FAQ Number 18-0019 **FAQ Revision** 0 (Draft v6)

FAQ Title Transient Fire Heat Release Rate Curves

Plant: Various

Date: March 13, 2019~~August 22, 2018~~

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Purpose of FAQ:

Using NUREG/CR-6850 Supplement 1 Section 17, Appendix A, and Appendix B data, this FAQ provides recommended steady state burn durations and decay durations for the standard transient packages.

Relevant NRC document(s):

NUREG/CR-6850 Supplement 1 (FAQ 08-0052)

Details:

NRC document needing interpretation (include document number and title, section, paragraph, and line numbers as applicable):

NUREG/CR-6850 Supplement 1 Section 17 (FAQ 08-0052)

Circumstances requiring interpretation or new guidance:

The guidance in NUREG/CR-6850 Supplement 1 Section 17 (FAQ 08-0052) specifies growth rates for typical transient packages but doesn't specify a steady state burn duration or decay ~~rate~~duration.

Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:

None.

Potentially relevant existing FAQ numbers:

FAQ 08-0052

Response Section:

Proposed resolution of FAQ and the basis for the proposal:

The guidance in NUREG/CR-6850 Supplement 1 Section 17 (FAQ 08-0052) does provide the basis for the growth rate in Appendices A and B. This includes several complete heat release rate (HRR) ~~growth~~ profiles. These same profiles are used to estimate the steady state burn duration and decay portions of the curve.

The risk contribution of transient scenarios is a function of the peak heat release rate and the total energy deposited from the fire. As the NUREG/CR-6850 guidance already provides the peak HRR (317 kW Table G-1), the burn durations and decay profiles should be related to the energy deposited by the fire. This is estimated by discretizing the HRR curves in the NUREG/CR-6850 Supplement 1 Appendices A and B to ~~assign a MJ total energy deposited~~determine the total energy released for each curve. The development for these curves is contained in Attachment 1 of this FAQ. Per NUREG/CR-68~~0~~50, Supplement 1 the LBL fires are discounted as not being typical of nuclear power plant applications. Here is the summary chart of the ~~bounding MJs~~total energy released for each ~~HRR test group~~test.

Table 1
Summary of NUREG/CR-6850 Supplement 1 Appendices A and B ~~HRR MJ~~Total Energy Released

#	Test	Total Energy [MJ]
A-1	NUREG/CR-4680 test 7, small trash can fire	33.5
A-2	NUREG/CR-4680 test 8, small trash can fire	74.3
A-3	NUREG/CR-4680 test 9, large trash can fire	239

Commented [MB1]: It's not clear what this sentence is attempting to convey. The guidance presented in NUREG/CR-6850 relied, in part, on empirical data that included HRR profiles.

Commented [MB2]: A basis for this statement should be provided especially since the presence of the curves in NUREG/CR-6850, Supplement 1 indicates that these fires are considered typical in NPPs.

Commented [MN3]: Why aren't the two tests from the NISTFR-4018 being used in this analysis for case A- These tests are referenced in Appendix A of NUREG-6850 Supplement 1 as part of the basis for the creation of the 8 minute fire growth profile..

" Overall, the five available tests indicate fire growth times that range from about 7 to 13 minutes. Based on these test results, the recommended practice for this type of fuel source, general refuse in a plastic trash receptacle, is to assume a fire growth time of 8 minutes." – Page A-5 NUREG-6850 Supplement 1

B-3	The heat release rate profile from SNL test 5 involving fuel package 3	15.2

Commented [MN4]: The 2 minute unconstrained fire is based on not only the SNL test 5 but also the LBL tests as documented in NUREG-6850 Supplement 1 Appendix B

"Given the available test results, the recommended general practice for the case of a trash bag fire (i.e., general refuse collected into a plastic bag but not contained within a trash receptacle) is based on a blending of the SNL and LBL test results." Page B-4 NUREG-6850 Supplement 1

Based on the already defined t-squared growth rates, a 317 kW transient fire proposed in NUREG/CR-6850 uses 12.7 MJ for the uncontained 2 minute growth rate and 50.7 MJ for the 8 minute growth rate. The integral of t-squared is t-cubed/3. As the equations is divided by t-squared, the integrated energy for a t-squared growth is T/3.

12.7 MJ = 317 kW * 120 seconds / 3 / 1000 kJ/MJ

50.7 MJ = 317 kW * 480 seconds / 3 / 1000 kJ/MJ

$$\dot{Q}(t) = HRR\ at\ time\ t\ (kW)$$
$$t = time\ (s)$$
$$\dot{Q}_{peak} = Steady\ State\ HRR\ (kW)$$
$$\tau = time\ to\ reach\ peak\ (s)$$
$$E_{growth} = energy\ used\ during\ growth\ (MJ)$$
$$\dot{Q}(t) = \dot{Q}_{peak} * \left(\frac{t}{\tau}\right)^2$$
$$E_{growth} = \int_0^{\tau} \dot{Q}(t)dt = \int_0^{\tau} \dot{Q}_{peak} * \left(\frac{t}{\tau}\right)^2 dt = \frac{\dot{Q}_{peak} * \tau^3}{3 * \tau^2}$$

If the remaining energy is assigned directly to the steady state burn duration, then the remaining burn durations for each test would be:

Table 2
Maximum Steady Burn Duration given Conservation of Test Energies

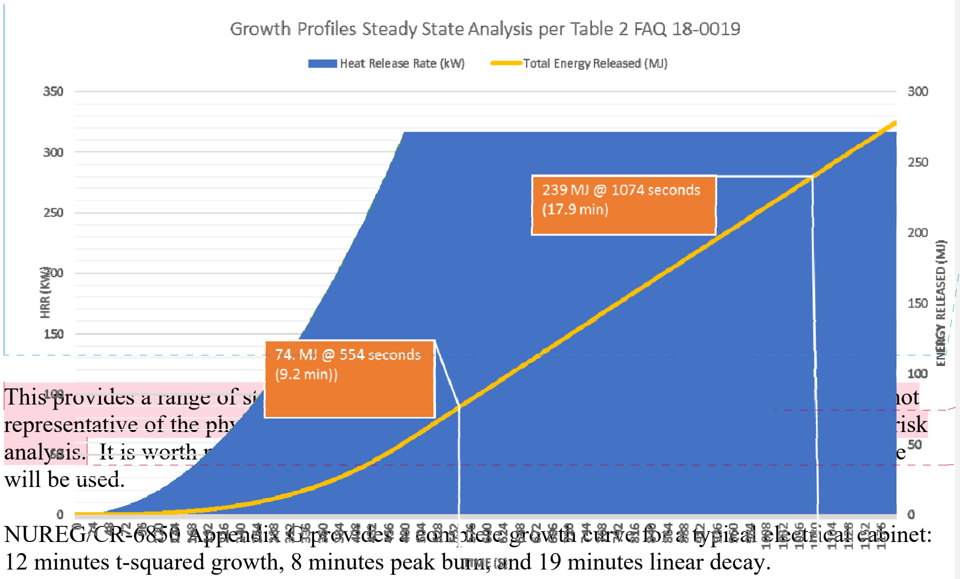
			Non-Contained Fires (time in minutes)			Contained Fires (time in minutes)		
#	**Total MJ**	**HRR kw**	**Growth mins**	**MJ Used in Growth**	**Steady mins**	**Growth mins**	**MJ Used in Growth**	**Steady mins**
A-1	33.5	317	N/A	N/A	N/A	8	50.7	0
A-2	74.3	317	N/A	N/A	N/A	8	50.7	0.2
A-3	239	317	N/A	N/A	N/A	8	50.7	8.8
B-3	15.2	317	2	12.7	0	N/A	N/A	0

Commented [MB5]: This approach only calculates the total energy released during the growth phase of a fire or given test but appears to ignore any energy released thereafter.

Commented [MN6]: Using this value when corresponding to the actual test results overlooks the distribution of possible heat release values presented in NUREG-6850 and only focuses on the 98th percentile HRR point value. While this can be used for illustrative purposes it is at odds with the severity factors that are used in practice when applying the current method on a scenario basis.

Commented [MN7]: This would be a more illustrative tool if the HRR's were normalized to show how the new generic HRR profiles match up with previous test data

Commented [MB8]: None of the fires in this table were 317 kW.



This provides a range of si... not representative of the phy... risk analysis. It is worth n... e will be used.

NUREG/CR-6850 Appendix G provides a complete growth curve for a typical electrical cabinet: 12 minutes t-squared growth, 8 minutes peak burn, and 19 minutes linear decay.

If these same ratios were applied to transient scenarios the resultant growth curves would be:

Table 3
Transient Growths Ratios from Electrical Cabinet Growth

		Transient	
	Electrical mins	2-min	8-min
t-Squared	12	2	8
Peak	8	1.3	5.3
Linear Decay	19	3.2	12.7

The final piece of data is the peak burn durations and decay time from the NUREG/CR-6850 Supplement 1 Appendices A and B tests. This is summarized as:

Table 4
NUREG/CR-6850 Supplement 1 Appendices A and B tests

#	Total Energy (MJ)	Peak (min)	Decay (min)
1	33.5	40	15
2	74.3	50	15
3	239	10	50

Commented [MN9]: This is my calculation if I were to assume you are continuing a steady state 317 fire in the table above. I get different results for the projected times

Commented [MB10]: See previous comment. This approach relies on a critical error in the math being used. This error is then continued through the rest of the FAQ.

Commented [MB11]: The first half of this sentence appears to contradict the second half since the PRA should reflect the underlying fire phenomena.

Commented [MB12]: How is this supported by the estimations provided in Attachment 1 other than conserving total energy released? What is the significance or benefit of analyzing a smaller fire over a longer duration compared to analyzing a larger one for a shorter duration? This should be discussed in the purpose section.

Commented [MB13]: These decay durations don't appear to have come from Attachment 1.

7	15.2	4	12

This shows a wide range of peak burn durations and decay times. The combination of this information should be done to ensure realistic modeling of transient fires. As peak HRR is already covered by existing guidance, the total amount of energy released should be the main driver in the establishment of the full growth profile.

In general, the peak heat release rate will be shorter than the growth, but to persevere the energy deposited the 2- min transient fire is considered to be twice as long as the peak time. The 8-minute transient fire is 2/3 of the peak time. The linear decay times are considered to be double the peak times.

Commented [MB14]: This statement doesn't make sense. How can a peak HRR be shorter than growth? Perhaps this is referring to peak duration vs. growth duration? This paragraph requires clarification.

Commented [MN15]: Why? Also I cannot back calculate this 2/3 value anywhere in the following results or conclusions.

Table 5
Recommended Transient Growth Curves

	Transient			
	2-min	8-min	317 kW MJ Released	
t-Squared	2	8	12.7	50.7
Peak	6	7	114.1	133.1
Linear Decay	12	14	114.1	133.1
		Total	241	317

These transient curves when used with a 317 kW peak HRR fire provide a bounding amount of energy released compared to the testing results shown in Attachment 1 of this FAQ. The total amount of energy released is the most important metric beyond the peak heat release rate which is already defined. As these curves bound the energy released in testing, this provides a reasonable representation of the room heat-up.

If appropriate, provide proposed rewording of guidance for inclusion in the next Revision:

Replace the guidance in NUREG/CR-6850 Supplement 1 Section 17 with Table 5 representing the full growth profile.

Commented [MN16]: This entire method appears to be based on matching the total energy released from testing to the total energy released in the hypothetical timeline of fire growth using the bounding value of 317 kw.

However, the value chosen to bound seems to be 239 kW based on test # A3. The 2 minute fire growth time from NUREG6850 is not based on any data from the A series of tests and therefore does not correlate to this value.

Also in Table 5 I do not understand why the 8 min growth cases are intrinsically linked to a total energy release of 317 MJ. There is no link in the data or total energy release to the 317 kW/m^2-s to tie these two values together.

Also the NIST tests are not investigated for the 8 minute case which may show a larger total energy release than test #A3

Commented [MN17]: Time to Peak, Steady Burning, Time to Decay would be more consistent with the 6850 terminology per table G-2

Commented [MB18]: The table to the right should be given a better label, i.e., Total energy released (MJ) from a 317 kW using the recommended profiles.

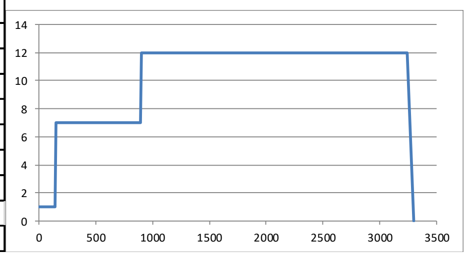
Commented [MB19]: This is only true because you only included test fires with peak HRRs much lower than 317 kW.

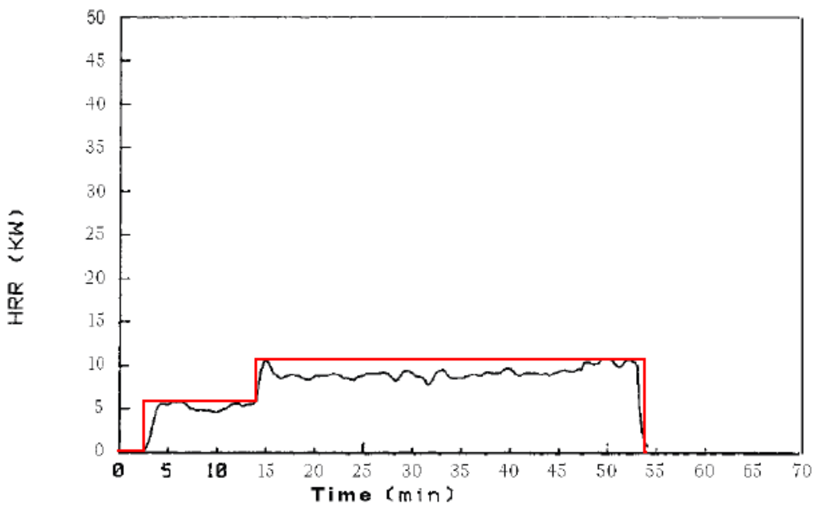
Attachment 1

The total ~~MJs~~ energy released in MJs for each of the tests contained in NUREG/CR-6850 Supplement 1 Appendices A and B is estimated by ~~discretized~~ estimating the bounding HRR distribution shown in each Figure. This is done by noting the key time points where the HRR changes in an Excel chart. The ~~kJ~~ HRR for each discretized step is ~~changing~~estimated by multiplying the seconds for each step by the average HRR for the endpoint of the step (i.e. linear ramp). The ~~kJ~~ HRR for all the steps are then summed. This total is divided by 1000 to convert to total MJs released. The analysis for each curve follows:

MJ Released for NUREG/CR-6850 Supplement 1 Figure A-1

Figure A-2			
Time [min]	Time [sec]	HRR [kW]	Energy [kJ]
0	0	1	0
2.4	144	1	144
2.5	150	7	42
14.9	894	7	5208
15	900	12	72
54	3240	12	28080
55	3300	0	0
		Sum Energy [MJ]	33.546

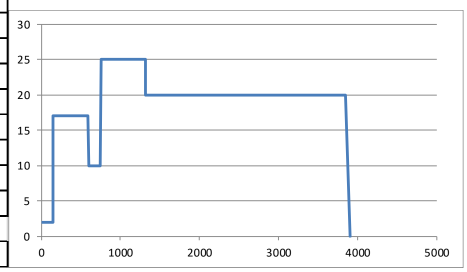


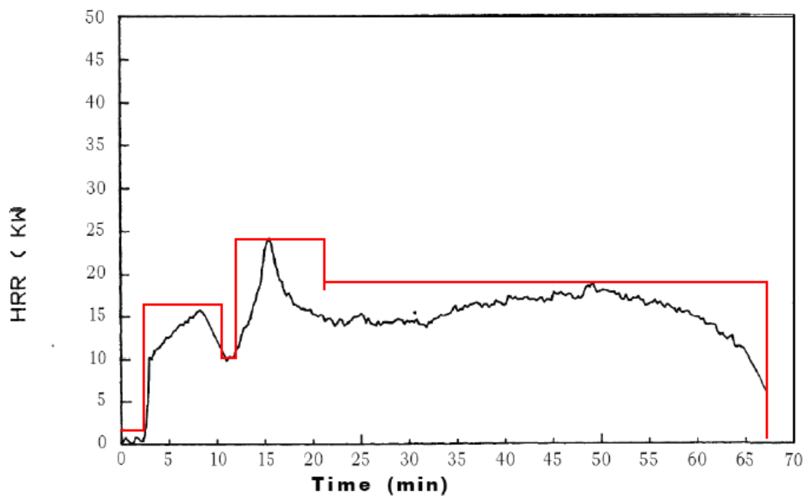


Attachment 1

MJ Released for NUREG/CR-6850 Supplement 1 Figure A-2

Figure A-1			
Time [min]	Time [sec]	HRR [kW]	Energy [kJ]
0	0	2	0
2.4	144	2	288
2.5	150	17	102
9.9	594	17	7548
10	600	10	60
12.4	744	10	1440
12.5	750	25	150
21.9	1314	25	14100
22	1320	20	120
64.1	3846	20	50520
65	3900	0	0
		Sum Energy [MJ]	74.328

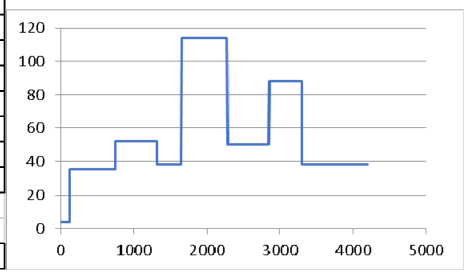


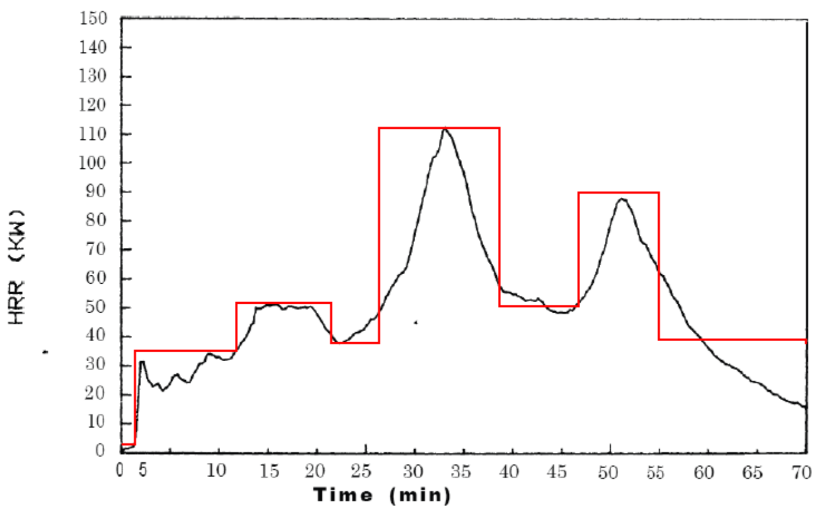


Attachment 1

MJ Released for NUREG/CR-6850 Supplement 1 Figure A-3

Figure A-3			
Time [min]	Time [sec]	HRR [kW]	Energy [kJ]
0	0	4	0
1.9	114	4	456
2	120	35	210
12.4	744	35	21840
12.5	750	52	312
21.9	1314	52	29328
22	1320	38	228
27.4	1644	38	12312
27.5	1650	114	684
37.9	2274	114	71136
38	2280	50	300
47.4	2844	50	28200
47.5	2850	88	528
54.9	3294	88	39072
55	3300	38	228
70	4200	38	34200
		Sum Energy [MJ]	239.034





Attachment 1

MJ Released for NUREG/CR-6850 Supplement 1 Figure B-3

Figure A-7			
Time [min]	Time [sec]	HRR [kW]	Energy [kJ]
0	0	2	0
1.9	114	2	228
2	120	27	162
6.9	414	27	7938
7	420	18	108
9.9	594	18	3132
10	600	10	60
13.9	834	10	2340
14	840	3	18
20.9	1254	3	1242
21	1260	0	0
		Sum Energy [MJ]	15.228