Entergy

Entergy Nuclear Northeast
Entergy Nuclear Operations, Inc.
James A. Fitzpatrick NPP
P.O. Box 110
Lycoming, NY 13093
Tel 315 349 6024 Fax 315 349 6480

Pete Dietrich
Site Vice President - JAF

August 27, 2008
JAFP-08-0086

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Subject: **Entergy Nuclear Operations, Inc.**
James A. FitzPatrick Nuclear Power Plant
Docket No. 50-333
License No. DPR-59

James A. FitzPatrick Nuclear Power Plant – Response to Request For Additional Information Regarding: Application for Amendment to Technical Specifications Regarding Diesel Fuel Oil, Lube Oil, and Starting Air Consistent with TSTF-501 and Diesel Fuel Oil Testing Program Consistent with TSTF-374 (TAC No. MD7927)

References:
1) Entergy Letter, JAFP-08-0006, Application for Amendment to Technical Specifications Regarding Diesel Fuel Oil, Lube Oil, and Starting Air Consistent with TSTF-501 and Diesel Fuel Oil Testing Program Consistent with TSTF-374 (TAC No. MD7927), dated January 22, 2008

2) Telephone Conference with Robert Wolfgang and Bhalchandra Vaidya on August 7, 2008

3) Telephone Conference with Robert Wolfgang, Khris Tarsczewski, and Bhalchandra Vaidya on August 12, 2008

Dear Sir or Madam:

Entergy Nuclear Operations, Inc. (ENO), as operator of the James A. FitzPatrick Nuclear Power Plant (JAF), hereby submits this response to the NRC's Request for Additional Information (RAI) received via teleconferences (References 2 and 3) regarding JAF's Application for Amendment to Technical Specifications Regarding Diesel Fuel Oil, Lube Oil, and Starting Air Consistent with TSTF-501 and Diesel Fuel Oil Testing Program Consistent with TSTF-374 (Reference 1).

There is one new commitment made in this letter and it is summarized in Attachment 4.

This letter does not affect the "No Significant Hazards" determination made in Reference 1.

A001
NRR

Should you have any questions concerning this letter, please contact Mr. Gene Dorman, Senior Lead Engineer, at (315) 349-6810.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on the 27th day of August, 2008.

Respectfully,

Pete Dietrich
Site Vice President

Attachments:
1. Response to RAI Questions
2. Calculation JAF-CALC-07-00020 Rev. 0, Revised Emergency Diesel Generator (EDG) Fuel Oil Storage Quantities for 7 Day and 6 Day Supplies
3. Calculation JAF-CALC-06-00114 Rev. 1, EDG Ultra Low Sulfur Fuel Oil Calculations
4. List of Commitments

cc:

Mr. Samuel J. Collins
Regional Administrator, Region I
U. S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406-1415

Office of Resident Inspector
James A. FitzPatrick Nuclear Power Plant
U. S. Nuclear Regulatory Commission
P. O. Box 136
Lycoming, New York 13093

Mr. Paul Eddy
New York State Department of
Public Service
3 Empire State Plaza
Albany, New York 12223-1350

Mr. Bhalchandra Vaidya, Project Manager
Plant Licensing Branch I-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Mail Stop O-8-G14
Washington, DC 20555-0001

Mr. Paul Tonko, President
New York State Energy Research
and Development Authority
17 Columbia Circle
Albany, New York 12203-6399

ATTACHMENT 1 to JAFP-08-0086

Entergy Nuclear Operations, Inc.
James A. FitzPatrick Nuclear Power Plant

Response to RAI Questions

ATTACHMENT 1 to JAFP-08-0086

Questions from Component Performance and Testing Branch

RAI Question:

1) "On Page 3 of 9 of Attachment 1, it is stated that "The fuel consumption calculation was performed assuming the worst parameter values allowed by the diesel fuel oil sampling program." ULSD fuel can have an API gravity as high as 42. What API gravity value was used in your fuel consumption calculation?"

Response:

Surveillance Requirement Bases 3.8.3.3 limits API gravity to 39 (range of 27 to 39). The JAF Fuel Oil Program requires sampling of fuel oil at the time of receipt. Portions of the fuel oil analysis are required to be complete prior to allowing fuel to be added to the fuel oil storage tanks. The test for API gravity is one of the initial acceptance tests, fuel oil with an API gravity greater that 39 would be rejected. Therefore, API gravity values of 27 – 39 were used in JAF-CALC-07-00020 Rev. 0.

RAI Question:

2) "On Page 5 of 9 of Attachment 1, it is stated that "The 7 day supply was calculated for API Gravity Values over the range allowed by ASTM-D975-95." Please provide a copy of ASTM-D975-95, indicating the specific location of the allowable API gravity range referenced."

Response:

The source of the API Gravity Range was misstated in Reference 1. Appendix C of ANSI/ANS-59.51 provides the API Gravity Range used as acceptance criteria for receiving fuel. This range is also specified in JAF's Technical Specification Bases for Surveillance Requirement 3.8.3.3.

RAI Question:

3) "Please submit your fuel consumption calculation and calculation JAF-CALC-07-00020, Revised Emergency Diesel Generator (EDG) Fuel Oil Storage Quantities for 7 Day and 6 Day Supplies."

Response:

JAF-CALC-07-00020 Revision 0, "Revised Emergency Diesel Generator (EDG) Fuel Oil Storage Quantities for 7 Day and 6 Day Supplies" is supplied as Attachment 2 to this correspondence. This calculation includes the information related to fuel consumption.

RAI Question:

4) "On Page 6 of 9 of Attachment 1, it is stated that "The specific volume of lube oil equivalent to a 7 and 6 day supply is based on the Emergency Diesel Generator (EDG) manufacturer's consumption values for the run time of the EDG." Please confirm that these volumes are for a lube oil that the EDG manufacturer has confirmed is compatible with ULSD fuel."

Response:

JAF has confirmed with EMD (the diesel engine manufacturer) that the lube oil in use at JAF is not affected by the use of ULSD fuel oil and the volume for a 7-day and 6-day supply is unchanged.

RAI Question:

5) "Tables B3.8.3-1 and B3.8.3-2 provide 7-day and 6-day (respectively) fuel oil storage tank quantities for API gravity values of 27, 30, 33, 36, and 39. If the API gravity of the fuel in a storage tank is in between these values or above 39, how are the 7-day and 6-day storage quantities determined?"

Response:

The Diesel Fuel Oil Testing Program only allows acceptance of fuel oil with an API Gravity between 27 and 39. Therefore, the API gravity of fuel in the storage tanks cannot exceed 39. Linear interpolation of the information presented in Tables B3.8.3-1 and B3.8.3-2 will be used for determining fuel oil volumes when the actual API Gravity is between the values specified in the tables.

RAI Question:

6) "Surveillance Requirement 3.8.1.4 states "Verify each day tank contains 327 gal of fuel oil." Please confirm that the minimum quantity of 327 gallons pertains to ULSD fuel."

Response:

The 327 gallons of fuel oil specified as acceptance criteria in SR 3.8.1.4 does pertain to ULSD fuel.

Questions from Steam Generator Tube Integrity and Chemical Engineering Branch

RAI Question:

1) "2.0 Proposed Changes

   The licensee modified Surveillance Requirement (SR) 3.8.3.1 by changing the maximum amount of fuel in storage tank from volume (in gallons) to the amount required to operate the Emergency Diesel Generators for 7 days and have a 6-day supply in the storage tank. This modification required a revision to the bases of SR 3.8.3.1 by adding the volume equivalent of a 7-day supply, which is tabulated in B3.8.3-1 and was calculated using Regulatory Guide (RG) 1.137, Rev. 1 (1979) ANIS/ANS-59.51-1997, and JAF-CALC-07-00020. The licensee is asked to [Please] describe the specific methods and procedures used for calculating these values."

Response:

The specific methodology used in the calculation is documented in JAF-CALC-07-00020 Rev. 0 (Attachment 2).

RAI Question:

2) "TS 5.5.10 and 4.2 Diesel Fuel Oil Testing Program

   Currently, the standard test method for determining free water and particulate contamination in diesel fuel oil is the "Clear and Bright Method" (ASTM D4176) providing "a clear and bright appearance with proper color". However, this method has several disadvantages: it produces only subjective pass/fail results and it cannot be used with fuel oil having low light transmission due to either large amount of contaminants, or tinting used to specify the fuel oil grade (amount of sulfur). In order to overcome these shortcomings, the licensee proposes to modify the procedure by including one of the two additional tests for determining water and sediment content: ASTM D1796 or D2709. The modified procedure "will have a clear and bright appearance with proper color or water and sediment content within limits."

   Since the proposed procedure is more complex and requires additional testing, [Please provide the detailed information as to how the procedure would be implemented,] does the licensee plan to use the "Clear and Bright" method only when the anticipated contamination of fuel oil is low, and the modified procedure when the anticipated amount of the impurities is high?"

Response:

JAF will continue to use the "Clear and Bright" Test method as the preferred test method during diesel fuel oil receipt testing. The water and sediment testing would be used as a back-up method when a clear and bright test cannot be performed. Since the water and sediment test is not currently an approved test method for JAF, the equipment and procedures necessary to perform the testing are not available. JAF will obtain the appropriate test equipment and develop the necessary procedural guidance as part of the implementation of this amendment if approved. As documented in Attachment 4 to this letter the development of a water and sediment testing procedure in accordance with ASTM-D1796 or ASTM-D2709 is a commitment.

RAI Question:

3) "3.0 Background

In the submittal the licensee made a statement implying that removal of sulfur and aromatics from the fuel oil will have an insignificant effect as long as the API gravity does not change significantly. The licensee is asked to [Please] provide the basis for this statement."

Response:

The basis for the statement is documented in Calculation JAF-CALC-06-00114 Rev. 1 (Attachment 3).

ATTACHMENT 2 to JAFP-08-0086

Entergy Nuclear Operations, Inc.
James A. FitzPatrick Nuclear Power Plant

Calculation JAF-CALC-07-00020 Rev. 0,
Revised Emergency Diesel Generator (EDG) Fuel Oil Storage Quantities for 7 Day and 6 Day Supplies

ATTACHMENT 9.2 **ENGINEERING CALCULATION COVER PAGE**

Sheet 1 of 2

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

CALCULATION COVER PAGE	(1) **EC #** 3021	(2) **Page 1 of 10**
(3) Design Basis Calc. ☒ YES ☐ NO	(4) ☒ CALCULATION ☐ EC Markup	
(5) **Calculation No:** JAF-CALC-07-00020		(6) **Revision:** 0
(7) **Title:** Revised Emergency Diesel Generator (EDG) Fuel Oil Storage Quantities for 7 Day and 6 Day Supplies		
(8) **System(s):** 93	(9) **Review Org (Department):** Eng. (Design)	
(10) **Safety Class:** ☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	(11) **Component/Equipment/Structure Type/Number:** Tank 93TK-6A Tank 93TK-6C	Tank 93TK-6B Tank 93TK-6D
(12) **Document Type:** CALC		
(13) **Keywords (Description/Topical Codes):** EDG Fuel Oil Vortex submergence		

REVIEWS

(14) Name/Signature/Date	(15) Name/Signature/Date	(16) Name/Signature/Date
P. Swinburne/ P Swinburne 11/19/07	D. Burch/ David T. Burch 19 Nov 07	T. MOSKALYK / T Moskalyk (ACTING) 11/20/07
Responsible Engineer	☒ **Design Verifier** ☐ **Reviewer** ☐ Comments Attached	**Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET

CALCULATION NO: JAF-CALC-07-00020
REVISION: 0

I. EC Markups Incorporated
1. None
2.
3.

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. JAF-CALC-07-00019		0	☑	☐	Y	EC 3021
2.			☐	☐		
3.			☐	☐		
4.			☐	☐		
5.			☐	☐		

III. CROSS REFERENCES:

1. ASTM D 975 -06, Standard Specification for Diesel Fuel Oils
2. ASTM D 4868 -00 (Reapproved 2005), Standard Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels
3. EMD 20-645 E4 Fuel Consumption Curve (vendor data)
4.
5.

IV. SOFTWARE USED:

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

V. DISK/CDS INCLUDED:

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

VI. OTHER CHANGES:

See Evaluation EC 3021 for other changes as a result of this calculation.

ATTACHMENT 9.4 RECORD OF REVISION

Sheet 1 of 1

Revision	Record of Revision
0	Initial issue.

Table of Contents

Purpose

The objective of this calculation is to determine 7 day and 6 day Emergency Diesel Generator (EDG) Fuel Oil Storage quantities in light of the density (API gravity) and vortex critical submergence issues raised with CR-JAF-2007-02392 and CR-JAF-2007-02490. The basic method is similar to that used for the Operability Evaluations prepared for the related CRs except that a more appropriate critical submergence correlation has been employed (Attachment 1 provides a comparison of critical submergence correlations) and calculation JAF-CALC-07-00019 is used to determine unavailable volume.

Conclusion

The following tabulated results for API Gravity values and limiting quantities (page 9) will be used to support the proposed Technical Specification amendment. At limiting fuel conditions (API 39) the new 7-day quantities are 33898, 34226, 34153 and 34197 gallons and the new 6-day quantities are 29260, 29588, 29515 and 29560 gallons for the A, B, C and D EDGs, respectively.

Input and Design Criteria

1. Original Specification AP-9, Emergency Diesel Generator Systems.
2. JSEM-90-033, Systems Engineering Memo, Results of EDG Fuel Consumption Test (TST-7), June 19, 1990.
3. JAF Technical Specification Bases B 3.8.3 Diesel Fuel Oil, Lube Oil and Starting Air.
4. ASTM D 975 - 06, Standard Specification for Diesel Fuel Oils.
5. ASTM D 4868 - 00 (Reapproved 2005), Standard Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels.
6. Crane Technical Paper No. 410, Flow of Fluids through Valves, Fittings and Pipe
7. EMD 20-645 E4 Fuel Consumption Curve and related email from Jack Murray of Engine Systems Inc. (Kirby Corp.) (see attachments)
8. Potential Affects of the Use of Ultra Low Sulfur Diesel Fuel Oil on Engine Fuel Consumption, Revision 1, Fairbanks Morse Owners' Group, May 11, 2007.
9. MPR-2980, Revision 0, Evaluation of Ultra Low Sulfur Diesel Fuel for Use in EDGs, December 4, 2006.
10. Knauss, J., "Swirling Flow Problems at Intakes," IAHR Hydraulic Structures Design Manual, 1987.
11. EC Markup 551 to Calculation JAF-CALC-06-00114, Rev. 1.
12. Vendor Manual R374-C005, Series AM, AP and AL Pumps - Bulletin 1-83-9.
13. Drawing FV-17A, Rev. 4, No. 2 Fuel Oil Storage Tanks 93TK-6A, 6B, 6C, 6D.
14. Drawing FM-93A, Rev. 22, Flow Diagram Fuel Oil Lines Emergency Diesel Generators.
15. Calculation JAF-CALC-07-00019, Volume in EDG Underground Fuel Oil Storage Tanks as a Function of Level.

Assumptions

1. Assume limiting fuel conditions per D 975 for S500 fuel. EC Markup 551 showed that at the same API gravity S500 (low sulfur fuel oil) actually had a slightly lower heat content than S15 (ultra low sulfur fuel oil). Limiting conditions means the maximum sulfur, ash and moisture/ sediment contents permitted by D 975 as these factors all tend to reduce heat content.
2. Assume a temperature of 59° F or 15° C for underground stored fuel. This is the reference temperature for density used in D 4868 and this is reasonable for underground tanks. At depths below four feet ground temperatures stay at a constant 50 to 55° F year-round so density at 59° F is conservative.
3. Assume that the ASTM D 4868 method provides a good method to determine heat content in lieu of specific calorimeter testing. The method is supported by the Fairbanks Morse Owners' Group report (input 8).

Method of Analysis

This analysis will determine 7 day and 6 day gross volume of EDG diesel fuel based on API gravity with S500 (low sulfur diesel) fuel. The limiting sulfur content for S500 will be used as a conservatism since it will be a long time before existing sulfur levels are diluted to the S15 limit. The unusable fuel oil tank volume will include a vortex prevention submergence using the Chang 1979 correlation (as presented by Knauss). The unusable tank volume will be determined from calculation JAF-CALC-07-00019. The day tank volume will not be credited since the new Technical Specification requires that the entire 7 or 6 day supply be located within the underground storage tanks. The ASTM D 4868 method for heat content estimation will be used but will also include a 95% confidence interval (0.35 MJ/kg). The vendor provided specific fuel consumption curve (EMD 20-645 E4) will be used as basis for fuel consumption rate.

Calculations

Density of water (60° F), Crane 410 A-6... $\rho_w := 62.371 \frac{lb}{ft^3}$ $\rho_w = 0.9991 \frac{gm}{cm^3}$ Define unit.. $MJ := 10^6 \cdot joule$

Vector for API gravity (over range permitted in TS Bases)..

Specific gravity from TS API gravity range (from definition of API gravity)...

Density of oil for TS API gravity range (at 60 F)

$$API := \begin{pmatrix} 39 \\ 36 \\ 33 \\ 30 \\ 27 \end{pmatrix} deg \qquad SG := \frac{141.5deg}{API + 131.5deg} \qquad SG = \begin{pmatrix} 0.8299 \\ 0.8448 \\ 0.8602 \\ 0.8762 \\ 0.8927 \end{pmatrix} \qquad \rho_o := SG \cdot \rho_w \qquad \rho_o = \begin{pmatrix} 51.762 \\ 52.69 \\ 53.65 \\ 54.647 \\ 55.681 \end{pmatrix} \frac{lb}{ft^3}$$

Limiting sulfur, moisture and ash from ASTM D 975 for S500 (low sulfur diesel). Note that ASTM D 975 specifies moisture in percent volume. ASTM D 4868 requires moisture in percent mass.

$s := 0.0500\%$ Sulfur $\qquad x := \frac{0.05\%}{SG}$ Water and sediment $\qquad y := 0.01\%$ Ash

Note that the water and sediment is reported as percent volume vs. percent weight for D4868 thus divided by SG to correct (water has greater density so weight percentage will be greater than volume percentage). This correction effectively considers that the specific gravity of the water and sediment fraction is 1. While this will be true for water "sediment" may have a higher specific gravity. Since the fraction of both water and sediment is generally very low (usually much less than D 975 limit) this is reasonable.

Weight based water and sediment..

$$x = \begin{pmatrix} 0.06 \\ 0.059 \\ 0.058 \\ 0.057 \\ 0.056 \end{pmatrix} \%$$

Density (d) in D4868 is at 15° C or 59° F. From Crane 410, A-7 graph there is an approximate 3.9% increase in specific gravity or density for a 100 F° temperature decrease (applies between 0° F and 100° F). Thus the increase in density from 60° F to 59° F (15° C) is given by..

$$d := \left(1 + \frac{3.9\%}{100}\right)\cdot\rho_o$$

Relative Density (60/60 deg F) | Density (15 deg C)

$$API = \begin{pmatrix} 39 \\ 36 \\ 33 \\ 30 \\ 27 \end{pmatrix} deg \qquad SG = \begin{pmatrix} 0.8299 \\ 0.8448 \\ 0.8602 \\ 0.8762 \\ 0.8927 \end{pmatrix} \qquad d = \begin{pmatrix} 829.478 \\ 844.334 \\ 859.733 \\ 875.703 \\ 892.278 \end{pmatrix} \frac{kg}{m^3}$$

Gross heat content or HHV per D 4868 with 0.35 MJ/kg reduction for 95% confidence interval..

$$Q_v := \overrightarrow{\left[\left(51.916\cdot\frac{MJ}{kg} - 8.792\cdot\frac{J\cdot m^6}{kg^3}\cdot d^2\right)\cdot[1 - (x + y + s)] + 9.420\,\frac{MJ}{kg}\cdot s - 0.35\,\frac{MJ}{kg}\right]}$$

NOTE: Arrow in the above expression means to "vectorize" or apply operators and functions element-wise to the arrays under the arrow.

Volume basis

$$Q_v = \begin{pmatrix} 45.466 \\ 45.248 \\ 45.019 \\ 44.776 \\ 44.519 \end{pmatrix} \frac{MJ}{kg} \qquad \boxed{Q_v = \begin{pmatrix} 19547 \\ 19453.3 \\ 19354.5 \\ 19250.1 \\ 19139.6 \end{pmatrix} \frac{BTU}{lb}} \qquad Q_{v\_vol} := \overrightarrow{(Q_v\cdot d)} \qquad \boxed{Q_{v\_vol} = \begin{pmatrix} 135311 \\ 137074 \\ 138865 \\ 140681 \\ 142522 \end{pmatrix} \frac{BTU}{gal}}$$

Net heat content or LHV per D 4868 with 0.35 MJ/kg reduction for 95% confidence interval..

$$Q_p := \left[\left(46.423\cdot\frac{MJ}{kg} - 8.792\cdot\frac{J\cdot m^6}{kg^3}\cdot d^2 + 3170\cdot J\cdot\frac{m^3}{kg^2}\cdot d\right)\cdot[1-(x+y+s)] + 9.420\frac{MJ}{kg}\cdot s - 2.449\frac{MJ}{kg}\cdot x - 0.35\frac{MJ}{kg}\right]$$

Volume basis

$$Q_p = \begin{pmatrix}42.605\\42.434\\42.253\\42.06\\41.856\end{pmatrix}\frac{MJ}{kg} \qquad Q_p = \begin{pmatrix}18316.8\\18243.3\\18165.4\\18082.7\\17994.8\end{pmatrix}\frac{BTU}{lb} \qquad Q_{p\_vol} := \overrightarrow{(Q_p\cdot d)} \qquad Q_{p\_vol} = \begin{pmatrix}126795\\128548\\130333\\132150\\133997\end{pmatrix}\frac{BTU}{gal}$$

The rated continuous duty load for an EDG is 2600 kW with generator efficiency of 96.04% (from AP-9 data sheets).

$P_{elec} := 2600kW$ $\quad \eta_{gen} := 96.04\%$ and diesel engine power is thus.. $\quad P_{eng} := \frac{P_{elec}}{\eta_{gen}}$ $\quad P_{eng} = 3630.4\,hp$

conversion used.. $1hp = 0.7457\,kW$

This is just slightly greater than the 3600 hp continuous rating.

The vendor data curve (EMD 20-645 E4) shows a specific fuel consumption of 0.371 lb/hp-hr. The standard fuel LHV of 18190 BTU/lb is indicated on the vendor curve.

Thus we have..

Vendor standard fuel consumption $\quad sfc_{std} := 0.371\frac{lb}{hp\cdot hr}$ $\quad$ Associated LHV for standard fuel $\quad LHV_{std} := 18190\frac{BTU}{lb}$

Lower heating value (net) for API range from D4868...

$$LHV_{fuel} := Q_p \qquad LHV_{fuel} = \begin{pmatrix}18316.8\\18243.3\\18165.4\\18082.7\\17994.8\end{pmatrix}\frac{BTU}{lb}$$

Same as the Q_p term above..

Correcting the "standard" fuel consumption for the calculated fuel LHV..

$$sfc_{corr} := sfc_{std} \cdot \frac{LHV_{std}}{LHV_{fuel}} \qquad sfc_{corr} = \begin{pmatrix} 0.368 \\ 0.37 \\ 0.372 \\ 0.373 \\ 0.375 \end{pmatrix} \frac{lb}{hp \cdot hr}$$

Fuel mass flow rate for engine power..

$$m_{fuel} := sfc_{corr} \cdot P_{eng} \qquad m_{fuel} = \begin{pmatrix} 1337.6 \\ 1343.0 \\ 1348.7 \\ 1354.9 \\ 1361.5 \end{pmatrix} \frac{lb}{hr}$$

Thus fuel volume flow rate is..

$$v_{fuel} := \frac{m_{fuel}}{d}$$

Volume required for 6 and 7 days operation at full power..

$$V_{6\_day} := v_{fuel} \cdot 6day \qquad V_{7\_day} := v_{fuel} \cdot 7day$$

$$v_{fuel} = \begin{pmatrix} 3.22 \\ 3.176 \\ 3.133 \\ 3.09 \\ 3.047 \end{pmatrix} gpm \qquad \boxed{V_{6\_day} = \begin{pmatrix} 27824 \\ 27445 \\ 27069 \\ 26697 \\ 26329 \end{pmatrix} gal} \qquad \boxed{V_{7\_day} = \begin{pmatrix} 32462 \\ 32019 \\ 31580 \\ 31146 \\ 30717 \end{pmatrix} gal}$$

As noted in CR-JAF-2007-02490, the original JSEM-90-033 evaluation did not include any submergence to prevent vortex air entrainment. The following determines the vortex submergence.

The fuel oil transfer pump flow rate.. $Q := 14.5gpm$ From Vendor Manual R374-C005 (conservatively neglecting slip)

Inlet pipe is 2" sch 80.. $d_p := 1.939in$ Pipe size from tank drawing FV-17A

Velocity at pipe entrance..

$$V_{en} := \frac{4Q}{\pi d_p^{\,2}} \qquad V_{en} = 1.575 \frac{ft}{sec}$$

gravity acceleration

$$g = 32.174 \frac{ft}{sec^2}$$

Froude number based on pipe diameter..

$$F_n := \frac{V_{en}}{\sqrt{d_p \cdot g}} \qquad F_n = 0.691$$

Using the Chang, 1979 correlation (as presented by Knauss) for submergence S for a vertical upward suction..

$$\frac{S}{d_p} = 1.35F_n \qquad \text{or} \qquad \frac{S}{d_p} = 1.35 \cdot \frac{V_{en}}{\sqrt{d \cdot g}}$$

Solving for critical submergence S_{ch} by the Chang 1979 correlation (as presented by Knauss)..

$$S_{ch} := 1.35 \cdot \frac{V_{en} \cdot d_p}{\sqrt{d_p \cdot g}} \qquad \boxed{S_{ch} = 1.809\,in}$$

System Engineering Memorandum JSEM-90-033 determined an unavailable volume of 1447.7 gallons based on a level of 12" from bottom (end of suction line from FV-17A) and calculation JAF-89-031. This level and associated unavailable volume does not include any allowance for submergence to prevent vortex air entrainment. Calculation JAF-CALC-07-00019 was prepared to provided an improved model of volume as a function of level. This calculation considers the impact of "tank tilt" (as reported in JMD-89-097) as well as addressing the volume impact of the stiffener rings and the spherical dished heads. The previous calculation (JAF-89-031) modeled the tank as a level flat-headed cylinder with an equivalent length which resulted in a tank volume of exactly 36000 gallons. From JAF-CALC-07-00019 the unavailable volume (level at suction of 13.809 inches or submergence of 1.809 inches) is:

$$V_{unavail} := \begin{pmatrix} 1436.0 \\ 1763.9 \\ 1691.1 \\ 1735.7 \end{pmatrix} gal \qquad \begin{matrix} \underline{\text{EDG}} \\ \text{A} \\ \text{B} \\ \text{C} \\ \text{D} \end{matrix}$$

$ORIGIN := 1$ Set beginning of matrix counter to start at 1 vs. 0

counter for vector elements $n := 1..4$

While JSEM-90-033 credited additional available fuel for 80% of the volume of the day tank this is not possible for the new Technical Specification since the entire 7 or 6 day supply must be located in the underground storage tanks. Thus the required quantities are determined from the previously calculated consumption with the addition of the unavailable amounts from calculation JAF-CALC-07-00019.

Required 7 day supply

$$V_{r\_7}^{\langle n \rangle} := V_{7\_day} + V_{unavail_n}$$

EDG

V_{r_7} (gal) A	B	C	D	API (deg)
33898	34226	34153	34197	39
33455	33783	33710	33755	36
33016	33344	33271	33316	33
32582	32910	32837	32882	30
32153	32481	32408	32453	27

Required 6 day supply

$$V_{r\_6}^{\langle n \rangle} := V_{6\_day} + V_{unavail_n}$$

EDG

V_{r_6} (gal) A	B	C	D	API (deg)
29260	29588	29515	29560	39
28881	29209	29136	29181	36
28505	28833	28760	28805	33
28133	28461	28388	28432	30
27765	28093	28020	28064	27

Conversion factors as used by Mathcad

$BTU = 1.055 \times 10^{-3}\,MJ$ $\quad lb = 0.454\,kg$ $\quad \frac{BTU}{lb} = 2.326 \times 10^{-3}\,\frac{MJ}{kg}$

$gal = 3.785\,liter$ $\quad ft^3 = 7.481\,gal$ $\quad \frac{lb}{ft^3} = 16.018\,\frac{kg}{m^3}$ $\quad gpm = 0.134\,\frac{ft^3}{min}$

Attachments

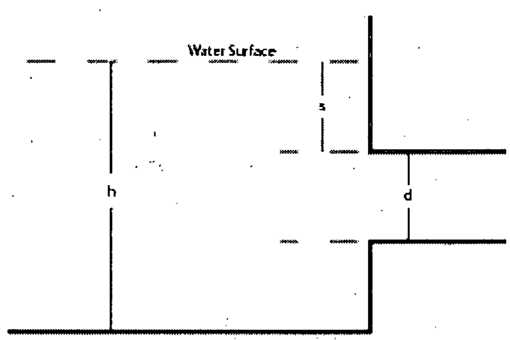
1. Critical Submergence Correlation Comparison (10 pages).
2. EMD 20-645 E4 Fuel Consumption Curve and associated email (2 pages).
3. API Gravity (from Wikipedia) (3 pages).

Required submergence to prevent air-entraining vortex formation as a function of flow velocity can be determined using a number of methods. Among the correlations available for horizontal intakes are:

Reddy, Y.R. and Pickford, J.A., 1972, "Vortices at Intakes in Conventional Sumps," Water Power, **24**, No. 3;
Padmanabhan, M., 1982, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors," NUREG/CR-2772, USNRC
Knauss, J., 1987, "Swirling Flow Problems at Intakes," IAHR Hydraulic Structures Design Manual;
Sanders, R.C. et al., 2001, "Air Entrainment in a Partially Filled Horizontal Pump Suction Line," ASME JPGC2001/PWR-19010

An available correlation for a vertically upward intake aligned along the axial centerline of the intake structure is provided in Knauss, 1987.

The following sketch defines the length variables used by Reddy and Pickford:



Reddy - Pickford Definition Sketch

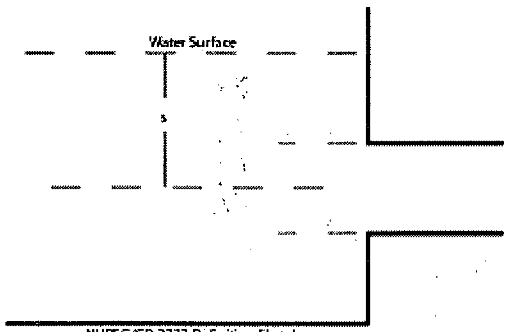
The Reddy-Pickford correlation is

$$s = d\cdot(1 + Fr)$$

$$Fr = \frac{v}{\sqrt{g\cdot d}}$$

Where v is velocity in the intake pipe, g is the acceleration due to gravity and length variables are as shown. Test results presented in the Reddy - Pickford paper cover Froude numbers up to 3.4.

The following sketch defines the length variables used for horizontal suctions in NUREG/CR-2772 (Padmanabhan):



NUREG/CR-2772 Definition Sketch

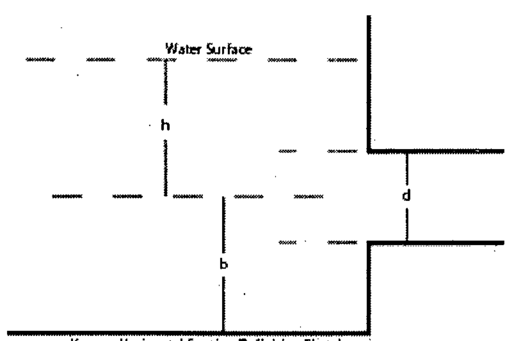
The acceptance criterion for acceptable suction performance in NUREG/CR-2772 (i.e., the submergence required to prevent significant air entrainment) is:

$$\mathrm{Fr} \le 0.8$$

$$\mathrm{Fr} = \frac{u}{\sqrt{g \cdot s}}$$

In this case, u is velocity in the intake pipe, g is the acceleration due to gravity and s is submergence of the pipe centerline to the water surface, as shown. The testing supporting this limit was done with a 24" nominal diameter suction pipe with flow rates between 3000 gpm and 12000 gpm and submergences of 2 ft, 3.5 ft and 5 ft. This corresponds to Froude numbers between 0.29 and 1.15 when pipe diameter is used as the defining length.

The following sketch defines the length variables used for horizontal suctions by Knauss:



Knauss Horizontal Suction Definition Sketch

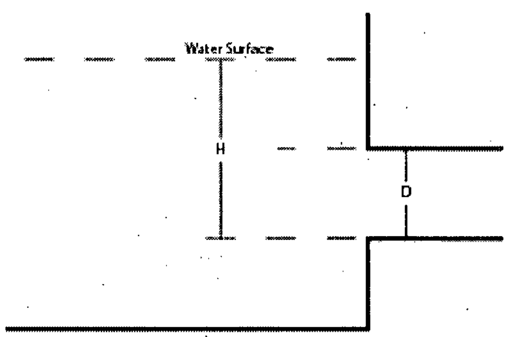
For suctions elevated off of the floor, the most directly applicable correlation presented in Knauss is:

$$h = d \cdot \left(3.3\sqrt{Fr} - \frac{1}{2}\right)$$

$$Fr = \frac{v}{\sqrt{g \cdot d}}$$

As before, v is velocity in the intake pipe, g is the acceleration due to gravity and length variables are as shown. The figure showing the results of this correlation in Knauss covers Froude numbers in the range of 0 to 2.

The following sketch defines the length variables used for horizontal suctions by Sanders, et al.:



Sanders, et al. Definition Sketch

The Sanders et al. bounding correlations for onset of air ingestion (including measurement uncertainty at the 95% confidence level) is:

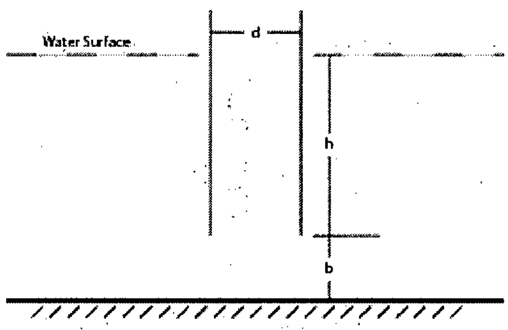
$$S = 2.087Fr^{0.670} \qquad 0 \le Fr \le 0.35$$

$$S = 1.363Fr^{0.261} \qquad 0.35 \le Fr \le 1.40$$

$$Fr = \frac{V}{\sqrt{g \cdot D}}$$

Where V is velocity in the intake pipe, g is the acceleration due to gravity, S=H/D and length variables are as shown. As shown above, the work of Sanders et al. covers the range of Froude number between 0 and 1.40.

The following sketch defines the length variables used for vertically upwards suctions by Knauss:



Knauss Vertical Upward Suction Definition Sketch

For a suction which is symmetric about the axial centerline, the applicable correlation presented in Knauss is:

$$h = d \cdot 1.35 Fr$$

$$Fr = \frac{v}{\sqrt{g \cdot d}}$$

As before, v is velocity in the intake pipe, g is the acceleration due to gravity and length variables are as shown. The figure showing the results of this correlation in Knauss covers Froude numbers in the range of 0 to 2.

To allow comparison between the correlations, the Reddy-Pickford definition sketch is chosen to provide common definitions. Furthermore, the Froude number used in all of the equivalent correlations will use pipe diameter as the length dimension. Using this sketch, the correlations can be transformed to yield expressions to determine equivalent critical submergences to allow direct comparison of the correlations. Before this is performed, common constants and the Froude number are defined.

$$d := 1.939 in \qquad d = 0.162\ ft$$

$$v := 0\frac{ft}{s}, 0.125\frac{ft}{s} .. 4\frac{ft}{s}$$

$$g = 32.174\ \frac{ft}{s^2}$$

$$Fr(v) := \frac{v}{\sqrt{g \cdot d}}$$

When transformed, the Reddy-Pickford correlation becomes:

$$s_{cRP}(v) := \text{if}[0 \le Fr(v) \le 3.4, d\cdot(1 + Fr(v)), 0]$$

The NUREG/CR-2772 acceptance criterion is transformed into a correlation involving suction pipe diameter by setting the critical Froude number (submergence) to 0.8.

$$Fr_c = 0.8$$

$$0.8 = \frac{u}{\sqrt{g\cdot s_{cN}}}$$

By comparison of the Reddy-Pickford and NUREG/CR-2772 definition sketches, it is apparent that the submergence in the NUREG/CR-2772 is equivalent to the submergence in Reddy-Pickford plus one-half of the pipe diameter. This allows a transformed expression for critical submergence (the submergence resulting in a Froude number of 0.8) to be developed as follows:

$$0.8 = \frac{v}{\sqrt{g\cdot\left(s + \frac{d}{2}\right)}}$$

$$\sqrt{g\cdot\left(s + \frac{d}{2}\right)} = \frac{v}{0.8}$$

$$g\cdot\left(s + \frac{d}{2}\right) = \frac{v^2}{0.64}$$

$$s + \frac{d}{2} = \frac{v^2}{0.64g}$$

$$s = \frac{d\cdot v^2}{0.64g\cdot d} - \frac{d}{2}$$

$$s_{cN}(v) := \text{if}\left[0.29 \le Fr(v) \le 1.15, d\cdot\left[\left(\frac{Fr(v)}{0.8}\right)^2 - \frac{1}{2}\right], 0\right]$$

Comparing the Reddy-Pickford definition sketch with that of Knauss for horizontal suctions, it can be observed that submergence in Knauss is equivalent to submergence in Reddy-Pickford plus one-half of the pipe diameter.

$$s + \frac{d}{2} = d\cdot\left(3.3\sqrt{Fr} - \frac{1}{2}\right)$$

$$s_{cKh}(v) := \text{if}\left[0 \le Fr(v) \le 2, d\cdot\left(3.3\sqrt{Fr(v)} - 1\right), 0\right]$$

Comparing the Sanders et al. and Reddy-Pickford definition sketches, the submergence in Sanders is equivalent to the submergence in Reddy-Pickford plus one pipe diameter. The transformation is then made as follows:

$$S = c_1(Fr)^{c_2}$$

$$H = D \cdot c_1(Fr)^{c_2}$$

$$s + d = d \cdot c_1(Fr)^{c_2}$$

$$s_{cS}(v) = d \cdot \left(c_1(Fr(v))^{c_2} - 1 \right)$$

where c_1=2.087, c_2=0.670 when 0 <= Fr <= 0.35 and
c_1=1.363, c_2=0.261 when 0.35 <= Fr <= 1.40:

$$s_{cS1}(v) := d \cdot \left(2.087 \cdot Fr(v)^{0.670} - 1 \right)$$

$$s_{cS2}(v) := d \cdot \left(1.363 \cdot Fr(v)^{0.261} - 1 \right)$$

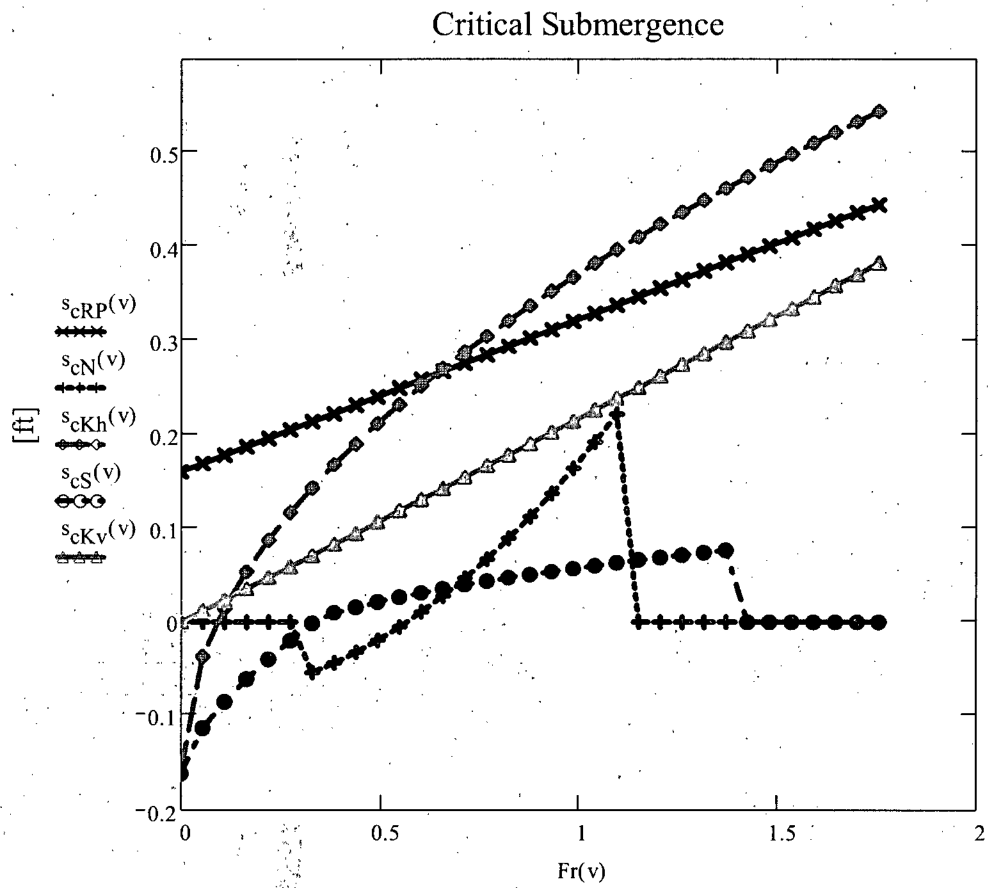
$$s_{cS}(v) := if\left(0 \le Fr(v) \le 0.35, s_{cS1}(v), if\left(0.35 < Fr(v) \le 1.40, s_{cS2}(v), 0\right)\right)$$

No transformation is required for the correlation for vertically oriented suctions, however the equation will be restated in terms of critical submergence:

$$s_{cKv}(v) := if(0 \le Fr(v) \le 2, d \cdot 1.35 \cdot Fr(v), 0)$$

Results of the calculations are shown numerically and graphically on the following pages.

v = (ft/s)	Fr(v) =	$s_{cRP}(v)$ = (ft)	$s_{cN}(v)$ = (ft)	$s_{cKh}(v)$ = (ft)	$s_{cS}(v)$ = (ft)	$s_{cKv}(v)$ = (ft)
0	0	0.162	0	-0.162	-0.162	0
0.125	0.055	0.17	0	-0.037	-0.113	0.012
0.25	0.11	0.179	0	0.015	-0.085	0.024
0.375	0.164	0.188	0	0.055	-0.061	0.036
0.5	0.219	0.197	0	0.088	-0.04	0.048
0.625	0.274	0.206	0	0.118	-0.02	0.06
0.75	0.329	0.215	-0.053	0.144	$-1.486 \cdot 10^{-3}$	0.072
0.875	0.384	0.224	-0.044	0.169	$9.943 \cdot 10^{-3}$	0.084
1	0.439	0.232	-0.032	0.192	0.016	0.096
1.125	0.493	0.241	-0.019	0.213	0.022	0.108
1.25	0.548	0.25	$-4.91 \cdot 10^{-3}$	0.233	0.027	0.12
1.375	0.603	0.259	0.011	0.252	0.031	0.132
1.5	0.658	0.268	0.028	0.271	0.036	0.144
1.625	0.713	0.277	0.047	0.289	0.04	0.155
1.75	0.768	0.286	0.068	0.306	0.044	0.167
1.875	0.822	0.294	0.09	0.322	0.048	0.179
2	0.877	0.303	0.113	0.338	0.051	0.191
2.125	0.932	0.312	0.139	0.353	0.055	0.203
2.25	0.987	0.321	0.165	0.368	0.058	0.215
2.375	1.042	0.33	0.193	0.383	0.061	0.227
2.5	1.096	0.339	0.223	0.397	0.064	0.239
2.625	1.151	0.348	0	0.411	0.067	0.251
2.75	1.206	0.356	0	0.424	0.07	0.263
2.875	1.261	0.365	0	0.437	0.072	0.275
3	1.316	0.374	0	0.45	0.075	0.287
3.125	1.371	0.383	0	0.463	0.078	0.299
3.25	1.425	0.392	0	0.475	0	0.311
3.375	1.48	0.401	0	0.487	0	0.323
3.5	1.535	0.41	0	0.499	0	0.335
3.625	1.59	0.418	0	0.511	0	0.347
3.75	1.645	0.427	0	0.522	0	0.359
3.875	1.699	0.436	0	0.534	0	0.371
4	1.754	0.445	0	0.545	0	0.383



General figures of merit to ensure that critical submergence is a function of Froude number alone are that the Reynolds number is above 3e4 to assure that viscous forces are negligible and that the Weber number is above 120 so that surface tension effects are negligible (Sanders, et al.). Using the following diesel fuel oil properties, the EDG fuel oil storage tank suctions may be evaluated.

$\rho := 828\,\frac{kg}{m^3}$ $\quad\mu := 0.00361\,\frac{kg}{m\cdot s}$ $\quad\sigma := 0.03180\,\frac{kg}{s^2}$ $\quad d = 0.049\,m$

$$Re(v) := \rho\cdot v\cdot\frac{d}{\mu}$$

$$We(v) := \rho\cdot v^2\cdot\frac{d}{\sigma}$$

v = (ft/s)	v = (m/s)	Fr(v) =	Re(v) =	We(v) =
0	0	0	0	0
0.125	0.038	0.055	430.387	1.862
0.25	0.076	0.11	860.775	7.446
0.375	0.114	0.164	$1.291\cdot10^{3}$	16.754
0.5	0.152	0.219	$1.722\cdot10^{3}$	29.784
0.625	0.191	0.274	$2.152\cdot10^{3}$	46.538
0.75	0.229	0.329	$2.582\cdot10^{3}$	67.014
0.875	0.267	0.384	$3.013\cdot10^{3}$	91.214
1	0.305	0.439	$3.443\cdot10^{3}$	119.136
1.125	0.343	0.493	$3.873\cdot10^{3}$	150.782
1.25	0.381	0.548	$4.304\cdot10^{3}$	186.151
1.375	0.419	0.603	$4.734\cdot10^{3}$	225.242
1.5	0.457	0.658	$5.165\cdot10^{3}$	268.057
1.625	0.495	0.713	$5.595\cdot10^{3}$	314.595
1.75	0.533	0.768	$6.025\cdot10^{3}$	364.855
1.875	0.571	0.822	$6.456\cdot10^{3}$	418.839
2	0.61	0.877	$6.886\cdot10^{3}$	476.546
2.125	0.648	0.932	$7.317\cdot10^{3}$	537.976
2.25	0.686	0.987	$7.747\cdot10^{3}$	603.128
2.375	0.724	1.042	$8.177\cdot10^{3}$	672.004
2.5	0.762	1.096	$8.608\cdot10^{3}$	744.603
2.625	0.8	1.151	$9.038\cdot10^{3}$	820.925
2.75	0.838	1.206	$9.469\cdot10^{3}$	900.969
2.875	0.876	1.261	$9.899\cdot10^{3}$	984.737
3	0.914	1.316	$1.033\cdot10^{4}$	$1.072\cdot10^{3}$
3.125	0.953	1.371	$1.076\cdot10^{4}$	$1.163\cdot10^{3}$
3.25	0.991	1.425	$1.119\cdot10^{4}$	$1.258\cdot10^{3}$
3.375	1.029	1.48	$1.162\cdot10^{4}$	$1.357\cdot10^{3}$
3.5	1.067	1.535	$1.205\cdot10^{4}$	$1.459\cdot10^{3}$
3.625	1.105	1.59	$1.248\cdot10^{4}$	$1.566\cdot10^{3}$
3.75	1.143	1.645	$1.291\cdot10^{4}$	$1.675\cdot10^{3}$
3.875	1.181	1.699	$1.334\cdot10^{4}$	$1.789\cdot10^{3}$
4	1.219	1.754	$1.377\cdot10^{4}$	$1.906\cdot10^{3}$

Velocity in the EDG fuel oil suction piping is:

$Q := 14.5\text{gpm}$

$v_{edg} := \frac{4\cdot Q}{\pi\cdot d^2}$ $\quad v_{edg} = 1.575\ \frac{ft}{s}$ $\quad v_{edg} = 0.48\ \frac{m}{s}$

This corresponds to the following Froude, Reynolds and Weber numbers:

$$Fr_{edg} := \frac{v_{edg}}{\sqrt{g \cdot d}} \qquad Fr_{edg} = 0.691$$

$$Re_{edg} := \frac{\rho \cdot v_{edg} \cdot d}{\mu} \qquad Re_{edg} = 5.424 \times 10^{3}$$

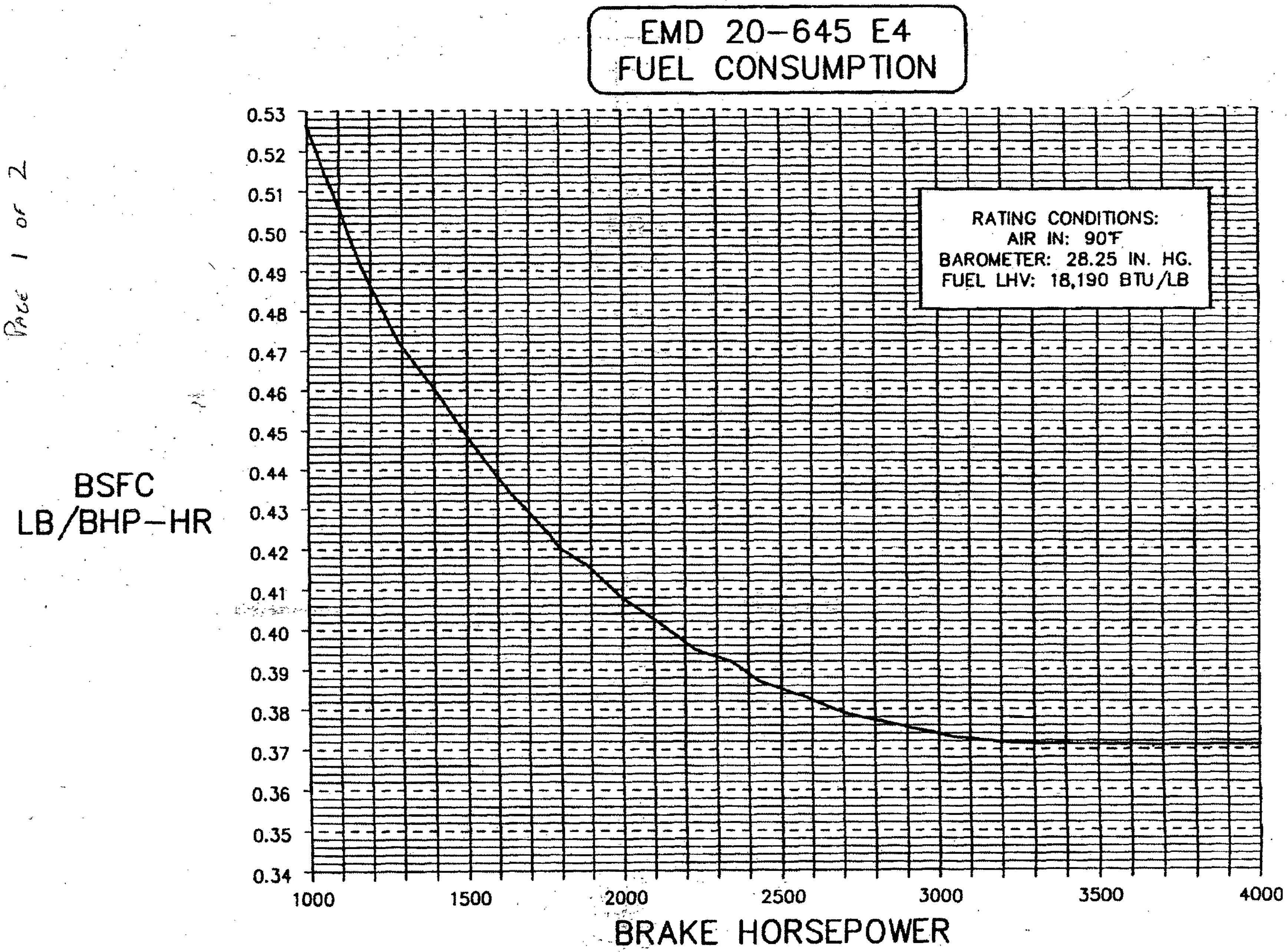
$$We_{edg} := \frac{\rho \cdot v_{edg}^{2} \cdot d}{\sigma} \qquad We_{edg} = 295.698$$

Conclusion:
While either the correlations of Sanders, et al., or that derived from NUREG/CR-2772 allow less submergence over a suction before air-entraining vortices form, it is questionable whether they provide reasonable results for the EDG fuel oil storage tank suctions and should not be used for the purpose of determining required submergence. This conclusion is based on the lack of geometric similarity compounded by flow conditions for which viscous forces may require consideration. While the question of whether viscous forces could affect the result are also applicable to the correlation presented in Knauss for suctions oriented vertically upward, it is the best available information and should be used to evaluate the potential for formation of air-entraining vortices at the EDG fuel oil suctions. The required submergence at the suction using the correlation from Knauss is:

$$s_{cKvedg} := \text{if}\left(0 \le Fr_{edg} \le 2, d \cdot 1.35 \cdot Fr_{edg}, 0\right)$$

$$s_{cKvedg} = 0.151 \text{ ft} \qquad s_{cKvedg} = 1.809 \text{ in}$$

Attachment 2 to JAF-CALC-07-00020
Page 1 of 2



Attachment 2 to JAF-CALC-07-00020
Page 2 of 2

Swinburne, Paul

From: Jack Murray [Jack.Murray@kirbycorp.com]
Sent: Tuesday, March 06, 2007 3:36 PM
To: Clark, Matthew; Abtey, Robert
Subject: Fwd: 20E4 Fuel Curve
Attachments: 20E4 Fuel Curve.pdf

Bob/Mark
I have attached the BSFC curve that I received from engineering. Hopefully this will provide the info that you need.
Jack

>>> Brad Abernathy 03/06/07 3:20 PM >>>
Jack,

Use the attached BSFC curve for the 20-E4.

It is based on EMD Standard Conditions - diesel fuel with LHV of 18,190 BTU/Lb. From this value, they can calculate the fuel consumption in BTU/BHP-Hr based on the fuel LHV. For information, the EMD standard fuel is based on 28 °API fuel, 7.387 Lb/Gal, 19,350 BTU/Lb HHV, 18,190 BTU/Lb LHV.

B. Aber

ATTACHMENT 3 TO JDF-CALC-07-00020

API gravity

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From Wikipedia, the free encyclopedia

The American Petroleum Institute gravity, or ***API gravity***, is a measure of how heavy or light a petroleum liquid is compared to water. If its API gravity is greater than 10, it is lighter and floats on water; if less than 10, it is heavier and sinks. API gravity is thus a measure of the relative density of a petroleum liquid and the density of water, but it is used to compare the relative densities of petroleum liquids. For example, if one petroleum liquid floats on another and is therefore less dense, it has a greater API gravity. Although mathematically API gravity has no units (see the formula below), it is nevertheless referred to as being in "degrees". API gravity is graduated in degrees on a hydrometer instrument and was designed so that most values would fall between 10 and 70 API gravity degrees.

Contents

History of development

The U.S. National Bureau of Standards in 1916 established the Baumé scale (see degrees Baumé) as the standard for measuring specific gravity of liquids less dense than water. Investigation by the U.S. National Academy of Sciences found major errors in salinity and temperature controls that had caused serious variations in published values. Hydrometers in the U.S. had been manufactured and distributed widely with a modulus of 141.5 instead of the Baumé scale modulus of 140. The scale was so firmly established that by 1921 the remedy implemented by the American Petroleum Institute was to create the API Gravity scale recognizing the scale that was actually being used.

API gravity formulas

The formula used to obtain the API gravity of petroleum liquids is thus:

$$\text{API gravity} = \frac{141.5}{SG} \text{at } 60°\text{F} - 131.5$$

Conversely, the specific gravity of petroleum liquids can be derived from the API gravity value as

$$\text{SG at } 60\ °\text{F} = \frac{141.5}{APIGravity + 131.5}$$

(Further tables give adjustments for temperature).

(See ASTM D1298)

ATTACHMENT 3 TO JAF-CALC-07-00020

Thus, a heavy oil with a specific gravity of 1.0 (i.e., with the same density as pure water at 60°F) would have an API gravity of:

$$\frac{141.5}{1.0} - 131.5 = 10.0 \text{ degrees API.}$$

Classifications or grades

Generally speaking 40 to 45 API gravity degree oils have a greatest commercial price and values outside this range have lower commercial price. Above 45 degrees API gravity the molecular chains become shorter and less valuable to a refinery.

Crude oil is classified as light, medium or heavy, according to its measured API gravity.

Light crude oil is defined as having an API gravity higher than 31.1 °API

Medium oil is defined as having an API gravity between 22.3 °API and 31.1 °API

Heavy oil is defined as having an API gravity below 22.3 °API.

Not all parties use the same grading.[1] (http://www.crudemonitor.ca/quickfacts/misc/grades.pdf) The US Geological Society uses slightly different definitions at [2] (http://pubs.usgs.gov/fs/2006/3133/pdf/FS2006-3133_508.pdf) Simply put, bitumen sinks in fresh water, while oil floats.

Oil which will not flow at normal temperatures or without dilution is named bitumen and the API gravity is generally less than 10 °API. Bitumen derived from the oil sands deposits in the Alberta, Canada area has an API gravity of around 8 °API. It is 'upgraded' to an API gravity of 31 °API to 33 ° API and the upgraded oil is known as synthetic crude.

External links

- link to hydrometer (http://www.koehlerinstrument.com/products/hydrometer.html)
- ConocoPhillips price adjustment by API gravity (http://www.conocophillips.com/products/buy/gravity/index.htm)
- comments on API gravity adjustment scale (http://dnr.louisiana.gov/sec/execdiv/techasmt/oil_gas/crude_oil_gravity/comments_1989.htm)
- instructions for using a glass hydrometer measured in API gravity (http://www.globalsecurity.org/military/library/policy/army/fm/10-67-1/APPI.HTML)
- API Degree history (http://www.sizes.com/units/hydrometer_api.htm)

Categories: Units of density | Petroleum

ATTACHMENT 3 TO JAF-CALC-07-00020

ATTACHMENT 3 to JAFP-08-0086

Entergy Nuclear Operations, Inc.
James A. FitzPatrick Nuclear Power Plant

Calculation JAF-CALC-06-00114 Rev. 1
EDG Ultra Low Sulfur Fuel Oil Calculations

ATTACHMENT 9.2 ENGINEERING CALCULATION COVER PAGE

Sheet 1 of 2

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

CALCULATION COVER PAGE	(1) **EC # 551**	(2) **Page 1 of 5**
(3) Design Basis Calc. ☒ YES ☐ NO	(4) ☐ CALCULATION	☒ EC Markup
(5) **Calculation No: JAF-CALC-06-00114**		(6) **Revision: 1**
(7) **Title: EDG Ultra Low Sulfur Fuel Oil Calculations**		
(8) **System(s): 93**	(9) **Review Org (Department): Design Eng.**	

(10) **Safety Class:**	(11) **Component/Equipment/Structure Type/Number:**	
☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	**93TK-6A,B,C & D**	
(12) **Document Type: Calculation**		
(13) **Keywords (Description/Topical Codes):** **EDG Fuel Oil**		

REVIEWS

(14) Name/Signature/Date P. Swinburne/ P Swinburne 8/6/07	(15) Name/Signature/Date T. Andersen/ TJ Andersen / 8/6/07	(16) Name/Signature/Date T. Howse/ Thomas Howse / 8/6/07
Responsible Engineer	☒ **Design Verifier** ☐ **Reviewer** ☐ Comments Attached	**Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET	CALCULATION NO: JAF-CALC-06-00114 REVISION: 1 (EC #551 Markup)

I. EC Markups Incorporated
1.
2.
3.
4.
5.

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. ANSI D4868, Standard Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels.		2005	■	☐	N	N/A
2. ANSI D975, Standard Specification for Diesel Fuel Oils		2006	■	☐	N	N/A
3.			☐	☐		
4.			☐	☐		

III. CROSS REFERENCES:
1.
2.
3.

IV. SOFTWARE USED:

Title:_______N/A_______ Version/Release:________ Disk/CD No.______

V. DISK/CDS INCLUDED:

Title:_______N/A_______ Version/Release________ Disk/CD No.______

VI. OTHER CHANGES:

PURPOSE

The purpose of this EC Markup is to replace the 4.5% assumed heat content reduction of calculation JAF-CALC-06-00114 with analysis using ASTM D4868 to show that at **the same API gravity**, there is no degradation in volumetric heat content associated with a change from low sulfur (S500) to ultra low sulfur (S15) fuel. Technical Specification Bases for SR 3.8.3.3 stipulates an API gravity range at 60 F from 27 degrees to 39 degrees. Thus any change in API gravity (density) associated with a change from S500 to S15 EDG fuel oil will be bounded by existing Technical Specification requirements. The acceptablity of the present Technical Specification EDG Fuel Oil Storage requirements with the permitted API gravity range will be addressed with response to CR-JAF-2007-02392.

REFERENCES/ INPUTS

1. ASTM D4868 - 00 (Reapproved 2005), Standard Test Method for Estimation of Net and Gross Heat of Combustion of Burner and Diesel Fuels, May 2005.
2. ASTM D975 - 06, Standard Specification for Diesel Fuel Oils, May 2006.
3. Crane Technical Paper No. 410.
4. JAF Technical Specification Bases SR 3.8.3.3
5. Fairbanks Morse Emergency Diesel Users Group, *Potential Affects of Use of Ultra Low Sulfur Diesel Fuel Oil on Engine Fuel Oil Consumption*, Final White Paper dated May 11, 2007, Rev. 1.

ASSUMPTIONS

1. Assume that diesel fuel temperature is 60° F or less. Reasonable for underground storage and for comparison does not really matter.

ANALYSIS

Comparison of heat content using ASTM D4868

The TS Bases for SR 3.8.3.3 establishes an API gravity range from 27 deg to 39 deg at 60° F. Thus use this range to calculate heat content range..

$$\text{API\_grav\_TS} := \begin{pmatrix} 39 \\ 27 \end{pmatrix} \text{deg}$$

Density of water (60° F), Crane 410, A-6...

$$\rho_w := 62.371 \frac{\text{lb}}{\text{ft}^3} \qquad \rho_w = 0.9991 \frac{\text{gm}}{\text{cm}^3}$$

Specific gravity from TS API gravity range (formula from definition of API gravity)...

$$SG := \frac{141.5\text{deg}}{\text{API\_grav\_TS} + 131.5\text{deg}} \qquad SG = \begin{pmatrix} 0.8299 \\ 0.8927 \end{pmatrix}$$

Density of oil for TS API gravity range, at 60° F

$$\rho_o := SG \cdot \rho_w \qquad \rho_o = \begin{pmatrix} 51.762 \\ 55.681 \end{pmatrix} \frac{\text{lb}}{\text{ft}^3} \qquad \rho_o = \begin{pmatrix} 829.155 \\ 891.93 \end{pmatrix} \frac{\text{kg}}{\text{m}^3}$$

Limiting sulfur, moisture and ash from ASTM D975 for S15 or ULSD (percent (%) unit is 0.01, see conversions at end)

$s := 0.0015\%$ Sulfur $\qquad x := 0.05\%$ Water and sediment $\qquad y := 0.01\%$ Ash

Density (d) in D4868 is at 15° C or 59° F. From Crane 410, A-7 graph there is an approximate 3.9% increase in specific gravity or density for a 100 F° temperature decrease (applies between 0° F and 100° F). Thus the increase in density from 60° F to 59° F (15° C) is given by..

$$d := \left(1 + \frac{3.9\%}{100}\right)\cdot\rho_o \qquad d = \begin{pmatrix}829.478\\892.278\end{pmatrix}\frac{kg}{m^3}$$

Gross heat content or HHV per D4868 Define unit.. $MJ := 10^6\cdot joule$

$$Q_v := \left(51.916\cdot\frac{MJ}{kg} - 8.792\cdot\frac{J}{kg^3}\cdot m^6\cdot d^2\right)\cdot[1-(x+y+s)] + 9.420\,\frac{MJ}{kg}\cdot s$$

$$Q_v = \begin{pmatrix}45.839\\44.889\end{pmatrix}\frac{MJ}{kg} \qquad \boxed{Q_v = \begin{pmatrix}19.707\times10^3\\19.299\times10^3\end{pmatrix}\frac{BTU}{lb}}$$

API 39
API 27

$$Q_{vol\_S15} := \overrightarrow{(Q_v\cdot d)} \qquad \boxed{Q_{vol\_S15} = \begin{pmatrix}136.419\times10^3\\143.706\times10^3\end{pmatrix}\frac{BTU}{gal}}$$

API 39
API 27

Net heat content or LHV per D4868..

$$Q_p := \left(46.423\cdot\frac{MJ}{kg} - 8.792\cdot\frac{J}{kg^3}\cdot m^6\cdot d^2 + 3170\cdot J\cdot\frac{m^3}{kg^2}\cdot d\right)\cdot[1-(x+y+s)] + 9.420\,\frac{MJ}{kg}\cdot s - 2.449\,\frac{MJ}{kg}\cdot x$$

$$Q_p = \begin{pmatrix}42.976\\42.225\end{pmatrix}\frac{MJ}{kg} \qquad \boxed{Q_p = \begin{pmatrix}18.476\times10^3\\18.153\times10^3\end{pmatrix}\frac{BTU}{lb}}$$

API 39
API 27

$$Q_{p\_vol\_S15} := \overrightarrow{(Q_p\cdot d)} \qquad \boxed{Q_{p\_vol\_S15} = \begin{pmatrix}127.899\times10^3\\135.177\times10^3\end{pmatrix}\frac{BTU}{gal}}$$

API 39
API 27

The heat content per pound is greater at the higher API gravity but the heat content per unit volume is much less because the lower density at higher API gravity is more significant.

For S500 change sulfur content.. $s := 0.05\%$ $s = 0.0500\,\%$

Recalculating gross or HHV with D4868 formula..

$$Q_v := \left(51.916\cdot\frac{MJ}{kg} - 8.792\cdot\frac{J}{kg^3}\cdot m^6\cdot d^2\right)\cdot[1-(x+y+s)] + 9.420\,\frac{MJ}{kg}\cdot s$$

$$Q_v = \begin{pmatrix}45.821\\44.871\end{pmatrix}\frac{MJ}{kg} \qquad \boxed{Q_v = \begin{pmatrix}19.7\times10^3\\19.291\times10^3\end{pmatrix}\frac{BTU}{lb}}$$

API 39
API 27

$$Q_{vol\_S500} := \overrightarrow{(Q_v \cdot d)} \qquad Q_{vol\_S500} = \begin{pmatrix} 136.367 \times 10^3 \\ 143.651 \times 10^3 \end{pmatrix} \frac{BTU}{gal}$$

API 39
API 27

Recalculating net or LHV with D4868 formula..

$$Q_p := \left(46.423 \cdot \frac{MJ}{kg} - 8.792 \cdot \frac{J}{kg^3} \cdot m^6 \cdot d^2 + 3170 \cdot J \cdot \frac{m^3}{kg^2} \cdot d\right) \cdot [1 - (x + y + s)] + 9.420 \frac{MJ}{kg} \cdot s - 2.449 \frac{MJ}{kg} \cdot x$$

$$Q_p = \begin{pmatrix} 42.959 \\ 42.209 \end{pmatrix} \frac{MJ}{kg} \qquad Q_p = \begin{pmatrix} 18.469 \times 10^3 \\ 18.146 \times 10^3 \end{pmatrix} \frac{BTU}{lb}$$

API 39
API 27

$$Q_{p\_vol\_S500} := \overrightarrow{(Q_p \cdot d)} \qquad Q_{p\_vol\_S500} = \begin{pmatrix} 127.85 \times 10^3 \\ 135.126 \times 10^3 \end{pmatrix} \frac{BTU}{gal}$$

API 39
API 27

Change in heating values (per gallon) for change from S500 to S15 as determined from D4868

$$HHV\_chg := \frac{Q_{vol\_S15}}{Q_{vol\_S500}} - 1 \qquad HHV\_chg = \begin{pmatrix} 0.03858 \\ 0.03837 \end{pmatrix} \%$$

Very slight increase

$$LHV\_chg := \frac{Q_{p\_vol\_S15}}{Q_{p\_vol\_S500}} - 1 \qquad LHV\_chg = \begin{pmatrix} 0.03791 \\ 0.03773 \end{pmatrix} \%$$

Very slight increase

CONCLUSION

The observed concern associated with ULSD (S15) lowering the heat content per volume is due primarily to a change in the typical API gravity. When adjusted for API gravity there is virtually no change in heat content associated with a change from S500 to ULSD (S15) fuel. It is incorrect to compare fuels with different API gravity readings and associate a loss of volume based heat content on the change is sulfur content. The primary source of difference is the typical change in API gravity.

Conversion factors as used by Mathcad

$BTU = 1.055 \times 10^3 \, J$ $\qquad lb = 0.454 \, kg$ $\qquad \frac{BTU}{lb} = 2.326 \times 10^{-3} \frac{MJ}{kg}$

$gal = 3.785 \, liter$ $\qquad ft^3 = 7.481 \, gal$ $\qquad \frac{lb}{ft^3} = 16.018 \frac{kg}{m^3}$

percent unit.. $\% = 0.01$

ATTACHMENT 4 to JAFP-08-0086

Entergy Nuclear Operations, Inc.
James A. FitzPatrick Nuclear Power Plant

List of Commitments

ATTACHMENT 4 to JAFP-08-0086

This table identifies actions discussed in this letter for which Entergy commits to perform. Any other actions discussed in this submittal are described for the NRC's information and are not commitments.

COMMITMENT	TYPE (Check one)		SCHEDULED COMPLETION DATE (If Required)
	ONE-TIME ACTION	CONTINUING COMPLIANCE	
Obtain test equipment and develop a test procedure for water and sediment testing in accordance with ASTM-D1796 or ASTM-D2709	X		60 Days After Receipt of Amendment