Entergy

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July 20, 2010

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT: License Amendment Request for Emergency Diesel Generator Fuel Oil and Lube Oil Systems

Palisades Nuclear Plant
Docket 50-255
License No. DPR-20

Dear Sir or Madam:

In accordance with the provisions of 10 CFR 50.90, Entergy Nuclear Operations (ENO) is submitting a license amendment request to revise the Technical Specifications (TS) for Palisades Nuclear Plant (PNP).

The proposed changes revise TS 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," by relocating the current stored diesel fuel oil and lube oil numerical volume requirements from the TS to the TS Bases so that they may be modified under licensee control. The TS are modified so that the stored diesel fuel oil and lube oil inventory will require that a 7-day supply be available for either diesel generator. Condition A and Condition B in the Action table are revised and Surveillance Requirements (SR) 3.8.3.1 and 3.8.3.2 are revised to reflect the above change.

The proposed changes also revise TS 3.8.3 by reducing the Completion Time for Condition C. Condition C currently requires that an inoperable fuel transfer system associated with fuel oil transfer pump P-18A be restored to operable status within 15 hours. The proposed TS change reduces the Completion Time for this Required Action from 15 to 12 hours. The Completion Time is reduced to reflect the amount of time that an emergency diesel generator fuel oil day tank can support emergency diesel generator operation under design conditions.

The proposed changes have been evaluated in accordance with 10 CFR 50.91(a)(1) using criteria in 10 CFR 50.92(c) and it has been determined that the changes involve no significant hazards consideration. The bases for these determinations are included in Attachment 1 along with a detailed description of the proposed changes, background and technical evaluation, and an environmental review consideration.

Attachment 2 provides TS page change instructions and the revised TS pages that reflect the proposed changes. Attachment 3 provides the annotated TS pages showing the proposed changes. Attachment 4 provides the annotated TS Bases pages that reflect the proposed changes. Attachment 5 provides a supporting fuel oil and lube oil inventory calculation. Attachment 6 provides a supporting fuel oil transfer pump P-18A allowed outage time computation.

Once approved, the amendment shall be implemented within 60 days.

A copy of this request has been provided to the designated representative of the State of Michigan.

This letter contains no new commitments and no revision to existing commitments.

I declare under penalty of perjury that the foregoing is true and correct. Executed on July 20, 2010.

Sincerely,

cjs/jse

Attachment(s):
1. Evaluation of Proposed Changes
2. Renewed Operating License Page Change Instructions and Revised Technical Specification Pages
3. Mark-up of Technical Specification Pages
4. Mark-up of Technical Specification Bases Pages
5. Fuel Oil and Lube Oil Inventory Calculation
6. Fuel Oil Transfer Pump P-18A Allowed Outage Time Computation

cc: Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ATTACHMENT 1

EVALUATION OF PROPOSED CHANGES

1.0 DESCRIPTION

Entergy Nuclear Operations, Inc. (ENO) requests amending the Renewed Facility Operating License DPR-20 for Palisades Nuclear Plant (PNP) to revise Appendix A, Technical Specifications (TS), as they apply to fuel oil and lube oil inventory requirements and fuel oil transfer system requirements.

The proposed changes revise TS 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," by relocating the stored diesel fuel oil and lube oil numerical volume requirements from the TS to the TS Bases so that they may be modified under licensee control. The TS are proposed to be revised so that the stored diesel fuel oil and lube oil inventory will require that a 7-day supply be available for the emergency diesel generators.

The NRC approved Revision 1 to Technical Specification Task Force (TSTF) Improved Standard Technical Specification Change Traveler-501, "Relocate Stored Fuel Oil and Lube Oil Volume Values to Licensee Control." The availability of this TS improvement was announced in the Federal Register on May 26, 2010, (FR 29588) as part of the consolidated line item improvement process (CLIIP).

There are two differences between the approved TSTF and this PNP proposed TS change. One difference is that the TSTF is written specifically for sites licensed for 7-day supplies of fuel oil and lube oil for each emergency diesel generator whereas PNP is licensed for 7-day supplies of fuel oil and lube oil for either emergency diesel generator. PNP has one fuel oil storage tank that supplies the two emergency diesel generators.

The other difference is that the TSTF refers to the 7-day fuel oil supply maintained within a fuel oil storage tank whereas PNP credits both the volume in the fuel oil storage tank as well as the volume in an emergency diesel generator fuel oil day tank as comprising the required 7-day fuel oil supply. The TS 3.8.1 Bases, Background section, states "A single buried Fuel Oil Storage Tank is used, along with an individual day tank for each DG, to maintain the required fuel oil inventory." This proposed PNP TS amendment refers to the combined volume of the fuel oil storage tank and a diesel fuel oil day tank as the "fuel oil storage subsystem."

In addition to the diesel fuel oil and lube oil inventory changes, the proposed changes also revise Technical Specification (TS) 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," by reducing the Completion Time for Condition C in the TS. Condition C pertains to the fuel oil transfer system associated with fuel oil transfer pump P-18A. The proposed TS change reduces the Completion Time for restoration of an inoperable fuel transfer P-18A system to operable status from 15 hours to 12 hours. The Completion Time is based on the time duration in which a diesel fuel oil day tank can support emergency diesel generator operation under design operating conditions.

2.0 PROPOSED CHANGE

Fuel Oil and Lube Oil Changes

The proposed changes revise TS 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," by relocating the stored diesel fuel oil and lube oil numerical volume requirements from the TS to the TS Bases so that they may be modified under licensee control. The TS are modified so that the stored diesel fuel oil and lube oil inventory will require that a 7-day supply be available for either emergency diesel generator. As a result:

- Condition A and Condition B in the Action table are revised. Currently, Condition A and Condition B are entered when the stored diesel fuel oil and lube oil numerical volume requirements are not met. As discussed in the current TS Bases, the numerical volume requirements in Condition A and Condition B are based on volumes less than a 7-day supply, but greater than a 6-day supply. The revision relocates the volumetric requirements from the TS and places them in the TS Bases. The TS are modified so that Condition A and Condition B are entered when the stored diesel fuel oil and lube oil inventory is less than a 7-day supply, but greater than a 6-day supply for either of the emergency diesel generators.

- Surveillance Requirements (SR) 3.8.3.1 and 3.8.3.2 are revised. Currently, SR 3.8.3.1 and SR 3.8.3.2 verify that the stored diesel fuel oil and lube oil numerical volume requirements are met. As discussed in the current TS Bases, the numerical volume requirements in SR 3.8.3.1 and SR 3.8.3.2 are based on maintaining at least a 7-day supply. The revision relocates the volumetric requirements from the TS and places them in the TS Bases. The TS are modified so that SR 3.8.3.1 and SR 3.8.3.2 verify that the stored diesel fuel oil and lube oil inventory is greater than or equal to a 7-day supply for either of the emergency diesel generators.

- The reference to Appendix B of ANSI N195–1976 in the TS Bases is deleted. As a result, the only reference will be to ANSI N195–1976.

Proposed revisions to the TS Bases for these fuel oil and lube oil changes are also included in this application, as information only. The changes to the affected TS Bases pages will be incorporated in accordance with the TS Bases Control Program.

The proposed TS changes above will enable ENO to address a non-conservative TS requirement for stored fuel oil to support 7 days of continuous emergency diesel generator operation under emergency conditions. The changes will also enable ENO to efficiently revise the fuel oil storage requirements contained in the TS Bases as changes may be needed to address future updates to regulations and standards governing diesel fuel oil quality.

Fuel Oil Transfer Pump Change

The proposed TS change also revises the Completion Time for Condition C in the Action table TS 3.8.3. Condition C contains requirements for the inoperable fuel transfer system associated with fuel oil transfer pump P-18A. The Completion Time for Condition C requires that the inoperable P-18A fuel transfer system be returned to operable status within 15 hours. The proposed TS change reduces the Completion Time for Condition C from 15 hours to 12 hours. This proposed TS change will correct a non-conservative TS.

Changes to the TS Bases pages associated with this fuel oil transfer pump TS change are included in this application. The TS Bases changes are provided for information. The associated TS Bases changes will be incorporated in accordance with the TS Bases Control Program.

3.0 BACKGROUND

The two PNP emergency diesel generators share a common fuel oil storage and transfer system. A single common buried fuel oil storage tank is used, along with an individual day tank for each emergency diesel generator, to maintain the required fuel oil inventory sufficient to operate either of the emergency diesel generators for a period of 7 days, while the emergency diesel generator is supplying maximum post-accident loads. Each day tank is required by TS SR 3.8.1.4 to contain at least 2500 gallons. Fuel oil is transferred from the fuel oil storage tank to the day tank by either of two fuel transfer systems, each associated with a separate fuel transfer pump.

Either fuel transfer pump is capable of supplying either emergency diesel generator. However, each fuel transfer pump is not normally capable of being powered from either emergency diesel generator. Emergency diesel generator 1-1 can power either fuel transfer pump, but emergency diesel generator 1-2 can only power fuel transfer pump P-18A.

Since emergency diesel generator 1-2 cannot power fuel transfer pump P-18B, without P-18A, emergency diesel generator 1-2 becomes dependant on offsite power or emergency diesel generator 1-1 for its fuel supply (beyond the duration it will operate on the day tank). The TS currently allow 15 hours to restore the fuel transfer system to operable status prior to declaring the associated emergency diesel generator inoperable.

The emergency diesel generator lubrication system is designed to provide sufficient lubrication to permit proper operation of its associated emergency diesel generator under all loading conditions. The system is required to circulate the lube oil to the diesel engine working surfaces and to remove excess heat generated by friction during operation. The onsite storage is sufficient to ensure 7 days of continuous operation. This supply is sufficient supply to allow the operator to replenish lube oil from offsite sources.

In January 2001 and in June 2004, the U.S. Environmental Protection Agency (EPA) finalized the Clean Diesel Trucks and Buses Rule and the Clean Nonroad Diesel Rule, respectively, with more stringent standards for new diesel engines and fuels (See NRC Information Notice 2006-22, "New Ultra-Low-Sulfur Diesel Fuel Oil Could Adversely Impact Diesel Engine Performance," October 12, 2006). The EPA rules require a reduction in the sulfur content of highway diesel fuel from its current level of 500 parts per million (ppm) low sulfur diesel (LSD) to 15-ppm ultra low sulfur diesel (ULSD). Refiners were required to start producing the cleaner-burning diesel fuel ULSD, for use in highway vehicles beginning June 1, 2006.

The EPA required sulfur reductions for land-based nonroad diesel fuel to be accomplished in two steps, with an interim step from previous uncontrolled levels to a 500 ppm cap starting in June 2007 and the final step to 15 ppm in June 2010.

In general, the processing required to reduce sulfur in ULSD also reduces the aromatics content and density of diesel fuel, resulting in a reduction in volumetric energy content (BTU/gallon). The requirements on diesel fuel oil may continue to change in the future and the addition of additives to compensate for the issues associated with ULSD discussed in Information Notice 2006-022 may further affect the volumetric energy content (and, as a result, the stored diesel fuel oil volume requirements). These changes would result in future license amendments to revise the stored fuel oil volume in order to ensure that the volume provides for at least 7 days of emergency diesel generator operation. In order to facilitate the expeditious revision of the fuel oil volume requirement when needed, and to avoid the unnecessary expenditure of ENO and NRC resources to prepare and review future license amendment requests that simply revise the volume equivalent to a 7-day supply, the proposed change places the requirement to have stored fuel oil sufficient to support 7 days of emergency diesel generator operation in the TS with the equivalent numerical volume under licensee control in the TS Bases.

The TS requirements on lube oil are also based on maintaining a 7-day supply. To maintain consistency within the TS and to avoid future amendments to the lube oil inventory numerical value equivalent to a 7-day supply, the proposed change places the requirement to have lube oil inventory sufficient to support 7 days of emergency diesel generator operation in the TS with the equivalent numerical volume in the TS Bases.

4.0 TECHNICAL ANALYSIS

Fuel Oil and Lube Oil Changes

4.1 Modification to LCO 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," Requirements

The emergency diesel generators are provided with a fuel oil capacity sufficient to operate either emergency diesel generator for a period of 7 days while the emergency diesel generator is supplying maximum load demand. This onsite fuel oil capacity is sufficient to operate an emergency diesel generator for longer than the time to replenish the onsite supply from outside sources.

The diesel generator lubrication system is designed to provide sufficient lubrication to permit proper operation of an emergency diesel generator under all loading conditions. The system is required to circulate the lube oil to the diesel engine working surfaces and to remove excess heat generated by friction during operation. The lube oil inventory is capable of supporting either emergency diesel generator for a minimum of 7 days. This supply is sufficient to allow the operator to replenish lube oil from outside sources.

In order to meet a 7-day supply of stored diesel fuel oil and lube oil for either emergency diesel generator, TS 3.8.3, "Diesel Fuel, Lube Oil, and Starting Air," currently contains numerical volume requirements associated with a 7-day supply for either emergency diesel generator. The TS Bases currently discuss that the numerical volume requirements are based on meeting a 7-day supply. The proposed change revises TS 3.8.3 by relocating the stored diesel fuel oil and lube oil numerical volume requirements from the TS to the TS Bases so that they may be modified under licensee control. The TS are modified so that the stored diesel fuel oil and lube oil inventory will require that a 7-day supply be available for either emergency diesel generator. No changes to the current plant configuration or current 7-day basis are proposed in the application; ENO is relocating the numerical volume requirements from the TS to the TS Bases and relocating the associated current 7-day basis from the TS Bases to the TS. The numerical volume requirements in the current TS will be revised in the TS Bases as described below.

Approval of this license amendment request will assist ENO in addressing a non-conservative TS. ENO performed a calculation in accordance with Regulatory Guide 1.137, Revision 1, "Fuel-Oil Systems for Standby Diesel Generators," and ANSI N195-1976, "Fuel Oil Systems for Standby Diesel Generators," to determine the fuel oil and lube oil inventories required to operate either emergency diesel generator for 7 days assuming accident loading conditions (Attachment 5). This calculation was prompted by the ULSD issue and non-conservative assumptions in stored diesel fuel oil inventory calculations discovered at another site. The calculation determined a required diesel fuel oil inventory that exceeded the fuel oil inventory required by TS LCO 3.8.3

Condition A. The calculated required fuel oil and lube oil inventories are shown as information in Attachment 4, "Mark-up of Technical Specification Bases Pages."

NRC Administrative Letter 98-10, "Dispositioning of Technical Specifications that are Insufficient to Assure Plant Safety," provides guidance for TS that are determined to be non-conservative. Imposing administrative controls as a compensatory measure is an acceptable short-term solution under this guidance. Following implementation of the administrative controls, a TS amendment is to be submitted to resolve the condition.

In accordance with this letter, ENO implemented administrative controls, as required, to maintain stored fuel oil inventory above the required inventory determined in the calculation until the condition is resolved.

Section 4.3 below discusses the methodology on how the stored diesel fuel oil and lube oil numerical volume basis in the TS Bases may be modified under ENO control. The use of this methodology will ensure that a 7-day supply of stored diesel fuel oil and lube oil for either emergency diesel generator will be met, thereby providing assurance that the lowest functional capability or performance levels of the diesel generator required for safe operation of the facility will be continued to be met.

4.2 Modification to Action Table for TS 3.8.3 "Diesel Fuel, Lube Oil, and Starting Air"

Currently, Condition A and Condition B are entered when the stored diesel fuel oil and lube oil numerical volume requirements are not met. As discussed in the current TS Bases, the numerical volume requirements in Condition A and Condition B are based on volumes less than a 7-day supply, but greater than an a 6-day supply. The proposal relocates the volumetric requirements from the TS and places it in the TS Bases. The TS are modified so that Condition A and Condition B are entered when the stored diesel fuel oil and lube oil inventory is less than a 7-day supply, but greater than a 6-day supply for either emergency diesel generator.

No other parts of Condition A and Condition B (i.e., Required Actions or Completion Times) are proposed to be modified in the application; ENO is relocating the numerical volume requirements that dictate Condition entry from the TS to the TS Bases and relocating the associated current less than 7-day but greater than 6-day basis for Condition entry from the TS Bases to the TS.

Section 4.3 below discusses the methodology on how the stored diesel fuel oil and lube oil numerical volume basis in the TS Bases may be modified under licensee control. The use of this methodology will ensure that the 7-day and 6-day supplies of stored diesel fuel oil and lube oil for either emergency diesel generator that dictate Condition entry will continue to be calculated in accordance with NRC-approved methods.

4.3 Modification to SRs 3.8.3.1 and 3.8.3.2

Currently, SR 3.8.3.1 and SR 3.8.3.2 verify that the stored diesel fuel oil and lube oil numerical volume requirements are met. SR 3.8.3.1 and SR 3.8.3.2 are revised to reflect the change in LCO requirements, namely that a 7-day supply be available for either emergency diesel generator. As a result, the SRs are modified so that SR 3.8.3.1 and SR 3.8.3.2 verify that the stored diesel fuel oil and lube oil inventory is greater than or equal to a 7-day supply for either emergency diesel generator.

No other parts of the SRs (i.e., Frequencies) are proposed to be modified in the application; the licensee is relocating the numerical volume requirement verification from the TS to the TS Bases and relocating the associated current 7-day basis for verification from the TS Bases to the TS.

The methodology for determining the 7-day stored diesel fuel oil supply for either emergency diesel generator, as well as the 6-day supply associated with Condition A, is calculated in accordance with RG 1.137, Revision 1, and ANSI N195 1976. ANSI N195-1976 discusses how the stored diesel fuel oil requirement shall be calculated based upon the diesel generators operating at the minimum required capacity for the plant condition which is most limiting for the calculation of such capacity. One method for calculating the stored diesel fuel oil supply takes into account the time dependence of diesel generator loads. That is, if diesel generator loads increase or decrease during the event, the load changes shall be included in the required fuel storage calculation. If the design includes provisions for an operator to supply power to equipment other than the minimum required for the plant condition, such additional loads shall be included in the calculation of required fuel storage capacity. RG 1.137, Revision 1, supplements the above by stating that for the time-dependent load method, the minimum required capacity should include the capacity to power the engineered safety features. A minimum margin of 10% shall be added to the calculated storage requirement if the alternate conservative calculation discussed next is not used. Another method for calculating the stored diesel fuel oil supply, which is more conservative than the time-dependent load method, is to calculate the storage capacity by assuming that the diesel operates continuously for seven days at its rated capacity. Both calculation methods include an explicit allowance for fuel consumption required by periodic testing. This includes the fuel required for operation of the engine at the minimum loads specified by the engine manufacturer. ENO accounts for fuel consumption during monthly SR testing by maintaining the fuel oil storage tank at a level that provides sufficient fuel oil inventory to support both periodic testing and the required 7-day fuel oil supply. For periodic 24-hour SR testing, the fuel oil storage tank is replenished as required prior to testing to ensure that the required 7-day fuel oil supply is maintained throughout the test.

One variable used in both stored diesel fuel oil calculation methods is the fuel consumption rate. The property of diesel fuel oil having the most significant effect on the fuel consumption rate is the energy content (heating value) of the fuel. There are standards which correlate the energy content to the fuel's American Petroleum Institute

(API) gravity or absolute specific gravity. At a minimum, ENO calculates required fuel storage values assuming the most limiting absolute specific gravity, and therefore, the most limiting fuel energy content. As long as the fuel oil placed in the storage tank is within the assumed absolute specific gravity range, the calculations of fuel consumption and required stored volume remain valid. Current SR 3.8.3.3 requires new fuel to be tested in order to verify that the new fuel API gravity or absolute specific gravity is within the range assumed in the stored diesel fuel oil calculation.

The lube oil inventory equivalent to a 7-day supply, as well as the 6-day supply associated with Condition B, is based on the emergency diesel generator manufacturer consumption values for the run time of the diesel generator.

The above methods still provide assurance that the necessary quality of systems and components is maintained, that PNP operation will be within safety limits, and that the LCOs will be met.

4.4 Deletion of Reference to Appendix B of ANSI N195-1976

The proposed change deletes the reference to Appendix B of ANSI N195-1976 in the TS Bases for TS 3.8.3. As a result, there will only be a reference to ANSI N195-1976. LCO 3.8.3 requires, in part, that the stored diesel fuel oil and lube oil shall be within limits for the emergency diesel generators. The basis for these limits is derived from RG 1.137, Revision 1, and Appendix B of ANSI N195-1976.

For proper operation of the emergency diesel generators, it is necessary to ensure the proper quality of the fuel oil. RG 1.137, Revision 1, addresses the recommended fuel oil practices as supplemented by ANSI N195-1976, Appendix B. The fuel oil properties that are checked to ensure the proper quality of the fuel oil are sediment content, the kinematic viscosity, specific gravity (or API gravity), and impurity level.

Although the reference to Appendix B of ANSI N195-1976 will be deleted, RG 1.137, Revision 1, which is currently referenced in the TS Bases, states, "Appendix B to ANSI N195-1976 addresses the recommended fuel oil practices. Although not a mandatory part of the standard, Appendix B can serve as an acceptable basis for a program to maintain the quality of fuel oil, as supplemented by regulatory position 2 of this guide." Regulatory Position 2 of RG 1.137 states, in part, "Appendix B to ANSI N195-1976 should be used as a basis for a program to ensure the initial and continuing quality of fuel oil." As a result, the use of Appendix B of ANSI N195-1976 is still referenced, although now indirectly, and therefore still provides a basis for ensuring the proper quality of the fuel oil; namely that water and sediment content, the kinematic viscosity, specific gravity (or API gravity), and impurity level are within the specified limits. Current SR 3.8.3.3 verifies these limits.

The change still provides assurance that the lowest functional capability or performance levels of equipment required for safe operation of the facility will be continued to be met.

Fuel Oil Transfer Pump Change

4.5 Modification to Action Table TS 3.8.3 "Diesel Fuel, Lube Oil, and Starting Air"

The Bases for TS LCO 3.8.1 currently describes an emergency diesel generator fuel oil consumption rate of about 2.6 gallons of fuel oil per minute at 2400 kW. The Bases also state that each emergency diesel generator day tank contains at least 2500 gallons and that each fuel oil day tank contains sufficient fuel for more than 15 hours of full load emergency diesel generator operation. Beyond that time, a fuel transfer pump is required to transfer additional fuel oil from the fuel oil storage tank to the emergency diesel generator day tank to support continued operation of the emergency diesel generator. This 15-hour duration is the basis for the Completion Time for TS 3.8.3 Condition C. The Completion Time for Condition C requires that the inoperable P-18A fuel transfer system be returned to operable status within 15 hours.

The ENO fuel oil storage inventory calculation that determined the fuel oil storage inventory required to operate one emergency diesel generator for 7 days computed fuel oil consumption rates that were greater than the consumption rates described in the Bases for TS LCO 3.8.1.

At the fuel oil consumption rate determined in the calculation, the 2500 gallons of fuel oil in each fuel oil day tank contains sufficient fuel for only about 13.5 hours of emergency diesel generator operation under accident loading conditions (Attachment 6). This calculated fuel day tank duration is less than the 15-hour duration described in TS B 3.8.1 and the 15-hour Completion Time for TS LCO 3.8.3 Condition C.

Reducing the TS LCO 3.8.3 Condition C Completion Time to 12 hours would conservatively bound the 13.5-hour duration that a day tank inventory will support emergency diesel generator operation under accident loading conditions.

ENO implemented administrative controls as a compensatory measure to limit the Completion Time for TS 3.8.3 Condition C to 12 hours. This administrative control bounds the 13.5-hour duration that the day tank inventory will support emergency diesel generator operation under accident loading conditions. The controls would be in place until the Completion Time for TS 3.8.3 Condition C is revised in a license amendment.

This compensatory measure is in accordance with NRC Administrative Letter 98-010, "Dispositioning of Technical Specifications that are Insufficient to Assure Plant Safety." This administrative letter provides guidance for Technical Specifications that are determined to be non-conservative. Imposing administrative controls as a compensatory measure is an acceptable short-term solution under this letter. Following implementation of the administrative controls, a Technical Specification amendment is to be submitted to resolve the condition.

5.0 REGULATORY SAFETY ANALYSIS

5.1 No Significant Hazards Consideration

Entergy (ENO) has evaluated the proposed changes to the Technical Specifications (TS) using the criteria in 10 CFR 50.92 and has determined that the proposed changes do not involve a significant hazards consideration.

The proposed changes would revise the TS by relocating the current stored diesel fuel oil and lube oil numerical volume requirements from the TS to the TS Bases so that they may be modified under licensee control. The TS would be modified so that the stored diesel fuel oil and lube oil inventory would require that a 7-day supply be available for either emergency diesel generator.

The proposed changes would also revise TS by requiring an inoperable P-18A fuel transfer system to be returned to operable status within 12 hours rather than 15 hours.

As required by 10 CFR 50.92(c), an analysis of the issue of no significant hazards consideration is presented below:

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No.

The proposed change relocates the volume of diesel fuel oil and lube oil required to support 7-day operation of the onsite emergency diesel generators, and the volume equivalent to a 6-day supply, to licensee control. The specific volume of fuel oil equivalent to a 7-day and 6-day supply is calculated using the NRC approved methodology described in Regulatory Guide 1.137, Revision 1, “Fuel Oil Systems for Standby Emergency diesel generators” and ANSI N195-1976, "Fuel Oil Systems for Standby Diesel Generators." The specific volume of lube oil equivalent to a 7-day and 6-day supply is based on the emergency diesel generator manufacturer's consumption values for the run time of the diesel generator. Because the requirement to maintain a 7-day supply of diesel fuel oil and lube oil is not changed and is consistent with the assumptions in the accident analyses, and the actions taken when the volume of fuel oil and lube oil are less than a 6-day supply have not changed, neither the probability or the consequences of any accident previously evaluated will be affected.

The proposed change also reduces the Completion Time for TS 3.8.3 Condition C for an inoperable P-18A fuel transfer system from 15 hours to 12 hours. Reducing the Completion Time to 12 hours bounds the 13.5-hour time duration that the emergency diesel generator day tank will support emergency diesel generator operation under accident loading conditions. The change in Completion Time does not affect required TS actions if the Completion Time is exceeded. The Completion Time change does not affect the probability or consequences of an accident previously evaluated.

Therefore, the proposed changes do not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No.

The proposed fuel oil and lube oil changes do not involve a physical alteration of the plant (i.e., no new or different type of equipment will be installed) or a change in the methods governing normal plant operation. The change does not alter assumptions made in the safety analysis but ensures that the emergency diesel generator operates as assumed in the accident analysis. The proposed change is consistent with the safety analysis assumptions.

The proposed change also reduces the Completion Time for TS 3.8.3 Condition C for an inoperable P-18A fuel transfer system from 15 hours to 12 hours. This change does not involve a physical alteration of the plant (i.e., no new or different type of equipment will be installed). This change does not create a condition in which a new or different kind of accident can occur. It does not alter assumptions made in the safety analysis.

Therefore, the proposed changes do not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

Response: No.

The proposed change relocates the volume of fuel oil and lube oil required to support 7-day operation of either emergency diesel generator, and the volume equivalent to a 6-day supply, to licensee control. As the bases for the existing limits on diesel fuel oil and lube oil are not changed, no change is made to the accident analysis assumptions and no margin of safety is reduced as part of this change.

The proposed change also reduces the Completion Time for TS 3.8.3 Condition C for an inoperable P-18A fuel transfer system from 15 hours to 12 hours. There are no adverse affects on margins of safety since a more stringent operability requirement will be applied to the P-18A fuel transfer system. Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Therefore, the proposed changes do not involve a significant reduction in a margin of safety.

Based on the above, the ENO concludes that the proposed changes present no significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

5.2 Applicable Regulatory Requirements/Criteria

General Design Criterion (GDC) 17, "Electric Power Systems," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the Code of Federal Regulations (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that an onsite electric power system and an offsite electric power system be provided to permit functioning of structures, systems, and components important to safety. In addition, GDC 17 contains requirements concerning system capacity, capability, independence, redundancy, availability, testability, and reliability.

Regulatory Guide 1.137, Revision 1, "Fuel Oil Systems for Standby Diesel Generators" dated October 1979, describes a method acceptable to the NRC staff for complying with the Commission's regulations regarding diesel fuel oil systems for standby diesel generators and assurance of adequate diesel fuel oil quality. Regulatory Guide 1.137 states that Appendix B to ANSI N195-1976 should be used as a basis for a program to ensure the initial and continuing quality of diesel fuel oil as supplemented by eight additional provisions described in the Regulatory Guide for maintaining the properties and quality of diesel fuel oil.

ANSI N195-1976, "Fuel Oil Systems for Standby Diesel Generators," requires that onsite fuel oil storage shall be sufficient to operate the minimum number of diesel generators following the limiting design basis accident for either 7 days, or the time required to replenish the oil from sources outside the plant site following any limiting design basis event without interrupting the operation of the diesel, whichever is longer. The ANSI standard also provides guidance for calculating storage requirements.

The proposed change does not affect the design of the onsite electric power system, the quality of the onsite electric power system, or the method of determining the necessary quantity of onsite diesel fuel oil or lube oil.

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the approval of the proposed change will not be inimical to the common defense and security or to the health and safety of the public.

6.0 ENVIRONMENTAL CONSIDERATION

The proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

ATTACHMENT 2

RENEWED OPERATING LICENSE PAGE CHANGE INSTRUCTIONS

AND

REVISED TECHNICAL SPECIFICATION PAGES

3.8.3-1

and

3.8.3-3

3 pages follow

ATTACHMENT TO LICENSE AMENDMENT NO.

RENEWED FACILITY OPERATING LICENSE NO. DPR-20

DOCKET NO. 50-255

Remove the following pages of Appendix A Technical Specifications and replace with the attached revised pages. The revised pages are identified by amendment number and contain lines in the margin indicating the areas of change.

REMOVE	INSERT
Page 3.8.3-1	Page 3.8.3-1
Page 3.8.3-3	Page 3.8.3-3

3.8 ELECTRICAL POWER SYSTEMS

3.8.3 Diesel Fuel, Lube Oil, and Starting Air

LCO 3.8.3 For each Diesel Generator (DG):

a. The stored diesel fuel oil, lube oil, and starting air subsystem shall be within limits, and

b. Both diesel fuel oil transfer systems shall be OPERABLE.

APPLICABILITY: When associated DG is required to be OPERABLE.

ACTIONS

---NOTE---
Separate Condition entry is allowed for each DG.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Fuel oil inventory less than a 7 day supply and greater than a 6 day supply.	A.1 Restore fuel oil inventory to within limits.	48 hours
B. Stored lube oil inventory less than a 7 day supply and greater than a 6 day supply.	B.1 Restore stored lube oil inventory to within limits.	48 hours
C. Fuel transfer system (P-18A) inoperable.	C.1 Restore fuel transfer system to OPERABLE status.	12 hours
D. Fuel transfer system (P-18B) inoperable.	D.1 Restore fuel transfer system to OPERABLE status.	7 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.8.3.1	Verify the fuel oil storage subsystem contains ≥ a 7 day supply of fuel.	24 hours
SR 3.8.3.2	Verify stored lube oil inventory is ≥ a 7 day supply.	31 days
SR 3.8.3.3	Verify fuel oil properties of new and stored fuel oil are tested in accordance with, and maintained within the limits of, the Fuel Oil Testing Program.	In accordance with the Fuel Oil Testing Program
SR 3.8.3.4	Verify each DG air start receiver pressure is ≥ 200 psig.	31 days
SR 3.8.3.5	Check for and remove excess accumulated water from the fuel oil storage tank.	92 days
SR 3.8.3.6	Verify the fuel oil transfer system operates to transfer fuel oil from the fuel oil storage tank to each DG day tank and engine mounted tank.	92 days

ATTACHMENT 3

MARK-UP OF TECHNICAL SPECIFICATION PAGES

(showing proposed changes; additions are highlighted and deletions are strikethrough)

2 pages follow

3.8 ELECTRICAL POWER SYSTEMS

3.8.3 Diesel Fuel, Lube Oil, and Starting Air

LCO 3.8.3 For each Diesel Generator (DG):

a. The stored diesel fuel oil, lube oil, and starting air subsystem shall be within limits, and

b. Both diesel fuel oil transfer systems shall be OPERABLE.

APPLICABILITY: When associated DG is required to be OPERABLE.

ACTIONS

---NOTE---

Separate Condition entry is allowed for each DG.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Fuel oil inventory ~~≤ 23,700 gallons and >20,110 gallons~~ less than a 7 day supply and greater than a 6 day supply ~~in storage tank~~.	A.1 Restore fuel oil inventory to within limits.	48 hours
B. Stored lube oil inventory ~~≤ 200 gallons and ≥ 160 gallons~~ less than a 7 day supply and greater than a 6 day supply.	B.1 Restore stored lube oil inventory to within limits.	48 hours
C. Fuel transfer system (P-18A) inoperable.	C.1 Restore fuel transfer system to OPERABLE status.	~~15~~ 12 hours
D. Fuel transfer system (P-18B) inoperable.	D.1 Restore fuel transfer system to OPERABLE status.	7 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.8.3.1	Verify the fuel oil storage ~~tank~~ subsystem contains ≥ ~~23,700 gallons~~ a 7 day supply of fuel.	24 hours
SR 3.8.3.2	Verify stored lube oil inventory is ≥ ~~200 gallons~~ a 7 day supply.	31 days
SR 3.8.3.3	Verify fuel oil properties of new and stored fuel oil are tested in accordance with, and maintained within the limits of, the Fuel Oil Testing Program.	In accordance with the Fuel Oil Testing Program
SR 3.8.3.4	Verify each DG air start receiver pressure is ≥ 200 psig.	31 days
SR 3.8.3.5	Check for and remove excess accumulated water from the fuel oil storage tank.	92 days
SR 3.8.3.6	Verify the fuel oil transfer system operates to transfer fuel oil from the fuel oil storage tank to each DG day tank and engine mounted tank.	92 days

ATTACHMENT 4

MARK-UP OF TECHNICAL SPECIFICATION BASES PAGES

B 3.8.1-2,

B 3.8.1-3,

B 3.8.1-16,

B 3.8.1-24,

and

B 3.8.3-1

through

B 3.8.3-7

11 pages follow

BACKGROUND (continued)

The three startup transformers are connected to a common 345 kV overhead line from the switchyard R bus. Startup transformers 1-1 and 1-3 supply 4160 V non-safety related station loads; Startup Transformer 1-2 can supply both safety related and non-safety related 2400 V loads. The startup transformers are available during operation and shutdown.

Safeguards Transformer 1-1 is connected to the switchyard F bus. It feeds station 2400 V loads through an underground line. It is available to supply these loads during operation and shutdown.

The onsite distribution system consists of seven main distribution buses (4160 V buses 1A, 1B, 1F, and 1G, and 2400 V buses 1C, 1D, and 1E) and supported lower voltage buses, Motor Control Centers (MCCs), and lighting panels. The 4160 V buses and 2400 V bus 1E are not safety related. Buses 1C and 1D and their supported buses and MCCs form two independent, redundant, safety related distribution trains. Each distribution train supplies one train of engineered safety features equipment.

In the event of a generator trip, all loads supplied by the station power transformers are automatically transferred to the startup transformers. Loads supplied by the safeguards transformer are unaffected by a plant trip. If power is lost to the safeguards transformer, the 2400 V loads will automatically transfer to startup transformer 1-2. If the startup transformers are not energized when these transfers occur, their output breakers will be blocked from closing and the 2400 V safety related buses will be energized by the DGs.

The two DGs each supply one 2400 V bus. They provide backup power in the event of loss of off-site power, or loss of power to the associated 2400 V bus. The continuous rating of the DGs is 2500 kW, with 110 percent overload permissible for 2 hours. The required fuel in the Fuel Oil Storage Tank and DG Day Tank will supply one DG for a minimum period of 7 days assuming accident loading conditions ~~and fuel conservation practices~~.

If either 2400 V bus, 1C or 1D, experiences a sustained undervoltage, the associated DG is started, the affected bus is separated from its offsite power sources, major loads are stripped from that bus and its supported buses, the DGs are connected to the bus, and ECCS or shutdown loads are started by an automatic load sequencer.

BACKGROUND (continued)

The DGs share a common fuel oil storage and transfer system. A single buried Fuel Oil Storage Tank is used, along with an individual day tank for each DG, to maintain the required fuel oil inventory. Two fuel transfer pumps are provided. The fuel transfer pumps are necessary for long-term operation of the DGs. Testing and analysis have shown that each DG consumes about ~~2.6 gallons of fuel oil per minute at 2400 kW.~~ 200 gallons of fuel oil per hour at 2750 kW and about 180 gallons of fuel oil per hour at 2500 kW. Each day tank is required to contain at least 2500 gallons~~. Therefore, each fuel oil day tank~~ and contains sufficient fuel for ~~more than~~ about 13.5 ~~15~~ hours of full load ~~(2500 kW)~~ operation (Ref. 8). Beyond that time, a fuel transfer pump is required for continued DG operation.

Either fuel transfer pump is capable of supplying either DG. However, each fuel transfer pump is not capable, with normally available switching, of being powered from either DG. DG 1-1 can power either fuel transfer pump, but DG 1-2 can only power P-18A. The fuel oil pumps share a common fuel oil storage tank, and common piping.

Fuel transfer pump P-18A is powered from MCC-8, which is normally connected to Bus 1D (DG 1-2) through Station Power Transformer 12 and Load Center 12. In an emergency, P-18A can be powered from Bus 1C (DG 1-1) by cross-connecting Load Centers 11 and 12.

Fuel transfer pump P-18B is powered from MCC-1, which is normally connected to Bus 1C (DG 1-1) through Station Power Transformer 19 and Load Center 19. P-18B cannot be powered, using installed equipment, from Bus 1D (DG 1-2).

APPLICABLE SAFETY ANALYSES

The safety analyses do not explicitly address AC electrical power. They do, however, assume that the Engineered Safety Features (ESF) are available. The OPERABILITY of the ESF functions is supported by the AC Power Sources.

The design requirements are for each assumed safety function to be available under the following conditions:

a. The occurrence of an accident or transient,

b. The resultant consequential failures,

c. A worst-case single active failure,

d. Loss of all offsite or all onsite AC power, and

e. The most reactive control rod fails to insert.

SURVEILLANCE REQUIREMENTS (continued)

SR 3.8.1.3

This Surveillance verifies that the DGs are capable of synchronizing with the offsite electrical system and accepting loads greater than or equal to the equivalent of the maximum expected accident loads for at least 15 minutes. A minimum total run time of 60 minutes is required to stabilize engine temperatures.

During the period when the DG is paralleled to the grid, it must be considered inoperable. This is because there are no provisions to automatically shift the DG controls from parallel mode to unit mode. Additionally, when paralleled, there are certain conditions where the protection schemes may not prevent DG overloading and subsequent breaker trip and lockout.

The 31-day Frequency for this Surveillance is consistent with the original Palisades licensing basis.

The SR is modified by three Notes. Note 1 states that momentary transients outside the required band do not invalidate this test. This is to assure that a minor change in grid conditions and the resultant change in DG load, or a similar event, does not result in a surveillance being unnecessarily repeated. Note 2 indicates that this Surveillance should be conducted on only one DG at a time in order to avoid common cause failures that might result from offsite circuit or grid perturbations. Note 3 stipulates a prerequisite requirement for performance of this SR. A successful DG start must precede this test to credit satisfactory performance.

SR 3.8.1.4

This SR provides verification that the level of fuel oil in the day tank is at or above the level at which fuel oil is automatically added. The specified level is adequate for a minimum of ~~15~~ 13.5 hours of DG operation at full load.

The 31-day Frequency is adequate to assure that a sufficient supply of fuel oil is available, since low-level alarms are provided and plant operators would be aware of any uses of the DG during this period.

REFERENCES

1. 10 CFR 50, Appendix A, GDC 17
2. Regulatory Guide 1.93, December 1974
3. Generic Letter 84-15, July 2, 1984
4. 10 CFR 50, Appendix A, GDC 18
5. Regulatory Guide 1.9, Rev. 3, July 1993
6. Regulatory Guide 1.137, Rev. 1, October 1979
7. Palisades Logic Drawing E-17, Sheet 4
8. Engineering Change 12118

3.8 ELECTRICAL POWER SYSTEMS

B 3.8.3 Diesel Fuel, Lube Oil, and Starting Air

BASES

BACKGROUND

The Diesel Generators (DGs) are provided with a storage ~~tank~~ subsystem having a required fuel oil inventory sufficient to operate one diesel for a period of 7 days, while the DG is supplying maximum post-accident loads. The fuel oil storage subsystem is comprised of the Fuel Oil Storage Tank and a fuel oil day tank. This onsite fuel oil capacity is sufficient to operate the DG for longer than the time to replenish the onsite supply from offsite sources.

Fuel oil is transferred from the Fuel Oil Storage Tank to either day tank by either of two Fuel Transfer Systems. The fuel oil transfer system which includes fuel transfer pump P-18A can be powered by offsite power, or by either DG. However, the fuel oil transfer system which includes fuel transfer pump P-18B can only be powered by offsite power, or by DG 1-1.

For proper operation of the standby DGs, it is necessary to ensure the proper quality of the fuel oil. Regulatory Guide (RG) 1.137 (Ref. 1) addresses the recommended fuel oil practices as supplemented by ANSI N195-1976 (Ref. 2).

The DG lubrication system is designed to provide sufficient lubrication to permit proper operation of its associated DG under all loading conditions. The system is required to circulate the lube oil to the diesel engine working surfaces and to remove excess heat generated by friction during operation. The onsite storage ~~in addition to the engine oil sump~~ is sufficient to ensure 7 days of continuous operation. This supply is sufficient supply to allow the operator to replenish lube oil from offsite sources. Implicit in this LCO is the requirement to assure, though not necessarily by testing, the capability to transfer the lube oil from its storage location to the DG oil sump, while the DG is running.

Each DG is provided with an associated starting air subsystem to assure independent start capability. The starting air system is required to have a minimum capacity with margin for a DG start attempt without recharging the air start receivers.

APPLICABLE SAFETY ANALYSES

A description of the Safety Analyses applicable in MODES 1, 2, 3, and 4 is provided in the Bases for LCO 3.8.1, "AC Sources - Operating"; during MODES 5 and 6, in the Bases for LCO 3.8.2, "AC Sources - Shutdown." Since diesel fuel, lube oil, and starting air subsystems support the operation of the standby AC power sources, they satisfy Criterion 3 of 10 CFR 50.36(c)(2).

LCO

Stored diesel fuel oil is required to have sufficient supply for 7 days of full accident load operation. It is also required to meet specific standards for quality. ~~The specified 7 day requirement and the 6 day quantity listed in Condition A are taken from the Engineering Analysis associated with Event Report E-PAL-93-026B.~~ Additionally, the ability to transfer fuel oil from the storage tank to each day tank is required from each of the two transfer pumps.

Additionally, sufficient lube oil supply must be available to ensure the capability to operate at full accident load for 7 days. This requirement is in addition to the lube oil contained in the engine sump. ~~The specified 7 day requirement and the 6 day quantity listed in Condition B are based on an assumed lube oil consumption of 0.8 to 1.0% of fuel oil consumption.~~

The starting air subsystem must provide, without the aid of the refill compressor, sufficient air start capacity, including margin, to assure start capability for its associated DG.

These requirements, in conjunction with an ability to obtain replacement supplies within 7 days, support the availability of the DGs. DG day tank fuel requirements are addressed in LCOs 3.8.1 and 3.8.2.

APPLICABILITY

DG OPERABILITY is required by LCOs 3.8.1 and 3.8.2 to ensure the availability of the required AC power to shut down the reactor and maintain it in a safe shutdown condition following a loss of off-site power. Since diesel fuel, lube oil, and starting air support LCOs 3.8.1 and 3.8.2, stored diesel fuel oil, lube oil, and starting air are required to be within limits, and the fuel transfer system is required to be OPERABLE, when either DG is required to be OPERABLE.

ACTIONS

A.1

In this Condition, the available DG fuel oil supply is less than the required 7 day supply, but enough for at least 6 days. The fuel oil inventory equivalent to a 6 day supply is 28,592 gallons (Ref. 5). This inventory is conservatively based on an uprated 2600 kW DG capacity. This condition allows sufficient time to obtain additional fuel and to perform the sampling and analyses required prior to addition of fuel oil to the tank. A period of 48 hours is considered sufficient to complete restoration of the required inventory prior to declaring the DGs inoperable.

B.1

In this Condition, the available DG lube oil supply in storage is less than the required 7 day supply, but enough for at least 6 days. The lube oil inventory equivalent to a 6 day supply is 268 gallons (Ref. 5). This inventory is conservatively based on an uprated 2600 kW DG capacity. This condition allows sufficient time to obtain additional lube oil. A period of 48 hours is considered sufficient to complete restoration of the required inventory prior to declaring the DGs inoperable.

C.1, D.1, and E.1

Since DG 1-2 cannot power fuel transfer pump P-18B, without P-18A, DG 1-2 becomes dependant on offsite power or DG 1-1 for its fuel supply (beyond the approximately 13.5 ~~15~~ hours it will operate on the day tank), and does not meet the requirement for independence. Since the condition is not as severe as the DG itself being inoperable, ~~15~~ 12 hours is allowed to restore the fuel transfer system to operable status prior to declaring the DG inoperable.

Without P-18B, either DG can still provide power to the remaining fuel transfer system. Therefore, neither DG is directly affected. Continued operation with a single remaining fuel transfer system, however, must be limited since an additional single active failure (P-18A) could disable the onsite power system. Because the loss of P-18B is less severe than the loss of one DG, a 7 day Completion Time is allowed.

If both fuel transfer systems are inoperable, the onsite AC sources are limited to about 13.5 ~~15~~ hours duration. Since this condition is not as severe as both DGs being inoperable, 8 hours is allowed to restore one fuel transfer pump to OPERABLE status.

ACTIONS (continued)

F.1

With the stored fuel oil properties, other than viscosity, and water and sediment, defined in the Fuel Oil Testing Program not within the required limits, but acceptable for short term DG operation, a period of 30 days is allowed for restoring the stored fuel oil properties. The most likely cause of stored fuel oil becoming out of limits is the addition of new fuel oil with properties that do not meet all of the limits. This 30 day period provides sufficient time to determine if new fuel oil, when mixed with stored fuel oil, will produce an acceptable mixture, or if other methods to restore the stored fuel oil properties are required. This restoration may involve feed and bleed procedures, filtering, or combinations of these procedures. Even if a DG start and load was required during this time interval and the fuel oil properties were outside limits, there is a high likelihood that the DG would still be capable of performing its intended function.

G.1

With a Required Action and associated Completion Time not met, or with diesel fuel oil, lube oil, or starting air subsystem not within limits for reasons other than addressed by Conditions A, B, or F, the associated DG may be incapable of performing its intended function and must be immediately declared inoperable.

In the event that diesel fuel oil with viscosity, or water and sediment is out of limits, this would be unacceptable for even short term DG operation. Viscosity is important primarily because of its effect on the handling of the fuel by the pump and injector system; water and sediment provides an indication of fuel contamination. When the fuel oil stored in the Fuel Oil Storage Tank is determined to be out of viscosity, or water and sediment limits, the DGs must be declared inoperable, immediately.

SURVEILLANCE REQUIREMENTS

SR 3.8.3.1

This SR provides verification that there is an adequate inventory of fuel oil in the storage ~~tank~~ subsystem to support either DG's operation for 7 days at full post-accident load. The fuel oil inventory equivalent to a 7 day supply is 33,054 gallons (Ref. 5) when calculated in accordance with References 1 and 2. This inventory is conservatively based on an uprated 2600 kW DG capacity. The required fuel storage volume is determined using the most limiting energy content of the stored fuel. Using the known correlation of diesel fuel oil absolute specific gravity or API gravity to energy content, the required diesel generator output, and the corresponding fuel consumption rate, the onsite fuel storage volume required for 7 days of operation can be determined. SR 3.8.3.3 requires new fuel to be tested to verify that the absolute specific gravity or API gravity is not less than the value assumed in the diesel fuel oil consumption calculations. The 7 day period is sufficient time to place the plant in a safe shutdown condition and to bring in replenishment fuel from an offsite location.

The 24 hour Frequency is specified to ensure that a sufficient supply of fuel oil is available, since the Fuel Oil Storage Tank is the fuel oil supply for the diesel fire pumps, heating and evaporator boilers, in addition to the DGs.

SR 3.8.3.2

This Surveillance ensures that sufficient stored lube oil inventory is available to support at least 7 days of full accident load operation for one DG. ~~The 200 gallons requirement~~ The lube oil inventory equivalent to a 7 day supply is 313 gallons and is based on an estimated consumption of ~~0.8 to~~ 1.0% of fuel oil consumption (Ref. 5). This inventory is also conservatively based on an uprated 2600 kW DG capacity.

A 31 day Frequency is adequate to ensure that a sufficient lube oil supply is onsite, since DG starts and run times are closely monitored by the plant staff.

SR 3.8.3.3

The tests listed below are a means of determining whether new fuel oil and stored fuel oil are of the appropriate grade and have not been contaminated with substances that would have an immediate, detrimental impact on diesel engine combustion.

Testing for viscosity, specific gravity, and water and sediment is completed for fuel oil delivered to the plant prior to its being added to the Fuel Oil Storage Tank. Fuel oil which fails the test, but has not been

SURVEILLANCE REQUIREMENTS

SR 3.8.3.3 (continued)

added to the Fuel Oil Storage Tank does not imply failure of this SR and requires no specific action. If results from these tests are within acceptable limits, the fuel oil may be added to the storage tank without concern for contaminating the entire volume of fuel oil in the storage tank.

Fuel oil is tested for other of the parameters specified in ASTM D975 (Ref. 3) in accordance with the Fuel Oil Testing Program required by Specification 5.5.11. Fuel oil determined to have one or more measured parameters, other than viscosity or water and sediment, outside acceptable limits will be evaluated for its effect on DG operation. Fuel oil which is determined to be acceptable for short term DG operation, but outside limits will be restored to within limits in accordance with LCO 3.8.3 Condition F.

SR 3.8.3.4

This Surveillance ensures that, without the aid of the refill compressor, sufficient air start capacity for each DG is available. The pressure specified in this SR is intended to reflect the acceptable margin from which successful starts can be accomplished.

The 31 day Frequency 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.

SR 3.8.3.5

Microbiological fouling is a major cause of fuel oil degradation. There are numerous bacteria that can grow in fuel oil and cause fouling, but all must have a water environment in order to survive. Removal of water from the Fuel Oil Storage Tank once every 92 days eliminates the necessary environment for bacterial survival. This is the most effective means of controlling microbiological fouling. In addition, it reduces the potential for water entrainment in the fuel oil during DG operation. Water may come from any of several sources, including condensation, ground water, rain water, contaminated fuel oil, and from breakdown of the fuel oil by bacteria. Frequent checking for and removal of accumulated water minimizes fouling and provides data regarding the watertight integrity of the fuel oil system. The Surveillance Frequencies and acceptance criteria are established in the Fuel Oil Testing Program based, in part, on those recommended by RG 1.137 (Ref. 1). This SR is for preventative maintenance.

SURVEILLANCE REQUIREMENTS

SR 3.8.3.5 (continued)

The presence of water does not necessarily represent failure of this SR provided the accumulated water is removed in accordance with the requirements of the Fuel Oil Testing Program.

SR 3.8.3.6

This SR demonstrates that each fuel transfer pump and the fuel transfer system controls operate and control transfer of fuel from the Fuel Oil Storage Tank to each day tank and engine mounted tank. This is required to support continuous operation of standby power sources.

This SR provides assurance that the following portions of the fuel transfer system is OPERABLE:

a. Fuel Transfer Pumps;

b. Day and engine mounted tank filling solenoid valves; and

c. Day and engine mounted tank automatic level controls.

The 92 day Frequency corresponds to the testing requirements for pumps in the ASME Code, Section XI (Ref. 4). Additional assurance of fuel transfer system OPERABILITY is provided during the monthly starting and loading tests for each DG when the fuel oil system will function to maintain level in the day and engine mounted tanks.

REFERENCES

1. Regulatory Guide 1.137

2. ANSI N195-1976~~, Appendix B~~

3. ASTM Standards, D975, Table 1

4. ASME, Boiler and Pressure Vessel Code, Section XI

5. Engineering Analysis EA-EC6432-01

ATTACHMENT 5

FUEL OIL AND LUBE OIL INVENTORY CALCULATION

Calculation No. EA-EC6432-01, Revision 1

Calculation Title: Palisades Emergency Diesel Generator
Diesel Fuel Oil Storage Requirements

54 pages follow

☐ ANO-1	☐ ANO-2	☐ GGNS	☐ IP-2	☐ IP-3	☒ PLP
☐ JAF	☐ PNPS	☐ RBS	☐ VY	☐ W3	
☐ NP-GGNS-3	☐ NP-RBS-3				

CALCULATION COVER PAGE	(1) EC # 6432	(2) Page 1 of 27
(3) Design Basis Calc. ☒ YES ☐ NO	(4) ☒ CALCULATION	☐ EC Markup
(5) **Calculation No: EA-EC6432-01**		(6) **Revision: 1**
(7) **Title: Palisades Emergency Diesel Generator Diesel Fuel Oil Storage Requirements**		(8) **Editorial** ☐ YES ☒ NO
(9) **System(s): EPS, FOS**	(10) **Review Org (Department): Design Engineering**	
(11) **Safety Class:** ☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	(12) **Component/Equipment/Structure Type/Number:**	
	Emergency Diesel Generator 1-1/K6A	**Fuel Oil Storage Tank/T-10A**
	Emergency Diesel Generator 1-2/K6B	**Level Transmitter/ LT-1400**
	Level Indicating Alarm/LIA-1400	**Level Switch/ LS-1400**
(13) **Document Type: CALC**		
(14) **Keywords (Description/Topical Codes):**	**EDG**	**Diesel Fuel Oil**
	Fuel Oil Storage Requirements	**Lube Oil**

REVIEWS

(15) Name/Signature/Date DJDepuydt/ [signature] 5-24-2010 **Responsible Engineer**	(16) Name/Signature/Date T Groth/ [signature] 5-24-10 ☒ **Design Verifier** ☐ **Reviewer** ☒ Comments Attached	(17) Name/Signature/Date PDMacMaster/ [signature] 5/24/2010 **Supervisor/Approval** ☐ Comments Attached

Revision	Record of Revision
0	Initial issue.
1	Revised to include 6 day run time fuel oil storage volume and added calculation of lube oil storage volume. Affected pages - 5,6,7,8,10,18,19,23,24,26 & 27

CALCULATION REFERENCE SHEET	CALCULATION NO: EA-EC6432-01 REVISION: 1

I. EC Markups Incorporated

1. None

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. EA-A-NL-92-337-01		2	☒	☐	Y	EC6432
2. EA-FC-958-04		2	☒	☐	Y	EC6432
3. EA-FC-958-05		3	☒	☐	N	
4. Dwg C228	2	0	☒	☐	N	
5. Dwg C228	3	1	☒	☐	N	
6 Procedure MO-7A-1		67	☒	☐	Y	EC6432
7. Procedure MO-7A-2		64	☒	☐	Y	EC6432
8. Procedure COP-22A		9	☒	☐	Y	EC6432
9. Procedure SOP-22		44	☐	☒	Y	EC6432

III. CROSS REFERENCES:

1. ANSI N195-1976 (ANS 59.51), "Fuel Oils Systems for Standby Diesel Generators"
2. ALCO Locomotive Vendor Manual M12 Sh. 44 "Test Reports" Dated, 8-13-1969
3. ANSI/ANS- 59.51-1997 "Fuel Oil Systems for Safety Related Emergency"
4. CRANE Technical Paper 410 "Flow of Fluids Through Valves, Fittings, and Pipe
5. Palisades Functional Equivalent Substitution FES-98-069
6. Level Transmitter LT-1400 Instrument Calibration Sheet, Rev. 12
7. Level Indicating Alarm LIA-1400 Instrument Calibration Sheet, Rev. 11
8. Palisades Drawing VEN-M0071A , "12' x 60' STI-P3 Double Wall Underground Storage Tank, Shts 1 thru 5, Rev 0
9. Water Power Article entitled "Vortices at Intakes in Conventional Sumps" by Reddy and Pickford, 1972
10. Palisades Specification Change SC-96-051-01, "Replace Pumps P-18A/B with New Pumps"
11. Palisades Engineering Change EC9610, "Evaluate Operation of the Site Diesel Fuel Burning Equipment with Diesel Fuel with Sulfur Content Less than 15 ppm (Ultra Low Sulfur Diesel Fuel)"
12. Entergy Engineering Guide EN-ME-G-001, "Evaluation of Pump Protection from Low submergence", Rev. 0
13. Vermont Yankee Calculation VYC-1404 "EDG Fuel Oil Usage and Storage Capacity" Rev. 2
14. Palisades Engineering Analysis EA-T-342-01 "Determination of Fuel Consumption Rate for the 1-1 & 1-2 Diesel Generators", Rev. 0
15. ASME B16.5-2003 "Pipe Flanges and Flanged Fittings"
16. Palisades Technical Specifications as revised through Amendment 238
17. Palisades Final Safety Analysis Report, Rev. 26
18. USNRC Regulatory Guide 1.137, "Fuel-Oil Systems for Standby Diesel Generators," Rev. 1

IV. SOFTWARE USED:

Title: Microsoft Excel Version/Release: 2003 Disk/CD No.______

V. DISK/CDS INCLUDED:

Title: N/A Version/Release________ Disk/CD No.______

VI. OTHER CHANGES: N/A

Table of Contents

1.0 PURPOSE

The primary purpose of this calculation is to determine the fuel oil storage requirements to operate one Emergency Diesel Generator (EDG) for seven (7) days assuming accident loading conditions employing current industry practices for determining fuel storage requirements. The secondary purpose of this calculation is to determine the lube oil storage requirements to operate one EDG for (7) days under accident loading conditions.

The following are the calculation objectives:

a. Determine Emergency Diesel Generator fuel oil consumption rates at continuous rated capacity.
b. Determine critical submergence depth to prevent air entrainment vortexing for the diesel fuel oil transfer pumps suction located in Diesel Fuel Oil Storage Tank T-10A
c. Determine amount of unusable fuel in Tank T-10A
d. Determine required diesel fuel oil storage volumes
e. Determine Tank T-10A levels associated with required storage volumes
f. Validate that the available Net Positive Suction Head (NPSHA) for the Diesel Fuel Oil Transfer Pumps, P-18A/18B is adequate
g. Determine required lube oil storage volume

This calculation supersedes calculation EA-A-NL-92-337-01, "Palisades EDG Diesel Fuel Oil Requirements for a DBA", Rev. 2. This calculation supersedes the level setting information in calculation EA-FC-958-04 "Calculation to Size and Provide Instrumentation Levels for the Replacement of the Diesel Fuel Oil Tank T-10 with T-10A", Rev. 2

2.0 CONCLUSION

- EDG diesel fuel consumption rates based on a fuel specific gravity of 0.830 are: @ 2600 KW fuel consumption rate = 185.94 gal/hr; @ 2850 KW fuel consumption rate = 205.56 gal/hr

- The critical submergence depth to prevent air entrainment vortexing for the fuel oil transfer pump suction line is 5" above suction line inlet level.

- The amount of unusable fuel in Tank T-10A due to the elevation of the diesel fuel oil transfer pump suction piping above the bottom of the tank, and the additional submergence depth to prevent vortexing is 1777 gals.

- Required diesel fuel storage volumes are as follows:

  Fuel required to operate 1 EDG for 7 Days (includes unusable volume) = 33054 gals. This is Palisades' License compliance volume.
  Fuel required to operate 1 EDG for 7 Days + amount to account for periodic EDG testing = 35254 gals

- The following gives the Tank T-10A required storage volumes vs. level. The volumes are total required stored volume minus EDG Day Tank stored volume of 2500 gals.

  (This information is extracted from table 6-2)

Item	Required Stored Volume Tank T-10A	Tank T-10A Level Adjusted for Instrument Inaccuracy
Inside top of Tank	N/A	N/A
LIA-1400 High Level Alarm	48227 gal	126.1"
LIA-1400 Low Level Alarm	32754 gal	92.48"
LIA-1400 7 Day EDG run storage	30554 gal	87.48"
Level Indicator Bottom of Range	N/A	N/A
Inside Bottom of Tank	N/A	N/A

- Available Net Positive Suction Head for Diesel Fuel Oil Transfer pumps was validated as adequate.

- The required lube oil storage volume needed to operate 1 EDG for 7 days = 313 gals

3.0 INPUT AND DESIGN CRITERIA

3.1 Palisades FSAR Section 8.4.1.3 states that IEEE 308-1978 requires sufficient fuel be onsite for operation of one diesel for seven days assuming accident loads (Ref. 7.1)

3.2 ANSI N195-1976 paragraph 5.4 will be used as guidance in determining the diesel fuel oil storage requirements (Ref. 7.2). Paragraph 5.4 presents two methods for calculating total fuel storage. The conservative method will be used in this calculation, which assumes that the diesel operates continuously for seven days at its rated capacity. Paragraph 5.4 also states that an explicit allowance for fuel consumption required by periodic testing be included. NRC Regulatory Guide 1.137 (Ref 7.31) accepts ANSI N195-1976 methodology for the calculation of fuel oil storage requirements for standby diesel generators.

3.3 The Palisades Emergency Diesel Generators (EDG) are currently rated at 2500 KW continuous with a two hour overload rating of 2750 KW per Palisades FSAR section 8.4.1.3.

There are plans to increase the EDGs output ratings to 2600 KW continuous and 2850 KW 2 hr overload rating. This calculation will be based on the planned increased ratings (ie, 2600 KW/2850 KW). The calculated fuel consumption values using the increased ratings will be conservative for the current EDG ratings of 2500 KW continuous and 2750 KW 2 hr overload rating.

3.4 The Palisades Diesel Fuel Oil Storage Tank,T-10A, is a horizontal, cylindrical tank with flat ends. Tank inside diameter is 12'-0" (144") with an inside length of 60' (720") per Palisades Vendor Drawing VEN-M0071A Sht. 3 (Ref. 7.3). The 60' tank length shown on Drawing VEN-M0071A Sht. 3 is listed as "nominal". No final as-built tank dimensional information was located, but the available record drawings information indicate the tank length as 60'. Therefore, 60' will be used as the tank length.

3.5 EDG fuel oil consumption rates are obtained from the original vendor test data which provides fuel consumption in lbs/hr at various loads (Ref. 7.4). The fuel consumption rates for EDG # 2 were the highest and will be utilized in this calculation. The data is repeated in the table below.

Kilowatts	Fuel Consumed Lbs/Hr
600	350
1330	671
1908	951
2503	1234
2827	1410

3.6 The EDG Day Tanks, T-25A & T-25B, are maintained with a minimum of 2500 gallons of diesel fuel each per Palisades Technical Specifications 3.8.1 (Ref. 7.21).

3.7 Each EDG is tested monthly per Palisades Technical Specification Surveillance Procedure MO-7A-1 & MO-7A-2 (Refs 7.5 & 7.6) during which the EDGs are operated nominally for 4 hours.

3.8 Required submergence to prevent air entrainment vortexing for the Diesel Fuel Oil Transfer Pumps P-18A and P-18B suction line in T-10A is calculated employing the Reddy/Pickford methodology presented in the *Water Power* article "Vortices at Intake in Conventional Sumps" (Ref. 7.7), included as Attachment 8.6. Reddy/Pickford is one of several available methods presented in Entergy Engineering Guide EN-ME-G-001 (Ref 7.18) for determining required submergence. The Reddy/Pickford method was chosen because it is applicable to the Tank T-10A suction piping configuration and will provide appropriately conservative results. Additionally, the Reddy/Pickford methodology has been applied by other nuclear plants for determining required submergence, including Entergy Vermont Yankee (Ref. 7.22)

3.9 Nominal design flow rate for the Diesel Fuel Oil Transfer Pumps P-18A and P-18B is 20 gpm per Ref. 7.8. The flow rate used in calculating the required submergence to prevent air entrainment is 25 gpm. The 25 gpm value comes from the post modification test results discussed in EA-FC-958-05 Section 5.8 (Ref. 7.9). The flow rate is based on one pump operation.

Pump P-18A is normally aligned and automatically transfers fuel to a day tank. Pump P-18B suction valve is locked closed and P-18B is operated manually only (Ref. 7.23).

3.10 This calculation employs current industry practices for determining required diesel fuel oil storage volume. In addition, this calculation includes large conservatisms such as the EDG operates continuously at rated capacity for 7 days, fuel in the EDG belly tank (also called bedplate tank – approximately 800 gals.) is not taken credit for in determining stored diesel fuel oil volume, and that operators take no action to refill Tank T-10A. This conservatism and inherent margin are mentioned to highlight the precision levels of this fuel oil storage calculation. Items that would have only very minimal impact on results are not considered. Examples of these include: the minor impact of temperature changes in tank T-10A on fuel density, minor impact on level indication/alarm setpoints due to measuring and test equipment (M&TE) accuracy and potential out of roundness of tank, etc. Again, calculation employs current industry practices and produces conservative results.

3.11 Lube oil consumption is a percentage of fuel oil consumption. It is stated on page B3.8.3-2 of Technical Specifications Bases 3.8.3 (Ref. 7.29) that lube oil consumption is 0.8 to 1.0% of fuel oil consumption. The reference for the Technical Specifications Bases lube oil consumption values is not provided in the Bases document. Available EDG vendor documentation (Ref.7.30) provides an upper range lube oil consumption factor of 0.7%. For the purposes of this calculation, a lube oil consumption factor of 1.0% of fuel oil consumption will be used to calculate lube oil consumption.

4.0 ASSUMPTIONS

4.1 The foot valve/strainer combination at the bottom of the suction piping in T-10A for the fuel oil transfer pumps provides no vortex suppression function.

4.2 EDG fuel oil consumption at continuous rated output is not impacted by operation at slightly higher frequency (speed) (61.2 Hz vs. 60 Hz). Specific fuel consumption, lbm/brake horsepower, is a function of power and is fairly constant near rated load.

4.3 The EDG fuel oil consumption rates obtained from the original manufacturer's test data (Ref. 7.4) remain valid for determining EDG fuel consumption. Maintenance of the diesels has not negatively impacted engine efficiency. Engineering Analysis EA-T-343-01 (Ref.7.24) evaluated the results of Special Test T-343 "Fuel Oil Consumption Test" and determined that the original manufacturer tested fuel consumption rates are conservative.

4.4 Determination of Diesel Fuel density is based on a stored fuel temperature of 60 °F. 60 °F is the standard reference temperature used for specifying fuel oil API gravity (Ref. 7.20, Att. 9). A 60 °F temperature is reasonable for underground tanks since ground temperature will remain fairly constant and generally in the 50 °F to 60 °F range at the latitude of Palisades.

4.5 Internal to Diesel Fuel Oil Storage Tank T-10A are piping and fixtures that reduce the total useable volume of the tank. That volume reduction is small (estimated to be less than 50 gallons of the total tank volume of 50,000 gallons) and will not be considered in the calculation of tank storage volume vs. level.

4.6 Diesel Fuel Oil Storage Tank T-10A is assumed to be installed with the tank ends level. There is no information on the Tank installation drawings (Refs. 7.12 & 7.22) that would indicate an out of plumb condition.

5.0 METHOD OF ANALYSIS

This analysis determines the required Diesel fuel oil storage inventory needed to operate one Emergency Diesel Generator for seven (7) days (168 hours) assuming accident loading conditions. The EDG fuel consumption rates are calculated assuming the EDG operates continuously for seven days at rated capacity, with the first two hours at the 2 hr overload rating.

The following methodologies are utilized in the calculation:

5.1 EDG Fuel consumption rate in lbs/hr at the continuous rated capacity of 2600KW will be computed by interpolation from the initial vendor testing data.

5.2 EDG Fuel consumption rate in lbs/hr at the 2 hr load rating of 2850KW will be computed by extrapolation from the initial vendor testing data. The highest tested KW value was 2827 KW. Reviewing the test data, it can be seen that the generator efficiency at the two highest output test values of 2503 KW and 2827 KW reached a constant value of 96.1 %. Additionally, specific fuel consumption (Lbs/BHPxHr) is essentially constant above 50% load. Therefore, linear extrapolation will provide an accurate value of EDG fuel consumption at the uprated value of 2850 KW.

5.3 Fuel consumption rates in lbs/hr will be converted to gallons per hour based on a diesel fuel Specific Gravity of 0.830. A Specific Gravity value of 0.830 is used for the following reasons:

Appendix C to ANSI/ANS-59.51-1997 "Fuel Oil Systems for Safety-Related Emergency Diesel Generators" recommends that fuel oil absolute specific gravity at 60/60 °F be greater than or equal to 0.83 but less than or equal to 0.89 (Ref. 7.10). ANSI/ANS-59.51-1997 is the latest revision of this standard, and is being used as best practice guidance only. Palisades is not committed to use of this standard.

Use of the 0.830 specific gravity value also accounts for the potential reduction in the heat content of the diesel fuel oil as a result of the change to Ultra Low Sulfur Diesel fuel (ULSD). As discussed in EC9610 (Ref. 7.11), Palisades is now receiving ULSD fuel. The ULSD fuel heat content in relation to specific gravity is estimated to be reduced 1% versus previous low sulfur diesel fuel. Diesel Fuel Oil Storage Tank T-10A monthly fuel oil sample data for the past five years indicates that the lowest fuel oil specific gravity was 0.845 (see Att. 8.4). To account for the potential 1% decrease in heat content at any specific gravity, the specific gravity of the fuel is reduced by the 1%; 0.845 x 0.99 =0.837. The resultant decrease in specific gravity to 0.837 is greater than the specific gravity value of 0.830, therefore use of a specific gravity of 0.830 is conservative.

In order to ensure that stored diesel fuel oil and new fuel deliveries meet the minimum specific gravity of 0.830, the Palisades Fuel Oil Program Procedure COP-22A (Ref. 7.20) should be revised to incorporate the minimum specific gravity requirement. The limit should be established at a specific gravity value of 0.838 to account for the potential 1% decrease in heat content, i.e. 0.830 + 1% = 0.838.

5.4 The total required diesel fuel oil storage quantity includes an amount of fuel needed for periodic testing. That fuel amount is the fuel required in any month for monthly EDG testing. Each of the two EDGs are tested each month per Surveillance Procedures MO-7A-1 (EDG 1-1) and MO-7A-2 (EDG 1-2). Each EDG is operated for less than 4 hours each at rated load.

The total amount of fuel to account for periodic testing will be based on 8 hrs total EDG run time at rated load of 2600 KW.

5.5 The method for determining Tank T-10A volume versus level above the bottom of the tank is based on the following formula for a horizontal cylindrical tank with flat ends. The formula was found through an internet search, see Attachment 8.5.

$V= L [R^2 \text{ ARCCOS } (1\text{-}H/R) – (R\text{-}H) \text{ SQRT } (H(2R\text{-}H))]$

Where: V is volume, L is the inside length, R is the inside radius and H is the level (height) of the diesel fuel in the tank. The ARCCOS must be in radians.

5.6 The unusable volume of fuel in storage tank T-10A will include a volume of fuel required to provide adequate submergence of the Fuel Oil Transfer Pump suction line to prevent air entrainment vortexing. The Reddy/Pickford methodology presented in the *Water Power* article "Vortices at Intake in Conventional Sumps" will be used to calculate the required submergence depth (Ref. 7.7).

The formula for determining required submergence takes the following form:

$S/d \geq 1 + F_n$,

Where,

S = submergence above intake

d = diameter of intake (id)

F_n= Froude Number = $v / \sqrt{(gd)}$

v = velocity of flow through intake

g = gravity constant (32.2 ft/sec^2)

6.0 CALCULATIONS

6.1 Determine the EDG fuel consumption rates in lb/hr at 2600KW and 2850 KW

EDG Fuel consumption rates in lbs/hr at various KW loadings are provided in the original EDG vendor test data, Design Input 3.5 consumption rates are not given at 2600 KW or 2850 KW. To determine the consumption rate at 2600KW the value will need to be interpolated from the available data. To determine the consumption rate at 2850 KW the value will need to be extrapolated from the available data.

The Design Input 3.5 EDG test data is repeated below:

Kilowatt	Fuel Consumed Lbs/Hr
600	350
1330	671
1908	951
2503	1234
2827	1410

Fuel consumption at 2600KW

Interpolate to determine fuel consumption rate at 2600 KW

$$1234+\left(\frac{2600-2503}{2827-2503}\right)*(1410-1234)=1286.69 \text{ lb/hr}$$

Fuel consumption at 2850KW

Extrapolate to determine fuel consumption rate at 2850KW

$$1234+\left(\frac{2850-2503}{2827-2503}\right)*(1410-1234)=1422.49 \text{ lb/hr}$$

6.2 Determine density of diesel fuel at a Specific Gravity of 0.830

In order to convert the EDG fuel consumption rates from lbs/hr to gal/hr, the density of the diesel fuel needs to be determined.

$\rho_{\text{diesel fuel}} = \rho_{\text{water}}$ x Spec. Gravity of diesel fuel

Specific Gravity of Diesel fuel = 0.830

The density will be based on a temperature of 60 °F.

Density of water @ 60 °F = 62.37 lbm/ft^3

$\rho_{\text{diesel fuel}} = 62.37 \times 0.830 = 51.77\ lbm/ft^3$

Next convert from lbm/ft^3 to lbm/gal

Conversion factor = 0.1337 ft^3/gal

Therefore: 51.77 lbm/ft^3 x 0.1337 ft^3/gal = 6.92 lbm/gal

6.3 Determine EDG fuel oil consumption with one EDG in operation supplying loads. First two hours of EDG operation at 2850 KW (2 hr rated capacity) and remaining 166 hrs at continuous rated capacity of 2600KW

Table 6.1 below gives EDG fuel consumption values based on the listed KW output values with a fuel specific gravity of 0.830. The table is an Excel spread sheet. The spread sheet cell formulas are shown in Attachment 8.1.

Table 6.1

			6 days	7 days
Time - hours (elapsed)	1	2	144	168
Kw	2850	2850	2600	2600
lbm/hr	1422.49	1422.49	1286.69	1286.69
gal/hr	205.56	205.56	185.94	185.94
gal used (based on .830 sg)	205.56	205.56	26403.18	4462.51
gal used cumulative (.830 sg)	205.56	411.12	26814.30	31276.81

6.4 Determine critical submergence to prevent air entrainment vortexing for the diesel fuel oil transfer pumps suction in T-10A

Critical submergence determines the level of fluid above an intake such that air entraining vortexing of the fluid is unlikely to occur. Critical submergence of the fuel oil transfer pumps suction in T-10A will be determined using the guidance of Input 3.8 and as discussed in Methodology 5.6.
The amount of submergence will be used in determining the total amount of unusable fuel in T-10A.

The following formula will be used to calculate critical submergence:

$S/d \geq 1 + F_n$,
Where,

S = submergence above intake
d = diameter of intake (id)
F_n= Froude Number = $v / \sqrt{(gd)}$
v = velocity of flow through intake
g = gravity constant (32.2 ft/sec^2)

The fuel transfer pumps suction pipe in T-10A is 1.5 inch nominal (Ref. 7.12). For this evaluation it is assumed that the pipe is Schedule 80 with inside diameter of 1.5" (Ref.7.13). The piping was considered to be Schedule 80 in EA-FC-958-05 (Ref. 7.9). It is conservative to assume Sch. 80 vs. Sch. 40, since the velocity through Sch. 80 pipe will be higher and the submergence Froude Number is velocity dependant.

Compute flow velocity, v, in suction line

v= Volumetric Flow/ Area

First compute volumetric flow, q

Volumetric flow = 25 gal/min * 0.1337 ft^3/gal * 1min/60sec
= 0.056 ft^3/sec

Next, compute pipe flow area:

$A = \pi d^2/4 = \pi * (1.5 \text{ in} / 12 \text{ in/ft})^2 / 4$
= 0.012 ft^2

Solving for flow velocity, v, yields:

v= Volumetric Flow/ Area
v= 0.056 ft^3/sec / 0.012 ft^2 = 4.67 ft/sec

Now, F_n, Froude Number = v / √(gd)
F_n = 4.67 ft/sec / √ [(32.2 ft/sec^2 x 1.5 in x (1 ft /12 in)]
F_n = 2.33

Rearranging the equations to solve for Critical Submergence, S_c, gives:

S_c = d + dFn

S_c = 1.5 in + 1.5 in x 2.33 = 5.0"

6.5 Determine amount of unusable fuel in Tank T-10A

There is an unusable volume of fuel in the bottom of storage Tank T-10A due to the elevation of the diesel fuel oil transfer pump suction piping above the bottom of the tank, and the additional submergence depth to prevent vortexing computed in item 6.4 above. T-10A tank drawing C-228 Sh. 3 (Ref. 7.12) shows the bottom of the suction line being 5" ± ½" min. above the tank bottom. The 5" dimension is to the inlet of the foot valve (top of foot valve strainer) located at the end of the suction line. The foot valve inlet dimension was verified per review of EDC-FC-958-21. For conservatism, the height above the bottom of the tank will be assumed to be 6". Note that the 6" height was also used in calculation EA-FC-958-05 (Ref. 7.9) which evaluated the performance of the fuel oil transfer system.

With the fuel oil transfer suction line located 6 inches from the tank bottom, that 6 inches of fuel will be unusable. Furthermore, due to critical submergence considerations described in 6.4 above, an additional 5 inches above the suction pipe level is also considered unusable. Therefore, the fuel contained below the 11" tank level is considered unusable.

In order to determine the volume contained below the 11" tank level, the volume versus level for Tank T-10A must be calculated. The method for calculating volume vs. level described in methodology 5.5 will be employed.

Attachment 8.2 is an Excel spreadsheet that gives Tank T-10A volume vs. level above the bottom of the tank. Attachment 8.3 shows the cell formulas for the spreadsheet in Att. 8.2.

(It should be noted that Tank T-10A volume versus level values per Attachment 8.2 are slightly different then those calculated in EA-FC-958-04 (Ref. 7.14) which is the current calculation of record for tank volume versus level values. The reason for the differences is that EA-FC-958-04 used 143" as the inside diameter for T-10A, while Att 8.2 values are based on a tank ID of 144".)

From Att. 8.2, the unusable volume below 11" is 1777 gals.

6.6 Determine required fuel oil storage volumes

6.6.1 Determine required storage volume for 7 day run time

The amount of on site stored fuel necessary to operate an EDG continuously for 7 days to comply with Palisades License Basis is equal to the following:

7 Day run fuel consumption volume + unusable fuel volume in T-10A

7 Day run fuel consumption volume = 31277 gal (per 6.3 above)

Unusable fuel volume in T-10A = 1777 gal (per 6.5 above & Att. 8.2)

Therefore, 7 Day run necessary stored volume = 31277 gal + 1777 gal
= **33054 gals**

To meet the total fuel storage requirements guidance of ANSI N195-1976, an amount of additional fuel to account for periodic testing of the EDGs must be included in the total stored quantity.

As discussed in Methodology 5.4, the quantity of fuel to account for periodic testing will be based on 8 hrs total EDG run time at rated load of 2600 KW. Fuel consumed operating an EDG at 2600 KW is calculated as follows:

Fuel consumption rate @ 2600 KW = 185.94 gal/hr per Table 6.1
Fuel consumed in 8 hrs = 185.94 gal/hr x 8 hrs = 1488 gals

The 1488 gal value is less than the current additional fuel volume of 2200 gals used to initially establish the T-10A low level alarm per EA-FC-958-04 (Ref. 7.14). The 2200 gals was based on operating the Plant Heating Boiler M-81 for 8 hours. For conservatism, the 2200 gal volume will be used here also, since it is greater than the calculated periodic testing volume of 1488 gals.

Periodic testing volume = 2200 gals.

Therefore, the total amount of on site stored fuel = 7 Day EDG run quantity + Periodic EDG testing quantity:
= 33054 + 2200 gals = <u>35254 gals</u>

6.6.2 Determine needed storage volume for 6 day run time

Technical Specifications include a 6 day run time fuel oil quantity. The 6 day fuel oil quantity is the lower bound for acceptable fuel oil inventory. The 6 day run time stored fuel volume is calculated similarly to the 7 day value calculated above in 6.6.1.

The 6 day stored volume = 6 day run fuel consumption volume (per 6.3 above) + unusable fuel volume in Tank T-10A:
= 26815 gals + 1777 gals = <u>28592 gals</u>

6.7 Determine Tank T-10A Levels and setpoints associated with necessary stored fuel volumes.

Attachment 8.2 spread sheet uses 9.50" above the bottom of Tank T-10A as the level where LT-1400 begins indicating. The basis for the 9.50" value is presented in Attachment 8.7 of this calculation.

6.7.1 Determine total instrument error for LT-1400 and LIA-1400

Tank T-10A Level Transmitter LT-1400 is calibrated to a 2% As Found tolerance and a 1% Final tolerance (Ref. 7.16). Level Indicator LIA-1400 is calibrated to a 2% As Found tolerance and a 1% Final tolerance (Ref. 7.17). The amount of instrument error will be calculated using the As Found tolerance of both instruments and the square root of the sum of the squares method.

Instrument Error:

$= [\text{LT-1440 error}^2 + \text{LIA-1400 error}^2]^{1/2}$
$= [2^2 + 2^2]^{1/2}$ = 2.83% (of the 137" indicator) = 3.9"

6.7.2 Determine T-10A tank level and LIA-1400 reading for the 7 Day EDG run required stored volume of 33054 gals.

T-10A stored volume = Required stored volume – volume in EDG Day Tank (T-25A or T-25B)
= 33054 gals – 2500gals = 30554 gals.

Per Att. 8.2, 30554 gals equates to a T-10A tank level of 83.58"
Then adding the instrument inaccuracy of 3.9" yields a level of 87.48". This corresponds to an indicated percentage of 56.92%

Next calculate the level instruments mA output for the 56.92% indication. The level instruments output a 4-20mA signal which corresponds to the range 0-137" (eg, 0" = 4 mA and 137" = 20 mA linearly). Calculate the output for a value of 56.92 % as follows:

56.92% x 16 mA + 4 mA = 13.11 mA

6.7.3 Determine T-10A tank level and LIA-1400 reading for the total required stored fuel volume of 35254 gals, which is the 7 Day EDG run quantity + Periodic EDG testing quantity. This value establishes the low level alarm setpoint for T-10A.

T-10A stored volume = Required stored volume – volume in EDG Day Tank (T-25A or T-25B)
= 35254 gals – 2500gals = 32754 gals.

Per Att. 8.2, 32754 gals equates to a T-10A tank level of 88.58"
Then adding the instrument inaccuracy of 3.9" yields a level of 92.48". This corresponds to an indicated percentage of 60.57%

Next calculate the level instruments mA output for the 60.57% indication.

60.57% x 16 mA + 4 mA = 13.69 mA (Low Level alarm setpoint)

6.7.4 Determine T-10A tank volume, tank level and alarm setpoint associated with the high level alarm.

The requirements for the T-10A high level were established per EA-FC-958-04 item 5.3 (Ref. 7.14). The automatic pump shutoff and the high level (overfill) level of the tank must be set at 95% of the total tank volume to comply with Section 2-10.3 of Michigan Storage and Handling of Flammable and Combustible Liquids (FL/CL) Rule 216. This section states that an underground storage tank shall be equipped with overfill prevention equipment that will automatically shut off the flow of the liquid into the tank when the tank is not more than 95% full. On high level indication from LT-1400, level switch LS-1400 opens the circuit to pump P-965 to stop transfer of fuel oil from Tank T-926. Local alarm (LA-1400) is located at the tank for immediate indication during a direct tanker fill of T-10A.

Per Attachment 8.2, 95% of Tank T-10A volume is at the 130" level. Then, subtracting the calculated instruments inaccuracy of 3.9" yields a level of 126.1". This level corresponds to an indicated percentage of 85.11%.

Next, calculate the level instruments mA output for the 85.11% indication.

85.11% x 16 mA + 4 mA = 17.62 mA (High Level alarm setpoint)

6.8 Summary of Tank T-10A Levels and setpoints associated with necessary stored fuel volumes

Table 6.2 below provides a summary of Diesel Fuel Oil Tank T-10A levels and volumes as were determined above.

Table 6.2

Item	Required Stored Volume Tank T-10A	Reference Tank T-10A Level, Inside	Tank T-10A Level Adjusted for Instrument Inaccuracy	LIA-1400 Level Indication	LIA-1400 Instrument Loop Current
Inside top of Tank	N/A	144"	N/A	98.18%	N/A
LIA-1400 High Level Alarm	48227 gal	130"	126.1"	85.11%	17.62 mA
LIA-1400 Low Level Alarm	32754 gal	88.58"	92.48"	60.57%	13.69 mA
LIA-1400 7 Day EDG run storage	30554 gal	83.58"	87.48	56.92%	13.11 mA
Level Indicator Bottom of Range	N/A	9.50"	N/A	0%	4 mA
Inside Bottom of Tank	N/A	0"	N/A	N/A	N/A

6.9 Validate that the available Net Positive Suction Head (NPSHA) for the Diesel Fuel Oil Transfer Pumps, P-18A/18B is adequate

Engineering Analysis EA-FC-958-05 (Ref 7.9) evaluated the performance of the diesel fuel oil transfer system for the current fuel oil transfer pumps taking suction from Tank T-10A. Attachment 4 of Ref. 7.9 assessed whether the NPSHA was adequate to meet the NPSH requirements of the Fuel Oil Transfer Pumps. The assessment evaluated the worst case of maximum pump flow at minimum Tank T-10A level. The assessment determined that adequate NPSH was available for proper operation of the transfer pumps.

That NPSH assessment was reviewed as part of preparing this calculation. The review determined that a non-conservative value had been used for determining the flow losses through the foot valve in the fuel oil transfer pumps suction piping. Condition Report CR-PLP-2008-01616 (Ref. 7.28) was initiated to document the finding.

In order to determine the affect on NPSHA due to the non-conservative flow loss value and validate whether NPSHA is adequate, a re-assessment of NPSH was performed. The re-assessment is included as Attachment 8.8.

The re-assessment determined that there is adequate available NPSH to meet the NPSH requirements of the Fuel Oil Transfer Pumps.

6.10 Assess whether the current licensing basis EDG fuel oil storage requirements are conservative considering fuel at minimum specific gravity and considering increased unusable fuel volume to account for required submergence of the fuel oil transfer system suction pipe

Appendix A contains an assessment that compares the current license basis EDG fuel oil storage requirements to a limiting case which assumes a worst case fuel oil specific gravity of 0.815 and includes the increase in unusable fuel in Tank T-10A to account for required submergence for the fuel oil transfer suction line inlet determined in Section 6.5. The assessment determined that current licensing basis fuel storage requirements are conservative using the same EDG load profile that established the requirements and taking into account minimum specific gravity fuel and increased unusable fuel volume in T-10A.

6.11 Determine EDG Lube Oil Consumption Based on EDG Fuel Oil Consumption

6.11.1 Determine EDG lube oil consumption for 7 day run time

As per Design Input 3.11, lube oil consumption will be calculated using a consumption factor of 1.0% of fuel oil consumption.

From Item 6.3, Table 6.1, the quantity of fuel oil consumed in the 7 day run time is 31277 gals.

To calculate the quantity of lube oil consumed in the 7 day run time, the quantity of fuel oil consumed is multiplied by the lube oil consumption factor.

Lube oil consumed in 7days = 31277 gals x 0.01 = <u>313 gals</u>

6.11.2 Determine EDG lube oil consumption for 6 day run time

The 6 day run time lube oil consumption is calculated similarly to the 7 day value calculated above in 6.11.1.

From Item 6.3, Table 6.1, the quantity of fuel oil consumed in the 6 day run time is 26815 gals.

Lube oil consumed in 6 days = 26815 gals x 0.01 = <u>268 gals</u>

6.12 Determine Required EDG Lube Oil Storage Volumes

As discussed in Technical Specifications Bases 3.8.3 (Ref. 7.29), sufficient lube oil supply must be available to ensure the capability to operate an EDG at full accident load for 7 days. The EDG engine sump does not have enough useable capacity to store the total 7 day lube oil supply. To ensure a sufficient lube oil supply is available, credit is taken for lube oil stored onsite, but external of the EDG oil sump. The externally stored lube oil is stored in barrels in the Palisades warehouse.

In the past, the total stored lube oil inventory included a portion of the oil in the EDG oil sump. For conservatism, this calculation will not credit any of the lube oil in the EDG engine sump.

Since no credit will be taken for lube oil in the EDG engine sump, the externally stored lube oil volumes will then simply be the 7 day and 6 day run time lube oil consumption volumes calculated in item 6.11 above.

Required 7 day run time lube oil stored volume = 313 gals

6 day run time lube oil stored volume = 268 gals

7.0 REFERENCES

7.1 Palisades Final Safety Analysis Report, Rev. 26

7.2 ANSI N195-1976 (ANS 59.51), "Fuel Oil Systems for Standby Diesel Generators"

7.3 Palisades Drawing VEN-M0071A , "12' x 60' STI-P3 Double Wall Underground Storage Tank", Shts 1 thru 5, Rev. 0

7.4 ALCO Locomotive Vendor Manual M12 Sh. 44 "Test Reports" Dated, 8-13-1969 (Cart/Frame G727/0280)

7.5 Palisades Technical Specification Surveillance Procedure MO-7A-1, "Emergency Diesel Generator 1-1", Rev. 67

7.6 Palisades Technical Specification Surveillance Procedure MO-7A-2, "Emergency Diesel Generator 1-2", Rev. 64

7.7 Water Power, Article entitled "Vortices at Intakes in Conventional Sumps" by Dr. Y.R. Reddy and J.A. Pickford, March 1972

7.8 Palisades Specification Change SC-96-051-01 "Replace Pumps P-18A/B with New Pumps"

7.9 Palisades Engineering Analysis EA-FC-958-05, "Calculation to Verify that the New Positive Displacement Transfer Pumps P-18A/B are Capable of Diesel Fuel Oil Transfer from New Tank T-10A to Tanks T-25A/B", Rev 3 (Cart/Frame 4090/2110)

7.10 ANSI/ANS- 59.51-1997 "Fuel Oil Systems for Safety Related Emergency Diesel Generators"

7.11 Palisades Engineering Change EC9610, "Evaluate Operation of the Site Diesel Fuel Burning Equipment with Diesel Fuel with Sulfur Content Less than 15 ppm (Ultra Low Sulfur Diesel Fuel)"

7.12 Palisades Drawing C228 Sh. 3, "Tank T-10A Foundation Section & Details", Rev. 1

7.13 CRANE Technical Paper 410 "Flow of Fluids Through Valves, Fittings, and Pipe"

7.14 Palisades Engineering Analysis EA-FC-958-04, "Calculation to Size and Provide Instrumentation Levels for the Replacement of the Diesel Fuel Oil Tank T-10 with T-10A", Rev. 2 (Cart/Frame 4090/2078)

7.15 Palisades Functional Equivalent Substitution FES-98-069, "LT-1400 Probe Replacement" (Cart/Frame 4538/0526)

7.16 Level Transmitter LT-1400 Instrument Calibration Sheet, Rev. 12, 11/21/1996

7.17 Level Indicating Alarm LIA-1400 Instrument Calibration Sheet, Rev. 11, 11/21/1996

7.18 Entergy Engineering Guide EN-ME-G-001, "Evaluation of Pump Protection from Low Submergence," Rev. 0

7.19 Palisades Engineering Analysis EA-A-NL-92-337-01, "Palisades EDG Diesel Fuel Oil Requirements for a DBA," Rev. 2 (Cart/Frame G335/0259)

7.20 Palisades Chemistry Operating Procedure COP-22A "Diesel Fuel Oil Testing Program," Rev. 9

7.21 Palisades Technical Specifications as amended through Amendment 238

7.22 Vermont Yankee Calculation VYC-1404 "Emergency Diesel Generator Fuel Oil Usage and Storage Capacity" Rev. 2 (See EC001876).

7.23 Palisades System Operating Procedure SOP-22 "Emergency Diesel Generators," Rev. 44

7.24 Palisades Engineering Analysis EA-T-343-01 "Determination of Fuel Consumption Rate for the 1-1 & 1-2 Diesel Generators" Rev. 0 (Cart/Frame F709/1475)

7.25 ASME B16.5-2003 "Pipe Flanges and Flanged Fittings"

7.26 Palisades Drawing C228 Sh. 2, "Tank T-10A Foundation", Rev. 0

7.27 Palisades Condition Report CR-PLP-2008-01496 "Diesel Fuel Oil Storage Tank T-10A Level Indication Dimension Discrepancy"

7.28 Palisades Condition Report CR-PLP-2008-01616 "Error Found in Engineering Calculation EA-FC-958-05"

7.29 Palisades Technical Specifications Bases as amended through Amendment 236

7.30 GE Design Base Documentation Search Report dated September 20, 1990, Report on Design Information Search by GE Locomotives of Canada for Palisades Emergency Diesel Generator, Section 2.7 (C843/1128)

7.31 US Nuclear Regulatory Commission Regulatory Guide 1.137, "Fuel-Oil Systems for Standby Diesel Generators", Rev. 1

8.0 ATTACHMENTS

8.1 Excel Spreadsheet – EDG Fuel Consumption cell formulas (basis for Table 6.1)

8.2 Excel Spreadsheet – Tank T-10A Volume vs. Level

8.3 Excel Spreadsheet – Tank T-10A Volume vs. Level cell formulas

8.4 Diesel Fuel Oil Storage Tank T-10A Specific Gravity Data

8.5 Formula for Calculating Volume vs. Level for a Horizontal Cylindrical Tank

8.6 *Water Power* Article – "Vortices at Intakes in Conventional Sumps

8.7 Determine Zero Level Indication Level for LT-1400

8.8 Validation of Adequate Available Net Positive Suction Head ($NPSH_A$) for Diesel Fuel Oil Transfer Pumps P-18A/18B

9.0 APPENDICES

A Assessment of Current Licensing Basis Fuel Oil Storage Requirements

	A	B	C	D	E
1	EDG 7 Days Fuel Consumption - first 2 hrs @ 2850 KW, next 166 hrs @ 2600 KW				
2				6 days	7 days
3	Time - hours (elapsed)	1	2	144	168
4	Kw	2850	2850	2600	2600
5					
6	lbm/hr	1422.49	1422.49	1286.69	1286.69
7	gal/hr	=B6/6.92	=C6/6.92	=D6/6.92	=E6/6.92
8	gal used (based on .830 sg)	=B7	=(C3-B3)*C7	=(D3-C3)*D7	=(E3-D3)*E7
9	gal used cumulative (.830 sg)	=+B8	=SUM(B8:C8)	=SUM(B8:D8)	=SUM(B8:E8)
10					
11					

T-10A Volume vs Level
With LT/LIA-1400 Settings

Distance from bottom of tank h (in)	Volume cu-in	Gallons	LIA-1400 Percentage Reading	Percentage of tank used %	
1	11495.97	49.77	0.00	0.10	
2	32447.38	140.46	0.00	0.28	
3	59484.15	257.51	0.00	0.51	
4	91388.15	395.62	0.00	0.78	
5	127447.44	551.72	0.00	1.09	
6	167176.36	723.71	0.00	1.43	
7	210214.45	910.02	0.00	1.79	
8	256279.32	1109.43	0.00	2.19	
9	305141.28	1320.96	0.00	2.60	
9.5	330559.94	1431.00	0.00	2.82	
10	356608.17	1543.76	0.36	3.04	
11	410515.77	1777.12	1.09	3.50	
12	466721.29	2020.44	1.82	3.98	
13	525098.81	2273.16	2.55	4.48	
14	585536.02	2534.79	3.28	4.99	
15	647931.73	2804.90	4.01	5.53	
16	712194.03	3083.09	4.74	6.07	
17	778238.79	3369.00	5.47	6.64	
18	845988.53	3662.29	6.20	7.21	
19	915371.49	3962.65	6.93	7.81	
20	986320.86	4269.79	7.66	8.41	
21	1058774.17	4583.44	8.39	9.03	
22	1132672.78	4903.35	9.12	9.66	
23	1207961.40	5229.27	9.85	10.30	
24	1284587.77	5560.99	10.58	10.96	
25	1362502.31	5898.28	11.31	11.62	
26	1441657.88	6240.94	12.04	12.29	
27	1522009.51	6588.79	12.77	12.98	
28	1603514.22	6941.62	13.50	13.67	
29	1686130.80	7299.27	14.23	14.38	
30	1769819.73	7661.56	14.96	15.09	
31	1854542.97	8028.32	15.69	15.82	
32	1940263.83	8399.41	16.42	16.55	
33	2026946.94	8774.66	17.15	17.29	
34	2114558.05	9153.93	17.88	18.03	
35	2203064.01	9537.07	18.61	18.79	
36	2292432.67	9923.95	19.34	19.55	
37	2382632.78	10314.43	20.07	20.32	
38	2473633.96	10708.37	20.80	21.10	
39	2565406.64	11105.66	21.53	21.88	
40	2657921.96	11506.16	22.26	22.67	
41	2751151.78	11909.75	22.99	23.46	
42	2845068.58	12316.31	23.72	24.26	
43	2939645.45	12725.74	24.45	25.07	
44	3034856.04	13137.90	25.18	25.88	
45	3130674.51	13552.70	25.91	26.70	
46	3227075.54	13970.02	26.64	27.52	
47	3324034.22	14389.76	27.37	28.35	
48	3421526.11	14811.80	28.10	29.18	

Distance from bottom of tank h (in)	Volume cu-in	Gallons	LIA-1400 Percentage Reading	Percentage of tank used %	
49	3519527.15	15236.05	28.83	30.01	
50	3618013.65	15662.40	29.56	30.85	
51	3716962.28	16090.75	30.29	31.70	
52	3816350.02	16521.00	31.02	32.55	
53	3916154.18	16953.05	31.75	33.40	
54	4016352.32	17386.81	32.48	34.25	
55	4116922.29	17822.17	33.21	35.11	
56	4217842.17	18259.06	33.94	35.97	
57	4319090.28	18697.36	34.67	36.83	
58	4420645.13	19136.99	35.40	37.70	
59	4522485.44	19577.86	36.13	38.57	
60	4624590.12	20019.87	36.86	39.44	
61	4726938.20	20462.94	37.59	40.31	
62	4829508.92	20906.97	38.32	41.19	
63	4932281.60	21351.87	39.05	42.06	
64	5035235.72	21797.56	39.78	42.94	
65	5138350.83	22243.94	40.51	43.82	
66	5241606.63	22690.94	41.24	44.70	
67	5344982.84	23138.45	41.97	45.58	
68	5448459.31	23586.40	42.70	46.47	
69	5552015.90	24034.70	43.43	47.35	
70	5655632.54	24483.26	44.16	48.23	
71	5759289.21	24931.99	44.89	49.12	
72	5862965.87	25380.80	45.62	50.00	
73	5966642.54	25829.62	46.35	50.88	
74	6070299.20	26278.35	47.08	51.77	
75	6173915.85	26726.91	47.81	52.65	
76	6277472.44	27175.21	48.54	53.53	
77	6380948.91	27623.16	49.27	54.42	
78	6484325.12	28070.67	50.00	55.30	
79	6587580.91	28517.67	50.73	56.18	
80	6690696.03	28964.05	51.46	57.06	
81	6793650.15	29409.74	52.19	57.94	
82	6896422.83	29854.64	52.92	58.81	
83	6998993.54	30298.67	53.65	59.69	
83.58	7058383.88	30555.77	54.07	60.19	
84	7101341.63	30741.74	54.38	60.56	
85	7203446.31	31183.75	55.11	61.43	
86	7305286.62	31624.62	55.84	62.30	
87	7406841.47	32064.25	56.57	63.17	
87.48	7455480.16	32274.81	56.92	63.58	New Tech Spec fuel setting
88	7508089.58	32502.55	57.30	64.03	
88.58	7566664.47	32756.12	57.72	64.53	
89	7609009.46	32939.43	58.03	64.89	
90	7709579.43	33374.80	58.76	65.75	
91	7809777.57	33808.56	59.49	66.60	
92	7909581.73	34240.61	60.22	67.45	
92.48	7957341.20	34447.36	60.57	67.86	New Low Level Alarm Setpoint
93	8008969.47	34670.86	60.95	68.30	

Distance from bottom of tank h (in)	Volume cu-in	Gallons	LIA-1400 Percentage Reading	Percentage of tank used %	
94	8107918.10	35099.21	61.68	69.15	
95	8206404.60	35525.56	62.41	69.99	
96	8304405.64	35949.81	63.14	70.82	
97	8401897.53	36371.85	63.87	71.65	
98	8498856.21	36791.59	64.60	72.48	
99	8595257.23	37208.91	65.33	73.30	
100	8691075.71	37623.70	66.06	74.12	
101	8786286.30	38035.87	66.79	74.93	
102	8880863.17	38445.30	67.52	75.74	
103	8974779.97	38851.86	68.25	76.54	
104	9068009.78	39255.45	68.98	77.33	
105	9160525.11	39655.95	69.71	78.12	
106	9252297.79	40053.24	70.44	78.90	
107	9343298.97	40447.18	71.17	79.68	
108	9433499.08	40837.66	71.90	80.45	
109	9522867.73	41224.54	72.63	81.21	
110	9611373.70	41607.68	73.36	81.97	
111	9698984.81	41986.95	74.09	82.71	
112	9785667.91	42362.20	74.82	83.45	
113	9871388.78	42733.28	75.55	84.18	
114	9956112.01	43100.05	76.28	84.91	
115	10039800.94	43462.34	77.01	85.62	
116	10122417.53	43819.99	77.74	86.33	
117	10203922.23	44172.82	78.47	87.02	
118	10284273.86	44520.67	79.20	87.71	
119	10363429.43	44863.33	79.93	88.38	
120	10441343.98	45200.62	80.66	89.04	
121	10517970.35	45532.34	81.39	89.70	
122	10593258.97	45858.26	82.12	90.34	
123	10667157.57	46178.17	82.85	90.97	
124	10739610.89	46491.82	83.58	91.59	
125	10810560.26	46798.96	84.31	92.19	
126	10879943.22	47099.32	85.04	92.79	
126.1	10886792.83	47128.97	85.11	92.84	High Level Alarm Setpoint
127	10947692.96	47392.61	85.77	93.36	
128	11013737.72	47678.52	86.50	93.93	
129	11078000.02	47956.71	87.23	94.47	
130	11140395.73	48226.82	87.96	95.01	
131	11200832.94	48488.45	88.69	95.52	
132	11259210.46	48741.17	89.42	96.02	
133	11315415.98	48984.48	90.15	96.50	
134	11369323.58	49217.85	90.88	96.96	
135	11420790.47	49440.65	91.61	97.40	
136	11469652.43	49652.18	92.34	97.81	
137	11515717.30	49851.59	93.07	98.21	
138	11558755.38	50037.90	93.80	98.57	
139	11598484.31	50209.89	94.53	98.91	
140	11634543.60	50365.99	95.26	99.22	
141	11666447.60	50504.10	95.99	99.49	

Distance from bottom of tank h (in)	Volume cu-in	Gallons	LIA-1400 Percentage Reading	Percentage of tank used %	
142	11693484.37	50621.14	96.72	99.72	
143	11714435.78	50711.84	97.45	99.90	
144	11725931.75	50761.61	98.18	100.00	

	A	B	C
1	Distance from	Volume	Gallons
2	bottom of tank	cu-in	
3	h (in)		
4	1	=12*60*((72^2*ACOS(1-A4/72))-((72-A4)*SQRT(A4*(2*72-A4))))	=B4/231
5	2	=12*60*((72^2*ACOS(1-A5/72))-((72-A5)*SQRT(A5*(2*72-A5))))	=B5/231
6	3	=12*60*((72^2*ACOS(1-A6/72))-((72-A6)*SQRT(A6*(2*72-A6))))	=B6/231
7	4	=12*60*((72^2*ACOS(1-A7/72))-((72-A7)*SQRT(A7*(2*72-A7))))	=B7/231
8	5	=12*60*((72^2*ACOS(1-A8/72))-((72-A8)*SQRT(A8*(2*72-A8))))	=B8/231
9	6	=12*60*((72^2*ACOS(1-A9/72))-((72-A9)*SQRT(A9*(2*72-A9))))	=B9/231
10	7	=12*60*((72^2*ACOS(1-A10/72))-((72-A10)*SQRT(A10*(2*72-A10))))	=B10/231
11	8	=12*60*((72^2*ACOS(1-A11/72))-((72-A11)*SQRT(A11*(2*72-A11))))	=B11/231
12	9	=12*60*((72^2*ACOS(1-A12/72))-((72-A12)*SQRT(A12*(2*72-A12))))	=B12/231
13	9.5	=12*60*((72^2*ACOS(1-A13/72))-((72-A13)*SQRT(A13*(2*72-A13))))	=B13/231
14	10	=12*60*((72^2*ACOS(1-A14/72))-((72-A14)*SQRT(A14*(2*72-A14))))	=B14/231
15	11	=12*60*((72^2*ACOS(1-A15/72))-((72-A15)*SQRT(A15*(2*72-A15))))	=B15/231
16	12	=12*60*((72^2*ACOS(1-A16/72))-((72-A16)*SQRT(A16*(2*72-A16))))	=B16/231
17	13	=12*60*((72^2*ACOS(1-A17/72))-((72-A17)*SQRT(A17*(2*72-A17))))	=B17/231
18	14	=12*60*((72^2*ACOS(1-A18/72))-((72-A18)*SQRT(A18*(2*72-A18))))	=B18/231
19	15	=12*60*((72^2*ACOS(1-A19/72))-((72-A19)*SQRT(A19*(2*72-A19))))	=B19/231
20	16	=12*60*((72^2*ACOS(1-A20/72))-((72-A20)*SQRT(A20*(2*72-A20))))	=B20/231
21	17	=12*60*((72^2*ACOS(1-A21/72))-((72-A21)*SQRT(A21*(2*72-A21))))	=B21/231
22	18	=12*60*((72^2*ACOS(1-A22/72))-((72-A22)*SQRT(A22*(2*72-A22))))	=B22/231
23	19	=12*60*((72^2*ACOS(1-A23/72))-((72-A23)*SQRT(A23*(2*72-A23))))	=B23/231
24	20	=12*60*((72^2*ACOS(1-A24/72))-((72-A24)*SQRT(A24*(2*72-A24))))	=B24/231
25	21	=12*60*((72^2*ACOS(1-A25/72))-((72-A25)*SQRT(A25*(2*72-A25))))	=B25/231
26	22	=12*60*((72^2*ACOS(1-A26/72))-((72-A26)*SQRT(A26*(2*72-A26))))	=B26/231
27	23	=12*60*((72^2*ACOS(1-A27/72))-((72-A27)*SQRT(A27*(2*72-A27))))	=B27/231
28	24	=12*60*((72^2*ACOS(1-A28/72))-((72-A28)*SQRT(A28*(2*72-A28))))	=B28/231
29	25	=12*60*((72^2*ACOS(1-A29/72))-((72-A29)*SQRT(A29*(2*72-A29))))	=B29/231
30	26	=12*60*((72^2*ACOS(1-A30/72))-((72-A30)*SQRT(A30*(2*72-A30))))	=B30/231
31	27	=12*60*((72^2*ACOS(1-A31/72))-((72-A31)*SQRT(A31*(2*72-A31))))	=B31/231
32	28	=12*60*((72^2*ACOS(1-A32/72))-((72-A32)*SQRT(A32*(2*72-A32))))	=B32/231
33	29	=12*60*((72^2*ACOS(1-A33/72))-((72-A33)*SQRT(A33*(2*72-A33))))	=B33/231
34	30	=12*60*((72^2*ACOS(1-A34/72))-((72-A34)*SQRT(A34*(2*72-A34))))	=B34/231
35	31	=12*60*((72^2*ACOS(1-A35/72))-((72-A35)*SQRT(A35*(2*72-A35))))	=B35/231
36	32	=12*60*((72^2*ACOS(1-A36/72))-((72-A36)*SQRT(A36*(2*72-A36))))	=B36/231

	D	E	F
1	LIA-1400	Percentage	
2	Percentage	of tank used	
3	Reading	%	
4	0	=(B4/11725931.7)*100	
5	0	=(B5/11725931.7)*100	
6	0	=(B6/11725931.7)*100	
7	0	=(B7/11725931.7)*100	
8	0	=(B8/11725931.7)*100	
9	0	=(B9/11725931.7)*100	
10	0	=(B10/11725931.7)*100	
11	0	=(B11/11725931.7)*100	
12	0	=(B12/11725931.7)*100	
13	=((A13-9.5)/137)*100	=(B13/11725931.7)*100	
14	=((A14-9.5)/137)*100	=(B14/11725931.7)*100	
15	=((A15-9.5)/137)*100	=(B15/11725931.7)*100	
16	=((A16-9.5)/137)*100	=(B16/11725931.7)*100	
17	=((A17-9.5)/137)*100	=(B17/11725931.7)*100	
18	=((A18-9.5)/137)*100	=(B18/11725931.7)*100	
19	=((A19-9.5)/137)*100	=(B19/11725931.7)*100	
20	=((A20-9.5)/137)*100	=(B20/11725931.7)*100	
21	=((A21-9.5)/137)*100	=(B21/11725931.7)*100	
22	=((A22-9.5)/137)*100	=(B22/11725931.7)*100	
23	=((A23-9.5)/137)*100	=(B23/11725931.7)*100	
24	=((A24-9.5)/137)*100	=(B24/11725931.7)*100	
25	=((A25-9.5)/137)*100	=(B25/11725931.7)*100	
26	=((A26-9.5)/137)*100	=(B26/11725931.7)*100	
27	=((A27-9.5)/137)*100	=(B27/11725931.7)*100	
28	=((A28-9.5)/137)*100	=(B28/11725931.7)*100	
29	=((A29-9.5)/137)*100	=(B29/11725931.7)*100	
30	=((A30-9.5)/137)*100	=(B30/11725931.7)*100	
31	=((A31-9.5)/137)*100	=(B31/11725931.7)*100	
32	=((A32-9.5)/137)*100	=(B32/11725931.7)*100	
33	=((A33-9.5)/137)*100	=(B33/11725931.7)*100	
34	=((A34-9.5)/137)*100	=(B34/11725931.7)*100	
35	=((A35-9.5)/137)*100	=(B35/11725931.7)*100	
36	=((A36-9.5)/137)*100	=(B36/11725931.7)*100	

	A	B	C
1	Distance from	Volume	Gallons
2	bottom of tank	cu-in	
3	h (in)		
37	33	=12*60*((72^2*ACOS(1-A37/72))-((72-A37)*SQRT(A37*(2*72-A37))))	=B37/231
38	34	=12*60*((72^2*ACOS(1-A38/72))-((72-A38)*SQRT(A38*(2*72-A38))))	=B38/231
39	35	=12*60*((72^2*ACOS(1-A39/72))-((72-A39)*SQRT(A39*(2*72-A39))))	=B39/231
40	36	=12*60*((72^2*ACOS(1-A40/72))-((72-A40)*SQRT(A40*(2*72-A40))))	=B40/231
41	37	=12*60*((72^2*ACOS(1-A41/72))-((72-A41)*SQRT(A41*(2*72-A41))))	=B41/231
42	38	=12*60*((72^2*ACOS(1-A42/72))-((72-A42)*SQRT(A42*(2*72-A42))))	=B42/231
43	39	=12*60*((72^2*ACOS(1-A43/72))-((72-A43)*SQRT(A43*(2*72-A43))))	=B43/231
44	40	=12*60*((72^2*ACOS(1-A44/72))-((72-A44)*SQRT(A44*(2*72-A44))))	=B44/231
45	41	=12*60*((72^2*ACOS(1-A45/72))-((72-A45)*SQRT(A45*(2*72-A45))))	=B45/231
46	42	=12*60*((72^2*ACOS(1-A46/72))-((72-A46)*SQRT(A46*(2*72-A46))))	=B46/231
47	43	=12*60*((72^2*ACOS(1-A47/72))-((72-A47)*SQRT(A47*(2*72-A47))))	=B47/231
48	44	=12*60*((72^2*ACOS(1-A48/72))-((72-A48)*SQRT(A48*(2*72-A48))))	=B48/231
49	45	=12*60*((72^2*ACOS(1-A49/72))-((72-A49)*SQRT(A49*(2*72-A49))))	=B49/231
50	46	=12*60*((72^2*ACOS(1-A50/72))-((72-A50)*SQRT(A50*(2*72-A50))))	=B50/231
51	47	=12*60*((72^2*ACOS(1-A51/72))-((72-A51)*SQRT(A51*(2*72-A51))))	=B51/231
52	48	=12*60*((72^2*ACOS(1-A52/72))-((72-A52)*SQRT(A52*(2*72-A52))))	=B52/231
53	49	=12*60*((72^2*ACOS(1-A53/72))-((72-A53)*SQRT(A53*(2*72-A53))))	=B53/231
54	50	=12*60*((72^2*ACOS(1-A54/72))-((72-A54)*SQRT(A54*(2*72-A54))))	=B54/231
55	51	=12*60*((72^2*ACOS(1-A55/72))-((72-A55)*SQRT(A55*(2*72-A55))))	=B55/231
56	52	=12*60*((72^2*ACOS(1-A56/72))-((72-A56)*SQRT(A56*(2*72-A56))))	=B56/231
57	53	=12*60*((72^2*ACOS(1-A57/72))-((72-A57)*SQRT(A57*(2*72-A57))))	=B57/231
58	54	=12*60*((72^2*ACOS(1-A58/72))-((72-A58)*SQRT(A58*(2*72-A58))))	=B58/231
59	55	=12*60*((72^2*ACOS(1-A59/72))-((72-A59)*SQRT(A59*(2*72-A59))))	=B59/231
60	56	=12*60*((72^2*ACOS(1-A60/72))-((72-A60)*SQRT(A60*(2*72-A60))))	=B60/231
61	57	=12*60*((72^2*ACOS(1-A61/72))-((72-A61)*SQRT(A61*(2*72-A61))))	=B61/231
62	58	=12*60*((72^2*ACOS(1-A62/72))-((72-A62)*SQRT(A62*(2*72-A62))))	=B62/231
63	59	=12*60*((72^2*ACOS(1-A63/72))-((72-A63)*SQRT(A63*(2*72-A63))))	=B63/231
64	60	=12*60*((72^2*ACOS(1-A64/72))-((72-A64)*SQRT(A64*(2*72-A64))))	=B64/231
65	61	=12*60*((72^2*ACOS(1-A65/72))-((72-A65)*SQRT(A65*(2*72-A65))))	=B65/231
66	62	=12*60*((72^2*ACOS(1-A66/72))-((72-A66)*SQRT(A66*(2*72-A66))))	=B66/231
67	63	=12*60*((72^2*ACOS(1-A67/72))-((72-A67)*SQRT(A67*(2*72-A67))))	=B67/231
68	64	=12*60*((72^2*ACOS(1-A68/72))-((72-A68)*SQRT(A68*(2*72-A68))))	=B68/231
69	65	=12*60*((72^2*ACOS(1-A69/72))-((72-A69)*SQRT(A69*(2*72-A69))))	=B69/231

	D	E	F
1	LIA-1400	Percentage	
2	Percentage	of tank used	
3	Reading	%	
37	=((A37-9.5)/137)*100	=(B37/11725931.7)*100	
38	=((A38-9.5)/137)*100	=(B38/11725931.7)*100	
39	=((A39-9.5)/137)*100	=(B39/11725931.7)*100	
40	=((A40-9.5)/137)*100	=(B40/11725931.7)*100	
41	=((A41-9.5)/137)*100	=(B41/11725931.7)*100	
42	=((A42-9.5)/137)*100	=(B42/11725931.7)*100	
43	=((A43-9.5)/137)*100	=(B43/11725931.7)*100	
44	=((A44-9.5)/137)*100	=(B44/11725931.7)*100	
45	=((A45-9.5)/137)*100	=(B45/11725931.7)*100	
46	=((A46-9.5)/137)*100	=(B46/11725931.7)*100	
47	=((A47-9.5)/137)*100	=(B47/11725931.7)*100	
48	=((A48-9.5)/137)*100	=(B48/11725931.7)*100	
49	=((A49-9.5)/137)*100	=(B49/11725931.7)*100	
50	=((A50-9.5)/137)*100	=(B50/11725931.7)*100	
51	=((A51-9.5)/137)*100	=(B51/11725931.7)*100	
52	=((A52-9.5)/137)*100	=(B52/11725931.7)*100	
53	=((A53-9.5)/137)*100	=(B53/11725931.7)*100	
54	=((A54-9.5)/137)*100	=(B54/11725931.7)*100	
55	=((A55-9.5)/137)*100	=(B55/11725931.7)*100	
56	=((A56-9.5)/137)*100	=(B56/11725931.7)*100	
57	=((A57-9.5)/137)*100	=(B57/11725931.7)*100	
58	=((A58-9.5)/137)*100	=(B58/11725931.7)*100	
59	=((A59-9.5)/137)*100	=(B59/11725931.7)*100	
60	=((A60-9.5)/137)*100	=(B60/11725931.7)*100	
61	=((A61-9.5)/137)*100	=(B61/11725931.7)*100	
62	=((A62-9.5)/137)*100	=(B62/11725931.7)*100	
63	=((A63-9.5)/137)*100	=(B63/11725931.7)*100	
64	=((A64-9.5)/137)*100	=(B64/11725931.7)*100	
65	=((A65-9.5)/137)*100	=(B65/11725931.7)*100	
66	=((A66-9.5)/137)*100	=(B66/11725931.7)*100	
67	=((A67-9.5)/137)*100	=(B67/11725931.7)*100	
68	=((A68-9.5)/137)*100	=(B68/11725931.7)*100	
69	=((A69-9.5)/137)*100	=(B69/11725931.7)*100	

	A	B	C
1	Distance from	Volume	Gallons
2	bottom of tank	cu-in	
3	h (in)		
70	66	=12*60*((72^2*ACOS(1-A70/72))-((72-A70)*SQRT(A70*(2*72-A70))))	=B70/231
71	67	=12*60*((72^2*ACOS(1-A71/72))-((72-A71)*SQRT(A71*(2*72-A71))))	=B71/231
72	68	=12*60*((72^2*ACOS(1-A72/72))-((72-A72)*SQRT(A72*(2*72-A72))))	=B72/231
73	69	=12*60*((72^2*ACOS(1-A73/72))-((72-A73)*SQRT(A73*(2*72-A73))))	=B73/231
74	70	=12*60*((72^2*ACOS(1-A74/72))-((72-A74)*SQRT(A74*(2*72-A74))))	=B74/231
75	71	=12*60*((72^2*ACOS(1-A75/72))-((72-A75)*SQRT(A75*(2*72-A75))))	=B75/231
76	72	=12*60*((72^2*ACOS(1-A76/72))-((72-A76)*SQRT(A76*(2*72-A76))))	=B76/231
77	73	=12*60*((72^2*ACOS(1-A77/72))-((72-A77)*SQRT(A77*(2*72-A77))))	=B77/231
78	74	=12*60*((72^2*ACOS(1-A78/72))-((72-A78)*SQRT(A78*(2*72-A78))))	=B78/231
79	75	=12*60*((72^2*ACOS(1-A79/72))-((72-A79)*SQRT(A79*(2*72-A79))))	=B79/231
80	76	=12*60*((72^2*ACOS(1-A80/72))-((72-A80)*SQRT(A80*(2*72-A80))))	=B80/231
81	77	=12*60*((72^2*ACOS(1-A81/72))-((72-A81)*SQRT(A81*(2*72-A81))))	=B81/231
82	78	=12*60*((72^2*ACOS(1-A82/72))-((72-A82)*SQRT(A82*(2*72-A82))))	=B82/231
83	79	=12*60*((72^2*ACOS(1-A83/72))-((72-A83)*SQRT(A83*(2*72-A83))))	=B83/231
84	80	=12*60*((72^2*ACOS(1-A84/72))-((72-A84)*SQRT(A84*(2*72-A84))))	=B84/231
85	81	=12*60*((72^2*ACOS(1-A85/72))-((72-A85)*SQRT(A85*(2*72-A85))))	=B85/231
86	82	=12*60*((72^2*ACOS(1-A86/72))-((72-A86)*SQRT(A86*(2*72-A86))))	=B86/231
87	83	=12*60*((72^2*ACOS(1-A87/72))-((72-A87)*SQRT(A87*(2*72-A87))))	=B87/231
88	83.58	=12*60*((72^2*ACOS(1-A88/72))-((72-A88)*SQRT(A88*(2*72-A88))))	=B88/231
89	84	=12*60*((72^2*ACOS(1-A89/72))-((72-A89)*SQRT(A89*(2*72-A89))))	=B89/231
90	85	=12*60*((72^2*ACOS(1-A90/72))-((72-A90)*SQRT(A90*(2*72-A90))))	=B90/231
91	86	=12*60*((72^2*ACOS(1-A91/72))-((72-A91)*SQRT(A91*(2*72-A91))))	=B91/231
92	87	=12*60*((72^2*ACOS(1-A92/72))-((72-A92)*SQRT(A92*(2*72-A92))))	=B92/231
93	87.48	=12*60*((72^2*ACOS(1-A93/72))-((72-A93)*SQRT(A93*(2*72-A93))))	=B93/231
94	88	=12*60*((72^2*ACOS(1-A94/72))-((72-A94)*SQRT(A94*(2*72-A94))))	=B94/231
95	88.58	=12*60*((72^2*ACOS(1-A95/72))-((72-A95)*SQRT(A95*(2*72-A95))))	=B95/231
96	89	=12*60*((72^2*ACOS(1-A96/72))-((72-A96)*SQRT(A96*(2*72-A96))))	=B96/231
97	90	=12*60*((72^2*ACOS(1-A97/72))-((72-A97)*SQRT(A97*(2*72-A97))))	=B97/231
98	91	=12*60*((72^2*ACOS(1-A98/72))-((72-A98)*SQRT(A98*(2*72-A98))))	=B98/231
99	92	=12*60*((72^2*ACOS(1-A99/72))-((72-A99)*SQRT(A99*(2*72-A99))))	=B99/231
100	92.48	=12*60*((72^2*ACOS(1-A100/72))-((72-A100)*SQRT(A100*(2*72-A100))))	=B100/231
101	93	=12*60*((72^2*ACOS(1-A101/72))-((72-A101)*SQRT(A101*(2*72-A101))))	=B101/231
102	94	=12*60*((72^2*ACOS(1-A102/72))-((72-A102)*SQRT(A102*(2*72-A102))))	=B102/231

	D	E	F
1	LIA-1400	Percentage	
2	Percentage	of tank used	
3	Reading	%	
70	=((A70-9.5)/137)*100	=(B70/11725931.7)*100	
71	=((A71-9.5)/137)*100	=(B71/11725931.7)*100	
72	=((A72-9.5)/137)*100	=(B72/11725931.7)*100	
73	=((A73-9.5)/137)*100	=(B73/11725931.7)*100	
74	=((A74-9.5)/137)*100	=(B74/11725931.7)*100	
75	=((A75-9.5)/137)*100	=(B75/11725931.7)*100	
76	=((A76-9.5)/137)*100	=(B76/11725931.7)*100	
77	=((A77-9.5)/137)*100	=(B77/11725931.7)*100	
78	=((A78-9.5)/137)*100	=(B78/11725931.7)*100	
79	=((A79-9.5)/137)*100	=(B79/11725931.7)*100	
80	=((A80-9.5)/137)*100	=(B80/11725931.7)*100	
81	=((A81-9.5)/137)*100	=(B81/11725931.7)*100	
82	=((A82-9.5)/137)*100	=(B82/11725931.7)*100	
83	=((A83-9.5)/137)*100	=(B83/11725931.7)*100	
84	=((A84-9.5)/137)*100	=(B84/11725931.7)*100	
85	=((A85-9.5)/137)*100	=(B85/11725931.7)*100	
86	=((A86-9.5)/137)*100	=(B86/11725931.7)*100	
87	=((A87-9.5)/137)*100	=(B87/11725931.7)*100	
88	=((A88-9.5)/137)*100	=(B88/11725931.7)*100	
89	=((A89-9.5)/137)*100	=(B89/11725931.7)*100	
90	=((A90-9.5)/137)*100	=(B90/11725931.7)*100	
91	=((A91-9.5)/137)*100	=(B91/11725931.7)*100	
92	=((A92-9.5)/137)*100	=(B92/11725931.7)*100	
93	=((A93-9.5)/137)*100	=(B93/11725931.7)*100	New Tech Spec fuel setting
94	=((A94-9.5)/137)*100	=(B94/11725931.7)*100	
95	=((A95-9.5)/137)*100	=(B95/11725931.7)*100	
96	=((A96-9.5)/137)*100	=(B96/11725931.7)*100	
97	=((A97-9.5)/137)*100	=(B97/11725931.7)*100	
98	=((A98-9.5)/137)*100	=(B98/11725931.7)*100	
99	=((A99-9.5)/137)*100	=(B99/11725931.7)*100	
100	=((A100-9.5)/137)*100	=(B100/11725931.7)*100	New Low Level Alarm Setpoint
101	=((A101-9.5)/137)*100	=(B101/11725931.7)*100	
102	=((A102-9.5)/137)*100	=(B102/11725931.7)*100	

	A	B	C
1	Distance from	Volume	Gallons
2	bottom of tank	cu-in	
3	h (in)		
103	95	=12*60*((72^2*ACOS(1-A103/72))-((72-A103)*SQRT(A103*(2*72-A103))))	=B103/231
104	96	=12*60*((72^2*ACOS(1-A104/72))-((72-A104)*SQRT(A104*(2*72-A104))))	=B104/231
105	97	=12*60*((72^2*ACOS(1-A105/72))-((72-A105)*SQRT(A105*(2*72-A105))))	=B105/231
106	98	=12*60*((72^2*ACOS(1-A106/72))-((72-A106)*SQRT(A106*(2*72-A106))))	=B106/231
107	99	=12*60*((72^2*ACOS(1-A107/72))-((72-A107)*SQRT(A107*(2*72-A107))))	=B107/231
108	100	=12*60*((72^2*ACOS(1-A108/72))-((72-A108)*SQRT(A108*(2*72-A108))))	=B108/231
109	101	=12*60*((72^2*ACOS(1-A109/72))-((72-A109)*SQRT(A109*(2*72-A109))))	=B109/231
110	102	=12*60*((72^2*ACOS(1-A110/72))-((72-A110)*SQRT(A110*(2*72-A110))))	=B110/231
111	103	=12*60*((72^2*ACOS(1-A111/72))-((72-A111)*SQRT(A111*(2*72-A111))))	=B111/231
112	104	=12*60*((72^2*ACOS(1-A112/72))-((72-A112)*SQRT(A112*(2*72-A112))))	=B112/231
113	105	=12*60*((72^2*ACOS(1-A113/72))-((72-A113)*SQRT(A113*(2*72-A113))))	=B113/231
114	106	=12*60*((72^2*ACOS(1-A114/72))-((72-A114)*SQRT(A114*(2*72-A114))))	=B114/231
115	107	=12*60*((72^2*ACOS(1-A115/72))-((72-A115)*SQRT(A115*(2*72-A115))))	=B115/231
116	108	=12*60*((72^2*ACOS(1-A116/72))-((72-A116)*SQRT(A116*(2*72-A116))))	=B116/231
117	109	=12*60*((72^2*ACOS(1-A117/72))-((72-A117)*SQRT(A117*(2*72-A117))))	=B117/231
118	110	=12*60*((72^2*ACOS(1-A118/72))-((72-A118)*SQRT(A118*(2*72-A118))))	=B118/231
119	111	=12*60*((72^2*ACOS(1-A119/72))-((72-A119)*SQRT(A119*(2*72-A119))))	=B119/231
120	112	=12*60*((72^2*ACOS(1-A120/72))-((72-A120)*SQRT(A120*(2*72-A120))))	=B120/231
121	113	=12*60*((72^2*ACOS(1-A121/72))-((72-A121)*SQRT(A121*(2*72-A121))))	=B121/231
122	114	=12*60*((72^2*ACOS(1-A122/72))-((72-A122)*SQRT(A122*(2*72-A122))))	=B122/231
123	115	=12*60*((72^2*ACOS(1-A123/72))-((72-A123)*SQRT(A123*(2*72-A123))))	=B123/231
124	116	=12*60*((72^2*ACOS(1-A124/72))-((72-A124)*SQRT(A124*(2*72-A124))))	=B124/231
125	117	=12*60*((72^2*ACOS(1-A125/72))-((72-A125)*SQRT(A125*(2*72-A125))))	=B125/231
126	118	=12*60*((72^2*ACOS(1-A126/72))-((72-A126)*SQRT(A126*(2*72-A126))))	=B126/231
127	119	=12*60*((72^2*ACOS(1-A127/72))-((72-A127)*SQRT(A127*(2*72-A127))))	=B127/231
128	120	=12*60*((72^2*ACOS(1-A128/72))-((72-A128)*SQRT(A128*(2*72-A128))))	=B128/231
129	121	=12*60*((72^2*ACOS(1-A129/72))-((72-A129)*SQRT(A129*(2*72-A129))))	=B129/231
130	122	=12*60*((72^2*ACOS(1-A130/72))-((72-A130)*SQRT(A130*(2*72-A130))))	=B130/231
131	123	=12*60*((72^2*ACOS(1-A131/72))-((72-A131)*SQRT(A131*(2*72-A131))))	=B131/231
132	124	=12*60*((72^2*ACOS(1-A132/72))-((72-A132)*SQRT(A132*(2*72-A132))))	=B132/231
133	125	=12*60*((72^2*ACOS(1-A133/72))-((72-A133)*SQRT(A133*(2*72-A133))))	=B133/231
134	126	=12*60*((72^2*ACOS(1-A134/72))-((72-A134)*SQRT(A134*(2*72-A134))))	=B134/231
135	126.1	=12*60*((72^2*ACOS(1-A135/72))-((72-A135)*SQRT(A135*(2*72-A135))))	=B135/231

T-10A Volume vs Level
With LT/LIA-1400 Settings

	D	E	F
1	LIA-1400	Percentage	
2	Percentage	of tank used	
3	Reading	%	
103	=((A103-9.5)/137)*100	=(B103/11725931.7)*100	
104	=((A104-9.5)/137)*100	=(B104/11725931.7)*100	
105	=((A105-9.5)/137)*100	=(B105/11725931.7)*100	
106	=((A106-9.5)/137)*100	=(B106/11725931.7)*100	
107	=((A107-9.5)/137)*100	=(B107/11725931.7)*100	
108	=((A108-9.5)/137)*100	=(B108/11725931.7)*100	
109	=((A109-9.5)/137)*100	=(B109/11725931.7)*100	
110	=((A110-9.5)/137)*100	=(B110/11725931.7)*100	
111	=((A111-9.5)/137)*100	=(B111/11725931.7)*100	
112	=((A112-9.5)/137)*100	=(B112/11725931.7)*100	
113	=((A113-9.5)/137)*100	=(B113/11725931.7)*100	
114	=((A114-9.5)/137)*100	=(B114/11725931.7)*100	
115	=((A115-9.5)/137)*100	=(B115/11725931.7)*100	
116	=((A116-9.5)/137)*100	=(B116/11725931.7)*100	
117	=((A117-9.5)/137)*100	=(B117/11725931.7)*100	
118	=((A118-9.5)/137)*100	=(B118/11725931.7)*100	
119	=((A119-9.5)/137)*100	=(B119/11725931.7)*100	
120	=((A120-9.5)/137)*100	=(B120/11725931.7)*100	
121	=((A121-9.5)/137)*100	=(B121/11725931.7)*100	
122	=((A122-9.5)/137)*100	=(B122/11725931.7)*100	
123	=((A123-9.5)/137)*100	=(B123/11725931.7)*100	
124	=((A124-9.5)/137)*100	=(B124/11725931.7)*100	
125	=((A125-9.5)/137)*100	=(B125/11725931.7)*100	
126	=((A126-9.5)/137)*100	=(B126/11725931.7)*100	
127	=((A127-9.5)/137)*100	=(B127/11725931.7)*100	
128	=((A128-9.5)/137)*100	=(B128/11725931.7)*100	
129	=((A129-9.5)/137)*100	=(B129/11725931.7)*100	
130	=((A130-9.5)/137)*100	=(B130/11725931.7)*100	
131	=((A131-9.5)/137)*100	=(B131/11725931.7)*100	
132	=((A132-9.5)/137)*100	=(B132/11725931.7)*100	
133	=((A133-9.5)/137)*100	=(B133/11725931.7)*100	
134	=((A134-9.5)/137)*100	=(B134/11725931.7)*100	
135	=((A135-9.5)/137)*100	=(B135/11725931.7)*100	High Level Alarm Setpoint

	A	B	C
1	Distance from	Volume	Gallons
2	bottom of tank	cu-in	
3	h (in)		
136	127	=12*60*((72^2*ACOS(1-A136/72))-((72-A136)*SQRT(A136*(2*72-A136))))	=B136/231
137	128	=12*60*((72^2*ACOS(1-A137/72))-((72-A137)*SQRT(A137*(2*72-A137))))	=B137/231
138	129	=12*60*((72^2*ACOS(1-A138/72))-((72-A138)*SQRT(A138*(2*72-A138))))	=B138/231
139	130	=12*60*((72^2*ACOS(1-A139/72))-((72-A139)*SQRT(A139*(2*72-A139))))	=B139/231
140	131	=12*60*((72^2*ACOS(1-A140/72))-((72-A140)*SQRT(A140*(2*72-A140))))	=B140/231
141	132	=12*60*((72^2*ACOS(1-A141/72))-((72-A141)*SQRT(A141*(2*72-A141))))	=B141/231
142	133	=12*60*((72^2*ACOS(1-A142/72))-((72-A142)*SQRT(A142*(2*72-A142))))	=B142/231
143	134	=12*60*((72^2*ACOS(1-A143/72))-((72-A143)*SQRT(A143*(2*72-A143))))	=B143/231
144	135	=12*60*((72^2*ACOS(1-A144/72))-((72-A144)*SQRT(A144*(2*72-A144))))	=B144/231
145	136	=12*60*((72^2*ACOS(1-A145/72))-((72-A145)*SQRT(A145*(2*72-A145))))	=B145/231
146	137	=12*60*((72^2*ACOS(1-A146/72))-((72-A146)*SQRT(A146*(2*72-A146))))	=B146/231
147	138	=12*60*((72^2*ACOS(1-A147/72))-((72-A147)*SQRT(A147*(2*72-A147))))	=B147/231
148	139	=12*60*((72^2*ACOS(1-A148/72))-((72-A148)*SQRT(A148*(2*72-A148))))	=B148/231
149	140	=12*60*((72^2*ACOS(1-A149/72))-((72-A149)*SQRT(A149*(2*72-A149))))	=B149/231
150	141	=12*60*((72^2*ACOS(1-A150/72))-((72-A150)*SQRT(A150*(2*72-A150))))	=B150/231
151	142	=12*60*((72^2*ACOS(1-A151/72))-((72-A151)*SQRT(A151*(2*72-A151))))	=B151/231
152	143	=12*60*((72^2*ACOS(1-A152/72))-((72-A152)*SQRT(A152*(2*72-A152))))	=B152/231
153	144	=12*60*((72^2*ACOS(1-A153/72))-((72-A153)*SQRT(A153*(2*72-A153))))	=B153/231

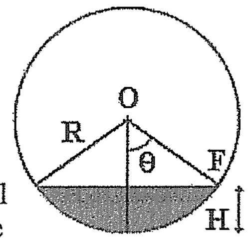
	D	E	F
1	LIA-1400	Percentage	
2	Percentage	of tank used	
3	Reading	%	
136	=((A136-9.5)/137)*100	=(B136/11725931.7)*100	
137	=((A137-9.5)/137)*100	=(B137/11725931.7)*100	
138	=((A138-9.5)/137)*100	=(B138/11725931.7)*100	
139	=((A139-9.5)/137)*100	=(B139/11725931.7)*100	
140	=((A140-9.5)/137)*100	=(B140/11725931.7)*100	
141	=((A141-9.5)/137)*100	=(B141/11725931.7)*100	
142	=((A142-9.5)/137)*100	=(B142/11725931.7)*100	
143	=((A143-9.5)/137)*100	=(B143/11725931.7)*100	
144	=((A144-9.5)/137)*100	=(B144/11725931.7)*100	
145	=((A145-9.5)/137)*100	=(B145/11725931.7)*100	
146	=((A146-9.5)/137)*100	=(B146/11725931.7)*100	
147	=((A147-9.5)/137)*100	=(B147/11725931.7)*100	
148	=((A148-9.5)/137)*100	=(B148/11725931.7)*100	
149	=((A149-9.5)/137)*100	=(B149/11725931.7)*100	
150	=((A150-9.5)/137)*100	=(B150/11725931.7)*100	
151	=((A151-9.5)/137)*100	=(B151/11725931.7)*100	
152	=((A152-9.5)/137)*100	=(B152/11725931.7)*100	
153	=((A153-9.5)/137)*100	=(B153/11725931.7)*100	

Tank T-10A Fuel Oil Sample
Specific Gravity

	Date	Time	System	Unit	Specific Grav
	1/7/2003	9:00:00 AM	T-10A	1	0.854
	2/3/2003	9:30:00 AM	T-10A	1	0.86
	3/4/2003	9:40:00 AM	T-10A	1	0.86
	3/25/2003	1:30:00 PM	T-10A	1	0.86
	4/3/2003	10:00:00 AM	T-10A	1	0.862
	4/29/2003	6:40:00 AM	T-10A	1	0.86
	5/28/2003	10:05:00 AM	T-10A	1	0.86
	6/25/2003	10:15:00 AM	T-10A	1	0.855
	7/2/2003	9:08:00 AM	T-10A	1	0.867
	7/23/2003	2:10:00 AM	T-10A	1	0.862
	8/20/2003	6:00:00 AM	T-10A	1	0.86
	9/17/2003	10:05:00 AM	T-10A	1	0.862
	10/15/2003	10:26:00 AM	T-10A	1	0.86
	11/12/2003	6:00:00 AM	T-10A	1	0.858
	12/10/2003	9:45:00 AM	T-10A	1	0.862
	1/7/2004	11:15:00 AM	T-10A	1	0.86
	1/14/2004	3:45:00 PM	T-10A	1	0.865
	2/4/2004	11:45:00 AM	T-10A	1	0.86
	3/3/2004	9:00:00 AM	T-10A	1	0.862
	3/31/2004	9:32:00 AM	T-10A	1	0.86
	4/29/2004	8:40:00 AM	T-10A	1	0.858
	5/26/2004	9:40:00 AM	T-10A	1	0.86
	6/23/2004	8:30:00 AM	T-10A	1	0.858
	7/1/2004	12:14:00 PM	T-10A	1	0.86
	7/20/2004	9:40:00 AM	T-10A	1	0.86
	8/18/2004	11:25:00 AM	T-10A	1	0.858
	9/15/2004	8:00:00 AM	T-10A	1	0.866
	10/11/2004	11:00:00 AM	T-10A	1	0.864
	11/10/2004	9:15:00 AM	T-10A	1	0.856
	11/10/2004	2:50:00 PM	T-10A	1	0.86
	12/8/2004	12:15:00 PM	T-10A	1	0.857
	1/4/2005	1:50:00 PM	T-10A	1	0.862
	2/1/2005	10:30:00 AM	T-10A	1	0.858
	3/2/2005	10:30:00 AM	T-10A	1	0.86
	3/28/2005	10:00:00 AM	T-10A	1	0.86
	4/25/2005	12:00:00 PM	T-10A	1	0.862
	5/23/2005	11:00:00 AM	T-10A	1	0.86
	5/23/2005	11:01:00 AM	T-10A	1	0.864
	6/20/2005	10:45:00 AM	T-10A	1	0.858
	7/18/2005	9:50:00 AM	T-10A	1	0.854
	8/15/2005	9:30:00 AM	T-10A	1	0.856
	9/13/2005	2:15:00 PM	T-10A	1	0.855
	10/11/2005	8:40:00 AM	T-10A	1	0.856
	11/7/2005	10:35:00 AM	T-10A	1	0.86
	12/2/2005	12:55:00 PM	T-10A	1	0.86
	1/6/2006	2:00:00 AM	T-10A	1	0.862
	1/6/2006	2:01:00 AM	T-10A	1	0.863
	2/6/2006	10:25:00 AM	T-10A	1	0.862
	3/6/2006	8:45:00 AM	T-10A	1	0.861
	4/3/2006	7:30:00 AM	T-10A	1	0.86
	5/8/2006	10:00:00 AM	T-10A	1	0.86

	6/5/2006	10:00:00 AM	T-10A	1	0.863	
	6/5/2006	10:01:00 AM	T-10A	1	0.864	
	7/5/2006	9:10:00 AM	T-10A	1	0.864	
	8/8/2006	1:15:00 PM	T-10A	1	0.862	
	9/5/2006	12:00:00 PM	T-10A	1	0.859	
	10/3/2006	9:15:00 AM	T-10A	1	0.856	
	11/6/2006	10:30:00 AM	T-10A	1	0.858	
	11/20/2006	10:55:00 AM	T-10A	1	0.862	
	12/4/2006	9:00:00 AM	T-10A	1	0.861	
	1/8/2007	10:00:00 AM	T-10A	1	0.856	
	2/5/2007	11:05:00 AM	T-10A	1	0.856	
	3/5/2007	11:00:00 AM	T-10A	1	0.865	
	4/2/2007	10:05:00 AM	T-10A	1	0.856	
	5/7/2007	10:15:00 AM	T-10A	1	0.854	
	6/4/2007	8:35:00 AM	T-10A	1	0.858	
	7/2/2007	11:05:00 AM	T-10A	1	0.852	
	8/6/2007	11:40:00 AM	T-10A	1	0.852	
	9/4/2007	7:40:00 PM	T-10A	1	0.848	
	10/3/2007	9:35:00 AM	T-10A	1	0.851	
	11/5/2007	11:00:00 AM	T-10A	1	0.848	
	12/3/2007	11:00:00 AM	T-10A	1	0.848	
	1/7/2008	9:40:00 AM	T-10A	1	0.846	
	2/4/2008	10:00:00 AM	T-10A	1	0.845	

schmeelke (2002-01-27)
If I know the dimensions of a cylindrical tank *on its side* [the axis of revolution is horizontal] and can measure the depth of the liquid inside, how do I calculate the volume of liquid present?



Let R be the radius of the tank, L its length and H the height of the liquid in it. Consider a (circular) vertical cross-section of the tank and call θ the angle (from the center O of the circle) between the vertical and the line OF, where F is one of the two points where the horizontal line representing the surface of the liquid meets the circle representing the wall of the tank [see figure at right].

We clearly have R-H = R cos(θ), which means θ is equal to arccos(1-H/R) and is thus readily obtained using the proper inverse trigonometric function on a scientific caculator. [Angle θ must be expressed in *radians* and is thus between 0 and π; don't forget to multiply a result in *degrees* by π/180, if applicable.]

The surface area corresponding to the liquid in that cross section is obtained as the difference of areas between a circular sector (a pie portion) and a triangle, namely $\theta R^2 - (R-H)\sqrt{(H(2R-H))}$. Just multiply this area by the tank's length L to obtain the formula for the volume V of the liquid in the tank, namely:

$$V = L [R^2 \arccos(1-H/R) - (R-H)\sqrt{(H(2R-H))}]$$

This formula is perfectly valid for the whole range of H (from 0 to 2R), although the above "visual" explanation (involving the "difference of two areas") assumed that H was less than R (tank at most half-full). The formula could have been obtained symbolically without splitting cases. I'll leave it up to you to "visualize" the other case (where the area of a circular sector is to be added to that of a triangle of height H-R), should you feel the urge to do so.

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:

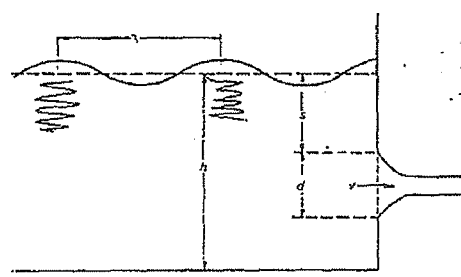


Fig. 1. Definition sketch of an intake

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

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:

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

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

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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:

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

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:

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

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

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

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:

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

Eq. (6) reduces to the form (Eq. 5) given by Gordon, with the value of $c = 0·176$ and 0·319 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 prevention the critical submergence should always be greater than the Froude number.

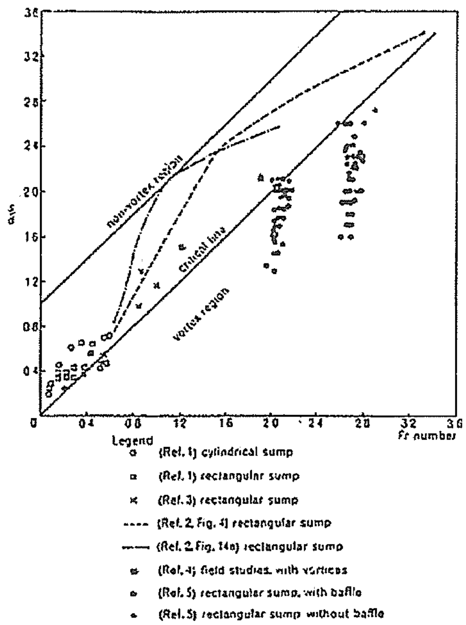


Fig. 2. Critical submergence dependence on Fr number

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).

25

Determine Zero Level Indication Level for LT-1400

As documented in Condition Report CR-PLP-2008-01496 (Ref. 7.27) a dimensional discrepancy was identified that brought into question what level in Tank T-10A corresponds to the zero % level indication for LT-1400. Per reference 7.14, existing setpoints were based on the zero point being 6 inches above the bottom of the tank. On page 2 is a depiction of the level probe configuration of Level Transmitter LT-1400 within Diesel Fuel Oil Storage Tank T-10A.

In order to determine the actual zero point location, the distance from the Tank T-10A mounting flange to the strike plate at the bottom of the tank was measured under Work Request WR00124879 using the fuel oil level dipstick. Based on that measurement the zero point location is determined as follows:

First, determine distance from the bottom of LT-1400 mounting flange to inside bottom of T-10A. That distance is equal to the distance measured from the T-10A flange to the strike plate (207 9/16") + the thickness of the strike plate (3/8" Ref. 7.3 Sht 3) + the flange gasket thickness (1/8") + the height of the raised face on the T-10A mounting flange (1/16" Ref. 7.25).

= 207 9/16" + 3/8" + 1/8" + 1/16" = 208 1/8"

Next determine the distance from the bottom end of LT-1400 to the bottom of T-10A. Per Ref. 7.15 the length of LT-1400 level probe from the underside of its mounting flange to the end of the probe shaft is 205 3/8". Therefore, the distance from the bottom end of LT-1400 to the tank bottom is:

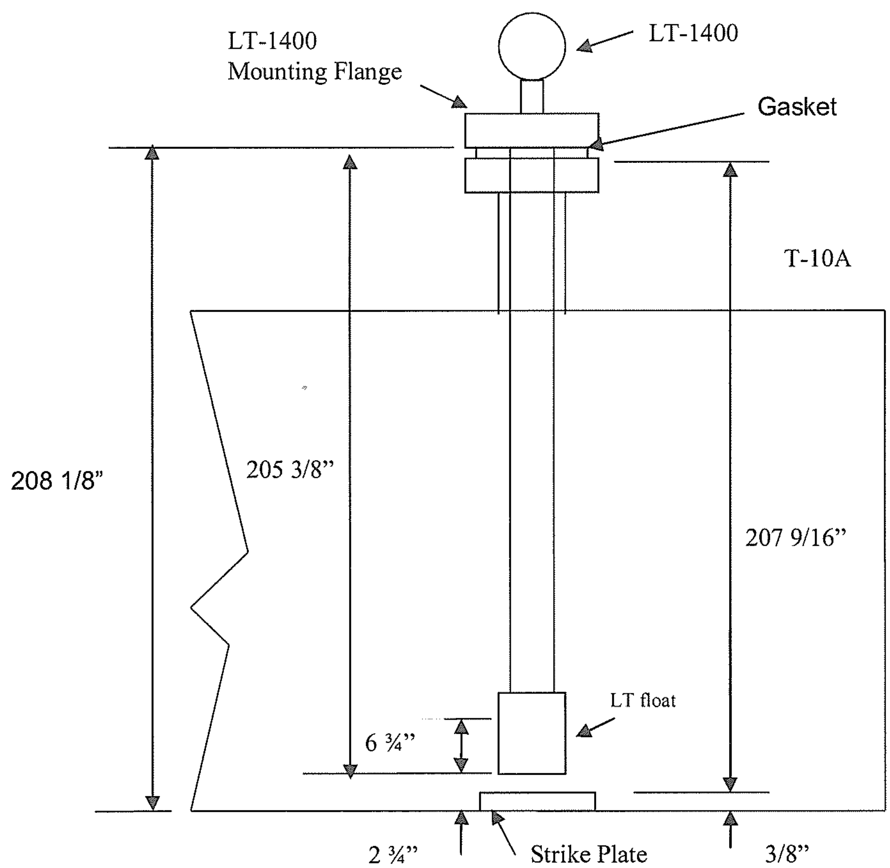
= 208 1/8" – 205 3/8" = 2 ¾"

Finally, the zero point dimension is determined by adding the distance the bottom of the probe is above the tank bottom to the probe's "Float Factor". The "Float Factor" is the minimum distance above the bottom of the probe where the probe begins indicating level. For LT-1400 the "Float Factor" dimension is 6 ¾"(Ref.7.15)
Therefore the zero point dimension is:

= 2 ¾" + 6 ¾" = **9 ½"** above the inside bottom of Tank T-10A

References per Section 7 in main body of calculation

Configuration of LT-1400 Within Tank T-10A



References per Section 7 in main body of calculation

Validation of Adequate Available Net Positive Suction Head ($NPSH_A$) for Diesel Fuel Oil Transfer Pumps P-18A/18B

Attachment 4 of Ref. 7.9 assessed whether the available Net Positive Suction Head was adequate to meet the NPSH requirements of the Fuel Oil Transfer Pumps P-18A and P-18B. The assessment evaluated the worst case condition of maximum pump flow at minimum Tank T-10 level. That worst case is when T-10A level is 6", while pump P-18A is supplying Tank T-24.

The NPSH assessment performed in Attachment 4 of Ref. 7.9, was based on a non-conservative value for the flow loss for the foot valve with strainer in the fuel oil transfer pumps suction piping. The flow losses were based on a resistance coefficient value or "K" value of 0.7 for the foot valve. A more appropriate K value for this poppet style foot valve with strainer is 8.82 as described below. The foot valve model information is shown on Ref. 7.12.

Below is an assessment of NPSH for the Fuel Oil Transfer Pumps using the larger K value for the foot valve. The below assessment uses the same methodology and inputs as the assessment in Attachment 4 of Ref. 7.9, with the following exceptions: larger K value for foot valve flow resistance; corrected T-10A level elevation and a diesel fuel oil specific gravity of 0.83 vs.0.86.

Ref. 7.13, Pg. A-28, provides the Resistance Coefficient "K" for a foot valve with strainer (poppet style) as $K = 420 f_T$. The "K" value is for a single poppet foot valve, whereas the foot valve in Tank T-10A is a double poppet valve. Although the type of valve differs slightly, the K value provided in Ref. 7.13 is the best available value based on a search of published flow resistance coefficient information. The difference in flow resistance between single and double poppet foot valve is assumed to be small.

$f_T = 0.021$ for 1.5" pipe per Ref. 7.13 Pg. A-26

Therefore, K = 420 (0.021) = 8.82

The K value of 8.82 is for 1.5" pipe. The equivalent K value for 3" pipe properties in terms of 1.5" pipe needs to be computed since the Ref. 7.9 flow model is in terms of the 3" pipe. The following relationship is used to calculate the equivalent K value for 3" pipe in terms of 1.5" pipe (Ref. 7.13, Equation 3-24, Pg. 3-5))

$$K_a = K_b\left(\frac{d_a}{d_b}\right)^4$$

$$K_{3"} = 8.82\left(\frac{3.068}{1.5}\right)^4 = 154.4$$

References per Section 7 in main body of calculation

Next, compute friction head loss for foot valve (Ref. 7.13, Equation 3-14, Pg. 3-4)

$$h_l = K\frac{v^2}{2g}$$

From Ref. 7.9, Att. 7 pg. 46, the fluid velocity for the worst case condition = 1.283 ft/sec

Therefore, $h_l = 154.4\frac{(1.283 ft/\sec)^2}{2(32.2 ft/\sec^2)}$ = 3.95 ft

Next, using the friction head loss value calculated above, compute the total friction head loss in the suction line.

From Attachment 4 of Ref. 7.9 the suction line friction losses are equal to the total of the losses in the 3 piping segments designated s0002, s0003 and PS. The total suction line friction losses using the original loss value for the foot valve was 6.71 ft.

To determine the total suction line friction losses considering the increased foot valve losses, the friction loss using the original foot valve K value will be subtracted from the total loss and then the new (larger) loss value for the foot valve will be added.

Calculate friction head loss for foot valve based on original (low) K value (Ref. 7.9 Att. 5):

$$h_l = 12.25\frac{(1.283 ft/\sec)^2}{2(32.2 ft/\sec^2)} = 0.31 \text{ ft}$$

Then, total suction line friction head loss with revised foot valve losses becomes:

h_{fa} = 3.851 + 0.364 + 2.49 -0.31 + 3.95 = 10.35 ft

Next, compute the total Net Positive Suction Head Available , $NPSH_A$

Per Ref. 7.9 Att. 4 , $NPSH_A = h_a - h_{vpa} - h_{st} - h_{fa}$

Where;

h_a :	pressure in Tank T-10A (expressed as head, feet)
h_{vpa}:	vapor pressure of No. 2 diesel fuel at 60 °F (feet)
h_{st} :	static head between T-10A and pump suction (feet)
h_{fa} :	friction losses in suction line (feet)

References per Section 7 in main body of calculation

h_a = 14.696 psia / ($\gamma\rho$/144) (Atmospheric pressure converted to feet of head)
where γ is specific gravity of diesel fuel
ρ is density of water at 60 °F

= 14.696 psia / (0.83 x 62.4 lbs/ft^3 / 144)
= 40.86 ft

$h_{vpa:}$ = 0.52 ft (from Ref. 7.9 Att. 4, conservatively assumes vapor pressure at 60 °F is equal to the maximum value at 100 °F)

h_{st} = 14.28 ft (Att. 4 of Ref. 7.9 used a value of 14.79' for h_{st}, which was based on T-10A fuel level of 6" above tank bottom as being at an elevation of 577'. The 6" level is actually at 577'-6 1/8" or 577.51' (Ref. 7.26)

h_{fa} = 3.851 ft. (calculated above)

$NPSH_A$ = 40.86 – 0.52 – 14.28 - 10.35 = 15.71 ft

From Ref. 7.9 Att. 4 the Net Positive Suction Head Required, $NPSH_R$, for the transfer pumps is 12.2 ft at a specific gravity of 1 (γ = 1). The pump's $NPSH_R$ for diesel fuel oil with a specific gravity of 0.83 is determined as follows:

$NPSH_{R\ (\gamma = 0.83)} = NPSH_{R\ (\gamma = 1.0)}$ (1/0.83)
= 12.2 ft (1/0.83)
= 14.7 ft

Therefore, NPSH Margin = $NPSH_A$ - $NPSH_R$

= 15.71 ft – 14.7 ft = 1.01ft

References per Section 7 in main body of calculation

Current licensing basis EDG fuel oil storage requirements are based on the fuel consumption values determined in calculation EA-A-NL-92-337-01 (Ref 7.19*). The volume of fuel needed to operate one EDG for 7 Days, was calculated in EA-A-NL-92-337-01 based upon a specific load profile and utilized a fuel oil specific gravity value of 0.852.

To assess whether the current design basis EDG fuel oil storage requirements are conservative, they will be compared to a limiting case that uses the same load profile, but assumes a worst case minimum fuel oil specific gravity value of 0.815 and includes an increase in unusable fuel in Tank T-10A to account for required submergence for the fuel oil transfer suction line to prevent air entrainment vortexing. A specific gravity of 0.815 can be considered as worst case since it is currently the lowest allowable value per COP-22A (Ref 7.20).

Table A below gives EDG fuel consumption values based on the same load profile used in EA-A-NL-92-337-01, but using the worst case fuel specific gravity of 0.815 vs 0.852 that was used in EA-A-NL-92-337-01. In order to calculate fuel consumption rates in gals/hr, the fuel specific gravity was converted to density using the same methodology employed in Section 6.2 of the main calculation. Fuel density at a sg of 0.815 = 6.79 lbm/gal.

Table A
EDG Fuel Consumption Based on Load Profile from EA-A-NL-92-337-01
@ a fuel Specific Gravity of 0.815

Time - hours (elapsed)	0.67	0.8	3.16	8	24	100	144	168 (7 Days)
Kw	2808.89	2572.46	2444.56	2302.96	2168.76	2168.76	2035.56	2035.56
lbm/hr	1400.162	1271.731	1206.204	1138.855	1075.025	1075.025	1011.671	1011.671
gal/hr	206.2094	187.2947	177.6442	167.7253	158.3247	158.3247	148.9943	148.9943
gal used (.815 sg)	138.1603	24.34831	419.2403	811.7906	2533.196	12032.68	6555.747	3575.862
gal used cumulative (.815 sg)	138.1603	162.5086	581.7489	1393.54	3926.735	15959.42	22515.16	26091.03

Next, the required storage volume is determined by adding the 7 Day EDG fuel consumption quantity from Table A above to the unusable fuel volume in Tank T-10A. The unusable fuel volume was determined to be 1777 gallons per Section 6.5 of the main calculation body.

Therefore, the quantity of stored fuel needed to meet the 7day EDG operating time requirement at 0.815 sg is = 26091 gal + 1777 gal = <u>27868 gal</u>

*References per Section 7 in main body of calculation

To determine whether the current design basis EDG fuel oil storage requirement is conservative it will be compared to the limiting case required volume of 27868 gals. calculated above.

The current licensing basis 7 Day fuel quantity compliance value for Tank T-10A is 53.77% level indication. As calculated per Ref. 7.14, the 53.77% level indication, with indicator error taken into account, equates to a stored volume of 26925 gallons in T-10A. As discussed in Attachment 8.7 of the main body of the calculation, the Tank T-10A level setting information calculated in Ref. 7.14 was based on the zero % indication being at 6" above tank bottom, but should have been based on the zero point being 9.5" above tank bottom. Therefore, the actual fuel level in tank T-10A at 53.77% indication will be 3.5" greater (9.5"- 6") than calculated in Ref. 7.14, resulting in a conservative stored fuel volume, i.e. more stored fuel volume than was credited.

From Table B below, the fuel volume in Tank T-10A at 53.77% indication adjusted for the 3.5" level zero shift is 28634 gals. The methodology and equations used in Table B are the same as used to compute volumes and levels in Table 8.2 of the main calculation.

Adding the quantity of fuel stored in the EDG day tank of 2500 gallons, to the T-10A volume at 53.77%, gives a total stored volume of 28634 + 2500 = 31134 gallons.

Next, compare the total stored volume to the Limiting case required volume:

Total Stored volume 31134 gal. > Limiting Case required volume 27868 gal.

Margin is 31134 gal – 27868 gal = 3266 gal.

Table B

Distance from bottom of tank h (in)	Volume cu-in	Gallons	LIA-1400 Percentage Reading	Percentage of tank used %
79	6587580.91	28517.67	50.73	56.18
79.26	6614405.20	28633.79	50.92	56.41
80	6690696.03	28964.05	51.46	57.06
81	6793650.15	29409.74	52.19	57.94
82	6896422.83	29854.64	52.92	58.81
83	6998993.54	30298.67	53.65	59.69
83.16	7015384.74	30369.63	53.77	59.83
84	7101341.63	30741.74	54.38	60.56
85	7203446.31	31183.75	55.11	61.43
86	7305286.62	31624.62	55.84	62.30

*References per Section 7 in main body of calculation

ATTACHMENT 6

FUEL OIL TRANSFER PUMP P-18A
ALLOWED OUTAGE TIME COMPUTATION

Engineering Change (EC) Reply 12118

EC Reply Title: Diesel Generator Day Tank Duration Computation

3 pages follow

Engineering Change	Print Date: 03/29/2010
EC Number : 0000012118 000 Status/Date : CLOSED 12/10/2008 Facility : PLP Type/Sub-type: RPLY	Entergy Page: 1

EC Title: DIESEL GENERATOR DAY TANK DURATION COMPUTATION

Mod Nbr : KW1: N KW2: N KW3: N KW4: Y KW5:

Master EC :	N	Work Group :		Temporary :	N
Outage :	N	Alert Group:	DESMECH	Aprd Reqd Date:	12/05/2008
WO Required :	N	Image Addr :		Exp Insvc Date:	
Adv Wk Appvd:		Alt Ref. :		Expires On :	12/10/2010
Auto-Advance:	Y	Priority :		Auto-Asbuild :	N
Caveat Outst:		Department :		Discipline :	
Resp Engr :	JEFFREY		ERICKSON		
Location :					

Milestone	Date	PassPort	Name		Req By
10-EC PREPARED	12/01/2008	JERICKS	ERICKSON	JEFFREY	H/APPR
20-EC REVIEWED	12/02/2008	DDEPUYD	DEPUYDT	DANIEL	APPROVED
30-EC APPROVED	12/10/2008	MNORDIN	000NORDIN	MICHAEL	APPROVED

Engineering Change Comments

Comments Last Updated By: **JERICKS** Last Updated Date: **12/10/2008**

This EC supported a compensatory measure implemented under CR-PLP-2008-04708 concerning the allowed outage time for fuel oil transfer pump P-18A. The allowed outage time for P-18A is based on the amount of time a diesel generator can be operated with required 2500 gallons in a fuel oil day tank.

JSErickson
12/2/08

Engineering Change Reply
EC12118

Description

The computation below determines how long an emergency diesel generator can be operated under design loading conditions with 2500 gallons of fuel oil.

Condition Report CR-PLP-2008-04708 documented that the fuel consumption rate used to establish the 15 hour allowed outage time for diesel fuel oil transfer pump P-18A in Technical Specification 3.8.3 was non-conservative. The 15 hour allowed outage time was established based on the time that an emergency diesel generator can be operated on the 2500 emergency diesel generator day tank inventory required by Technical Specification Surveillance Requirement SR 3.8.1.4 and assuming a fuel oil consumption rate of 2.6 gpm. Since the assumed fuel consumption rate was found to be non-conservative, the actual time that an emergency diesel generator can be operated on 2500 gallons is less than 15 hours.

This computation is being performed to establish an allowed outage time for P-18A based on the duration that an emergency diesel generator can operate on 2500 gallons of fuel under design loading conditions using an appropriate fuel oil consumption rate.

Assumptions

Fuel oil specific gravity is assumed to be at its procedurally minimum value of 0.815 (Ref: 1).

Diesel generator is operating under design loading conditions (2750 kW for two hours and 2500 kW afterward).

Fuel temperature is assumed to be 60°F. Water density at this temperature is 62.371 lbm/ft^3. This is consistent with EA-EC6432-01 (Ref. 2).

References

1. Chemistry Operating Procedure COP-22A, "Diesel Fuel Oil Testing Program", Revision 9.
2. EA-EC6432-01, "Palisades Emergency Diesel Generator Fuel Oil Storage Requirements", Revision 0.

Computation

Fuel consumption rates are obtained from the original vendor test data which provides fuel consumption in lbm/hr at various loads (Ref. 2). The fuel consumption rates for emergency diesel generator 1-2 were highest and are used in this computation. The data is repeated below:

Kilowatts	Fuel Consumed, lbm/hr
600	350
1330	671
1908	951
2503	1234
2827	1410

Fuel consumption at 2750 kW and 2500 kW is determined by interpolation from this table.

At 2750 kW:

$$\frac{2750\text{ kW} - 2503\text{ kW}}{2827\text{ kW} - 2503\text{ kW}}(1410\text{ lbm/hr} - 1234\text{ lbm/hr}) + 1234\text{ lbm.hr} = 1368.17\text{ lbm/hr}$$

At 2500 kW:

$$\frac{2500\text{ kW} - 1908\text{ kW}}{2503\text{ kW} - 1908\text{ kW}}(1234\text{ lbm/hr} - 951\text{ lbm/hr}) + 951\text{ lbm.hr} = 1232.57\text{ lbm/hr}$$

Fuel consumption is converted from lbm/hr to gal/hr as follows:

At 2750 kW: $(1368.17\text{ lbm/hr})(1/(62.371\text{ lbm/ft}^2)(0.815))(7.48\text{ gal/ft}^3) = 201.3\text{ gal/hr}$

At 2500 kW: $(1232.57\text{ lbm/hr})(1/(62.371\text{ lbm/ft}^2)(0.815))(7.48\text{ gal/ft}^3) = 181.37\text{ gal/hr}$

2500 gal = (2 hours)(201.3 gal/hr) + (T – 2)(181.37 gal/hr)

T = 13.5 hours

Conclusion

Based on the above, a diesel generator can be operated with 2500 gallons under design loading conditions for 13.5 hours. A conservative allowed outage time for the diesel fuel oil transfer pump P-18A is 12 hours.