REFUELING OPERATION

3/4.9.9 WATER LEVEL - SPENT FUEL STORAGE POOL

LIMITING CONDITION FOR OPERATION

3.9.9 At least 20 feet 6 inches of water shall be maintained over the top of the irradiated fuel rods seated in the spent fuel storage pool racks.

APPLICABILITY: Whenever irradiated fuel assemblies are in the spent fuel storage pool.

ACTION:

With the requirements of the above specification not satisfied, suspend all movement of fuel assemblies and crane operations with loads in the spent fuel storage pool area after placing the load in a safe location. Restore the water level to within its limit within 4 hours. The provisions of Specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

4.9.9 The water level in the spent fuel storage pool shall be determined to be at least its minimum required depth at least once per 7 days.

3/4.9.6 CRANE AND HOIST OPERABILITY

The OPERABILITY requirements of the cranes and hoists used for movement of fuel assemblies ensures that: 1) each has sufficient load capacity to lift a fuel element, and 2) the core internals and pressure vessel are protected from excessive lifting force in the event they are inadvertently engaged during lifting operations.

3/4.9.7 CRANE TRAVEL-SPENT FUEL STORAGE POOL

The restriction on movement of loads in excess of the weight specified provides some assurance that with the failure of the lifting device the fuel pool would not be damaged to such a degree that the irradiated fuel would be subjected to a loss-of-coolant.

3/4.9.8 and 3/4.9.9 WATER LEVEL-REACTOR VESSEL AND SPENT FUEL STORAGE POOL

The restrictions on minimum water level ensure that sufficient water depth is available to remove 98% of the assumed 10% iodine gap activity released from the rupture of irradiated fuel assembly. This minimum water depth is consistent with the assumptions of the accident analysis.

3/4.9.10 CONTROL ROD REMOVAL

This specification ensures that maintenance or repair on control rods or control rod drives will be performed under conditions that limit the probability of inadvertent criticality. The requirements for simultaneous removal of more than one control rod are more stringent since the SHUTDOWN MARGIN specification provides for the core to remain subcritical with only one control rod fully withdrawn.

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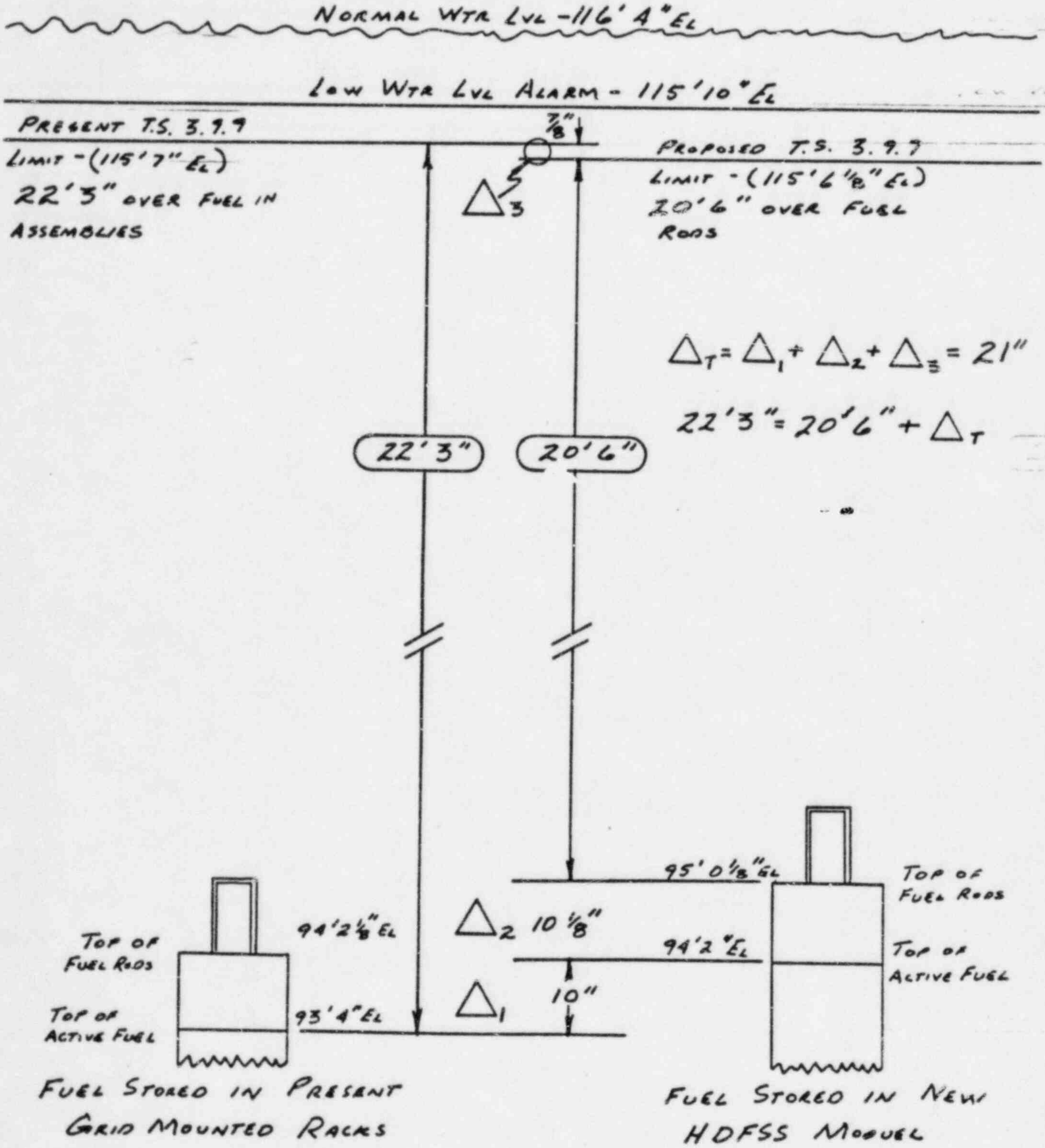
Figure 1

Demonstration of Numerical Difference in Water Depth Between New HDFSS Modules and Old Grid Mounted Racks



Carolina Power & Light Company
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Raleigh, North Carolina 27602

ANALYSIS

FOR

BSEP SPENT FUEL POOL STORAGE EXPANSION

for

DF FOR A FUEL HANDLING ACCIDENT

Analysis I.D. 80011-M-02-F

Safety Classification: (Q)
Seismic Classification: (—)

Approval

Rev. No.	Prepared by/ Date	Verified by/ Date	Prin. or Res. Eng./ Date	Pages Affected
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Computed by: RA Leber Date: 12/14/83 Checked by: [signature] Date: 12/19/83 TAR No.: 80-011	CAROLINA POWER & LIGHT COMPANY NUCLEAR PLANT ENGINEERING DEPARTMENT CALCULATION SHEET	Calculation ID: 80011-M-02-F Pg. 1 of 12 Rev. 0 File: 0011-500-xxx-xxx
Project Title: BSEP SPENT FUEL STORAGE EXPANSION		
Calculation Title: DF_{eff} FOR A FUEL HANDLING ACCIDENT		
Status: Prelim. ☐ Final ☒ Void ☐		

1.0 PURPOSE

1.1 BSEP TECH. SPEC. 3.9.9 REQUIRES AT LEAST 22 FEET 3 INCHES OF WATER TO BE MAINTAINED OVER THE TOP OF ACTIVE IRRADIATED FUEL ASSEMBLIES SEATED IN THE SPENT FUEL POOL.

1.2 REG GUIDE 1.25, REFERENCE 4.1, USES 23 FEET OVER THE TOP OF THE FUEL RODS AS A REFERENCE.

1.3 USING A "WORST CASE" OF 8×8 FUEL, TECH. SPEC. 3.9.7 RESULTS IN 21'5" OF WATER OVER THE TOP OF THE FUEL RODS FOR THE PRESENT GRID MOUNTED RACKS.

1.4 FUEL STORED IN THE NEW HIGH DENSITY FUEL STORAGE SYSTEM (HDFSS) MODULES WILL BE APPROX. 10" HIGHER THAN THE PRESENT GRID MOUNTED RACKS.

1.5 THIS CALCULATION PROVIDES THE JUSTIFICATION FOR LOWERING THE BSEP TECH. SPEC. 3.9.9 LIMIT TO 20 FEET 6 INCHES OVER THE TOP OF THE FUEL RODS OF THE FUEL ASSEMBLIES STORED IN THE SPENT FUEL STORAGE POOL RACKS.

NOTE: THIS INCLUDES BOTH A REDUCTION OF WATER DUE TO THE HIGHER HDFSS RACKS PLUS A CHANGE OF REFERENCE FROM TOP OF ACTIVE IRRADIATED FUEL ASSEMBLIES TO TOP OF FUEL RODS.

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2.0 SUMMARY OF RESULTS

2.1 A CONSERVATIVE APPROACH TO CALCULATE DF_{inorg} AT VARIOUS HEIGHTS OF WATER IS THE USE OF THE FORMULA:

2.1.1 $$DF_{inorg} = e^{\left(\frac{\ln 133}{23}\right)h}$$ WHERE h IS THE HEIGHT OF WATER OVER THE TOP OF THE FUEL RODS IN FEET.

2.2 APPLICATION OF FORMULA 2.1.1 TO BOTH THE PRESENT GRID MOUNTED RACKS (h = 21'5") AND THE HDFSS RACKS (h = 20'6") YIELDS A DF_{inorg} OF 95.0 AND 78.2 RESPECTIVELY. THIS RESULTS IN A DF_{eff} OF:

76.9 FOR THE PRESENT RACKS AND
65.5 FOR THE NEW HDFSS RACKS.

2.3 FROM REFERENCE 4.1, THE THYROID DOSE (D) IS INDIRECTLY PROPORTIONAL TO THE EFFECTIVE IODINE DECONTAMINATION FACTOR FOR POOL WATER (DF_p). THIS YIELDS THE FOLLOWING EQUATION:

2.3.1 $$D_f = \frac{DF_{pi}}{DF_{pf}} D_i$$ WHERE D_f IS A NEW THYROID DOSE FOR HDFSS RACKS

DF_{pi} = 76.9 FOR EXISTING RACKS
DF_{pf} = 65.5 FOR HDFSS RACKS
D_i = THYROID DOSE FOR REFUELING ACCIDENT WITH EXISTING RACKS

2.4 APPLICATION OF THE "WORST CASE" RESULTS OF REFERENCE 4.2, 6.31×10^{-3} REM (0-2 HOUR DOSE FOR THYROID AT THE EXCLUSION DISTANCE) AND 1.01×10^{-2} REM (0-30 DAY DOSE FOR THYROID AT THE LOW POPULATION ZONE), TO FORMULA 2.3.1 YIELD:

7.41×10^{-3} REM THYROID AT THE EXCLUSION ZONE (0-2 HR)
1.19×10^{-2} REM THYROID AT THE LOW POPULATION ZONE (0-30 DAY)

2.5 THE RESULTS OF 2.4 ARE WELL BELOW THE 10CFR100 GUIDELINE OF 300 REM THYROID AND RESULTS IS A REDUCTION OF THE "WORST CASE" (LOW POPULATION ZONE) SAFETY FACTOR FROM 29,703 TO 25,210. (15% REDUCTION)

3.0 DISCUSSION

3.1 THE CONSERVATIVE ASSUMPTIONS OF REFERENCE 4.1 ARE MAINTAINED WITH THE EXCEPTION OF THE 23 FOOT MINIMUM WATER DEPTH AND DF_{inorg} EQUAL TO 133.

3.2 THE RESULTS ARE APPLIED TO REFERENCE 4.2 WHICH IS A REFUELING ACCIDENT WITH A DROP OF 30 FEET. THE REFUELING ACCIDENT UNDER CONSIDERATION IS A DROP OF APPROX 6 INCHES. THIS ADDS ADDITIONAL CONSERVATISM.

3.3 FROM THE EQUATIONS GIVEN IN REFERANCE 4.3, IT WILL BE SHOWN THAT THE INORGANIC IODINE DECONTAMINATION FACTOR (DF_{INORG}) EQUATION $e^{(6/d_b)(K_{eff})(H)/v_b}$ (PAGE 26)

CAN BE REDUCED TO THE FORM $e^{\alpha H}$ WHERE α IS A CONSTANT FOR A SPECIFIC FUEL CONFIGURATION AND H

IS THE BUBBLE RISE HEIGHT (IN CM). $h = \frac{H}{(12)(2.54)}$ WHERE h IS THE HEIGHT OF WATER OVER THE TOP OF THE FUEL RODS (IN ft).

3.4 FROM THE RELATIONSHIP, $DF_{INORG.} = e^{\alpha h}$, AN α WILL BE DETERMINED FOR THE CONSERVATIVE CASE IN REFERENCE 4.1 ie AN α SUCH THAT $DF_{INORG} = 133$ AT AN $h = 23$ feet. $\alpha = \ln 133/23$

3.5 THE DERIVED REFERENCE 4.1 α WILL BE APPLIED TO THE PRESENT GRID MOUNTED RACKS ($h = 21'5"$) AND THE HDFSS RACKS ($h = 20'6"$).

3.6 $DF_{eff.}$'S WILL BE DETERMINED AND BE USED TO CALCULATE A "WORST CASE" RELEASE ON IODINE FOR A REFUELING ACCIDENT INVOLVING HDFSS RACKS

4.0 REFERENCES

4.1 REG. GUIDE 1.25 - ASSUMPTIONS USED FOR EVALUATING THE POTENTIAL RADIOLOGICAL CONSEQUENCES OF A FUEL HANDLING ACCIDENT IN THE FUEL HANDLING AND STORAGE FACILITY FOR BOILING AND PRESSURIZED WATER REACTORS

4.2 BRUNSWICK 1 + 2 UPDATED FSAR, SECTION 15.7.1 REFUELING ACCIDENT.

4.3 G. BURLEY, EVALUATION OF FISSION PRODUCT RELEASE AND TRANSPORT FOR A FUEL HANDLING ACCIDENT, OCTOBER 5, 1971

5.0 BASES AND ASSUMPTIONS

5.1 THE ASSUMPTIONS ESTABLISHED IN THE REGULATORY POSITION OF REFERENCE 4.1 WILL BE USED, WITH THE FOLLOWING EXCEPTIONS:

5.1.1 MINIMUM WATER DEPTH BETWEEN THE TOP OF THE DAMAGED FUEL RODS AND THE FUEL POOL SURFACE OF 23 FEET WILL NOT BE USED. 21 FEET 5 INCHES WILL BE ASSUMED FOR THE EXISTING GRID MOUNTED RACKS AND 20 FEET 6 INCHES WILL BE ASSUMED FOR THE HDFSS RACKS.

5.1.2 THE POOL DECONTAMINATION FACTOR FOR INORGANIC IODINE SPECIES WILL NOT BE 133. NEW DF_{inorg}'S WILL BE CALCULATED FOR THE EXISTING RACKS AND THE HDFSS RACKS IN ORDER TO SHOW COMPARISON

5.2 SECTION C.3.a (3) OF REFERENCE 4.1 ESTABLISHES THE FOLLOWING FORMULA FOR USE IN APPROXIMATING THE INHALATION THYROID DOSE:

$$D = \frac{F_g \times I \times F \times P \times B \times R\,(\chi/Q)}{(DF_p)(DF_f)}$$

THE ONLY TERM IN THIS FORMULA WHICH IS A FUNCTION OF WATER DEPTH IS THE EFFECTIVE IODINE DECONTAMINATION FACTOR FOR POOL WATER (DF_p). THIS ESTABLISHES THAT

$$\text{THYROID DOSE } (D) \propto \frac{1}{DF_p}$$

5.3 REFERENCE 4.1 STATES THAT "THE ASSUMPTIONS SET FORTH IN THIS GUIDE ARE ... BELIEVED TO BE APPROPRIATELY CONSERVATIVE" (PAGE 25.1). ALL DATA USED FROM REFERENCE 4.1 WILL BE ASSUMED TO BE CONSERVATIVE.

5.4 REFERENCE 4.2 ESTABLISHES THE DESIGN BASIS REFUELING ACCIDENT AS ONE IN WHICH ONE FUEL ASSEMBLY IS ASSUMED TO FALL ONTO THE TOP OF THE REACTOR CORE (LESS THAN 30 ft.). THE PRESENT GRID MOUNTED RACKS, WITH AN ACCIDENT DROP HEIGHT OF APPROX. 6 INCHES AND A WATER DEPTH OF 21 FEET 5 INCHES OVER THE FUEL RODS STORED IN THE RACK, ARE BOUNDED BY THIS ANALYSIS. HOWEVER, TO INSURE CONSERVATISM THE IODINE RELEASES OF REFERENCE 4.2 WILL BE USED IN THIS CALCULATION.

5.5 FROM 5.3 AND 5.4 IT IS ASSUMED THAT THE THYROID DOSE (D) AS A RESULT OF A FUEL HANDLING ACCIDENT OVER THE SPENT FUEL POOL IS INDIRECTLY PROPORTIONAL TO THE EFFECTIVE IODINE DECONTAMINATION FACTOR FOR THE POOL (DF_{eff}). THIS YIELDS THE FOLLOWING RELATIONSHIP:

5.5.1 $D_f = \frac{(DF_{eff})_i}{(DF_{eff})_f} D_i$ WHERE D_f IS THE THYROID DOSE BASED ON AN ACCIDENT OVER THE HDFSS RACKS (6 INCH DROP); $(DF_{eff})_f$ IS THE DF_{eff} FOR THE HDFSS RACKS; $(DF_{eff})_i$ IS THE DF_{eff} FOR THE EXISTING GRID MOUNTED RACKS; D_i IS THE THYROID DOSE GIVEN IN REFERENCE 4.2.

THIS FORMULA (5.5.1) IS CONSIDERED CONSERVATIVE SINCE IT IS BASED ON THE CONCLUSIONS OF 5.3 AND 5.4 ABOVE WHICH ARE CONSERVATIVE. THE ASSUMPTION IS THAT THE STARTING POINT (REFUELING ACCIDENT OVER THE EXISTING GRID MOUNTED RACKS WITH A DROP OF LESS THAN 30 FEET) IS BOUNDED

BY REFERENCE 4.2. A FURTHER ASSUMPTION IS THAT ONLY THE PARAMETER OF DF_{eff} WILL VARY BETWEEN A REFUELING ACCIDENT OVER THE EXISTING GRID MOUNTED RACKS AND THE NEW HDFSS RACKS.

5.6 THE FOLLOWING FORMULAS WILL BE ASSUMED FROM REFERENCE 4.3:

5.6.1 $DF_{INORG} = e^{(6/d_b)(K_{eff})(H)/V_b}$ (PAGE 26)

5.6.2 $DF_{eff} = \dfrac{1}{\dfrac{\text{FRACTION INORGANIC}}{DF_{INORG}} + \dfrac{\text{FRACTION ORGANIC}}{1}}$ (PAGE 26)

5.7 FROM PAGE 18 OF REFERENCE 4.3:

5.7.1 THE OBSERVED BUBBLE DIAMETER (d_b) IS A FUNCTION OF THE ORIFICE DIAMETER (D). D IS ASSUMED TO BE A FUNCTION OF THE SPECIFIC FUEL GEOMETRY, IE THE INSIDE DIAMETER OF THE FUEL ROD.

5.7.2 THE VOLUME OF THE BUBBLE (V) CAN BE APPROXIMATED BY THE RELATIONSHIP $V/D = 0.231$. V IS ASSUMED TO BE A FUNCTION OF SPECIFIC FUEL GEOMETRY, IE THE INSIDE DIAMETER OF THE FUEL ROD AND MAXIMUM FUEL ROD PRESSURIZATION (1200 PSIG). THE DIFFERENCE IN WATER PRESSURE BETWEEN 21'5" AND 20'6" IS NEGLIGIBLE COMPARED WITH 1200 PSIG AND WILL BE NEGLECTED.

5.8 FROM PAGE 20 OF REFERENCE 4.3:

5.8.1 THE BUBBLE RISE VELOCITY (V_b) IS A FUNCTION OF THE BUBBLE VOLUME AND, THEREFORE A FUNCTION OF SPECIFIC FUEL GEOMETRY ie INSIDE DIAMETER OF THE FUEL ROD AND INTERNAL FUEL ROD PRESSURE.

5.9 FROM PAGE 17 OF REFERENCE 4.3:

5.9.1 THE MASS TRANSFER (K_{eff}) CALCULATION IS A FUNCTION OF I_2 DIFUSIVITY IN He (D_G), I_2 DIFUSIVITY IN WATER (D_L), I_2 PARTITION FACTOR (P), d_b AND V_b. D_G, D_L AND P (AN ASSUMED LOW VALUE TO MANTAIN CONSERVATISM) ARE CONSTANTS AND d_b AND V_b ARE FUNCTIONS OF SPECIFIC FUEL GEOMETRY. IT IS THEREFORE ASSUMED THAT K_{eff} IS A FUNCTION OF SPECIFIC FUEL GEOMETRY

5.10 THE BUBBLE RISE HEIGHT IN CM. (H) IS RELATED TO THE MINIMUM WATER DEPTH (h) BETWEEN THE TOP OF THE DAMAGED FUEL RODS AND THE FUEL POOL SURFACE AS FOLLOWS:

5.10.1 $$H(cm) = (2.54\ cm/in)(12\ in/ft)(h\ (ft))$$

OR

$$H = 30.48h$$

5.11 EQUATION 5.6.1 CAN BE REWRITTEN IN TERMS OF h BY THE USE OF 5.10.1. THIS YIELDS:

5.11.1 $$DF_{INORG} = e^{\left(\frac{6 \times 30.48 \times K_{eff}}{d_b \times V_b}\right) h}$$

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5.12 THE TERMS IN EQUATION 5.11.1 THAT ARE IN THE PARENTHESES ARE ALL CONSTANTS OR FUNCTIONS OF SPECIFIC FUEL GEOMETRY ONLY. EQUATION 5.11.1 CAN BE REWRITTEN AS FOLLOWS:

5.12.1 $DF_{inorg} = e^{\alpha h}$ WHERE α IS A FUNCTION OF ONLY SPECIFIC FUEL GEOMETRY

5.13 IF THE FUEL GEOMETRY REMAINS CONSTANT THEN α WILL BE CONSTANT AND DF_{inorg} WILL BE A FUNCTION OF h ONLY.

5.14 EQUATION 5.12.1 CAN BE APPLIED TO THE CONSERVATIVE CASE OF REFERENCE 4.1. FOR THIS CONSERVATIVE CASE $DF_{inorg} = 133$ AT 23 FEET. FROM EQUATION 5.12.1 A CONSERVATIVE α CAN BE CALCULATE.

5.14.1 $133 = e^{23\alpha}$ OR $\alpha = \frac{\ln 133}{23}$

5.14.2 THE APPLICATION OF $\alpha = \frac{\ln 133}{23}$ TO THE BSEP CASE WILL MAINTAIN CONSERVATISM BECAUSE IT IS BASED ON DOCUMENTS PUBLISHED BY THE NRC. THE FORMULA IS DEVELOPED FROM REFERENCE 4.2 AND THE VALUES COME FROM PAGE 25.2 OF REFERENCE 4.1.

6.0 CALCULATIONS

6.1 DF_{inorg} FROM 5.12.1 AND 5.14.1

6.1.1 A CONSERVATIVE DF_{inorg} FOR THE EXISTING GRID MOUNTED RACKS IS:

$$DF_{inorg} = e^{\left(\frac{\ln 133}{23}\right)\left(21\frac{5}{12}\right)} \qquad h = 21'5''$$

$$\underline{DF_{inorg} = 95.0}$$

6.1.2 A CONSERVATIVE DF_{inorg} FOR THE NEW HDFSS RACKS IS

$$DF_{inorg} = e^{\left(\frac{\ln 133}{23}\right)(20.5)} \qquad h = 20'6''$$

$$\underline{DF_{inorg} = 78.2}$$

6.2 DF_{eff} FROM 5.6.2 AND REFERENCE 4.1

6.2.1 THE DF_{eff} FOR THE EXISTING GRID MOUNTED RACKS IS:

$$(DF_{eff})_i = \frac{1}{\frac{0.9975}{95.0} + \frac{0.0025}{1}}$$

FROM REFERENCE 4.1

FRACTION INORGANIC = 99.75%

FRACTION ORGANIC = 0.25%

$$\underline{(DF_{eff})_i = 76.9}$$

6.2.2 THE DF_{eff} FOR THE NEW HDFSS RACKS IS

$$(DF_{eff})_F = \frac{1}{\frac{0.9975}{78.2} + \frac{0.0025}{1}}$$

$$\underline{(DF_{eff})_f = 65.5}$$

6.3 NEW "WORST CASE" CONSERVATIVE THYROID DOSES AS A RESULT OF A REFUELING ACCIDENT OVER THE NEW HDFSS MODULES FROM 5.5.1, 6.2 AND REFERENCE 4.2:

6.3.1 NEW 0-2 HR DOSE AT THE EXCLUSION DISTANCE IS

$$D = \left(\frac{76.9}{65.5}\right) 6.31 \times 10^{-3} \text{ REM THYROID}$$

$$\underline{D = 7.41 \times 10^{-3} \text{ REM THYROID}}$$

6.3.2 NEW 0-30 DAY DOSE AT THE LOW POPULATION ZONE IS

$$D = \left(\frac{76.9}{65.5}\right) 1.01 \times 10^{-2} \text{ REM THYROID}$$

$$\underline{D = 1.19 \times 10^{-2} \text{ REM THYROID}}$$

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7.0 CONCLUSION

7.1 REDUCTION OF THE MINIMUM WATER DEPTH BETWEEN THE TOP OF THE FUEL RODS STORED IN THE SPENT FUEL STORAGE RACKS FROM 21'5" TO 20'6" REDUCED THE THYROID DOSE SAFETY FACTOR FOR A REFUELING ACCIDENT BY 15% BASED ON A VERY CONSERVATIVE APPROACH. SAFETY FACTOR = D_L/D WHERE D_L IS THE 10 CFR 100 GUIDELINE LIMIT OF 300 REM THYROID.

7.1.1 EXCLUSION DISTANCE SAFETY FACTORS

GRID MOUNTED RACKS - $\frac{300}{6.31\times10^{-3}} = 47,544$

HDFSS RACKS - $\frac{300}{7.41\times10^{-3}} = 40,486$

7.1.2 LOW POPULATION ZONE SAFETY FACTORS

GRID MOUNTED RACKS - $\frac{300}{1.01\times10^{-2}} = 29,703$

HDFSS RACKS - $\frac{300}{1.19\times10^{-2}} = 25,210$

7.2 THE BSEP TECH. SPEC. 3.9.9 CAN BE SAFELY REDUCED TO 20'6" OF WATER TO BE MAINTAINED OVER THE TOP OF THE FUEL RODS FOR FUEL STORED IN THE SPENT FUEL STORAGE RACKS.