = UF_1 + UF_2$$

$$UF_T = 133.3 \text{ gallons} + 16.5 \text{ gallons} = 149.8 \text{ gallons}$$

Total Unusable fuel in the bottom of the tanks will be considered to be 150 gallons.

The usable volume that is below the overflow and above the unusable fuel in the bottom of the tanks after taking into account the assumed 2% tank volume inaccuracy, as stated in the original calculation, is as follows:

Usable Volume = Total Volume - Overflow Unusable Volume - Unusable Fuel - Tank Volume Error

Usable Volume = 1744 - 57 - 150 - 35 = 1502 gallons

The CA-90-023 states that the burn rate of an EDG is 1576 gallons in an 8 hour period of full load (2500 kW) operation. Also, per Ref. 8, fuel volume contained in the base tank is available to supplement the capacity of the day tank to provide the required fuel for 8 hours of full load (2500 kW) EDG operation. Per Ref. 9, the normal level in the base tank is maintained at a nominal 325 gallons by the primary fuel transfer pump. If this pump were to fail, the secondary pump would maintain the level at a nominal 190 gallons. Reference 10 has taken credit for a minimum of 150 gallons of the base tank capacity as a supplement to the oil in the day tank to ensure EDG operability. If fuel level in the day tank is noted to be below 190 gallons while the EDG is in operation, investigation of the system is required to evaluate and maintain continued EDG operability.

The resultant fuel volume combination in the worst case is as follows:

Combination Fuel Volume = Day Tank Volume + Min. Base Tank Volume

Combination Fuel Volume = 1502 + 150 gallons = 1652 gallons.

This analysis supports the USAR statement that the EDG day tank / base tank combinations are sized sufficiently to provide an 8 hour supply of fuel to the respective EDG at full load (2500 kW) after addressing day tank vortexing concerns.

G. CONCLUSIONS

1. Technical Specification 3.9.B.3.c should be revised to indicate 38,300 gallons, the equivalent of 8 feet of fuel oil, in lieu of the current 34,500 gallons. This change will address vortexing concerns, a non-conservatism in the assumed suction source location for the Diesel Oil Transfer Pump, and will provide additional margin to the calculated value of minimum required fuel. This margin will be available for future use in mitigating any minor setpoint methodology issues which may be raised.

2. The day tank / base tank combinations are sized sufficiently to supply the respective EDG for 8 hours of full load (2500 kW) operation with the revised storage requirements which address vortexing concerns in the day tanks.

H. FUTURE NEEDS

- CR20001767
- Update USAR section 8.4.1.2
- Update Tech Spec 3.9.B.3.c and associated Bases
- Set point change for T-44 LO Level
- Setpoint change for T-44 LO-LO Level
- Update CML for set point changes
- Update Ops Man Section B.9.8-05
- Update Ops Man Section B.8.11-02
- Update Ops Man Section B.8.11-03
- Update Ops Man Section B.8.11-04

- Update Ops Man Section B.8.11-05
- Update Training Center Materials
- Update the following operating procedures and logs:

0187-1	11 EMERGENCY DIESEL GENERATOR START AND LOAD TEST
0187-2	12 EMERGENCY DIESEL GENERATOR START AND LOAD TEST
0192	DIESEL FUEL OIL QUALITY CHECK
2014	TURBINE/RECOMBINER/TRANSFORMER DAILY LOG AND CHECK SHEEETS
2020	CONSUMABLE ITEMS LOG
1361	FUEL TRANSFER FROM DIESEL OIL STORAGE TANK TO HEATING BOILER OIL STORAGE TANK
8132	FUEL TRANSFER FROM DIESEL OIL STORAGE TANK TO HEATING BOILER DAY TANK

I. ATTACHMENTS

1. Water Power, Article titled: Vortices at Intakes in Conventional Sumps, March 1972.
2. Alden Research Laboratories, Inc. Report 277-97/M295F, Simulated Vortex Formation Testing of a #2 Diesel Fuel Oil Storage Tank.
3. Summary of data extracted from the Alden Research Labs Report, 2nd order curve fits of that data and a comparison of the curves over the range of flows from 0 to 30 gpm.
4. MACHINE DESIGN Tech Brief, "Liquid Level in Tanks" by T. V. Seshadri, Fruehauf Corp.
5. Calculation / Analysis Verification Checklist, Form 3495.

J. REFERENCES

1. Drawing NH-36051 Rev. AC, P&ID Diesel Oil System
2. Drawing NX-8431-5, 60,000 GAL U.G. Storage Tank
3. Drawing NX-8431-29, 1500 GAL Diesel Day Tank
4. Piping Specification M-40
5. Crane Technical Paper 410, Flow of Fluids through valves, fittings, and Pipe, Pipe Data, Carbon and Alloy Steel - Stainless Steel, Page B-16.
6. Ops Man B.8.11-06 Rev. 2, Diesel Oil, Figures, Table 1 Diesel Oil Storage Tank Level vs Gallons Chart
7. Tech Manual NX-9216-7, 999 System Generating Plant, Section 4, Engine Accessory Equipment, Page 17.
8. USAR Section 8.4.1.2
9. Ops Man B.9.8-03 Rev. 3, Emergency Diesel Generators, Instrumentation and Controls
10. Ops Man B.9.8-05 Rev. 6, Emergency Diesel Generators, System Operations
11. Procedure 2154-14 Rev. 12, Fuel Oil System Prestart Valve Checklist
12. Drawing NF-119034-1 Rev. C, Section XI – Fuel Oil Flow Meter Installation
13. Drawing NF-36760 Rev. E, Grading, Drainage & Utilities Details – Sh. 3 of 5.

ATTACHMENT 1
PAGE 1 OF 3

IEC/TC4 terms at international level.

This approach was less evident in the promotion of a "Turbine Specification".

The steps taken to unify the expertise of IEC/TC4 and IEC/SC2D for the consideration of salient pole alternators and motors in turbine and storage-pump testing in terms of losses, power output/input, their measurement and allocation, seem justified. Several problems allied with electrical, friction, windage, thrust and other losses await reconciliation, however.

There were few indications that the "Governor Guide Specification" would embrace frequency-response data mentioned in the "Speed Governing System Test Code" (IEC Publication No. 308/1970).

Although approval of the "Model Storage Pump Test Code" under the Six-Months Rule and the Geneva release of Chapter XI on "Model Turbine Cavitation" (Publication No. 193A) will complete difficult assignments and will (with the "Model Testing Standardization" report) embody valuable material, much remains to be done.

Tasks on "Scale Effect Formulae" and "Turbine Model Dimensional Verification" herald amendments to IEC No. 193. 1965, and perhaps codification with the "Model Storage Pump Test Code".

Consideration of long-term work did not, in the event, produce a specific programme because current demands on the 18 working groups were heavy enough to defer additional undertakings.

After recognizing that working groups should scrutinize sponsored publications, their constitution—including ISO representation—was reviewed and modified where appropriate.

Although establishment of apparently effective IEC/ISO liaison should avoid delays and ensure consistency of codes sharing common ground, it remains to be seen whether successful initiation is maintained subsequently.

The absence of Committee of Action references was a tribute to "Specialist/User" understanding of practical problems, especially in terms of prototype interpretation, and to the spirit prevailing throughout the sessions.

These were presided over by Professor L. C. Neale, USA, who succeeds Professor L. J. Hooper, USA. Professor Hooper now retires as Chairman of IEC/TC4 in accordance with IEC rules, although he attended in a consultative capacity.

After expressing appreciation for their services, as well as for BSI aid and NEL facilities, the meeting adjourned. It left the date and location of the next session to the Chairman's discretion, but favoured Munich in 1973.

Vortices at intakes in conventional sumps

By Dr. Y. R. Reddy* and J. A. Pickford*

This article describes the development of a design criterion to avoid vortices in pump sumps and at intakes from reservoirs

THE FUNCTION of an intake is to convey water from a reservoir into the penstock in a hydroelectric power plant or to supply water from a sump to a pump.

If the depth of water above the intake is low air-entraining vortices develop, and these adversely affect the efficiency of the hydraulic machinery by reducing flow rate and by giving extra swirl to the fluid, in addition to causing vibration and noise.

In shallow reservoirs wave action develops an unstable boundary layer (depending on the wave length and celerity) and this is generally responsible for the change in vorticity which leads to the formation of air-entraining vortices.

The largest single factor contributing to vortex formation in pump inlets is the flow pattern within the sump, which in turn is governed by the entry conditions. All the vorticity responsible for vortex formation is generated at a flow boundary and this then diffuses into the flow.

Vortices also develop as a result of boundary discontinuities, which is the main reason for different critical submergences for the same intake diameter and velocity, when the sump geometry is changed.

However, only inlets where there is no induced swirl due to artificial boundary changes are considered here and it is thus assumed that the air-entraining vortex in a conventional inlet (Fig. 1) is only a function of the following variables:

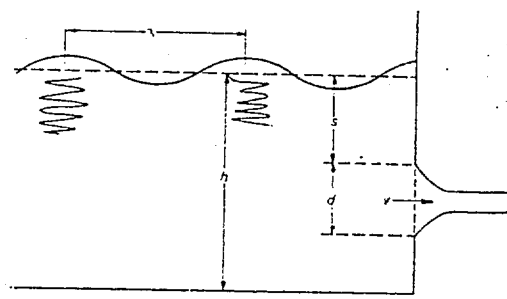


Fig. 1. Definition sketch of an intake

$$f(s, d, v, \mu, \rho, h, \lambda, g) = 0 \quad \ldots \quad (1)$$

where s is submergence above the intake; d is the diameter of the intake; v is the velocity of flow through the intake; μ and ρ are fluid viscosity and density, respectively; h is the total water depth; λ is wave length; and g is the acceleration due to gravity.

Using Buckingham's π-theorem, Eq. (1) can be reduced to the following form of dimensionless numbers:

$$\psi(Fr, Re, s/d, \lambda/h) = 0 \quad \ldots \quad (2)$$

* University of Technology, Loughborough, Leicestershire, U.K.

15

25

ATTACHMENT 1
PAGE 2 OF 3

nor, in the event ... rrent demands on ... gh to defer addi...

... should scrutinize ... n—including ISO ... dified where ap...

effective IEC/ISO ... re consistency of ... nains to be seen ... ed subsequently. ... references was a ... ding of practical ... pe interpretation ... he sessions. ... sor L. C. Neale ... Hooper, USA ... nan of IEC/TC4 ... he attended in ...

r services, as well ... eeting adjourned ... xt session to the ... nich in 1973.

kes in ... mps

... and at intakes

... (1)

... is the diameter ... ugh the intake ... spectively; h is ... and g is the ac...

... can be reduced ... nbers:

... (2)

Several writers[1-4] have studied air entrainment but it is difficult to conclude from the individual experiments how the air entrainment varied with other parameters.

Some use submergence as a function of velocity head, and others use submergence as a function of velocity itself.

In Eq. (2), *Re* (Reynolds' number) can safely be eliminated from the field of the present problem, since vortex formation is a surface phenomenon.

Hence the formation of a vortex depends on the Froude number (Fr), critical submergence (s/d), and wave parameters (λ/h). Therefore:

$$s/d = f(Fr, \lambda/h) \quad \ldots \quad (3)$$

The strength of the vortex depends on the velocity of flow and hence on the Froude number. However, the inception of a vortex as a dimple formation depends on the fluctuation of vorticity, which again depends on the wave parameter.

Several types of baffles were suggested for vortex prevention[1,2] and all reduce the wave parameter near the intake, thus reducing the change in vorticity and hence vortex formation.

For shallow water λ/h is a decisive parameter for vortex formation, but for deep water its influence will be negligible. However, there is no published experimental data available to correlate critical submergence as a function of wave parameter.

In experiments at Loughborough University, UK[5], vortex formation was reduced in a rectangular sump by using vertical baffles which suppressed the wave parameter near the intake.

Recently Gordon[4] showed the scale effect by comparing field studies with the laboratory studies of Denny and Young[2]. The disparity between the two sets of results could have been narrowed if the results were plotted at the same wave parameter.

In a conventional hydroelectric power plant the total depth, h, of water is generally large compared to the wave length, λ, and Eq. (3) may be written:

$$s/d = f(Fr) = f[v/\sqrt{(gd)}] \quad \ldots \quad (4)$$

Gordon[4] found, by trial and error, a design equation for critical submergence, which was:

$$s = cvd^{\frac{1}{2}} \quad \ldots \quad (5)$$

where the value of c varied from 0·3 to 0·4.

However, some of the results which he quoted from Swedish sources had c values of 0·1 and 0·28. It is reasonable, therefore, to assume that c is a function of shape (geometry) of the intake.

For symmetrical and well-designed intakes, the value of c will be low and for complicated designs the value of c can be higher.

If one assumes that Eq. (4) holds good for a general case then:

$$s/d = v/\sqrt{(gd)} \text{ or } s = vd^{\frac{1}{2}}/\sqrt{g} \quad \ldots \quad (6)$$

Eq. (6) reduces to the form (Eq. 5) given by Gordon, with the value of $c = 0{\cdot}176$ and $0{\cdot}319$ with British and SI units, respectively.

In Fig. 2, test results[1-5] are plotted in non-dimensional form with s/d on the y-axis and Froude number [$v/\sqrt{(gd)}$] on the x-axis, up to a Froude number of 3·4. The results of Gordon[4] represent intakes with vortices, whereas all the other results represent critical submergence.

Except for two or three stray cases, all the results lie above the critical line $s/d = Fr$, indicating that for vortex

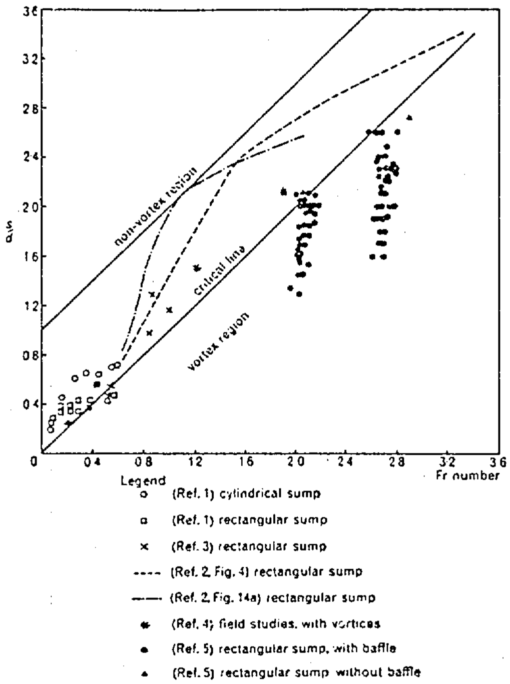


Fig. 2. Critical submergence dependence on Fr number

prevention the critical submergence should always be greater than the Froude number.

Thus vortex inception is possible when $s/d < Fr$, and the vortex-formation tendency is least when $s/d > Fr$.

All the experimental results lie on a band, the lower line of which corresponds to $s/d = Fr$, and the upper line $s/d = 1 + Fr$.

Moreover, it should be noted that the results of Denny and Young[2] are based on pipe diameter instead of inlet diameter, d, and the s/d curves should be lower than those shown in the figure. This analysis is correct only for the case of conventional inlets.

By using devices like vertical or horizontal baffles, or floating rafts, the critical submergence line can be brought down (as shown by the thick circles in Fig. 2), thus reducing s/d requirements.

In conclusion, when vortex prevention devices are used, $s/d = Fr$ (otherwise $s/d = 1 + Fr$) will give vortex-free operation either in hydroelectric practice or pump sump design.

It is hoped that future research will indicate the influence of the wave parameter on vortex formation.

References

1. MARKLAND, E. and POPE, J. A. "Experiments on a small pump suction well, with particular reference to vortex formations", *Proceedings*, The Institution of Mechanical Engineers, Vol 170, 1956.
2. DENNY, D. F. and YOUNG, G. A. J. "The prevention of vortices and swirl at intakes", *Proceedings*, IAHR 7th Congress, Lisbon, 1957.
3. IVERSEN, H. W. "Studies of submergence requirements of high specific speed pumps", *Transactions* ASME, Vol 75, 1953.
4. GORDON, J. L. "Vortices at Intakes", WATER POWER, April, 1970.
5. PICKFORD, J. A. and REDDY, Y. R. "Influence of baffle position on vortex suppression in a storm over-flow" (awaiting publication).

16

25

ATTACHMENT 1
PAGE 3 OF 3

not, in the even
rrent demands on
:h to defer addi

should scrutinize
1—including ISO
lified where ap

effective IEC/ISO
consistency of
ains to be seen
d subsequently.
references was
ing of practical
e interpretation
e sessions.
or L. C. Neale
Hooper, USA
an of IEC/TC4
e attended in

services, as well
eting adjourned
t session to the
ich in 1973.

kes in
nps

and at intakes

... (1)

is the diameter
igh the intake
pectively; h is
d g is the ac

an be reduced
bers:

... (2)

ver March 1972

Several writers[1-4] have studied air entrainment but it is difficult to conclude from the individual experiments how the air entrainment varied with other parameters.

Some use submergence as a function of velocity head, and others use submergence as a function of velocity itself.

In Eq. (2), *Re* (Reynolds' number) can safely be eliminated from the field of the present problem, since vortex formation is a surface phenomenon.

Hence the formation of a vortex depends on the Froude number (*Fr*), critical submergence (s/d), and wave parameters (λ/h). Therefore:

$$s/d = f(Fr, \lambda/h) \qquad \dots \qquad (3)$$

The strength of the vortex depends on the velocity of flow and hence on the Froude number. However, the inception of a vortex as a dimple formation depends on the fluctuation of vorticity, which again depends on the wave parameter.

Several types of baffles were suggested for vortex prevention[1,2] and all reduce the wave parameter near the intake, thus reducing the change in vorticity and hence vortex formation.

For shallow water λ/h is a decisive parameter for vortex formation, but for deep water its influence will be negligible. However, there is no published experimental data available to correlate critical submergence as a function of wave parameter.

In experiments at Loughborough University, UK[5], vortex formation was reduced in a rectangular sump by using vertical baffles which suppressed the wave parameter near the intake.

Recently Gordon[4] showed the scale effect by comparing field studies with the laboratory studies of Denny and Young[2]. The disparity between the two sets of results could have been narrowed if the results were plotted at the same wave parameter.

In a conventional hydroelectric power plant the total depth, h, of water is generally large compared to the wave length, λ, and Eq. (3) may be written:

$$s/d = f(Fr) = f[v/\sqrt{(gd)}] \qquad \dots \qquad (4)$$

Gordon[4] found, by trial and error, a design equation for critical submergence, which was:

$$s = cvd^{\frac{1}{2}} \qquad \dots \qquad (5)$$

where the value of c varied from 0·3 to 0·4.

However, some of the results which he quoted from Swedish sources had c values of 0·1 and 0·28. It is reasonable, therefore, to assume that c is a function of shape (geometry) of the intake.

For symmetrical and well-designed intakes, the value of c will be low and for complicated designs the value of c can be higher.

If one assumes that Eq. (4) holds good for a general case then:

$$s/d = v/\sqrt{(gd)} \text{ or } s = vd^{\frac{1}{2}}/\sqrt{g} \qquad \dots \qquad (6)$$

Eq. (6) reduces to the form (Eq. 5) given by Gordon, with the value of $c = 0{\cdot}176$ and $0{\cdot}319$ with British and SI units, respectively.

In Fig. 2, test results[1-5] are plotted in non-dimensional form with s/d on the y-axis and Froude number $[v/\sqrt{(gd)}]$ on the x-axis, up to a Froude number of 3·4. The results of Gordon[4] represent intakes with vortices, whereas all the other results represent critical submergence.

Except for two or three stray cases, all the results lie above the critical line $s/d = Fr$, indicating that for vortex

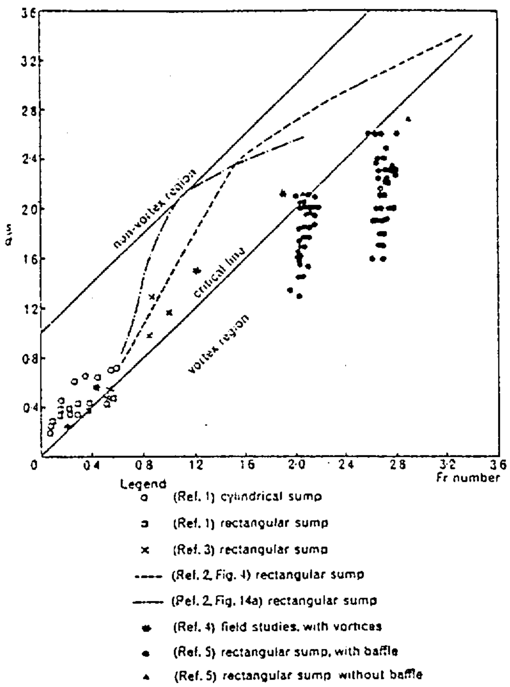


Fig. 2. Critical submergence dependence on Fr number

prevention the critical submergence should always be greater than the Froude number.

Thus vortex inception is possible when $s/d < Fr$, and the vortex-formation tendency is least when $s/d > Fr$.

All the experimental results lie on a band, the lower line of which corresponds to $s/d = Fr$, and the upper line $s/d = 1 + Fr$.

Moreover, it should be noted that the results of Denny and Young[2] are based on pipe diameter instead of inlet diameter, d, and the s/d curves should be lower than those shown in the figure. This analysis is correct only for the case of conventional inlets.

By using devices like vertical or horizontal baffles, or floating rafts, the critical submergence line can be brought down (as shown by the thick circles in Fig. 2), thus reducing s/d requirements.

In conclusion, when vortex prevention devices are used, $s/d = Fr$ (otherwise $s/d = 1 + Fr$) will give vortex-free operation either in hydroelectric practice or pump sump design.

It is hoped that future research will indicate the influence of the wave parameter on vortex formation.

References

1. MARKLAND, E. and POPE, J. A. "Experiments on a small pump suction well, with particular reference to vortex formations", *Proceedings*, The Institution of Mechanical Engineers, Vol 170, 1956.
2. DENNY, D. F. and YOUNG, G. A. J. "The prevention of vortices and swirl at intakes", *Proceedings*, IAHR 7th Congress, Lisbon, 1957.
3. IVERSEN, H. W. "Studies of submergence requirements of high specific speed pumps", *Transactions* ASME, Vol 75, 1953.
4. GORDON, J. L. "Vortices at Intakes", WATER POWER, April, 1970.
5. PICKFORD, J. A. and REDDY, Y. R. "Influence of baffle position on vortex suppression in a storm over-flow" (awaiting publication).

17

25X

Northeast Utilities System

TELECOPIER COVER LETTER (FAX)

NU4761-1 REV. 9-94

DATE:	TIME:	TOTAL NUMBER OF PAGES BEING SENT: (Including this page)
7/29/98		52

TO:

COMPANY	
DEPARTMENT/DIVISION	
ATTENTION: BOB OLSON	TELEPHONE NUMBER (612) 271-5157
TELECOPIER TELEPHONE NUMBER (INCLUDE AREA CODE)	(612) 295-1017

FROM:

NAME: RUDY SCHAUFLER	ROOM NO.	TELEPHONE NUMBER * (860) 447-1791 X2363
DEPARTMENT/DIVISION		
TELECOPIER TELEPHONE NUMBER (INCLUDE AREA CODE)	( )	

[redacted]

COMMENTS/DIRECTIONS

Bob,

See Attach Report

SENDING IN TWO SECTIONS

18

225

SIMULATED VORTEX FORMATION TESTING OF A #2 DIESEL FUEL OIL STORAGE TANK

By

Andrew E. Johansson

Johannes Larsen

Submitted to

NORTHEAST UTILITIES SERVICE COMPANY

P.O. #02012608

December 1997

ALDEN RESEARCH LABORATORY, INC.

Solving Flow Problems Since 1894

277-97/M295F

December 1997

19

SIMULATED VORTEX FORMATION TESTING OF A #2 DIESEL FUEL OIL STORAGE TANK

By

Andrew B. Johansson

Johannes Larsen

Submitted to

NORTHEAST UTILITIES SERVICE COMPANY

P.O. #02012608

December 1997

ALDEN RESEARCH LABORATORY, INC.

30 Shrewsbury Street

Holden, MA 01520

Printed at ARL - December 1997

TABLE OF CONTENTS

ABSTRACT

Northeast Utilities (NU) is using a calculated pump submergence requirement of 11" (24.5" oil depth) to alleviate possible vortex formation within a #2 diesel fuel oil storage tank at the Millstone Nuclear Power Station. Due to the limited size of the tank and fuel volume requirement, there is a need to determine the oil level at which air-drawing free surface vortices form for various likely operating flows. From this data, one can determine the actual required submergence of the pump suction bowl and accurately calculate how much fuel oil is available for use in the storage tank.

Alden Research Laboratory, Inc. (ARL) was contracted by NU to construct and test a 1:1 geometric scale model to simulate a portion of the #2 diesel fuel oil storage tank. The study involved evaluating the vortex formation around the oil tank pump as well as determining the depth at which air entraining vortices form for various flows.

Data indicated that at the maximum pump flow of 31.6 gpm, the oil level could be lowered to 14.7" above the bottom of the tank before air ingestion occurred. At an oil level of 14.25" above the bottom of the tank and a flow of 31.6 gpm, the pump would ingest air. The withdrawal flow rate had to be reduced to 24 gpm to eliminate air entrainment into the pump at this oil level. Data recorded for oil levels of 14.06", 13.88", and 13.75" indicated maximum flows without air entrainment were approximately 19 gpm, 15.5 gpm, and 11.9 gpm, respectively. These data allowed a plot of the maximum air free flow versus the oil level in the tank to be constructed, see Figure 10. This plot can be used to determine the depth at which air ingestion forms versus flows. The plot indicates that once the oil level drops below 14.7", the flow will have to be reduced below 31.6 gpm to eliminate air ingestion.

23

25

SIMULATED VORTEX FORMATION TESTING OF A #2 DIESEL FUEL OIL STORAGE TANK

1.0 INTRODUCTION

At the request of Northeast Utilities (NU), a hydraulic model of a #2 diesel fuel oil storage tank for the Millstone Nuclear Power Station was constructed and tested at the Alden Research Laboratory, Inc. (ARL). The objective of the testing was to determine the fluid level at which free surface vortices form for various likely operating flows, and to derive simple modifications which would allow lower operating levels without the formation of vortices, particularly air entraining vortices [1].

The actual tank is a 25,000 gallon horizontal tank (10 ft-6" diameter x 40 ft-9" long) in which two 6 stage vertical turbine pumps are mounted. The pumps are located 23 ft-9" and 19 ft-9" from the end of the cylindrical section of the tank. A suction bowl, shown in Figure 2, is attached to the bottom of each pump with a clearance of 12" to the bottom of the tank. The #2 diesel fuel oil is removed from the tank via either one of the two vertical pumps with flow approaching from both sides of the tank. Plan and end views of the #2 diesel fuel oil storage tank are shown in Figure 1.

2.0 MODEL SIMILITUDE

The model was constructed with a geometric scale of 1:1 with the following exceptions. The curved bottom of the tank was only modeled to a height of 11.3", from which flat sides were extended vertically. Also, the section of the modeled tank was 8 ft long instead of 40 ft-9". The basis for these exceptions are the assumptions that vortices occur at lower fluid levels and that any differences caused by the absence of this curvature would be negligible. Also, the flow distribution is uniform away from the pump where the modeled tank began and flow in the model was uniformly introduced with the help of a flow straightening device. With the same flow scale of 1:1 and using the same liquid (#2 fuel oil) as in the Millstone oil storage tank, dynamic similarity of both flow and relative air entrainment was achieved in the model. Oil temperature was monitored during testing to ensure minimum variations in the oil viscosity and density. A change in oil viscosity and density would change the Reynold's number and Weber's number, and, hence, the viscous and surface tension forces. This in turn could influence the formation and strength of vortices [2].

3.0 MODEL DESCRIPTION

Using the following assumptions, only a portion of the fuel storage tank was modeled:

1. An 8 ft long tank would be adequate to provide uniform flow.
2. Vortexing is a problem at decreasing levels so the full diameter of the tank is not required.
3. Vertical sides versus curved sides have no effect on flow distribution at the pump.

The model was constructed out of steel plate to a geometric scale of 1:1 with respect to the curvature of the actual tank and simulated a portion of the actual oil tank approximately 8 ft long, 6 ft wide, and 5.5 ft deep. The model included the curved bottom of the oil tank to a height of approximately 11.3", from which point walls were extended vertically. The model is depicted in Figure 3. Acrylic windows were installed at various locations of the tank to allow for flow visualization. The flow, which was introduced at the ends of the model, passed through flow straightening devices to produce uniform inflow from both ends of the tank.

While the oil surface will be lowered continuously in the actual oil tank as the fuel is withdrawn, the rate of surface drop is slow due to the large surface area of the tank and the low withdrawal flow. Hence, the decrease in surface with time does not influence flow patterns at a given surface level, and testing at steady fluid levels reasonably simulated actual flow conditions in the tank. A recirculating flow loop was constructed for this purpose. A laboratory pump was used to withdraw flow out of the model tank through a simulated pump suction pipe, with an attached actual pump suction bowl supplied by NU. The bottom of the suction bowl was located in the center of the tank 12" from the bottom of the tank. Withdrawn flow was then returned to the upstream side of both flow distributors, thus maintaining a constant level for each test. Suction flow as well as each of the individual flows returning to the upstream side of the flow distributors were measured using either a turbine meter or an orifice plate. A diagram of the model piping and flow loop can be seen in Figure 4.

Due to environmental concerns related to possible oil leaks, the entire model (tank, pump, piping instrumentation, etc.) was housed inside a secondary containment tank, see Figure 5.

4.0 INSTRUMENTATION AND MEASURING TECHNIQUES

4.1 FLOW

Flows in the model were measured with a calibrated turbine meter and an orifice meter conforming to ASME guidelines [2]. The turbine meter calibration was conducted at the ARL calibration facility and is NIST traceable. The pulse signal from the turbine meter was recorded and averaged to calculate the pipe flow using a personal computer with data acquisition software. The differential head from the orifice meter was measured using a differential pressure transducer. The voltage signal from the differential pressure transducer was recorded and averaged, and the pipe flow was calculated using the same computer and data acquisition software as with the turbine meter. The accuracy of the turbine meter is 0.5%, while the flow through the orifice meter was checked against the turbine meter and was found to be within 2%. Calibrations of the turbine meter, differential pressure cell and orifice meter are included in Appendix A.

4.2 LIQUID LEVELS

Liquid levels, referenced to the tank bottom in the center of the tank, were measured using a scale (with 1" increments) installed on the tank walls, see Figure 6. The scale was also used in conjunction with a hand held scale to allow for finer measurements. Both scales were calibrated using an NIST traceable 100 ft steel tape. Using this method, the liquid levels could be read to an accuracy of ±1/16". The scale calibrations are included in Appendix A.

4.3 FREE SURFACE VORTICES

In order to systematically evaluate the strength of vortices in pump sumps, ARL uses a vortex strength scale ranging from Type 1 to Type 6, as shown in Figure 7, where Type 1 is a surface swirl and Type 6 is an open air-core vortex to the pump inlet. Vortex types are usually identified in the model by visual observation with the help of dye tracers, cotton balls, etc. Due to the fact that the test fluid is red in color and air drawing vortices could not easily be seen, an air trap was developed to determine if any air was being drawn into the pump, see Figures 8 and 9. Video documentation of all vortex activity was obtained, as necessary.

5.0 ACCEPTANCE CRITERIA

Possible problems associated with vortexing at pump intakes are an unbalanced loading of pump impellers and reduced pumping efficiency due to air ingestion or, in NU's case, a reduction in creditable inventory. For these reasons, any vortices of Type 3 or greater are considered objectionable.

6.0 TEST PLAN

6.1 PRELIMINARY TESTS

Due to environmental and health concerns, preliminary testing of the model was conducted with water as the test fluid. Testing with water would give an indication at what fluid level and flow rate vortices may start to form in the test tank. This would also reduce the amount time the #2 fuel oil would have to be stored in the test tank. With water, vortex formation was documented starting at a fluid height of 30" and suction rates of 5.5 gpm and 31.6 gpm. The fluid level was then lowered in the model until vortex activity, particularly air-drawing vortices, were observed. Once air-drawing vortices were observed at a particular fluid level, the flow rate was reduced until the air ingestion was eliminated.

6.2 FINAL TESTS

Final documentation testing was conducted using the #2 diesel fuel oil as the test fluid with a starting depth slightly higher than the level at which air ingestion occurred with the water tests to eliminate unnecessary tests, and with suction flows of 5.5 gpm and 31.6 gpm. These two flows were chosen since 5.5 gpm is the minimum safe flow for continuous operation of the pump and 31.6 gpm is the maximum allowable flow for this pump. As with the preliminary testing, the fluid level was lowered in the model until vortex activity, particularly air-drawing vortices, were observed. Once air-drawing vortices were observed and categorized at a particular fluid level, the flow rate was reduced until the air ingestion was eliminated.

The following data were recorded during each test, unless otherwise noted:

a) Suction flow
b) Return (or discharge) flow approaching from each end of the model

c) Fluid level
d) Temperature
e) Vortex strength/type
f) Air ingestion

7.0 RESULTS

Preliminary testing with water showed that no air ingestion was present down to a fluid height of 14.6" with a flow rate of 31.6 gpm. At fluid levels of 14.13" and 13.75", the withdrawal flow had to be reduced approximately 24.0 gpm and 14.8 gpm, respectively, to eliminate air ingestion.

The final documentation tests with #2 diesel fuel oil were recorded for the following conditions:

1) 5.5 gpm at 18" oil depth
2) 31.6 gpm at 18" oil depth
3) 5.5 gpm at 16.5" oil depth
4) 31.6 gpm at 16.5" oil depth
5) 5.5 gpm at 15.5" oil depth
6) 31.6 gpm at 15.5" oil depth
7) 31.6 gpm at 14.94" oil depth
8) 24.6 gpm at 14.25" oil depth
9) 19.05 gpm at 14.063" oil depth
10) 15.54 gpm at 13.88" oil depth
11) 11.89 gpm at 13.75" oil depth

The lowest anticipated operating level is 15.5" at 31.6 gpm, which is based on information supplied by NU to meet the technical specification required inventory of 23,400 gallons of fuel oil. Final documentation tests showed that the strongest vortex recorded in the operating level

29

25

(15.5" and higher) was a weak intermittent surface dimple, Type 2 vortex. This strength was also recorded and confirmed by dye tracing intermittently during tests with water, which were expected to yield conservative results in vortex formation when compared to the #2 fuel oil for the following reason. Lower viscous and surface tension forces associated with water versus higher comparable forces associated with #2 fuel oil could influence the formation and strength of vortices [3].

To establish the lowest level that could be achieved without ingesting air, a series of tests at different flows were conducted in which the tank level was lowered at a given flow until air was ingested. Data from these tests, presented in Figure 10 and Table 2, determined that for the #2 oil, air ingestion can be expected at a level of 14.7" at the maximum design flow of 31.6 gpm, and at a level of 13.6" at the lowest flow of 5.5 gpm. The graph indicates that preliminary tests with water as the test fluid were slightly non-conservative, probably due to the fact that as the Reynolds number decreased (given the oil's higher viscosity), the head loss through the pump suction bowl screen increased and, therefore, reduced the actual oil level inside the pump suction bowl. Hence, for this particular configuration, air entraining vortices occurred at slightly higher liquid heights in the tank with oil than with water.

Test results are listed in Table 1 and data sheets are provided in Appendix B.

8.0 CONCLUSIONS

The study of the #2 fuel oil storage tank at the Millstone Nuclear Power Station using a 1:1 geometric scale hydraulic model provided the following conclusions:

- Tests at liquid levels in the normal operating range (15.5" and higher) showed no objectionable vortices.
- No air ingestion occurred for the 5.5 gpm withdrawal flow for oil above level 13.6".
- At 31.6 gpm withdrawal, there was no air ingestion above oil level 14.7".
- Test data indicate that with an oil level in the tank of 14.7" or higher, a withdrawal flow of 31.6 gpm can be achieved without air ingestion, see Figure 10. Once the oil level drops below 14.7", the flow will have to be reduced to eliminate air ingestion.
- Figure 10 can be used to determine what oil height needs to be maintained for a particular suction flow to prevent vortexing without the use of a vortex suppression device.

31

25

9.0 REFERENCES

[1] Padmanabhan, M., "Proposal for Fuel Oil Tank Vortex Formation Testing," Alden Research Laboratory, Inc., May 1996.

[2] Research Committee on Fluid Meters, "Fluid Meters," The American Society of Mechanical Engineers, 1971.

[3] Padmanabhan, M. and Hecker, G.E., "Scale Effects in Pump Sump Models," The American Society of Civil Engineers, November 1984.

TABLES

TABLE 1

MILLSTONE #2 FUEL OIL STORAGE TANK VORTEX FORMATION TESTS

Test #	Fluid Height (in)	Flow (gpm)	Oil Temp (° F)	Observation
1-16	18	5.5	53.6	No air drawing vortices
2-16	18	31.6	54.8	No air drawing vortices
3-16	16.5	5.5	57.2	No air drawing vortices
4-16	16.5	31.6	56.1	No air drawing vortices
5-16	15.5	5.5	58.3	No air drawing vortices
6-16	15.5	31.6	60.6	No air drawing vortices
7-16	14.25	24.6	62.9	Just starting to draw air
8-16	14.94	31.6	63.6	No air drawing vortices
9-16	14.063	19.05	62.4	Just starting to draw air
10-16	13.88	15.54	65.9	Just starting to draw air
11-16	13.75	11.89	66.1	Just starting to draw air

TABLE 2

MAXIMUM ATTAINABLE FLOW VERSUS FLUID DEPTH FOR THE MILLSTONE # 2 FUEL OIL STORAGE TANK

Flow (gpm)	Fluid Depth From Bottom Of Tank (inches)
5.5	13.59
7.5	13.64
9.5	13.69
11.5	13.75
13.5	13.82
15.5	13.89
17.5	13.97
19.5	14.05
21.5	14.14
23.5	14.24
25.5	14.35
27.5	14.46
29.5	14.57
31.5	14.70
31.6	14.70

FIGURES

P.O # 02012608

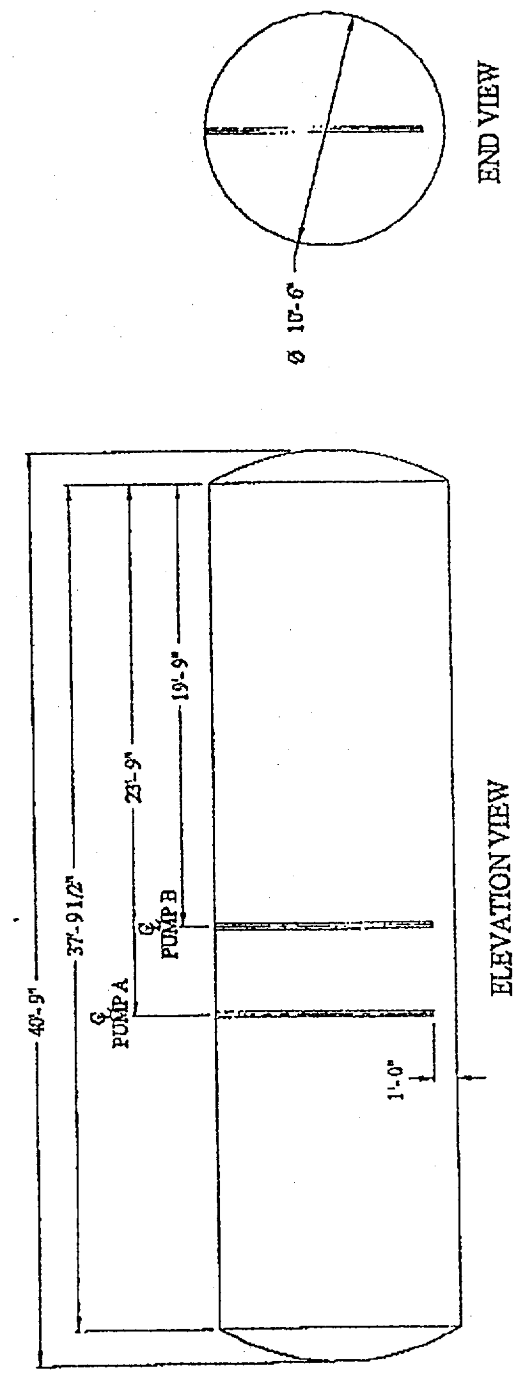
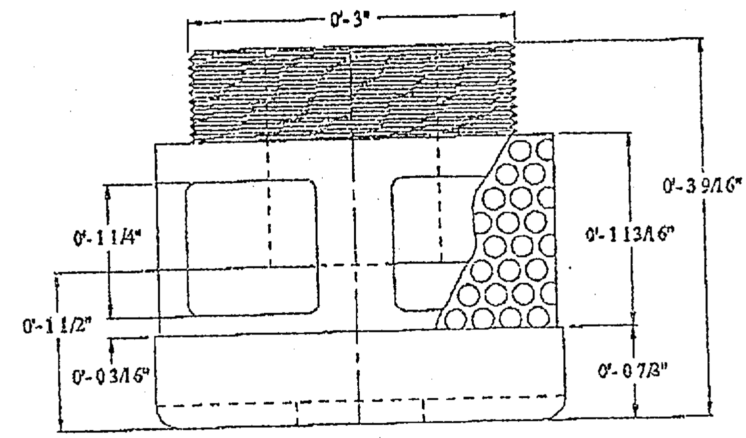
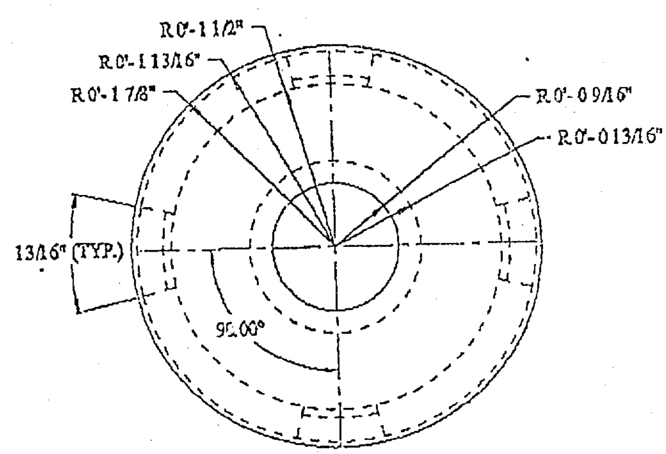


FIGURE 1 #2 FUEL OIL STORAGE TANK

P.O # 02012608



ELEVATION VIEW



PLAN VIEW

FIGURE 2 PUMP SUCTION BOWL

ARL

38

25×

P.O # 02012608

ARL

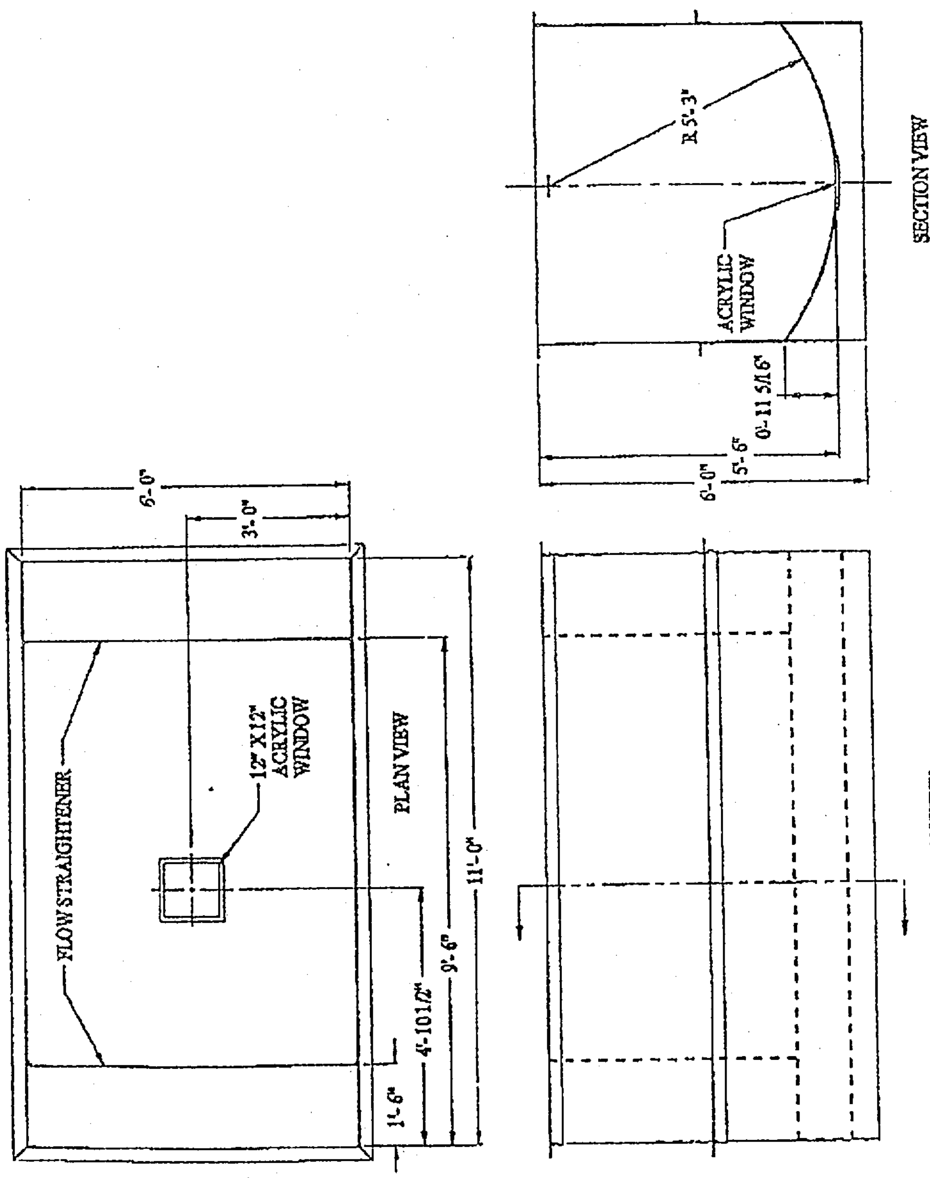
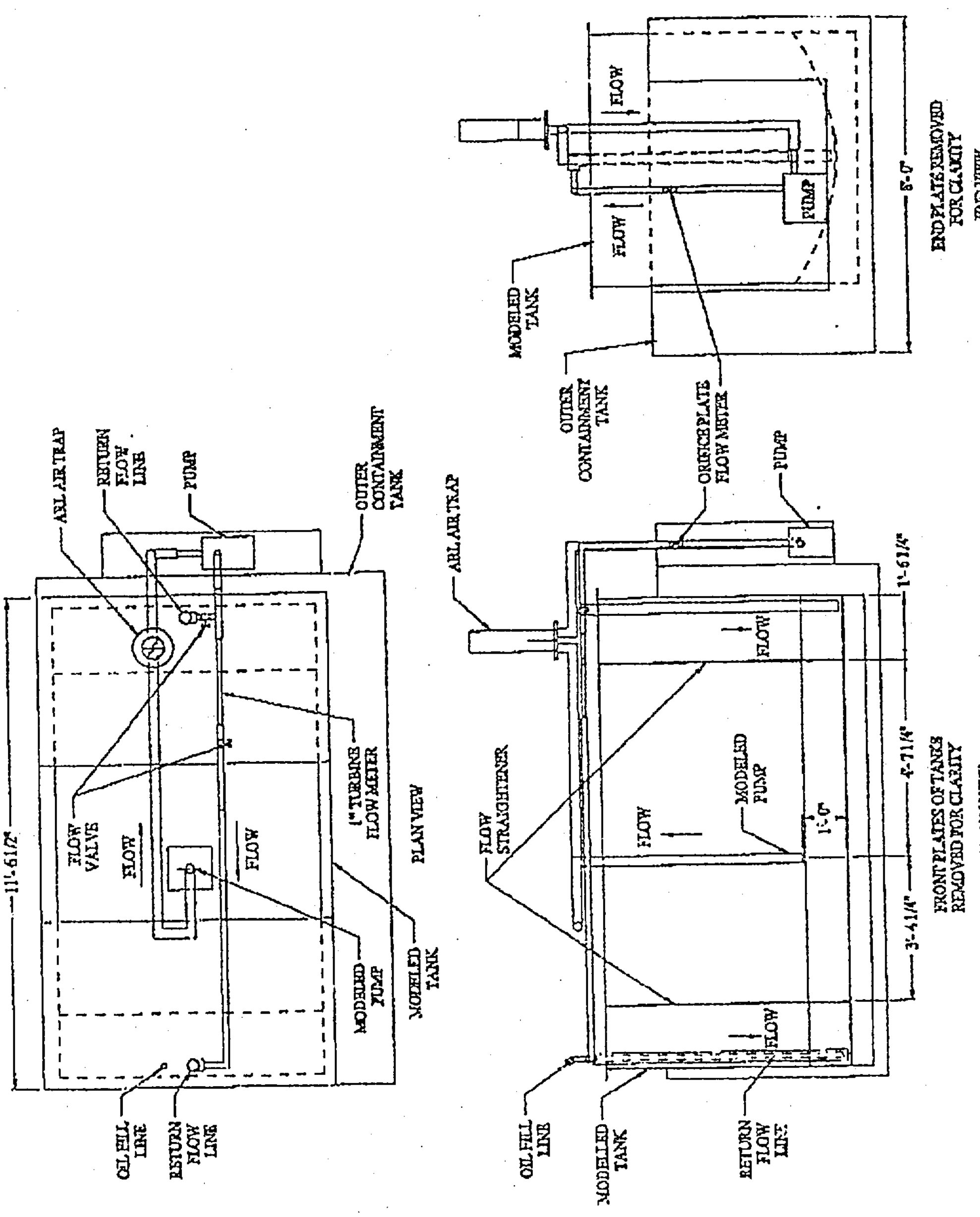


FIGURE 3 PORTION OF #2 FUEL OIL STORAGE TANK MODELLED

25X

P.O # 02012608



ARL

FIGURE 4 MODEL PIPING DIAGRAM

40

P.O # 02012608

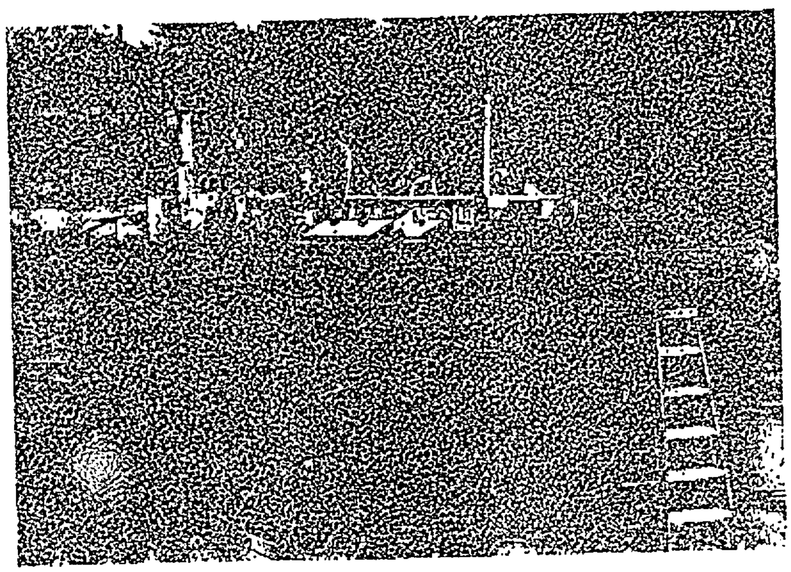


FIGURE 5 PHOTOGRAPH OF MODEL SETUP

ARL

P.O # 02012608

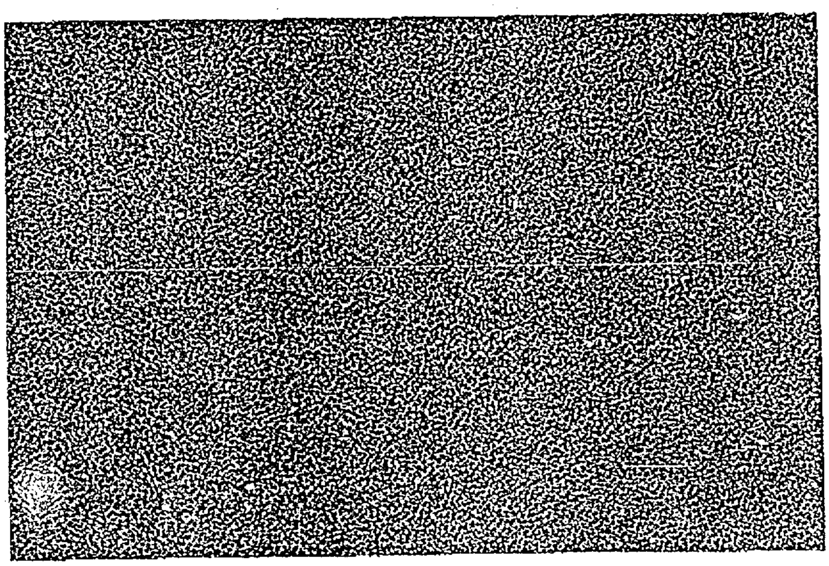


FIGURE 6 PHOTOGRAPH OF MODELLED PUMP AND FLUID LEVEL MEASURING SCALE

ARL

P.O # 02012608

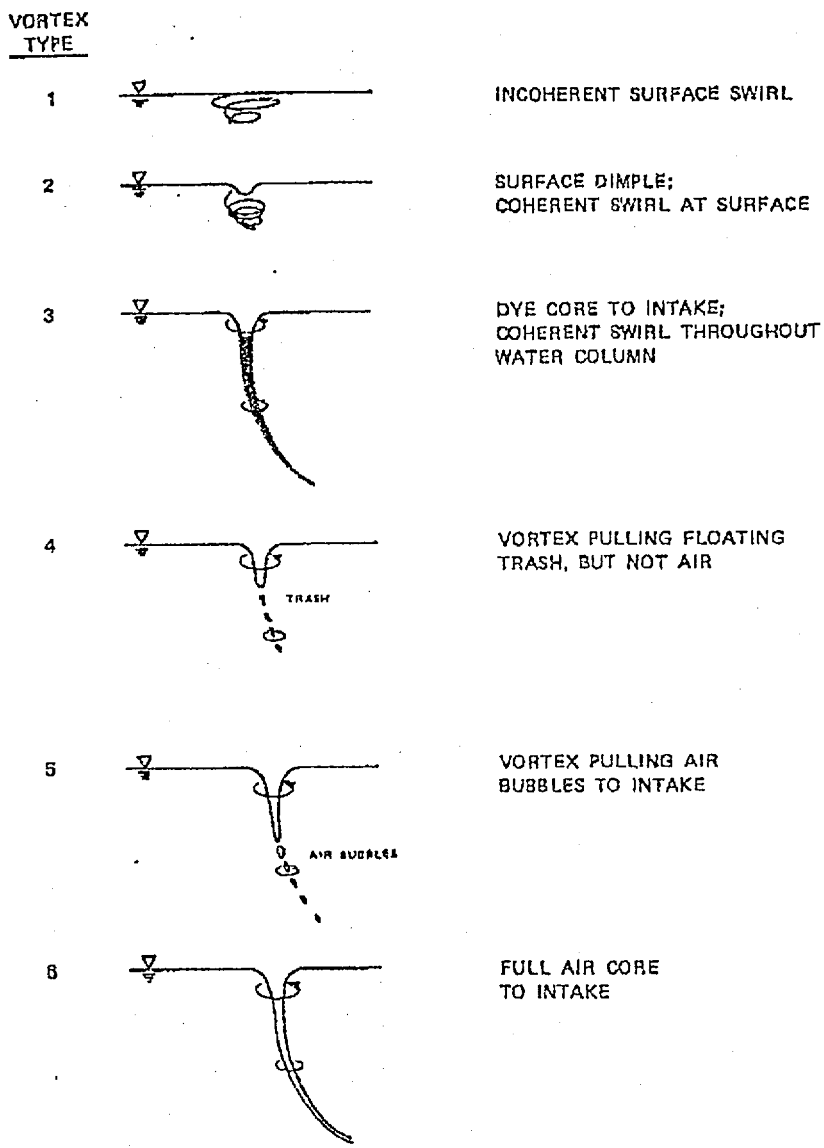
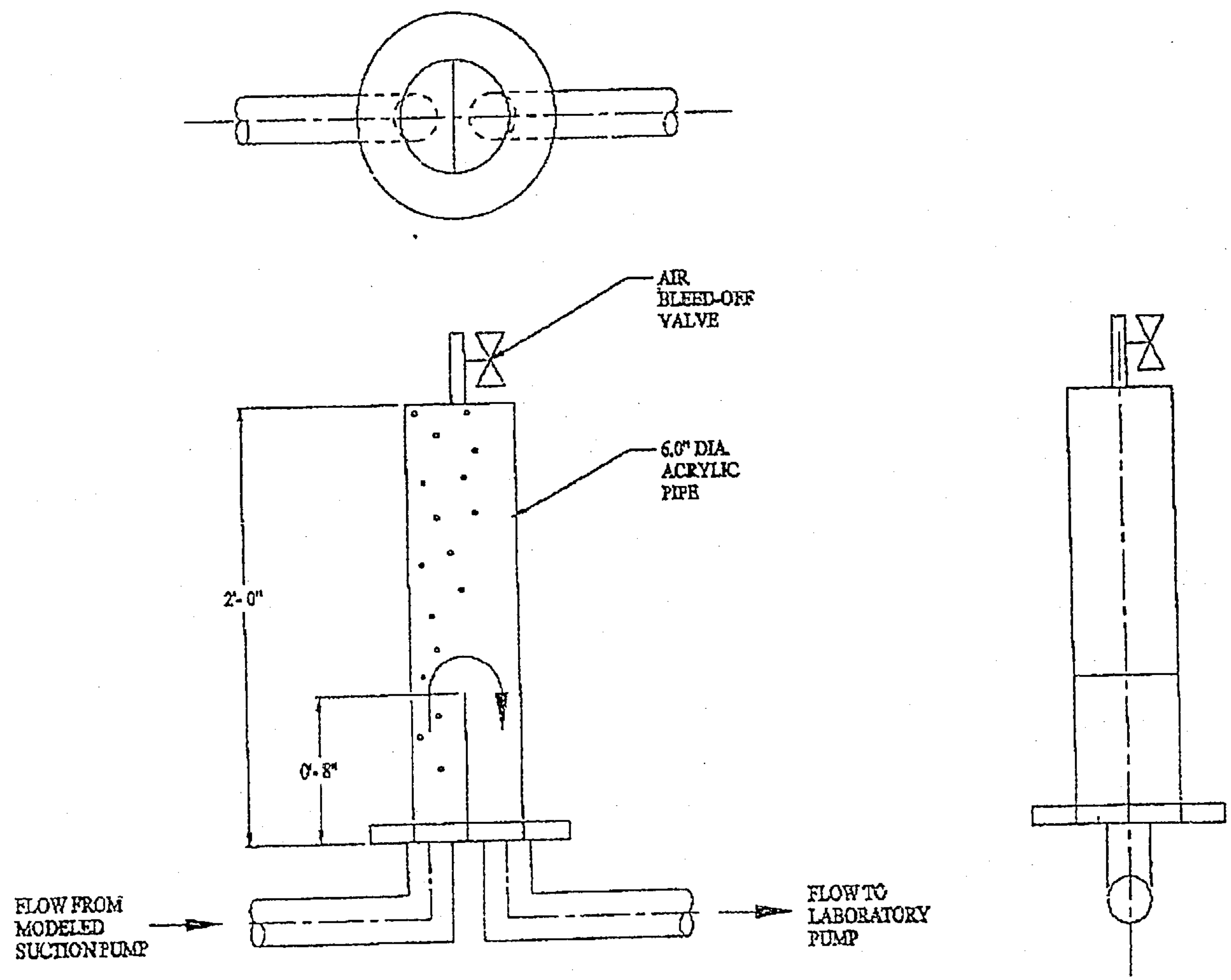


FIGURE 7 ARL FREE SURFACE VORTEX CLASSIFICATION

ARL

P.O # 02012608



ARL

FIGURE 8 MODEL AIR TRAP

P.O # 02012608

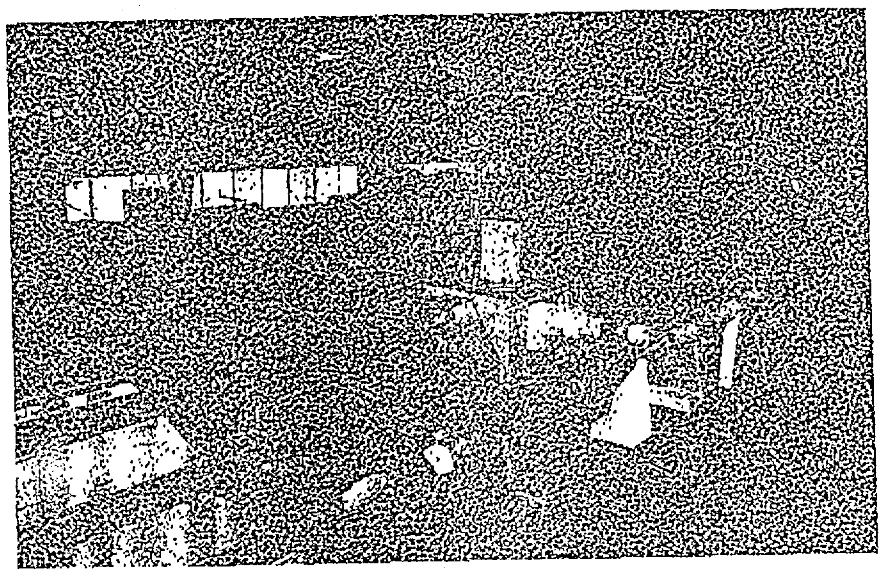


FIGURE 9 PHOTOGRAPH OF MODEL PIPING WITH AIR TRAP

ARL

P.O # 02012608

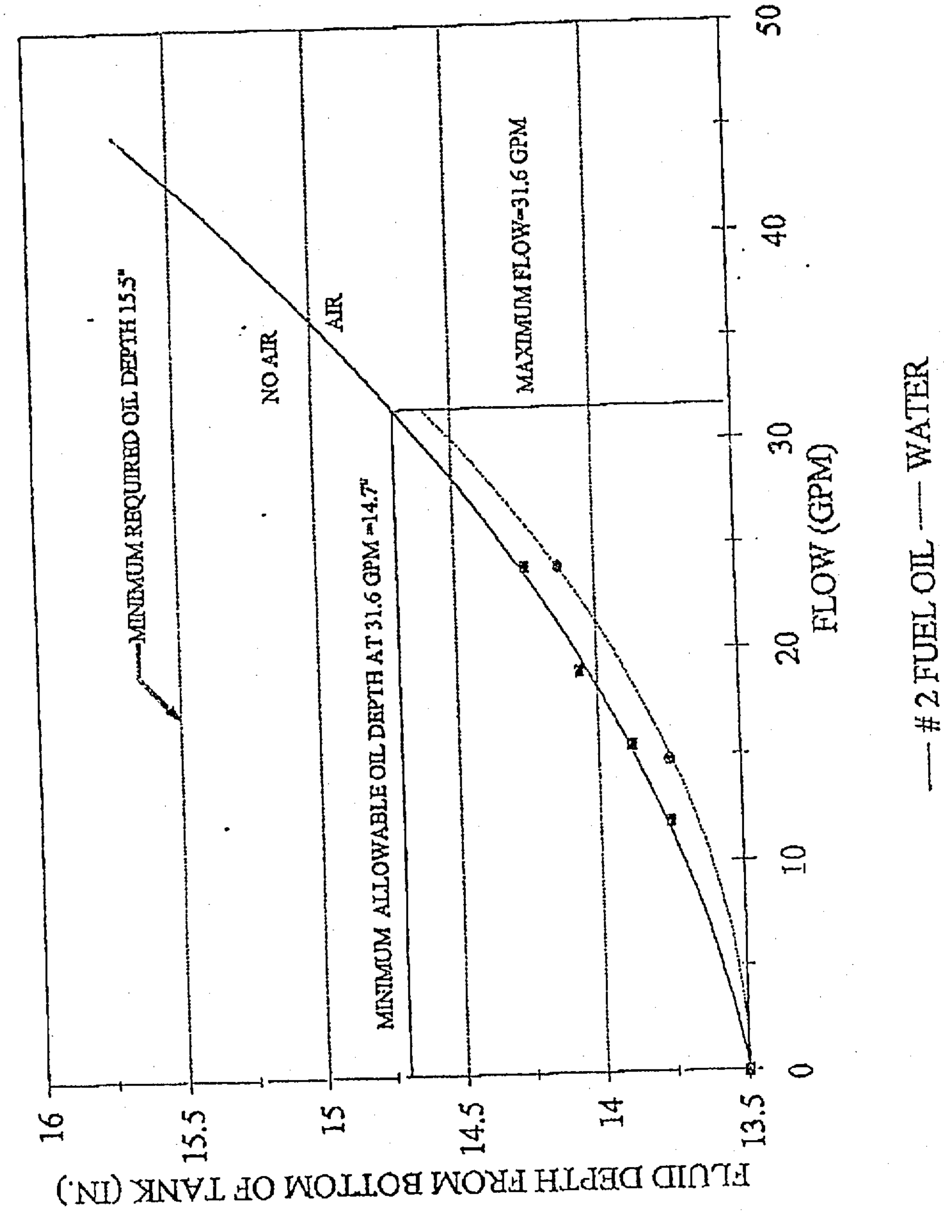


FIGURE 10 MAXIMUM ATTAINABLE FLOW VERSUS FLUID DEPTH

APPENDIX A

INSTRUMENT AND METER CALIBRATIONS

1" Turbine
Serial Number: FMC-16M50-L142

CALIBRATION
DATE: December 14, 1995

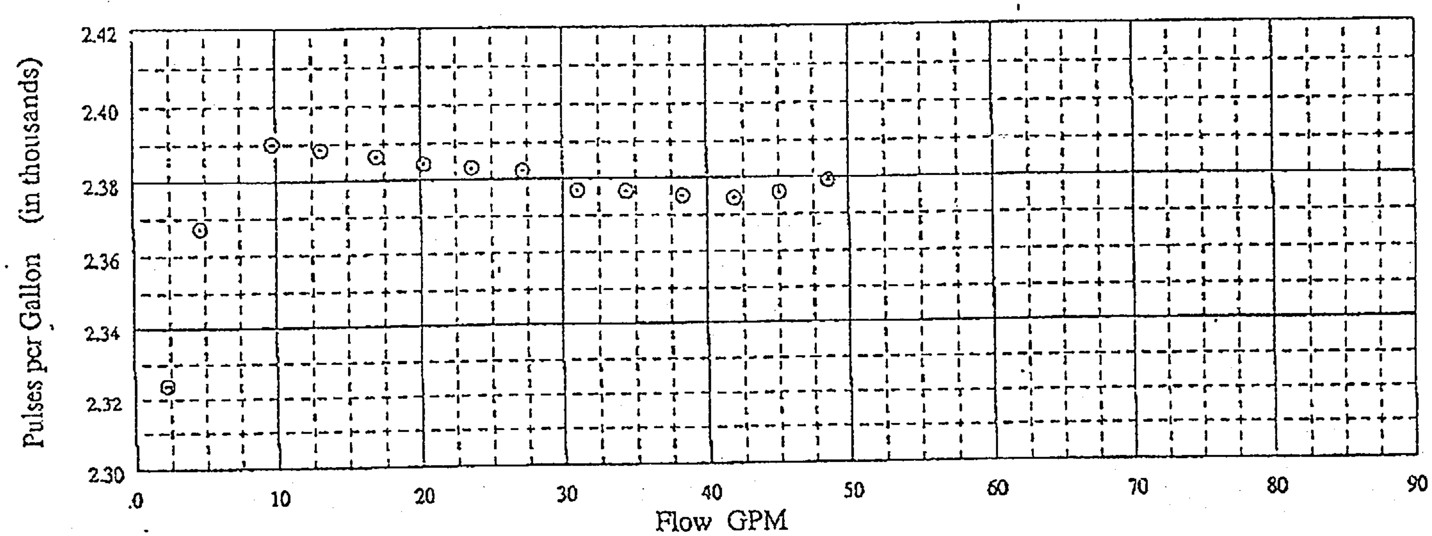
Run #	Line Temp Deg F	Net Weight lb.	Run Duration secs.	Reading Pulses	Flow GPM	Total Gallons	Pulses per Gallon	Deviation from Average percent
11	42	1502.8	258.296	428143	41.88	180.30	2374.6	-0.24
12	42	1502.8	240.279	428395	45.02	180.30	2376.0	-0.18
13	42	1503.3	222.960	429112	48.53	180.36	2379.1	-0.05
14	42	1500.8	314.637	427934	34.33	180.06	2376.6	-0.16
15	39	1501.8	282.300	427981	38.29	180.18	2375.3	-0.21
16	39	1499.8	347.945	427692	31.02	179.94	2376.8	-0.15
17	39	526.2	139.369	150407	27.18	63.13	2382.3	0.09
18	39	507.2	154.459	145031	23.63	60.85	2383.2	0.12
19	39	506.2	179.796	144821	20.26	60.73	2384.5	0.18
20	39	506.4	214.446	145002	16.99	60.76	2386.5	0.26
21	39	504.1	276.386	144463	13.13	60.48	2388.5	0.34
22	39	506.9	373.754	145361	9.763	60.82	2390.1	0.41
23	39	300.9	461.861	85450	4.689	36.10	2367.4	-0.54
24	39	101.8	322.767	28377	2.269	12.21	2323.8	-2.37

For GPM above 10 Avg Pulses per Gallon = 2380.31 With Std Dev = 4.90382
The data reported on herein was obtained by measuring equipment the calibration of which is traceable to NIST, following the installation and test procedures referenced in this report, resulting in a flow measurement uncertainty of +/- 0.25% or less.

CERTIFIED BY

CALIBRATED BY: BJM

48

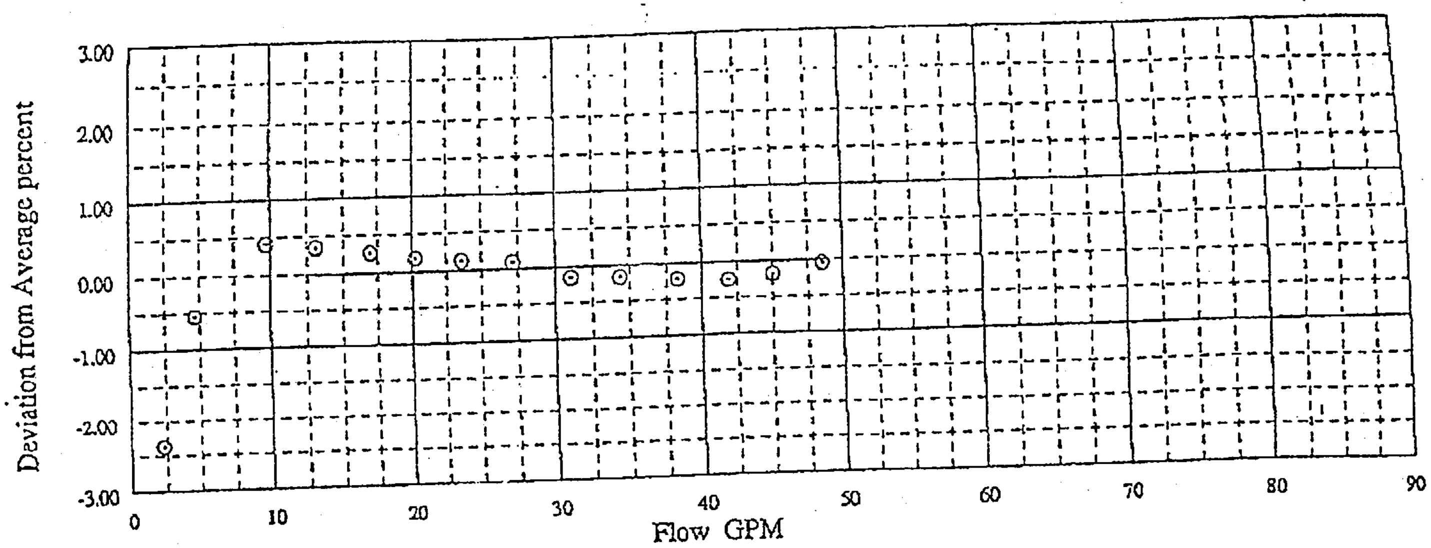


December 14, 1995
1" Turbine
Serial Number: FMC-16M50-L142

Certified By:

ARL

49



EB/Tray
1" Turbine
Serial Number: FMC-16M50-L142

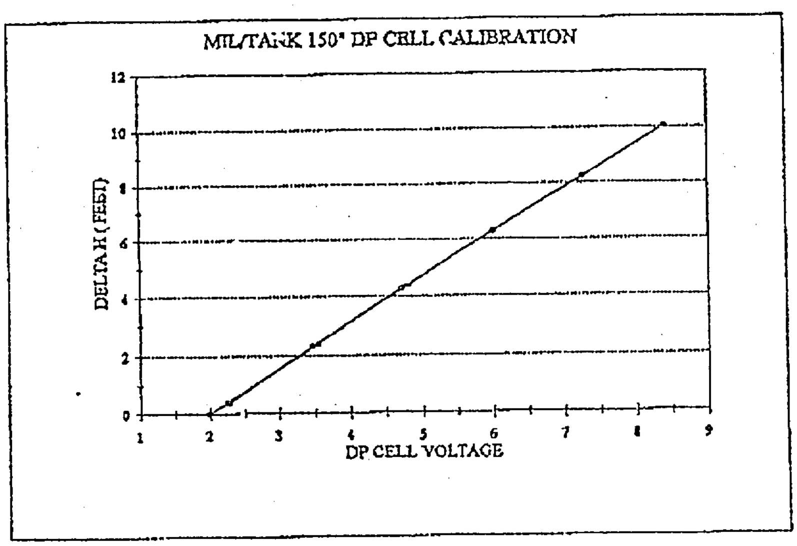
Certified By:

MILLSTONE FUEL OIL TANK VORTEX FORMATION TESTING 150" DP CELL CALIBRATION
4-4-97 ROSEMONT 0 -150" DIFFERENTIAL PRESSURE CELL(SERIAL # 1820254)

ΔH (INCHE	ΔH (FT)	VOLTS
0.00	0.00	1.99
4.62	0.39	2.28
27.62	2.30	3.46
51.43	4.29	4.73
75.35	6.28	6.01
99.25	8.27	7.29
120.43	10.04	8.43
99.06	8.26	7.28
75.20	6.27	6.01
52.68	4.39	4.80
28.62	2.39	3.54
4.68	0.39	2.25
0.00	0.00	1.99

Regression Output:

Constant		-3.13301
Std Err of Y Est		0.02225
R Squared		0.99996
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	1.56473	
Std Err of Coef.	0.00287	



CHECK OF OLD ORIFICE PLATE DESIGN FOR milstone tank 04-04-1997

PLATE DESIGN

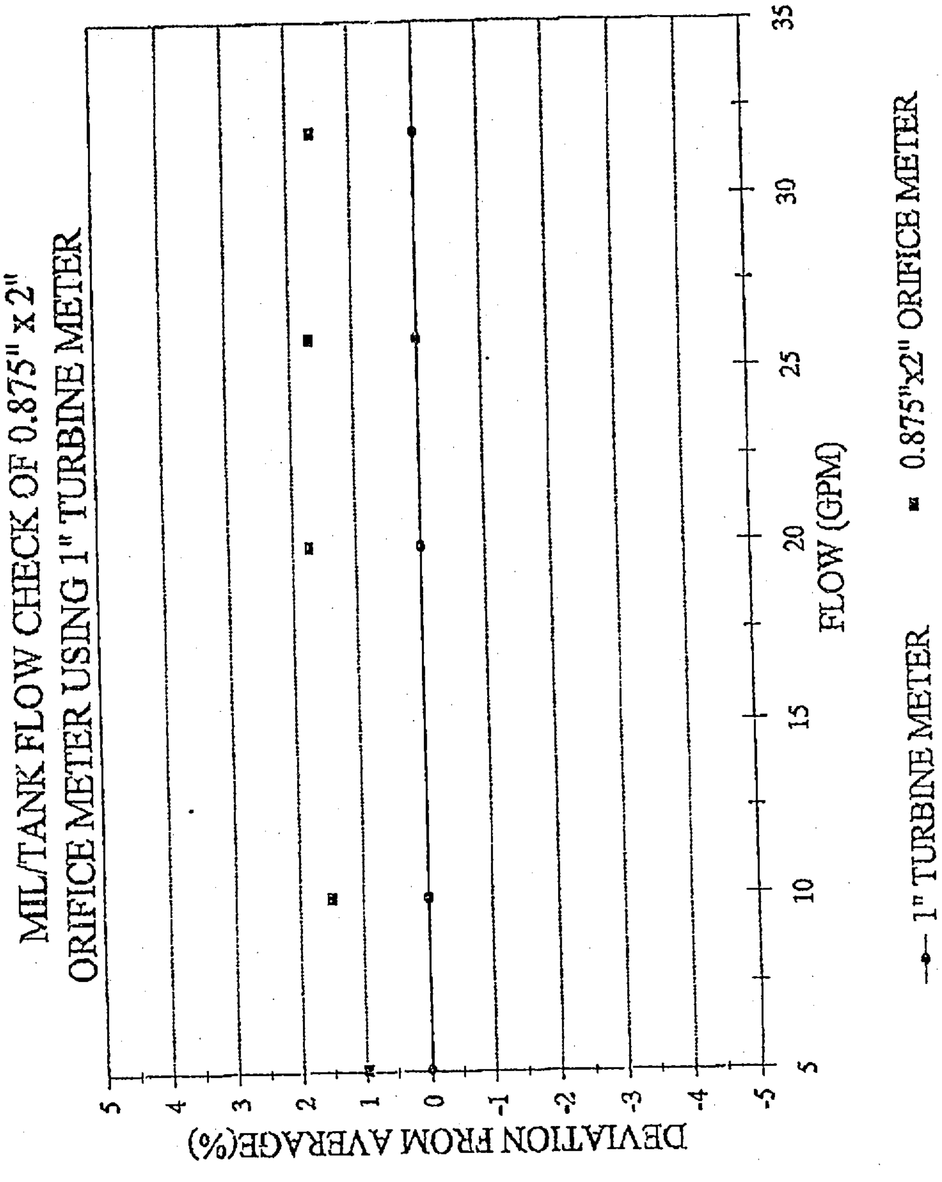
ORIFICE DIAMETER = 0.875
PIPE DIAMETER = 2
BETA RATIO = .4375
FLUID TEMPERATURE = 65
Q/SQR(H) = 2.061795E-02 EQ 1
FLOW SCALE RATIO * Q/SQR(H) = 2.061795E-02 EQ 1A
MODEL SCALE RATIO = 1

AT DESIGN FLOW OF 4.123585E-02 CFS 18.5149 GPM

DEFLECTION = 4.000
PIPE REYNOLDS NUMBER = 27000
ORIFICE REYNOLDS NUMBER = 63000
K = 0.6153
METER LOSS (% OF DEFL) = 80

EQUATIONS 1 AND 1A ARE BASED ON USING A CONSTANT COEFF OF .6152592
IN COLUMN 2 BELOW THE PERCENTAGE ERROR AT DIFFERENT FLOW RATES ARE GIVEN

H	K/Kdesign	RE #	Qmodel	Qproto	C
0.001	109.0	1200	0.001	0.00	0.6580
0.006	105.9	2500	0.002	0.00	0.6395
0.013	104.5	3800	0.002	0.00	0.6313
0.024	103.7	5100	0.003	0.00	0.6265
0.038	103.2	6300	0.004	0.00	0.6231
0.055	102.8	7600	0.005	0.00	0.6207
0.075	102.5	8900	0.006	0.01	0.6188
0.098	102.2	10200	0.007	0.01	0.6172
0.125	102.0	11400	0.007	0.01	0.6160
0.154	101.8	12700	0.008	0.01	0.6149
0.629	100.9	25000	0.016	0.02	0.6091
1.428	100.4	38000	0.025	0.02	0.6065
2.551	100.2	51000	0.033	0.03	0.6049
4.000	100.0	63000	0.041	0.04	0.6039
5.775	99.9	76000	0.049	0.05	0.6031
7.876	99.8	89000	0.058	0.06	0.6025
10.304	99.7	102000	0.066	0.07	0.6020
13.058	99.6	114000	0.074	0.07	0.6016
16.139	99.6	127000	0.082	0.08	0.6013


MIL/TANK FLOW CHECK OF 0.875" x 2"
ORIFICE METER USING 1" TURBINE METER
DEVIATION FROM AVERAGE(%)
5
4
3
2
1
0
-1
-2
-3
-4
-5
5
10
15
20
25
30
35
FLOW (GPM)
1" TURBINE METER
0.875"x2" ORIFICE METER

PG 37 OF 52
This document refers to ARL S/N 0271

S.V.K.
21SEP92

The Commonwealth of Massachusetts

Executive Office of Consumer Affairs
Division of Standards

One Ashburton Place, Boston 02108

January 9, 1991

Alden Research Laboratory, Inc.
30 Shrewsbury St.
Holden, MA 01520

RECEIVED
FEB 12 1991
ARL
CALIBRATION

Mass. Test No. 9091-F040

Dear Sir:

The 100 foot Starrett chrome-steel reel-type tape, which you submitted to this office for calibration has been compared with the 50 foot length bench standard. This standard has traceability to NIST. Comparison was made at a temperature of 79 degrees F with the tape being supported throughout and held at a tension of 10 lbs.

Interval (ft)	Length of Tape Tested 79 °F (Ft)
0-20	20.002
0-40	40.004
0-60	60.008
0-80	80.011
0-100	100.014

Interval (ft)	Length of Tape Calculated to 68 °F (Ft)
0-20	20.001
0-40	40.001
0-60	60.004
0-80	80.006
0-100	100.008

Coefficient of expansion assumed .00000645 per degree F.
The tape meets tolerance requirements of NIST Handbook 44 (1990).

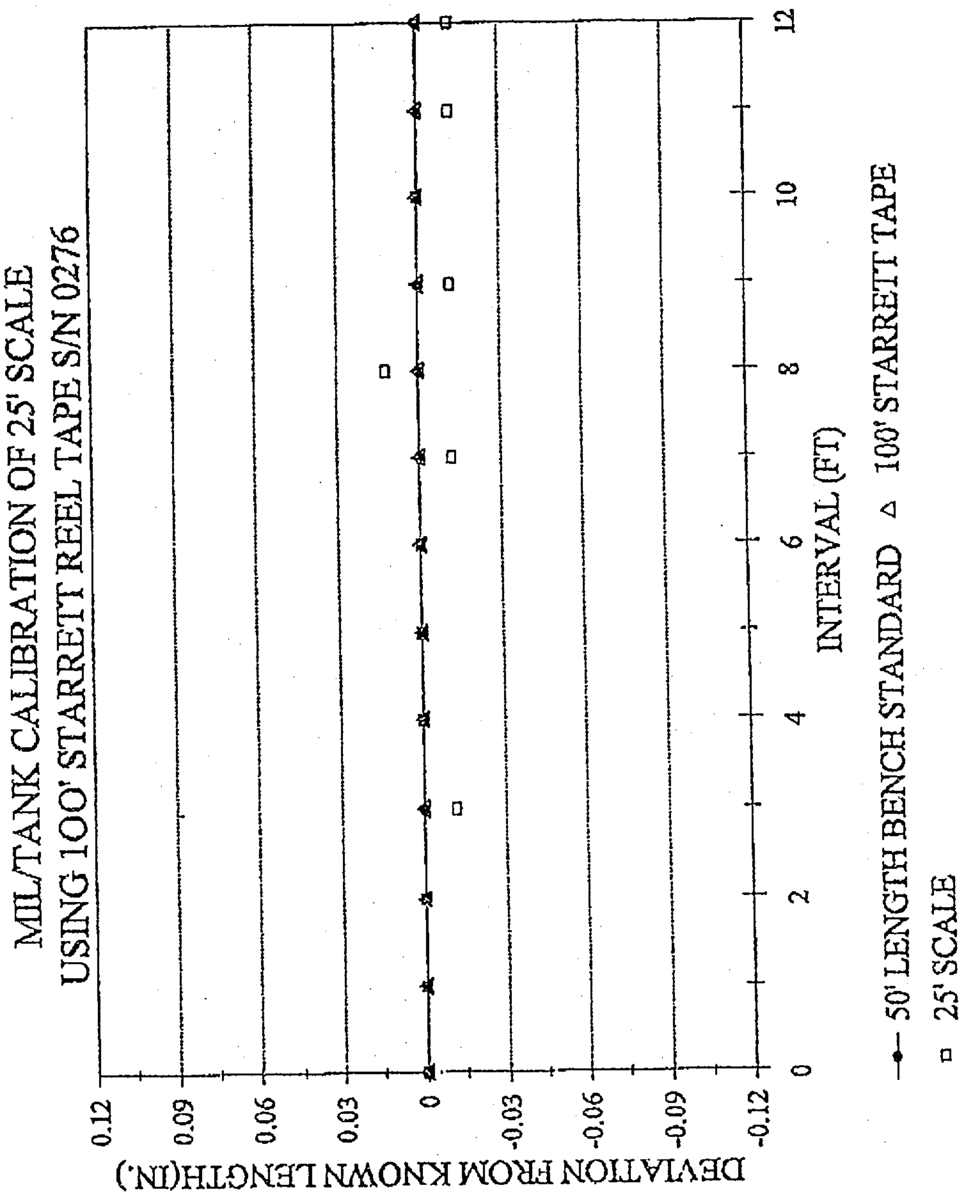
Very truly yours,

Donald Smith
Inspector of Standards II

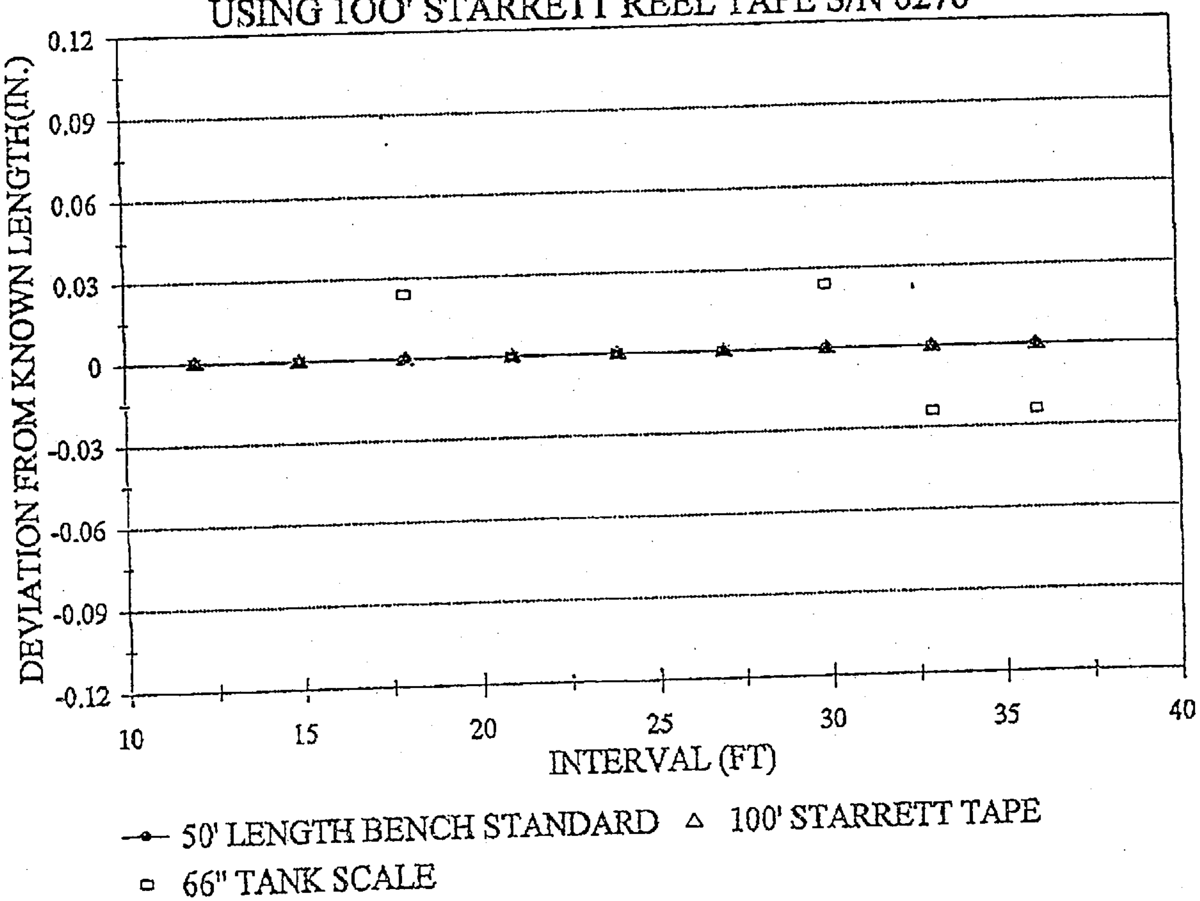
CHC/DS

54

25


MIL/TANK CALIBRATION OF 25' SCALE
USING 100' STARRETT REEL TAPE S/N 0276
DEVIATION FROM KNOWN LENGTH(IN.)
0.12
0.09
0.06
0.03
0
-0.03
-0.06
-0.09
-0.12
INTERVAL (FT)
0
2
4
6
8
10
12
50' LENGTH BENCH STANDARD
100' STARRETT TAPE
25' SCALE

MIL/TANK CALIBRATION OF 66" TANK SCALE
USING 100' STARRETT REEL TAPE S/N 0276



56

APPENDIX B

TEST DATA SHEETS

MIL/TANK

TEST ID # =1-16 04-16-1997 08:52:09 DEPTH = 18 INCHES FLOW = 5.5 GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 53.6 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
2.683962	5.449841	2.765879

MIL/TANK

TEST ID # =2-16 04-16-1997 09:15:50 DEPTH = 18 INCHES FLOW = 31.6GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 54.8 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
15.80398	31.54021	15.73624

MIL/TANK
TEST ID # =3-16 04-16-1997 10:02:51 DEPTH = 16.5 INCHES FLOW = 5.5 GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 57.2 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
2.63038	5.501105	2.870725

MIL/TANK

TEST ID # = 4-16 04-16-1997 09:38:00 DEPTH = 16.5 INCHES FLOW = 31.6GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 56.1 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
15.85647	31.58851	15.73204

MIL/TANK

TEST ID # =5-16 04-16-1997 10:20:01 DEPTH = 15.5 INCHES FLOW =5.5 GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 58.3 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
2.673703	5.544884	2.871181

MIL/TANK
TEST ID # =6-16 04-16-1997 10:39:49 DEPTH = 15.5 INCHES FLOW
= 31.6 GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 60.6 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
15.9165	31.65657	15.74007

25

MIL/TANK

TEST ID # =7-16 04-16-1997 11:22:17 DEPTH = 14.25 INCHES FLOW = 24 GPM #2 FUEL OIL TEST just starting to draw air OIL TEMP = 62.9.6 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
12.30354	24.60775	12.30421

MIL/TANK

TEST ID # =8-16 04-16-1997 11:42:08 DEPTH = 14.94 INCHES FLOW =31.6 GPM #2 FUEL OIL TEST NO AIR OIL TEMP = 63.6 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
15.7139	31.68736	15.97346

65

MIL/TANK

TEST ID # =9-16 04-16-1997 12:05:32 DEPTH = 14.063 INCHES FLOW = 19 GPM #2 FUEL OIL TEST just starting to draw air OIL TEMP = 62.4 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
9.17736	19.05465	9.877286

PG 50 OF 52

MIL/TANK

TEST ID # =10-16 04-16-1997 12:41:56 DEPTH = 13.88 INCHES FLOW

15 GPM #2 FUEL OIL TEST just starting to draw air OIL

TEMP = 65.9 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133

SLOPE AND INTERCEPT CH 2: 175.11 -346

AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
7.629894	15.54025	7.910358

67

MIL/TANK
TEST ID # =11-16 04-16-1997 12:51:10 DEPTH = 13.75 INCHES FLOW = 12 GPM #2 FUEL OIL TEST just starting to draw air OIL TEMP = 66.1 F

SLOPE AND INTERCEPT CH 1: 1.5647 -3.133
SLOPE AND INTERCEPT CH 2: 175.11 -346
AVERAGE METER OUTPUTS (GPM)

INFLOW1	PUMP	INFLOW2
5.717876	11.89364	6.175765

Solving Flow Problems Since 1894

ALDEN RESEARCH LABORATORY, INC.
30 SHREWSBURY STREET, HOLDEN, MASSACHUSETTS 01520
TELEPHONE 508-829-4323 • FAX (508) 829-5939

69

Att. 3 to CA-90-023 Add. 1

Summary of Data Extracted from Alden Research Lab Report

FLOW (GPM)	FUEL SUBMERGENCE (INCHES)	WATER SUBMERGENCE (INCHES)	SUBMERGENCE % DIFFERENCE FUEL TO WATER	VELOCITY IN 1.5 INCH SCH. 80 PIPE (FT/SEC)	WATER SUBMERGENCE BASED ON INTAKE FROUDE + 1 (INCHES)	FUEL SUBMERGENCE BASED ON 120% OF WATER INTAKE FROUDE + 1 (INCHES)
0	1.8864	1.5729		0	1.5	1.8
0.25	1.87790625	1.57145		0.045395273	1.533940556	1.840728667
0.5	1.869675	1.57015		0.090790546	1.567881111	1.881457334
0.75	1.86170625	1.569		0.136185819	1.601821667	1.922186001
1	1.854	1.568		0.181581092	1.635762223	1.962914668
1.25	1.84655625	1.56715		0.226976365	1.669702779	2.003643334
1.5	1.839375	1.56645		0.272371638	1.703643334	2.044372001
1.75	1.83245625	1.5659		0.317766911	1.73758389	2.085100668
2	1.8258	1.5655		0.363162184	1.771524446	2.125829335
2.25	1.81940625	1.56525		0.408557457	1.805465002	2.166558002
2.5	1.813275	1.56515		0.45395273	1.839405557	2.207286669
2.75	1.80740625	1.5652		0.499348003	1.873346113	2.248015336
3	1.8018	1.5654		0.544743276	1.907286669	2.288744003
3.25	1.79645625	1.56575		0.590138549	1.941227225	2.32947267
3.5	1.791375	1.56625		0.635533822	1.97516778	2.370201336
3.75	1.78655625	1.5669		0.680929095	2.009108336	2.410930003
4	1.782	1.5677		0.726324368	2.043048892	2.45165867
4.25	1.77770625	1.56865		0.771719641	2.076989448	2.492387337
4.5	1.773675	1.56975		0.817114914	2.110930003	2.533116004
4.75	1.76990625	1.571		0.862510187	2.144870559	2.573844671
5	1.7664	1.5724		0.90790546	2.178811115	2.614573338
5.25	1.76315625	1.57395		0.953300733	2.212751671	2.655302005
5.5	1.760175	1.57565		0.998696007	2.246692226	2.696030672
5.75	1.75745625	1.5775		1.04409128	2.280632782	2.736759338
6	1.755	1.5795		1.089486553	2.314573338	2.777488005
6.25	1.75280625	1.58165		1.134881826	2.348513894	2.818216672
6.5	1.750875	1.58395		1.180277099	2.382454449	2.858945339
6.75	1.74920625	1.5864		1.225672372	2.416395005	2.899674006
7	1.7478	1.589		1.271067645	2.450335561	2.940402673
7.25	1.74665625	1.59175		1.316462918	2.484276116	2.98113134
7.5	1.745775	1.59465		1.361858191	2.518216672	3.021860007
7.75	1.74515625	1.5977		1.407253464	2.552157228	3.062588674
8	1.7448	1.6009		1.452648737	2.586097784	3.10331734
8.25	1.74470625	1.60425		1.49804401	2.620038339	3.144046007
8.5	1.744875	1.60775		1.543439283	2.653978895	3.184774674
8.75	1.74530625	1.6114		1.588834556	2.687919451	3.225503341
9	1.746	1.6152		1.634229829	2.721860007	3.266232008
9.25	1.74695625	1.61915		1.679625102	2.755800562	3.306960675
9.5	1.748175	1.62325		1.725020375	2.789741118	3.347689342
9.75	1.74965625	1.6275		1.770415648	2.823681674	3.388418009

ATT. 3 PAGE 1 OF 5

70

Summary of Data Extracted from Alden Research Lab Report

FLOW (GPM)	FUEL SUBMERGENCE (INCHES)	WATER SUBMERGENCE (INCHES)	SUBMERGENCE % DIFFERENCE FUEL TO WATER	VELOCITY IN 1.5 INCH SCH. 80 PIPE (FT/SEC)	WATER SUBMERGENCE BASED ON INTAKE FROUDE + 1 (INCHES)	FUEL SUBMERGENCE BASED ON 120% OF WATER INTAKE FROUDE + 1 (INCHES)
10	1.7514	1.6319		1.815810921	2.85762223	3.429146676
10.25	1.75340625	1.63645		1.861206194	2.891562785	3.469875342
10.5	1.755675	1.64115	6.97833836	1.906601467	2.925503341	3.510604009
10.75	1.75820625	1.646	6.816904617	1.95199674	2.959443897	3.551332676
11	1.761	1.651	6.66262871	1.997392013	2.993384453	3.592061343
11.25	1.76405625	1.65615	6.515487728	2.042787286	3.027325008	3.63279001
11.5	1.767375	1.66145	6.375455175	2.088182559	3.061265564	3.673518677
11.75	1.77095625	1.6669	6.24250105	2.133577832	3.09520612	3.714247344
12	1.7748	1.6725	6.116591928	2.178973105	3.129146676	3.754976011
12.25	1.77890625	1.67825	5.997691047	2.224368378	3.163087231	3.795704678
12.5	1.783275	1.68415	5.885758394	2.269763651	3.197027787	3.836433344
12.75	1.78790625	1.6902	5.780750799	2.315158924	3.230968343	3.877162011
13	1.7928	1.6964	5.682622023	2.360554197	3.264908899	3.917890678
13.25	1.79795625	1.70275	5.59132286	2.40594947	3.298849454	3.958619345
13.5	1.803375	1.70925	5.506801229	2.451344743	3.33279001	3.999348012
13.75	1.80905625	1.7159	5.429002273	2.496740016	3.366730566	4.040076679
14	1.815	1.7227	5.357868462	2.542135289	3.400671121	4.080805346
14.25	1.82120625	1.72965	5.293339693	2.587530562	3.434611677	4.121534013
14.5	1.827675	1.73675	5.23535339	2.632925835	3.468552233	4.16226268
14.75	1.83440625	1.744	5.18384461	2.678321108	3.502492789	4.202991346
15	1.8414	1.7514	5.138746146	2.723716381	3.536433344	4.243720013
15.25	1.84865625	1.75895	5.09998863	2.769111654	3.5703739	4.28444868
15.5	1.856175	1.76665	5.067500637	2.814506927	3.604314456	4.325177347
15.75	1.86395625	1.7745	5.041208791	2.8599022	3.638255012	4.365906014
16	1.872	1.7825	5.021037868	2.905297474	3.672195567	4.406634681
16.25	1.88030625	1.79065	5.006910898	2.950692747	3.706136123	4.447363348
16.5	1.888875	1.79895	4.99874927	2.99608802	3.740076679	4.488092015
16.75	1.89770625	1.8074	4.996472834	3.041483293	3.774017235	4.528820682
17	1.9068	1.816	5	3.086878566	3.80795779	4.569549348
17.25	1.91615625	1.82475	5.009247842	3.132273839	3.841898346	4.610278015
17.5	1.925775	1.83365	5.024132195	3.177669112	3.875838902	4.651006682
17.75	1.93565625	1.8427	5.044567754	3.223064385	3.909779458	4.691735349
18	1.9458	1.8519	5.070468168	3.268459658	3.943720013	4.732464016
18.25	1.95620625	1.86125	5.101746138	3.313854931	3.977660569	4.773192683
18.5	1.966875	1.87075	5.138313511	3.359250204	4.011601125	4.81392135
18.75	1.97780625	1.8804	5.180081366	3.404645477	4.045541681	4.854650017
19	1.989	1.8902	5.22696011	3.45004075	4.079482236	4.895378684
19.25	2.00045625	1.90015	5.278859564	3.495436023	4.113422792	4.93610735
19.5	2.012175	1.91025	5.335689046	3.540831296	4.147363348	4.976836017
19.75	2.02415625	1.9205	5.397357459	3.586226569	4.181303904	5.017564684

PAGE 2 OF 5

71

Att. 3 to CA-90-023 Add. 1

Summary of Data Extracted from Alden Research Lab Report

FLOW (GPM)	FUEL SUBMERGENCE (INCHES)	WATER SUBMERGENCE (INCHES)	SUBMERGENCE % DIFFERENCE FUEL TO WATER	VELOCITY IN 1.5 INCH SCH. 80 PIPE (FT/SEC)	WATER SUBMERGENCE BASED ON INTAKE FROUDE + 1 (INCHES)	FUEL SUBMERGENCE BASED ON 120% OF WATER INTAKE FROUDE + 1 (INCHES)
20	2.0364	1.9309	5.46377337	3.631621842	4.215244459	5.058293351
20.25	2.04890625	1.94145	5.53484509	3.677017115	4.249185015	5.099022018
20.5	2.061675	1.95215	5.610480752	3.722412388	4.283125571	5.139750685
20.75	2.07470625	1.963	5.690588385	3.767807661	4.317066126	5.180479352
21	2.088	1.974	5.775075988	3.813202934	4.351006682	5.221208019
21.25	2.10155625	1.98515	5.863851598	3.858598207	4.384947238	5.261936686
21.5	2.115375	1.99645	5.956823361	3.90399348	4.418887794	5.302665352
21.75	2.12945625	2.0079	6.053899597	3.949388753	4.452828349	5.343394019
22	2.1438	2.0195	6.154988859	3.994784026	4.486768905	5.384122686
22.25	2.15840625	2.03125	6.26	4.040179299	4.520709461	5.424851353
22.5	2.173275	2.04315	6.368842229	4.085574572	4.554650017	5.46558002
22.75	2.18840625	2.0552	6.481425165	4.130969845	4.588590572	5.506308687
23	2.2038	2.0674	6.597658895	4.176365118	4.622531128	5.547037354
23.25	2.21945625	2.07975	6.717454021	4.221760391	4.656471684	5.587766021
23.5	2.235375	2.09225	6.840721711	4.267155664	4.69041224	5.628494688
23.75	2.25155625	2.1049	6.967373747	4.312550937	4.724352795	5.669223354
24	2.268	2.1177	7.097322567	4.35794621	4.758293351	5.709952021
24.25	2.28470625	2.13065	7.230481309	4.403341483	4.792233907	5.750680688
24.5	2.301675	2.14375	7.366763848	4.448736756	4.826174463	5.791409355
24.75	2.31890625	2.157	7.50608484	4.494132029	4.860115018	5.832138022
25	2.3364	2.1704	7.648359749	4.539527302	4.894055574	5.872866689
25.25	2.35415625	2.18395	7.793504888	4.584922575	4.92799613	5.913595356
25.5	2.372175	2.19765	7.941437445	4.630317848	4.961936686	5.954324023
25.75	2.39045625	2.2115	8.092075514	4.675713121	4.995877241	5.99505269
26	2.409	2.2255	8.245338126	4.721108394	5.029817797	6.035781356
26.25	2.42780625	2.23965	8.401145268	4.766503667	5.063758353	6.076510023
26.5	2.446875	2.25395	8.559417911	4.811898941	5.097698908	6.11723869
26.75	2.46620625	2.2684	8.720078029	4.857294214	5.131639464	6.157967357
27	2.4858	2.283	8.88304862	4.902689487	5.16558002	6.198696024
27.25	2.50565625	2.29775	9.048253726	4.94808476	5.199520576	6.239424691
27.5	2.525775	2.31265	9.215618446	4.993480033	5.233461131	6.280153358
27.75	2.54615625	2.3277	9.385068952	5.038875306	5.267401687	6.320882025
28	2.5668	2.3429	9.556532502	5.084270579	5.301342243	6.361610692
28.25	2.58770625	2.35825	9.729937454	5.129665852	5.335282799	6.402339358
28.5	2.608875	2.37375	9.90521327	5.175061125	5.369223354	6.443068025
28.75	2.63030625	2.3894	10.08229053	5.220456398	5.40316391	6.483796692
29	2.652	2.4052	10.26110095	5.265851671	5.437104466	6.524525359
29.25	2.67395625	2.42115	10.44157735	5.311246944	5.471045022	6.565254026
29.5	2.696175	2.43725	10.62365371	5.356642217	5.504985577	6.605982693
29.75	2.71865625	2.4535	10.80726513	5.40203749	5.538926133	6.64671136

PAGE 3 OF 5

72

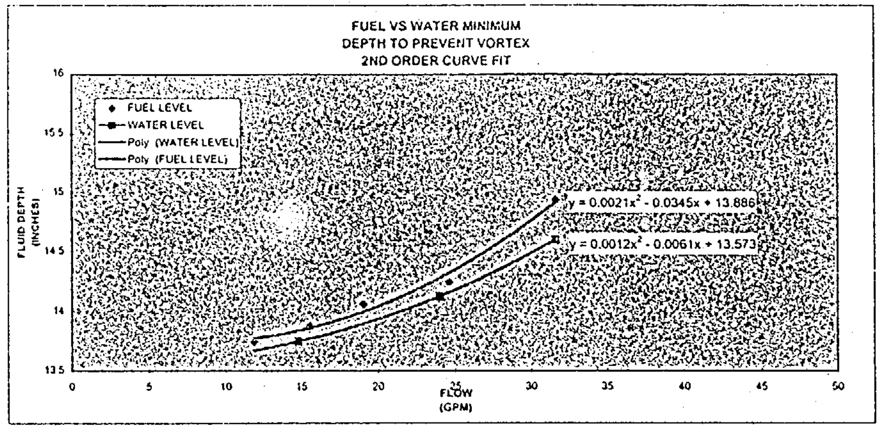
Att. 3 to CA-90-023 Add. 1
Summary of Data Extracted from Alden Research Lab Report

FLOW (GPM)	FUEL SUBMERGENCE (INCHES)	WATER SUBMERGENCE (INCHES)	SUBMERGENCE % DIFFERENCE FUEL TO WATER	VELOCITY IN 1.5 INCH SCH. 80 PIPE (FT/SEC)	WATER SUBMERGENCE BASED ON INTAKE FROUDE + 1 (INCHES)	FUEL SUBMERGENCE BASED ON 120% OF WATER INTAKE FROUDE + 1 (INCHES)
30	2.7414	2.4699	10.99234787	5.447432763	5.572866689	6.687440027
30.25	2.76440625	2.48645	11.17883931	5.492828036	5.606807245	6.728168694
30.5	2.787675	2.50315	11.36667799	5.538223309	5.6407478	6.76889736
30.75	2.81120625	2.52	11.55580357	5.583618582	5.674688356	6.809626027
31	2.835	2.537	11.74615688	5.629013855	5.708628912	6.850354694
31.25	2.85905625	2.55415	11.93767985	5.674409128	5.742569468	6.891083361
31.5	2.883375	2.57145	12.13031558	5.719804401	5.776510023	6.931812028
31.75	2.90795625	2.5889	12.32400827	5.765199674	5.810450579	6.972540695
32	2.9328	2.6065	12.51870324	5.810594947	5.844391135	7.013269362

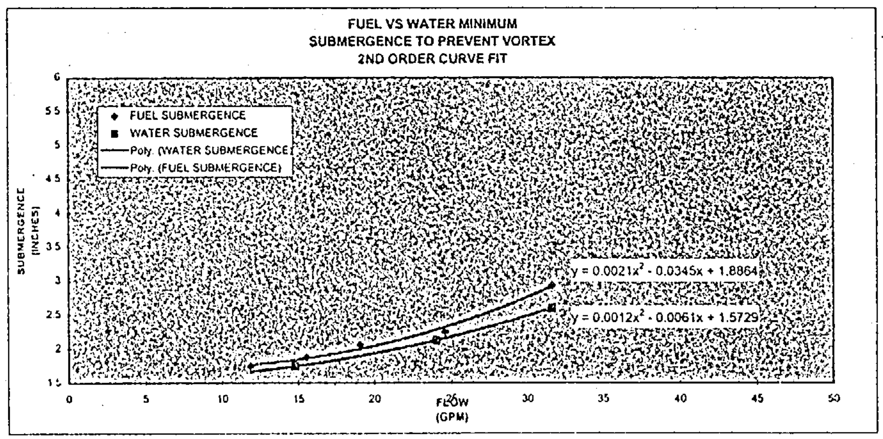
73

PAGE 4 OF 5

FLUID FLOW (gpm)	FUEL DEPTH (inches)	WATER DEPTH (inches)
0		
11.89	13.75	
14.8		13.75
15.54	13.88	
19.05	14.063	
24		14.13
24.6	14.25	
31.6	14.94	14.6
50		



FLUID FLOW (gpm)	FUEL SUBMERGENCE (inches)	WATER SUBMERGENCE (inches)
0		
11.89	1.75	
14.8		1.75
15.54	1.88	
19.05	2.063	
24		2.13
24.6	2.25	
31.6	2.94	2.6
50		



The levels indicated in these graphs are indicative of the points where either air drawing vortexes are just starting to form.

PAGE 5 OF 5

74

ATTACHMENT 4 PG 1 OF 1

LIQUID LEVEL IN TANKS

T. V. SESHADRI
Principal Engineer
Systems
Fruehauf Corp.
Detroit, Mich.

THE height of liquid in a storage tank often must be known to determine the effects of sloshing or center-of-gravity shifts. The relationship between height and volume for flat-ended cylindrical and elliptical tanks was presented in the May 8, 1980, issue as

$$p = 1 + \frac{2(2\alpha-1)\sqrt{\alpha(1-\alpha)}}{\pi} - \frac{\cos^{-1}(2\alpha-1)}{\pi}$$

where p = ratio of liquid volume to total volume, and α = ratio of liquid height to total height. But many tanks have hemispherical or ellipsoidal ends, and the relationship is more complex.

For spherical and ellipsoidal tanks, the relationship between proportional liquid volume p_2 and height is

$$p_2 = \alpha^2(3 - 2\alpha)$$

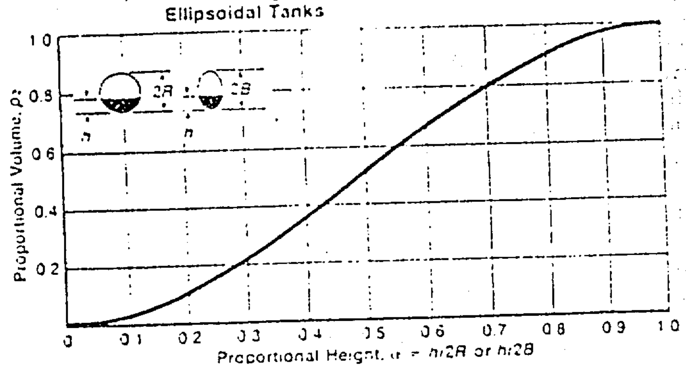
This equation is plotted in the first graph.

For cylindrical tanks with hemispherical ends, the relationship is

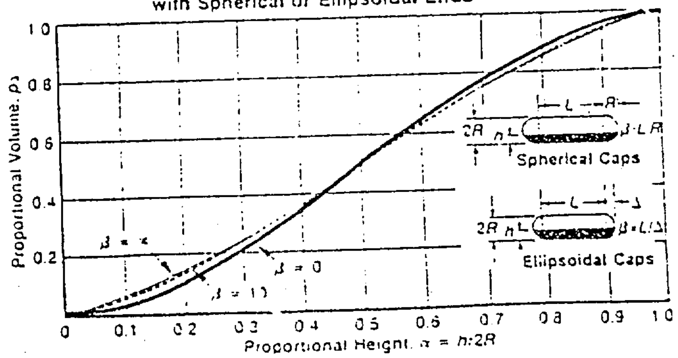
$$p_3 = \frac{3p\beta + 4p_2}{3\beta + 4}$$

where $\beta = L/R$, L = length of cylindrical section, and R = radius of spherical section. This relationship is the same for cylindrical tanks with ellipsoidal ends, except that $\beta = L/\Delta$, where Δ = length of ellipsoidal section. The equation is plotted in the second graph for various values of β. MD

1 — Volume/Height Relationship for Spherical and Ellipsoidal Tanks



2 — Volume Height Relationship for Cylindrical Tanks with Spherical or Ellipsoidal Ends



12

75

25X1

GENERAL COMPUTATION SHEET
Form 17-4103 (6-93)

NSP Northern States Power Company

PROJECT MINIMUM ALLOWABLE FUEL OIL TANK LEVEL
SUBJECT T-44 VERIFICATION CALCULATION

E NO. ____
SHEET NO 1 OF 2
DATE ____
COMP. BY ____ C'K'D BY ____

ALTERNATE CALCULATION USING MAXIMUM FROUDE NUMBER OF .30 FOR LESS THAN 2% AIR INGESTION, DERRIVED FROM EMPIRICAL DATA. (REG GUIDE 1.82 - TABLE A-2.)

$$S \geq d\,(1 + Fr)$$

$$S \geq .125\,ft\,(1 + .30)$$

$$S \geq .163\,ft\,\left(\frac{12\,IN}{1\,ft}\right)$$

$$\boxed{S \geq 1.9\,IN}$$

THE CRITICAL SUBMERGENCE CALCULATION OF 5 IN (PAGE 6 OF 14) IS MORE CONSERVATIVE THAN THE 1.9 INCHES OBTAINED USING THE VERIFICATION METHOD.

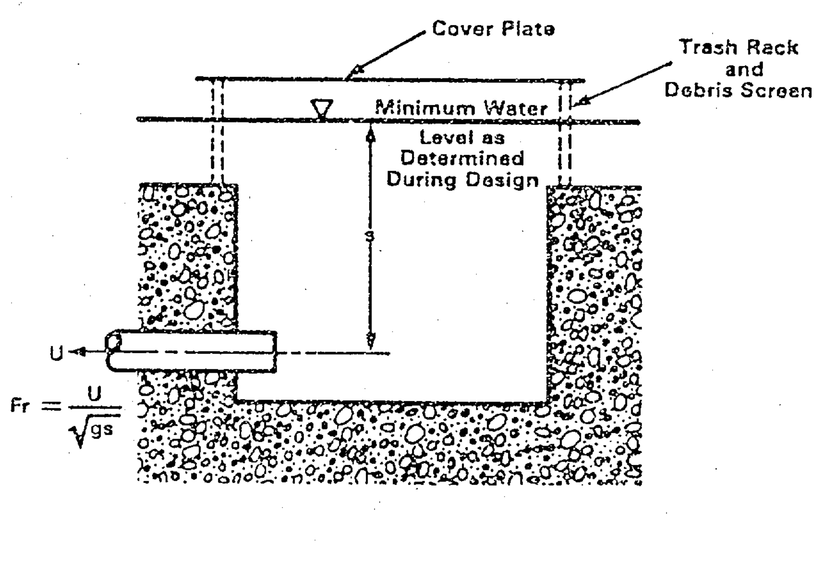
25

TABLE A-2

HYDRAULIC DESIGN GUIDELINES FOR AIR INGESTION <2%

Air ingestion (α) is empirically calculated as
$\alpha = \alpha_o + (\alpha_1 \times Fr)$
where α_o and α_1 are coefficients derived from test results as given in the table below.

Item	Horizontal Outlets		Vertical Outlets	
	Dual	Single	Dual	Single
Coefficient α_o	-2.47	-4.75	-4.75	-9.14
Coefficient α_1	9.38	18.04	18.69	35.95
Minimum Submergence, s (ft)	7.5	8.0	7.5	10.0
(m)	2.3	2.4	2.3	3.1
Maximum Froude Number, Fr	0.5	0.4	0.4	$\boxed{0.3}$
Maximum Pipe Velocity, U (ft/s)	7.0	6.5	6.0	5.5
(m/s)	2.1	2.0	1.8	1.7
Maximum Screen Face Velocity (blocked and minimum submergence) (ft/s)	3.0	3.0	3.0	3.0
(m/s)	0.9	0.9	0.9	0.9
Maximum Approach Flow Velocity (ft/s)	0.36	0.36	0.36	0.36
(m/s)	0.11	0.11	0.11	0.11
Maximum Sump Outlet Coefficient, C_L	1.2	1.2	1.2	1.2



77

25X

ATTACHMENT 6 PAGE 1 OF 1

MONTICELLO NUCLEAR GENERATING PLANT		3495
TITLE:	**CALCULATION/ANALYSIS VERIFICATION CHECKLIST**	Revision 5
		Page 1 of 1

Place initial by items verified.

CA - 90-023 - ADD 1
Attachment 5
Page 1 of

REVIEW		Verified
1.	Inputs correctly selected.	MJM
2.	Assumptions described and reasonable.	MJM
3.	Applicable codes, standards and regulations identified and met.	MJM
4.	Appropriate method used.	MJM
5.	Applicable construction and operating experience considered.	MJM
6.	Applicable structure(s), system(s), and component(s) listed.	MJM
7.	Formulas and equations documented, unusual symbols defined.	MJM
8.	Detailed to allow verification without recourse to preparer.	MJM
9.	Neat and legible, pages all correctly numbered.	MJM
10.	Signed by preparer.	MJM
11.	Interface requirements identified and satisfied.	MJM
12.	Acceptance criteria identified, adequate and satisfied.	MJM
13.	Result reasonable compared to inputs.	MJM
14.	Basis of all assumptions, acceptance criteria and inputs are identified.	MJM
15.	Conclusions not in conflict with previous analysis, USAR, Technical Specifications or NRC Safety Evaluations. NOTE: USAR AND TECH SPEC REVISIONS REQUIRED.	MJM

ALTERNATE CALCULATION		
16.	Alternate calc results consistent with original.	MJM
17.	Items 1-4 above verified. (Required by ANSI N.45.2.11)	MJM

TESTING		
18.	Testing requirements fully described and adequate. NOTE: NO TESTING REQUIRED.	N/A MJM
19.	Shows adequacy of tested feature at worst case conditions.	N/A MJM
20.	If test is for overall design adequacy, all operating modes considered in determining test conditions.	N/A MJM
21.	If model test, scaling laws and error analysis established. NOTE: NO MODELING REQUIRED	N/A MJM
22.	Results meet acceptance criteria, or documentation of acceptable resolution is attached. NOTE: NO ACCEPTANCE CRITERIA SPECIFIED, CALCULATION IS CONSERVATIVELY BOUNDED.	N/A MJM

OTHER (Explain) ______________________

FINAL DOCUMENTATION (Verify applicable items included)

23.	Alternate or check calcs	MJM
24.	Summary of test results. NOTE: CALCULATIONS PROVIDE SUMMARY.	MJM
25.	Comments (errors, discrepancies, recommendations). NO ERRORS, DISCREPANCIES NOTED, RECOMMENDATIONS AND FUTURE NEEDS NOTED.	MJM
26.	Method of resolution of comments. COMMENTS INCORPORATED.	MJM

Completed By: Michael J. Morris   Date: 4-25-00

3087 (DOCUMENT CHANGE, HOLD AND COMMENT FORM) incorporated: 97-1042				
FOR ADMINISTRATIVE USE ONLY	Resp Supv: GSE-NGS	Assoc Ref: AWI-05.01.25	SR: N	Freq: 0 yrs
	ARMS: 3495	Doc Type: 3042	Admin initials:	Date: 7/10/97

M/jrs

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED: DWG. NO. B779R3 "60,000 GAL U.G. OIL TK FOR BECHTEL CORP." WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DOCUMENT/REPORT NUMBER B779R3

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

Supplemental License Amendment Request and Response to Request for Additional Information Regarding License Amendment Request for Revision to Standby Diesel Generators Technical Specifications and Surveillance Requirements

Current Monticello Technical Specification Pages
Marked Up With Proposed Change

This Exhibit consist of current Monticello Technical Specification and Technical Specification Bases pages marked up with the proposed changes. These pages replace the pages included in Exhibit B of NMC submittal dated September 27, 2001 and should be inserted as described below:

Remove and Insert Instructions for Previously Submitted Pages:

Remove Pages:	Insert Pages:
Insert for Page 202	Insert for Page 202
Insert for Page 204	Insert for Page 204
Insert for Page 205	Insert for Page 205

Insert for page 202

3.0 LIMITING CONDITIONS FOR OPERATION

c. When a diesel generator is required to be operable, maintain air pressure for both associated air starting receivers $\geq$ 165 psig.

1) With one diesel generator starting air receiver pressure < 165 psig, restore **[both]** starting air receiver**[s]** pressure to $\geq$ 165 psig within 7 days, or declare the associated diesel generator inoperable.

2) With both diesel generator starting air receivers pressure < 165 psig~~,~~ **[but $\geq$ 125 psig, restore one starting air receiver to $\geq$ 165 psig and enter TS LCO 3.9.B.3.c.1, or restore both starting air receivers pressure to $\geq$ 165 psig within 48 hours. If neither action can be accomplished within 48 hours,]** ~~immediately~~ declare the associated diesel generator inoperable.

[3) With both diesel generator starting air receivers pressure < 125 psig, immediately declare the associated diesel generator inoperable.]

4.0 SURVEILLANCE REQUIREMENTS

c. Verify each required operable diesel generator air start receiver pressure is $\geq$ 165 psig once per month.

Insert for page 204

Each diesel generators starting air receiver**[s]** ~~has~~**[have]** the capability of providing a minimum of at least ~~two (2)~~ **[three (3)]** engine starts without any assistance from the air compressors when maintained at greater than or equal to 165 psig. If one starting air receiver is below its required pressure **[of 165 psig,]** then ~~it must be returned to its required pressure within 7 days,~~ **[restore both starting air receivers pressure to ≥ 165 psig within 7 days. The 7 days to restore pressure to ≥ 165 psig is acceptable because there is sufficient air pressure to start the associated diesel generator a minimum of three (3) times. If the action cannot be performed within 7 days, declare the]** ~~or its~~ associated diesel generator ~~must be declared~~ inoperable. **[With both diesel generator starting air receivers pressure < 165 psig but ≥ 125 psig, restore one starting air receiver to ≥ 165 psig and enter TS LCO 3.9.B.3.c.1, or restore both starting air receivers pressure to ≥ 165 psig within 48 hours. If neither action can be accomplished within 48 hours declare the associated diesel generator inoperable. The 48 hours to restore one of the starting air receivers to ≥ 165 psig and entering the TS LCO 3.9.B.3.c.1, or restoring both starting air receivers to ≥ 165 psig within 48 hours is acceptable based on the remaining air start capacity, the fact that most DG starts are accomplished on the first attempt, and the low probability of an event during this brief period.]** If both starting air receivers, for the same diesel generator, are below ~~their required pressure~~ **[of 125 psig]**, immediately declare the associated diesel generator inoperable.

Insert for page 205

The Surveillance Requirement for diesel generator starting air receivers ensures that, without the aid of the refill compressors, sufficient air start capacity for each diesel generator is available. The system design requirements provide **[power to start each diesel generator engine from two independent air starting systems. Each system consist of a pair of compressed air starting motors, an air dryer, strainer, air line lubricator, and related storage tanks, that provide 100 percent redundancy for each diesel generator's starting air system. Starting at a nominal pressure of 200 psig, each air starting system has adequate capacity to start its associated diesel generator five times without recharging. The limit of 165 psig provides]** minimum air pressure to support ~~two~~ **[three DG]** engine starts, from each of the two starting air receivers associated with each diesel generator, without recharging**[, this provides for a total of six (6) starts for the associated diesel generator.]**. The monthly surveillance requirement frequency for verifying the pressure in each starting air receiver takes into account the capacity, capability, redundancy, and diversity of the AC sources and other indications available in the control room, including alarms, to alert the operator to below normal air start pressure.

Supplemental License Amendment Request and Response to Request for Additional Information Regarding License Amendment Request for Revision to Standby Diesel Generators Technical Specifications and Surveillance Requirements

Revised Monticello Technical Specification Pages

This Exhibit consist of revised Monticello Technical Specification and Technical Specification Bases pages that incorporate the proposed changes. These pages replace the pages included in Exhibit C of NMC submittal dated September 27, 2001 and should be inserted as described below:

Remove and Insert Instructions for Previously Submitted Pages:

Remove Pages:	Insert Pages:
202	202
204	204
204a	204a
205	205

3.0 LIMITING CONDITIONS FOR OPERATION

b. For the diesel generators to be considered operable, there shall be a minimum of 38,300 gallons of diesel fuel (7 days supply for 1 diesel generator at full load @ 2500 KW) in the diesel oil storage tank.

c. When a diesel generator is required to be operable, maintain air pressure for both associated air starting receivers $\geq$165 psig.

1) With one diesel generator starting air receiver pressure <165 psig, restore both starting air receivers pressure to $\geq$165 psig within 7 days, or declare the associated diesel generator inoperable.

2) With both diesel generator starting air receivers pressure <165 psig but $\geq$125 psig, restore one starting air receiver to $\geq$165 psig and enter TS LCO 3.9.B.3.c.1, or restore both starting air receivers pressure to $\geq$165 psig within 48 hours. If neither action can be accomplished within 48 hours, declare the associated diesel generator inoperable.

3) With both diesel generator starting air receivers pressure <125 psig, immediately declare the associated diesel generator inoperable.

4.0 SURVEILLANCE REQUIREMENTS

b. 1) Once a month the quantity of diesel fuel available shall be logged.

2) During the monthly generator test, the diesel fuel oil transfer pump and diesel oil service pump shall be operated.

3) Once a month a sample of diesel fuel shall be taken and checked for quality.

c. Verify each required operable diesel generator air start receiver pressure is $\geq$165 psig once per month.

Bases 3.9:

The general objective is to assure an adequate supply of power with at least one active and one standby source of power available for operation of equipment required for a safe plant shutdown, to maintain the plant in a safe shutdown condition, and to operate the required engineered safeguards equipment following an accident.

AC for shutdown requirements and operation of engineered safeguards equipment can be provided by either of the two standby sources of power (the diesel generators) or any of the three active sources of power (No. 1R, No. 2R, or No. 1AR transformers). Refer to Section 8 of the USAR.

To provide for maintenance and repair of equipment and still have redundancy of power sources, the requirement of one active and one standby source of power was established. The plant's main generator is not given credit as a source since it is not available during shutdown.

The plant 250 V dc power is supplied by two batteries. Most station 250 V loads are supplied by the original station 250 V battery. A new 250 V battery has been installed for HPCI loads and may be used for other station loads in the future. Each battery is maintained fully charged by two associated chargers which also supply the normal dc requirements with the batteries as a standby source during emergency conditions. The plant 125 V dc power is normally supplied by two batteries, each with an associated charger. Backup chargers are available.

The minimum diesel fuel supply of 38,300 gallons will supply one diesel generator for a minimum of seven days of full load (2500 KW) operation. Actual fuel consumption during this period would be 33,096 gallons, but the minimum tank level has been established at the higher 38,300 gallon value to allow for instrument inaccuracy, pump suction vortexing, tank volume uncertainties, and the location of the suction piping within the tank. Additional diesel fuel can normally be obtained within a few hours. Maintaining at least 7 days supply is therefore conservative.

Each diesel generator starting air receivers have the capability of providing a minimum of at least three (3) engine starts without any assistance from the air compressors when maintained at greater than or equal to 165 psig. If one starting air receiver is below its required pressure of 165 psig, restore both starting air receivers pressure to $\geq$165 psig within 7 days. The 7 days to restore pressure to $\geq$165 psig is acceptable because there is sufficient air pressure to start the associated diesel generator a minimum of three (3) times. If the action cannot be performed within 7 days, declare the associated diesel generator inoperable. With both diesel generator starting air receivers pressure $<$165 psig but $\geq$125 psig, restore one starting air receiver to $\geq$165 psig and enter TS LCO 3.9.B.3.c.1, or restore both starting air receivers pressure to $\geq$165 psig within 48 hours. If neither action can be accomplished within 48 hours, declare the associated diesel generator inoperable. The 48 hours to restore one of the starting air receivers to $\geq$165 psig and entering the TS LCO 3.9.B.3.c.1, or restoring both starting air receivers to $\geq$165 psig within 48 hours is acceptable based on the remaining air start capacity, the fact that most diesel generator starts are accomplished on the first attempt, and the low probability of an event during this brief period. If both starting air receivers for the same diesel generator are below 125 psig, immediately declare the associated diesel generator inoperable.

In the normal mode of operation, power is available from the offsite sources. One diesel may be allowed out of service based on the availability of offsite power provided that the remaining diesel generator is demonstrated to be operable within 24 hours. This test is required even if the inoperable diesel is restored to operability within 24 hours. Thus, though one diesel generator is temporarily out of service, the offsite sources are available, as well as the remaining diesel generator. Based on a monthly testing period (Specification 4.9), the seven day repair period is justified. (1)

---

(1) "Reliability of Engineered Safety Features as a Function of Testing Frequency", I.M. Jacobs, Nuclear Safety, Volume 9, No. 4, July - August 1968.

Bases 4.9:

The monthly test of the diesel generator is conducted to check for equipment failures and deterioration. Testing is conducted up to equilibrium operating conditions to demonstrate proper operation at these conditions. The diesel will be manually started, synchronized to the bus and load picked up. It is expected that the diesel generator will be run for one to two hours. Diesel generator experience at other generating stations indicates that the testing frequency is adequate to assure a high reliability of operation should the system be required. In addition, during the test when the generator is synchronized to the bus it is also synchronized to the offsite power source and thus not completely independent of this source. To maintain the maximum amount of independence, a thirty day testing interval is also desirable.

The Surveillance Requirement for diesel generator starting air receivers ensures that, without the aid of the refill compressors, sufficient air start capacity for each diesel generator is available. The system design requirements provide power to start each diesel generator engine from two independent air starting systems. Each system consists of a pair of compressed air starting motors, an air dryer, strainer, air line lubricator, and related storage tanks that provide 100 percent redundancy for each diesel generator's starting air system. Starting at a nominal pressure of 200 psig, each air starting system has adequate capacity to start its associated diesel generator five times without recharging. The limit of 165 psig provides minimum air pressure to support three diesel generator engine starts, from each of the two starting air receivers associated with each diesel generator, without recharging, this provides for a total of six (6) starts for the associated diesel generator. The monthly surveillance requirement frequency for verifying the pressure in each starting air receiver takes into account the capacity, capability, redundancy, and diversity of the AC sources and other indications available in the control room, including alarms, to alert the operator to below normal air start pressure. During the monthly load test of the diesel generators, the diesel fuel oil transfer pump and diesel oil service pump will be operated. A sample of diesel fuel will be taken monthly to assure that the quality remains high.

The test of the emergency diesel generator during the refueling outage will be more comprehensive in that it will functionally test the system, i.e., it will check diesel starting and closure of diesel breaker and sequencing of loads on the diesel. The diesel will be started by simulation of a loss of coolant accident. In addition, an undervoltage condition will be imposed to simulate a loss of offsite power. The timing sequence will be checked to assure proper loading in the time required. The only load on the diesel is that due to friction and windage and a small amount of bypass flow on each pump. Periodic tests between refueling outage check the diesel to run at full load and the pumps to deliver full flow. Periodic testing of the various components plus a functional test at a refueling interval are sufficient to maintain adequate reliability.

Although station batteries will deteriorate with time, utility experience indicates there is almost no possibility of precipitous failure. The type of surveillance described in this specification is that which has been demonstrated over the years to provide an indication of a cell becoming irregular or unserviceable long before it becomes a failure.

In addition, the checks described also provide adequate indication that the batteries have the specified ampere-hour capability.