April 2020

Revision 20B

NAC-UMS

Universal MPC System

SAFETY ANALYSIS REPORT

Supplement to Damaged BWR
Amendment 8

Non-Proprietary Version

Docket No. 72-1015

NAC INTERNATIONAL

Atlanta Corporate Headquarters: 3930 East Jones Bridge Road, Norcross, Georgia 30092 USA
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Enclosure 1

Supporting Calculation

for the

NAC-UMS FSAR
Supplement to Damaged BWR Amendment 8
Revision 20B
(Docket No 72-1015)

NAC International

April 2020

List of Calculations

1. **EA790-2521, Revision 1**

CALCULATION WITHHELD IN ITS ENTIRETY PER 10 CFR 2.390

Enclosure 2

List of Changes

for the

NAC-UMS FSAR
Supplement to Damaged BWR Amendment 8
Revision 20B
(Docket No 72-1015)

NAC International

April 2020

List of Changes for the NAC-UMS FSAR, Revision 20B

Chapter/Page/ Figure/Table	Description of Change
Note:	The List of Effective Pages and the Chapter Table of Contents, List of Figures and List of Tables have been revised accordingly to reflect the list of changes detailed below, if needed.
Chapter 1	
Page 1.8-2	Modified Section 1.8.1 where indicated.
Chapter 2 – no changes	
Chapter 3	
Pages 3.9-12 thru 3.9-14	Modified and added text at the end of Section 3.9.2.2 where indicated.
Pages 3.9-15 thru 3.9-17	Text flow changes.
Chapter 4 – no changes	
Chapter 5 – no changes	
Chapter 6 – no changes	
Chapter 7 – no changes	
Chapter 8 – no changes	
Chapter 9 – no changes	
Chapter 10 – no changes	
Chapter 11 – no changes	
Chapter 12 – no changes	
Chapter 13 – no changes	

Enclosure 3

List of Drawing Changes

for the

NAC-UMS
Supplement to Damaged BWR Amendment 8
Revision 20B
(Docket No 72-1015)

NAC International

April 2020

List of Drawing Changes, NAC-UMS SAR, Revision 20B

Drawing 790-601, Sheet 1, Revision 2P

Sheet 1:

[redacted]

Drawing 790-601, Sheet 1, Revision 1NP

Sheet 1:

1. Clouded out B.O.M. details indicating them as proprietary.
2. Clouded out Note details indicating them as proprietary.
3. Clouded out Assembly 99 identification balloon and title.

Enclosure 4

FSAR Changed Pages

for the

NAC-UMS
Supplement to Damaged BWR Amendment 8
Revision 20B
(Docket No 72-1015)

NAC International

April 2020

April 2020

Revision 20B

NAC-UMS

Universal MPC System

FINAL SAFETY ANALYSIS REPORT

for the UMS Universal Storage System

Non-Proprietary Version

Docket No. 72-1015

NAC INTERNATIONAL

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List of Effective Pages

Chapter 1

List of Effective Pages (continued)

Chapter 2

Chapter 3

List of Effective Pages (continued)

Chapter 4

List of Effective Pages (continued)

Chapter 5

List of Effective Pages (continued)

Chapter 6

Chapter 7

Chapter 8

List of Effective Pages (continued)

Chapter 9

9-i thru 9-ii ..... Revision 19A
9.1-1 ..... Revision 4
9.1-2 ..... Revision 8
9.1-3 ..... Revision 4
9.1-4 ..... Revision 5
9.1-5 ..... Revision 4
9.1-6 ..... Revision 10
9.1-7 thru 9.1-20 ..... Revision 19A
9.2-1 ..... Revision 7
9.2-2 ..... Revision 9
9.2-3 ..... Revision 7
9.3-1 ..... Revision 8
9.3-2 ..... Revision 5

Chapter 10

10-i thru 10-ii ..... Revision 19A
10.1-1 ..... Revision 3
10.1-2 ..... Revision 6
10.2-1 thru 10.2-2 ..... Revision 19A
10.3-1 thru 10.3-3 ..... Revision 19A
10.3-4 ..... Revision 0
10.3-5 thru 10.3-6 ..... Revision 3
10.3-7 ..... Revision 0
10.3-8 thru 10.3-9 ..... Revision 3
10.4-1 thru 10.4-2 ..... Revision 19A
10.4-3 thru 10.4-5 ..... Revision 3
10.5-1 ..... Amendment 1
10.6-1 thru 10.6-3 ..... Revision 19A
10.7-1 ..... Revision 19A

Chapter 11

11-i ..... Amendment 1
11-ii ..... Revision 3
11-iii ..... Revision 5
11-iv ..... Revision 19A
11-v ..... Revision 3
11-vi ..... Revision 19A
11-vii thru 11-x ..... Revision 3
11-1 ..... Revision 0
11.1.1-1 ..... Revision 6
11.1.1-2 ..... Revision 3
11.1.1-3 thru 11.1.1-6 ..... Revision 0
11.1.2-1 ..... Revision 6
11.1.2-2 ..... Revision 0
11.1.2-3 ..... Revision 3
11.1.3-1 ..... Revision 3
11.1.3-2 thru -11.1.3-3 ..... Revision 12
11.1.3-4 thru -11.1.3-16 ..... Revision 3
11.1.4-1 thru 11.1.4-2 ..... Revision 6
11.1.5-1 thru 11.1.5-2 ..... Revision 0
11.1.6-1 ..... Amendment 1
11.2-1 ..... Amendment 1
11.2.1-1 thru 11.2.1-7 ..... Revision 3
11.2.2-1 ..... Revision 8
11.2.3-1 ..... Revision 3
11.2.3-2 ..... Revision 0
11.2.4-1 thru 11.2.4-11 ..... Revision 3
11.2.4-12 ..... Revision 13
11.2.4-13 thru 11.2.4-21 ..... Revision 0
1.2.4-22 thru 11.2.4-24 ..... Revision 3
11.2.4-25 ..... Revision 7
11.2.4-26 thru 11.2.4-27 ..... Revision 3
11.2.5-1 ..... Revision 0
11.2.6-1 thru 11.2.6-2 ..... Revision 3
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11.2.8-2 ..... Revision 0

List of Effective Pages (continued)

Chapter 12

List of Effective Pages (continued)

Chapter 13

1.8 License Drawings

This section presents the list of License Drawings for the Universal Storage System.

1.8.1 License Drawings for the UMS® Universal Storage System

Drawing Number	Title	Revision No.	No. of Sheets
790-501	Canister/Basket Assembly Table, NAC-UMS®	3	1
790-559	Assembly, Transfer Adapter, NAC-UMS®	7	4
790-560	Assembly, Standard Transfer Cask (TFR), NAC-UMS®	17	7
790-561	Weldment, Structure, Vertical Concrete Cask (VCC), NAC-UMS®	16	4
790-562	Reinforcing Bar and Concrete Placement, Vertical Concrete Cask (VCC), NAC-UMS®	20	8
790-563	Lid, Vertical Concrete Cask (VCC), NAC-UMS®	6	1
790-564	Shield Plug, Vertical Concrete Cask (VCC), NAC-UMS®	8	3
790-565	Nameplate, Vertical Concrete Cask (VCC), NAC-UMS®	5	1
790-570	Fuel Basket Assembly, 56 Element BWR, NAC-UMS®	6	3
790-571	Bottom Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®	3	1
790-572	Top Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®	4	1
790-573	Support Disk and Misc. Basket Details, 56 Element BWR, NAC-UMS®	8	1
790-574	Heat Transfer Disk, Fuel Basket, 56 Element BWR, NAC-UMS®	3	1
790-575	BWR Fuel Tube, NAC-UMS®	11	2
790-581	PWR Fuel Tube, NAC-UMS®	9	2
790-582	Shell Weldment, Canister, NAC-UMS®	13	2
790-583	Assembly, Drain Tube, Canister, NAC-UMS®	9	1
790-584	Details, Canister, NAC-UMS®	20	3
790-585	Transportable Storage Canister (TSC), NAC-UMS®	25	3
790-587	Spacer Shim, Canister, NAC-UMS®	1	1
790-590	Loaded Vertical Concrete Cask (VCC), NAC-UMS®	9	2
790-591	Bottom Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®	6	2

License Drawings (continued)

Drawing Number	Title	Revision No.	No. of Sheets
790-592	Top Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®	8	1
790-593	Support Disk and Misc. Basket Details, 24 Element PWR, NAC-UMS®	7	2
790-594	Heat Transfer Disk, Fuel Basket, 24 Element PWR, NAC-UMS®	2	1
790-595	Fuel Basket Assembly, 24 Element PWR, NAC-UMS®	10	2
790-601	Damaged Fuel Can (DFC), BWR, NAC-UMS®	1NP*	1
790-605	BWR Fuel Tube, Over-Sized Fuel, NAC-UMS®	12	2
790-613	Supplemental Shielding, VCC Inlets, NAC-UMS®	2	1
790-617	Door Stop, NAC-UMS®	4	2
790-671	Bottom Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®	1	1
70-672	Top Weldment, Fuel Basket, 56 Element BWR DF, NAC-UMS®	1	1

*Proprietary Drawing Removed

1.8.3 Site Specific Spent Fuel License Drawings

Drawing Number	Title	Revision No.	No. of Sheets
412-501	Spent Fuel Can Assembly, Maine Yankee (MY), NAC-UMS®	4	2
412-502	Fuel Can Details, Maine Yankee (MY), NAC-UMS®	6	6

REV	CHANGE
0NP	INITIAL ISSUE - DCR A
1NP	INC DCR 0NPA

PROPRIETARY INFORMATION
REMOVED

<1>

NOTES:

96 ASSY	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
QUANTITY									

NAC INTERNATIONAL

UNLESS OTHERWISE STATED
DIMENSIONING AND TOLERANCING SHALL BE PER ASME Y14.5M-94.
ALL THREAD DEPTH CALLOUTS ARE TO BE CONSIDERED AS A MIN. DEPTH OF PERFECT THREADS
ALL DIMENSIONS ARE IN INCHES
MACHINED SURFACES SHALL BE 125 OR BETTER
NEXT ASSEMBLY: 790-585
DRAWING TYPE: LICENSE

GROUP	NAME	DATE
PREPARER		3/19/20
CHECKER		3-19-20
PROJECT MANAGER	J R Dargis	3-19-20
ENGINEERING		3-19-20
LICENSING		3/20/20
QUALITY		3/20/20

DAMAGED FUEL CAN (DFC)
BWR, NAC - UMS®

PROJECT	DRAWING	REV
790	601	1NP
	SH 1 OF 1	3/19/2020

$$FS_u = \frac{S_u}{\sigma_{max}} = \frac{63{,}300}{1659} = 38.2 > 10$$

DFC tube body welds evaluation

The welds joining the tube body to the flange and bottom assembly are full penetration welds (ASME, Section III, Subsection NG, Type III, paragraph NG-3352.3). Per Subsection NG, Table NG-3352-1, the weld quality factor (n) for a Type III weld with visual surface inspection is 0.5.

The weld stress (σ_w) is:

$$\sigma_w = \frac{1.1(P)}{A} = \frac{1.1(809)}{1.097} = 811 \text{ psi}$$

where:

P = the combined weight of the tube body, the neutron absorber weight, bottom assembly, the cladding weight, and can contents;
62 + 26 +7 + 12 + 702 = 809 lb.

A = cross sectional area of thinner member joined = 1.097 in^2

The factors of safety on material yield strength (FS_y) and ultimate strength (FS_u) of Type 304 Stainless Steel at 600°F are:

$$FS = \frac{n \cdot S_y}{\sigma_w} = \frac{0.5(18{,}600)}{811} = 11.5 > 6$$

$$FS = \frac{n \cdot S_u}{\sigma_w} = \frac{0.5(63{,}300)}{811} = 39.0 > 10$$

Therefore, the criteria of NUREG-0612 and ANSI N14.6 for the lifting of non-redundant systems are satisfied.

DFC tube body tensile stress evaluation

The tube body will be subjected to tensile loads during lifting operations. The load (P) includes the can contents (702 lb design weight), the tube body weight (62 lb) , the neutron absorber weight

(26 lb), the cladding weight (12 lb) and the bottom assembly weight (7 lb) for a total of 809 lb. A load of 809 lb with a 10% dynamic load factor is used for the analysis.

The tensile stress (σ_t) is then:

$$\sigma_t = \frac{1.1P}{A} = \frac{1.1(809\ lb)}{1.097\ in.^2} = 811 \text{ psi}$$

where:

$A = 6.14^2 - 6.05^2 = 1.097$ in^2

The margin of safety (MS) based on allowable for primary membrane (tensile) stress (Sm) for Type 304 Stainless Steel at 600°F is:M

$$MS = 1.0\ Sm / \sigma_t - 1 = 16{,}700 / 811 - 1 = +19.6$$

Bottom Plate Evaluation

The DFC bottom plate is evaluated for the lift condition using ASME Boiler and Pressure Vessel Code, Section III, Subsection NG [6]. Since the DFC lifting operations always occur underwater, material properties are evaluated at 200°F.

Bending Stress

The controlling stress in the DFC bottom plate is the bending stress occurring in the 0.17-inch thick disk located in the middle of the bottom plate. Case No. 17 in Table 24 of Roark's Formulas for Stress and Strain [26] provides the expression for the moment for a uniform load over a circular area at the center of a uniform thick disk with fixed boundary conditions around its perimeter. This is applicable for the evaluation of the 0.17-inch thick disk located in the middle of the bottom plate. Therefore, the maximum bending moment occurring at the center of the bottom plate disk ($M_{max,c}$) is calculated:

$$M_{max,c} = \frac{W \times DLF}{4\pi} \times (1 + \nu) \times \ln\left(\frac{a}{r_o'}\right) = 171 \text{ in-lb}$$

where:

W = 702 lb, weight of BWR fuel assembly

DLF = 1.1, dynamic load factor (10%)

ν = 0.31, Poisson's Ratio

$a = \frac{2.5}{2}$ = 1.25 in, radius of 0.17" thick disk

$r'_o = r_o$ = 0.15 in, because $r_o > 0.5t$

$r_o = \frac{d_o}{2}$ = 0.15 in, radius of the applied load

d_o = 0.3 in, bearing area diameter of the applied load

t = 0.17 in, thickness of the middle disk

The maximum bending moment that occurs around the outer radius (1.25-inch) of the 0.17-inch thick disk ($M_{max.r}$) is calculated:

$$M_{max.r} = \frac{W \times DLF}{4\pi} = 61 \text{ in-lb}$$

The maximum bending moment at the center of the disk is greater than that at the outer radius; therefore, the maximum disk bending moment (in units of kip-inch) corresponds to the center of the disk.

$$M_{max} = \frac{M_{max,c}}{1000} = 0.171 \text{ kip-in}$$

The maximum bending stress (σ_{max}) at the center of the disk is calculated:

$$\sigma_{max} = 6 \times \frac{M_{max}}{t^2} = 35.4 \text{ ksi}$$

The margin of safety for the maximum bending stress of the disk is calculated as follows. Note that the allowable membrane plus bending stress is $1.5S_m$.

$$MS = \frac{1.5S_m}{\sigma_{max}} - 1 = +0.4$$

where:

S_m = 33.1 ksi, design stress intensity of SA-240 Type XM-19 at 200°F

Bearing Stress

The bearing stress ($\sigma_{bearing}$) from the BWR fuel assembly on the DFC bottom plate is calculated:

$$\sigma_{bearing} = \frac{W \times DLF}{\pi \times r_o^2} = 10.9 \text{ ksi}$$

where:

W = 702 lb, weight of BWR fuel assembly

DLF = 1.1, dynamic load factor (10%)

$r_o = \frac{d_o}{2}$ = 0.15 in, radius of the applied load

d_o = 0.3 in, bearing area diameter of the applied load (see Figure 5.4)

The margin of safety (MS) for bearing stress is calculated based on the allowable bearing stress of S_y.

$$MS = \frac{S_y}{\sigma_{bearing}} - 1 = +3.3$$

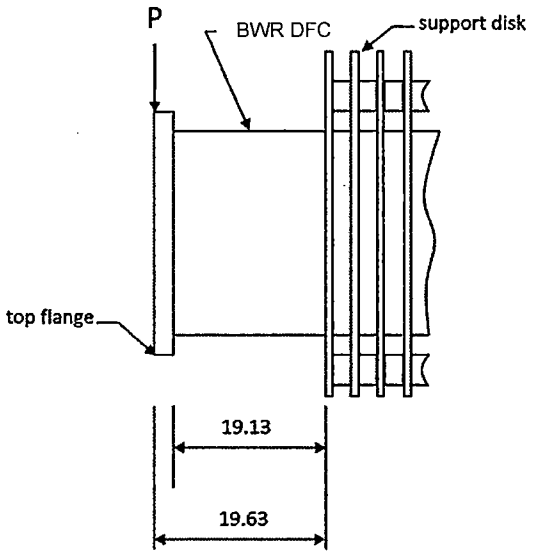
where:

S_y = 47.1 ksi, yield strength of SA-240 Type XM-19 at 200°F

3.9.2.3 BWR Damaged Fuel Can Tube Body–Side Impact

The governing side impact condition corresponding to the hypothetical cask tip-over accident is evaluated in this section. The majority of the BWR damaged fuel can (DFC) tube body is contained in the basket assembly. Because both the tube body and the support disks of the basket have square cross sections, they will be in full contact (for 158.83 inches longitudinally) during the side impact and no significant bending stress will be introduced into the support disk. The last 19.63 inches (tube body and top flange) will be unsupported past the support disk in the side impact configuration.

The tube body will be evaluated as a cantilevered beam with the combined weight (P) of the overhanging tube body, top flange, and lid assembly multiplied by the appropriate acceleration factor and, conservatively, concentrated at the top end of the top flange.



(Unit: inch)

The maximum bending stress (f_b) is determined as follows.

$$f_b = \frac{M_{max} c}{I} = \frac{11{,}778(3.07)}{6.793} = 5{,}322 \ psi$$

where:

M_{max} = $P \times a \times L = 20(30)(19.63) = 11{,}778$ lb·in

a = 30g

P = 20 lb; (lid plate, 2 lb + lid wall, 2 lb + top flange, 2 lb + tube body (62 lb × 19.13/177.57 in/in = 6.68 lb) + cladding (12 lb × 19.13/177.1 in/in = 1.3 lb) + neutron absorber (26 lb × 19.13/176.3 in/in = 2.82 lb), which is equal to 16.8 lb; use 20 lb bounding)

L = 19.63 in (total overhang length of the tube body and top flange)

c = 6.14/2 = 3.07 in

I = $\frac{bh^3 - b_i h_i^3}{12} = \frac{6.14^4 - 6.05^4}{12} = 6.793 \ in^4$

The shear stress (τ) is:

$$\tau = \frac{Pg}{A} = \frac{20(30)}{1.097} = 547 \ psi$$

where:

$A = 6.14^2 - 6.05^2 = 1.097\ in^2$

$$\sigma_1, \sigma_2 = \frac{1}{2}\left(f_b \pm \sqrt{f_b^2 + 4\tau^2}\right) = \frac{1}{2}\left(5{,}322 \pm \sqrt{5{,}322^2 + 4(547)^2}\right) = 5{,}378.\ psi\ and\ -56\ psi$$

The stress intensity (σ_{max}) = $|\sigma_1 - \sigma_2|$ = 5,434 psi

The margin of safety (MS) is:

$$MS = \frac{1.0\ S_u}{\sigma_{max}} - 1 = \frac{1.0(63{,}300)}{5{,}434} - 1 = +10.6$$

3.9.2.4 BWR Damaged Fuel Can Tube Body–End Impact

The DFC is evaluated for a bottom end impaction corresponding to the cask 24-inch drop accident in this section. For the bottom end drop, the top flange, the lid assembly (Lid plate + Lid wall), neutron absorber, cladding and the tube body act against the bottom assembly (Bottom plate weldment + Collar + Bottom lid). The total weight is conservatively used for tube body compression.

DFC tube body compressive stress evaluation

For the end impact accident conditions, the tube is evaluated for a 60g acceleration. The compressive load (P) on the tube is the combined weight of the lid assembly, top flange, and tube body times 60g:

The compressive load (P) is:

P = 113lb × 60g = 6,780 lb;

The compressive stress (S_c) in the tube body is:

$$S_c = \frac{P}{A} = \frac{6{,}780\ lb}{1.097\ in.^2} = 6{,}180\ psi$$

The margin of safety (MS) is then:

$$MS = \frac{0.7S_u}{S_c} - 1 = \frac{0.7(63{,}300)\ psi}{6{,}180\ psi} - 1 = +6.2$$ for accident conditions at 600°F.

DFC tube body buckling evaluation

The tube is evaluated, using the Euler formula, to determine the critical buckling load (P_{cr}):

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2 \left(25.2 \times 10^6\right)\left(6.793\right)}{\left[2\left(177.57\right)\right]^2} = 13{,}396 \text{ lb}$$

where:

E = 25.2×10^6 psi

I = $\frac{6.14^4 - 6.05^4}{12} = 6.793 in.^4$

L_e = 2L (worst case condition)

L = tube body length (177.57 in)

Because the maximum compressive load (6,780 lb under the accident condition) is much less than the worst-case critical buckling load (13,396 lb) and the support disks also provide lateral constrains to the body tube, the tube has adequate resistance to buckling.

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