Table 6. DOE WPs Emplaced After CSNF Emplacement is Complete (Continued)

Acceptance Criterion	TAD Trans Cask Heat Limit	Preclosure Limits	Target Midpillar Temperature (°C)	Initial Blending Inventory (Years)	DOE WPs
YFF5	22 kW	30kW, 2.2kW/m	85	4	223
YFF5	30 kW	18kW, 2.0kW/m	96	2	977
YFF5	30 kW	18kW, 2.0kW/m	87	4	93
YFF5	30 kW	30kW, 2.2kW/m	96	2	1,384
YFF5	30 kW	30kW, 2.2kW/m	86	4	190
SYFF5	N/A	18kW, 2.0kW/m	96	2	0
SYFF5	N/A	18kW, 2.0kW/m	88	4	0
SYFF5	N/A	30kW, 2.2kW/m	96	2	1,050
SYFF5	N/A	30kW, 2.2kW/m	88	4	126

Table 7 shows the emplacement period duration for the 12 scenarios. Note that as the thermal content of the waste stream increases, the amount of time required to emplace the waste stream also increases, to the point that two of the Strict YFF5 scenarios cannot be emplaced within the desired 50 year operating period.

Table 7. Emplacement Period

Acceptance Criterion	TAD Trans Cask Heat Limit	Preclosure Limits	Target Midpillar Temp (°C)	Initial Blending Inventory (Years)	Emplacement Period (Years)[1]
YFF5	22 kW	18kW, 2.0kW/m	96	2	34
YFF5	22 kW	18kW, 2.0kW/m	85	4	36
YFF5	22 kW	30kW, 2.2kW/m	96	2	34
YFF5	22 kW	30kW, 2.2kW/m	85	4	36
YFF5	30 kW	18kW, 2.0kW/m	96	2	43
YFF5	30 kW	18kW, 2.0kW/m	86	4	43
YFF5	30 kW	30kW, 2.2kW/m	96	2	38
YFF5	30 kW	30kW, 2.2kW/m	87	4	40

Table 7. Emplacement Period (Continued)

Acceptance Criterion	TAD Trans Cask Heat Limit	Preclosure Limits	Target Midpillar Temp (°C)	Initial Blending Inventory (Years)	Emplacement Period (Years)[1]
SYFF5	N/A	18kW, 2.0kW/m	96	2	52
SYFF5	N/A	18kW, 2.0kW/m	88	4	52
SYFF5	N/A	30kW, 2.2kW/m	96	2	38
SYFF5	N/A	30kW, 2.2kW/m	88	4	40

Note 1: Measured from start of receipt in 2017.

Another measure of system performance is the net CSNF in aging. Figures 13 - 15 show the net in aging (in MTHM) for the 12 scenarios. Table 8 summarizes the maximum CSNF in aging for each case.

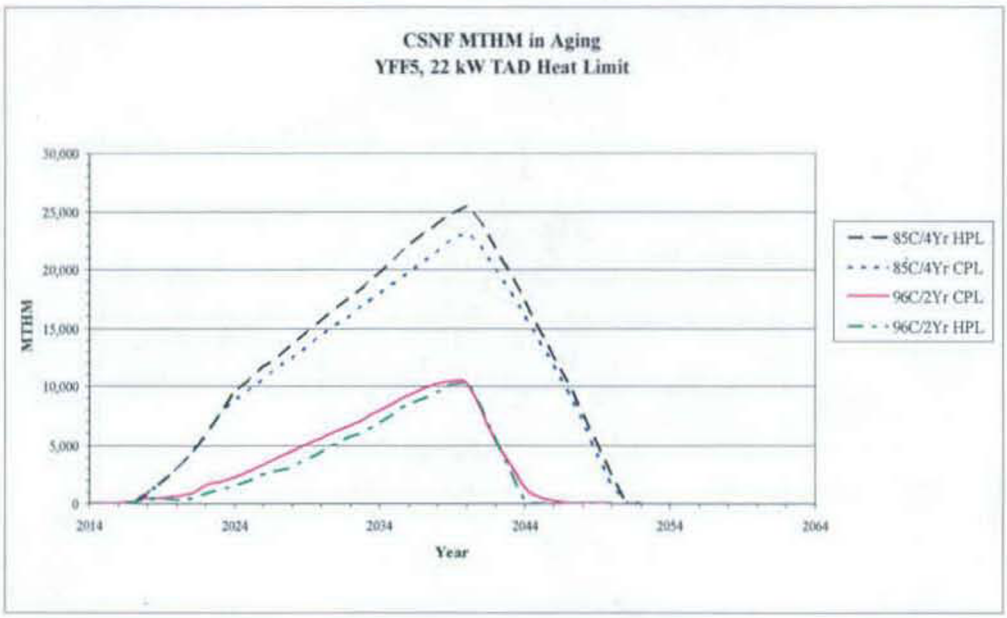

Figure 13. Net MTHM In Aging, YFF5, 22KW TAD Transportation Cask Heat Limit

Note: CPL = Current preclosure limits (18kW/WP, 2.0kW/m); HPL = higher preclosure limits (30kW/WP, 2.2kW/m)

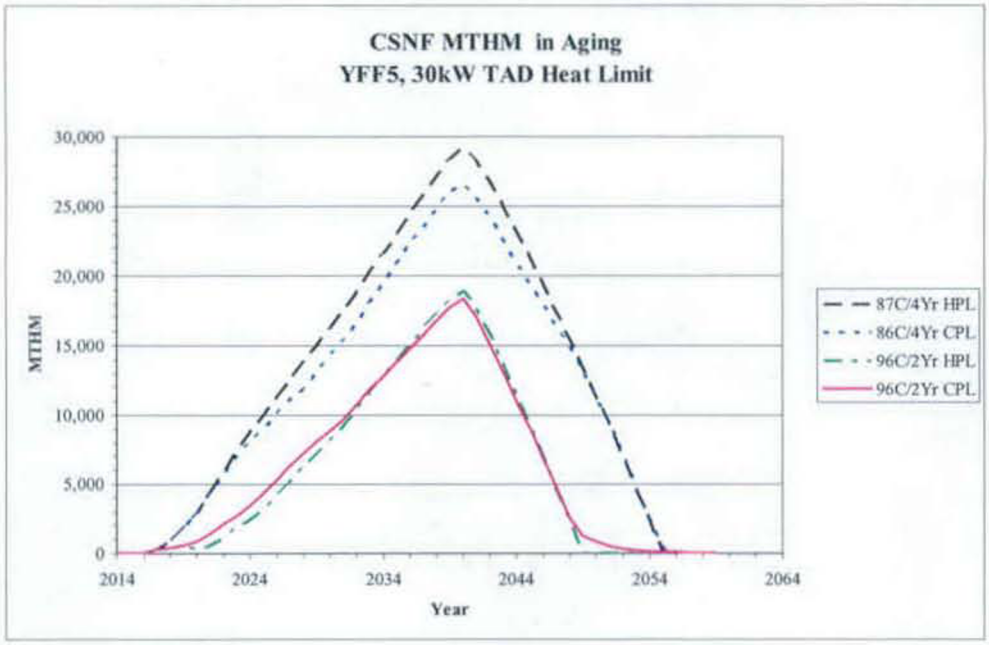

Figure 14. Net MTHM In Aging, YFF5, 30 kW TAD Transportation Cask Heat Limit

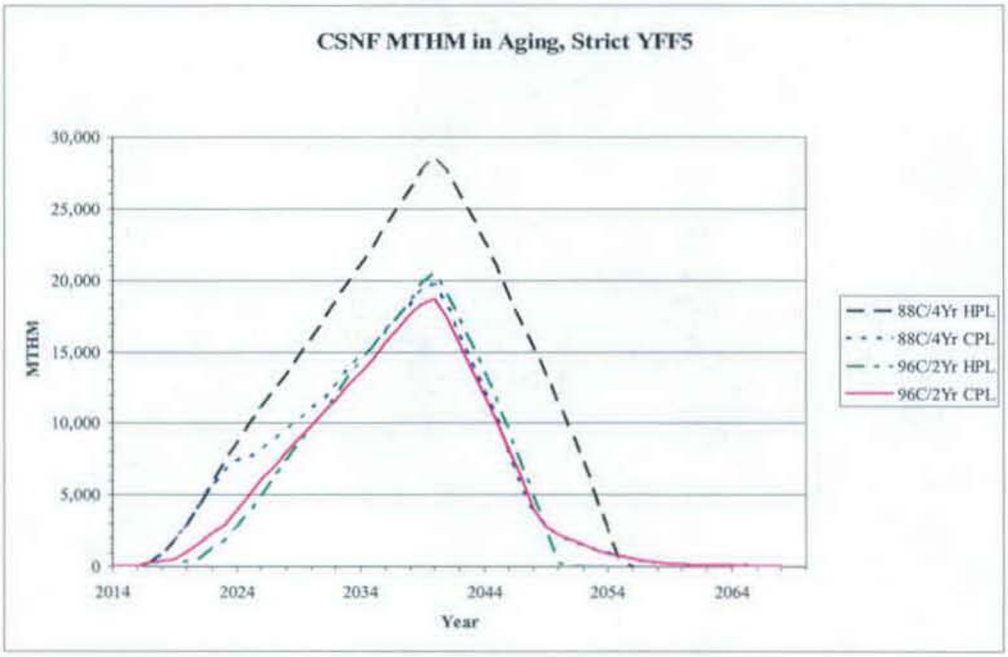

Figure 15. Net CSNF MTHM in Aging, Strict YFF5

Table 8. Maximum CSNF MTHM In Aging[1]

Acceptance Criterion	TAD Trans Cask Heat Limit	Preclosure Limits	Target Midpillar Temp (°C)	Initial Blending Inventory (Years)	MTHM In Aging[2]
YFF5	22 kW	18kW, 2.0kW/m	96	2	10,400
YFF5	22 kW	18kW, 2.0kW/m	85	4	23,200
YFF5	22 kW	30kW, 2.2kW/m	96	2	10,300
YFF5	22 kW	30kW, 2.2kW/m	85	4	25,500
YFF5	30 kW	18kW, 2.0kW/m	96	2	18,300
YFF5	30 kW	18kW, 2.0kW/m	86	4	26,600
YFF5	30 kW	30kW, 2.2kW/m	96	2	18,900
YFF5	30 kW	30kW, 2.2kW/m	87	4	29,100
SYFF5	N/A	18kW, 2.0kW/m	96	2	18,700
SYFF5	N/A	18kW, 2.0kW/m	88	4	19,700
SYFF5	N/A	30kW, 2.2kW/m	96	2	20,500
SYFF5	N/A	30kW, 2.2kW/m	88	4	28,600

Note 1: MTHM are estimated in "WP_Emplace" workbooks from TAD canister results using average MTHM/assembly data from the IS File for BWR, PWR, and South Texas CSNF.
Note 2: The values in the shaded boxes are greater than the 21,000 MTHM aging pad capacity.

For this analysis, an additional metric was devised, the cumulative frequency of "time in aging" for CSNF TAD canisters. Figures 16 – 18 show these results for the 12 scenarios. The median values of time in aging (rounded to the nearest year) are given in Table 9.

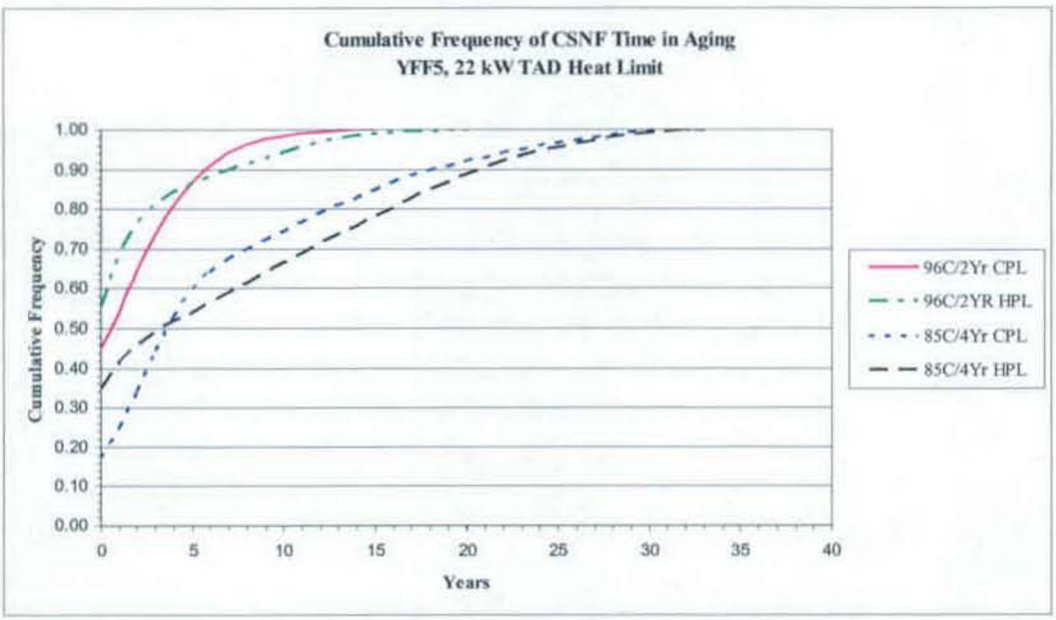

Figure 16. Cumulative Frequency of CSNF Time in Aging, YFF5, 22 kW TAD Transportation Cask Heat Limit

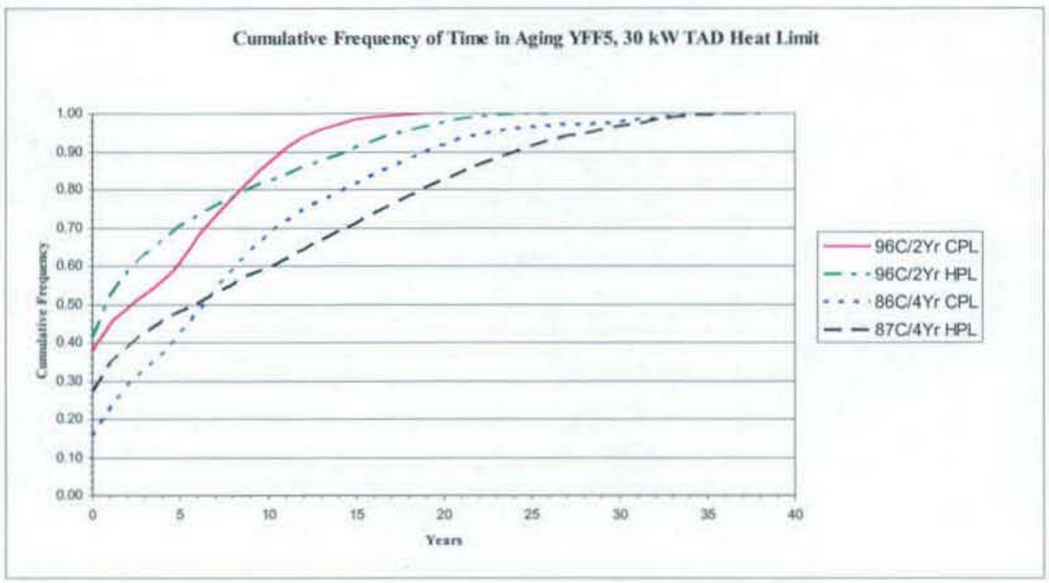

Figure 17. Cumulative Frequency of CSNF Time in Aging, YFF5, 30 kW TAD Transportation Cask Heat Limit

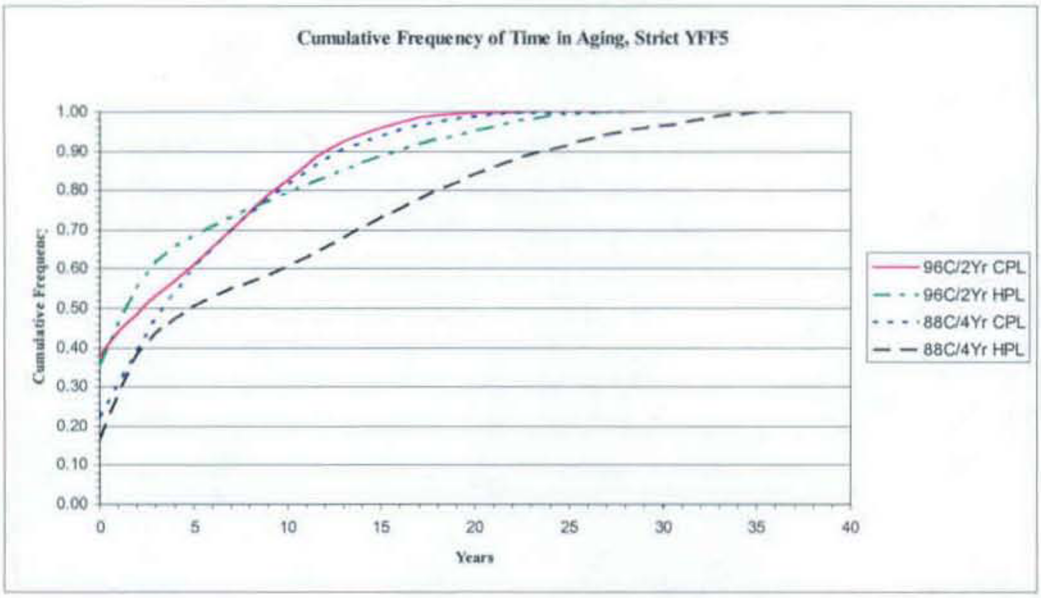

Figure 18. Cumulative Frequency of CSNF Time in Aging, Strict YFF5

Table 9. CSNF Median and Maximum Time in Aging

Acceptance Criterion	TAD Trans Cask Heat Limit	Preclosure Limits	Target Midpillar Temp (°C)	Initial Blending Inventory (Years)	Median Time in Aging[1] (Years)	Maximum Time in Aging[1] (Years)
YFF5	22 kW	18kW, 2.0kW/m	96	2	1	15
YFF5	22 kW	18kW, 2.0kW/m	85	4	4	33
YFF5	22 kW	30kW, 2.2kW/m	96	2	0	12
YFF5	22 kW	30kW, 2.2kW/m	85	4	4	33
YFF5	30 kW	18kW, 2.0kW/m	96	2	2	20
YFF5	30 kW	18kW, 2.0kW/m	86	4	6	38
YFF5	30 kW	30kW, 2.2kW/m	96	2	1	26
YFF5	30 kW	30kW, 2.2kW/m	87	4	6	37
SYFF5	N/A	18kW, 2.0kW/m	96	2	2	29
SYFF5	N/A	18kW, 2.0kW/m	88	4	3	28[2]
SYFF5	N/A	30kW, 2.2kW/m	96	2	1	28
SYFF5	N/A	30kW, 2.2kW/m	88	4	5	37

Note 1: Rounded to the nearest year.
Note 2: This value does not reflect the fact that several WPs were not emplaced in this scenario.

6 OBSERVATIONS

The emplacement trials conducted in this study demonstrate that, if the midpillar temperature is the limiting postclosure thermal constraint, the hottest waste stream that can be accepted, consistent with the limiting CSNF age of 5 years (Strict YFF5), can be emplaced within the 96°C midpillar temperature limit. In fact, this bounding waste stream can be successfully emplaced at a temperature of 88°C (or very slightly higher) under the current preclosure limits of 18 kW/WP and 2.0 kW/m.

The emplacement results for the ELWS (YFF5, 22 kW TAD Transportation Cask Heat Limit, current preclosure limits) in this study, with a 23°C ambient temperature and a rock mass conductivity of 1.87 W/(m*K), are only slightly different than in the Phase 1 study, which used a 25°C ambient temperature and a rock mass conductivity of 1.89 W/(m*K). Table 10 compares the results for the 2 cases.

Table 10. Comparison of ELWS Phase 1 and Phase 2 Results

	Lowest Target Temperature (°C)	DOE WPs Emplaced after CSNF	Maximum CSNF in Aging (MTHM)
96°C Target, 2 Year Blending Inventory			
ELWS, Phase 1[1]	N/A	1,366	11,400
ELWS, Phase 2	N/A	1,600	10,400
Lowest Temperature, 4 Year Blending Inventory			
ELWS, Phase 1[1]	86	213	23,700
ELWS, Phase 2	85	235	23,200

Note 1: Phase 1 results from reference BSC 2007a

In general, the higher the target midpillar temperature, the lower the amount of CSNF in aging. As shown in Table 10, the minimum aging requirement to meet the 96°C midpillar temperature limit with the current preclosure limits is 10,400 MTHM. The 21,000 MTHM aging pad capacity was exceeded only for scenarios with the lowest target temperature and 4 years initial blending inventory.

The median time in aging for TAD canisters in all cases was 6 years or less. However, for some scenarios there were TAD canisters that remained in aging for up to 37 years. As the thermal content of the waste stream increased, the maximum aging requirements increased.

As the thermal content of the waste stream increased, the emplacement period increased. However, the emplacement period was within the 50 year repository operations period in all but two cases with the hottest waste stream (Strict YFF5).

The impact of raising the preclosure limits from the current 18 kW/WP and 2.0 kW/m line load to 30 kW/WP and 2.2 kW/m line load depended on the waste stream assumed. For the ELWS, increasing the preclosure thermal limits had relatively little effect, reducing the median and maximum time in aging and increasing the amount of "left over" DOE WPs at the 96°C target midpillar temperature, and slightly increasing the maximum amount in aging at the lowest midpillar temperature. For the hotter waste streams, the effects were somewhat greater: in general the maximum amount in aging and the "left over" DOE WPs increased, the emplacement period decreased, and for the 96°C target midpillar temperature, the median time in aging decreased. These impacts are as expected: preclosure limits have a greater impact as the incoming waste stream gets hotter.

The following conservatisms were identified during the preparation of the analysis:

- In the "WP_Decay" workbooks, the thermal decay curves generated by the TSM team began for each WP on the date that each it was "created" at the GROA (i.e., was received as a TAD, canister created as a CSNF WP in the WHF, or created as a DOE WP a CRCF). However, the energy density calculation performed by the Lead Laboratory thermal analysis team assumed that the preclosure ventilation period for emplaced WPs began at the date of WP "creation" specified in the WP decay tables, rather than the actual date that the WP was emplaced (i.e., no credit was taken for the time that TAD canisters were in aging prior to emplacement). This resulted in some conservatism in the energy density calculations, since some WPs were not given credit for heat dissipated during the time spent on the aging pad prior to emplacement.

- The candidate ELWS used for the thermal analysis included 69 additional DOE codisposal (HLW-only) and Navy WPs that were to have been generated in the IHF and emplaced prior to full operation (see Section 2.1, items 3 and 4). Due to a misunderstanding, peak mid-pillar temperatures were not provided for these WPs by the Lead Laboratory thermal analysis team. Since these WPs were effectively identical to codisposal and Naval waste packages from the first year of full operation, the peak mid-pillar temperature from waste packages within the first year were used as a substitute. This resulted in a very small conservatism in the emplacement analysis.