FAQ Number 18-0015 **FAQ Revision** 0 (Draft v6)

FAQ Title Transient Fire Growth Curve

Plant:	Various	Date:	August 22, 2018
Contact:	Robert Cavedo	Phone:	(301) 938-0397
	Mark Schairer		(508) 532-7137
	Patricia Pringle		(410) 495-4496
	Ashley Lindeman		(704) 595-2538
	Travis Weber		(508)532-7141
		Email:	Robert.cavedo@exeloncorp.com mvs@epm-inc.com patricia.pringle@exeloncorp.com alindeman@epri.com tjw@epm-inc.com

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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.

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 for each curve. The development for these curves is contained in Attachment 1 of this FAQ. Per NUREG/CR-68050 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 released for each HRR test group.

Table 1
Summary of NUREG/CR-6850 Supplement 1 Appendices A and B HRR MJ 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
B-3	The heat release rate profile from SNL test 5 involving fuel package 3	15.2

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

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

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

This provides a range of steady state burn durations from 0 minutes to 9 minutes. Although not representative of the physical fire phemonon, the total energy released is a key metric in fire risk analysis. It is worth noting the bounding values in the context of how the HRR growth profile 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 MJ	Peak	Decay
1	33.5	40	15
2	74.3	50	15
3	239	10	50
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.

Table 5
Recommend 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 amount of energy is the most important metric beyond the peak heat release rate which is already define. 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:

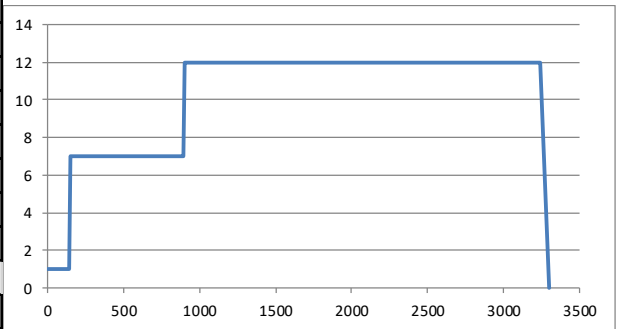
Replace the guidance in NUREG/CR-6850 Supplement 1 Section 17 with Table 5 representing the full growth profile.

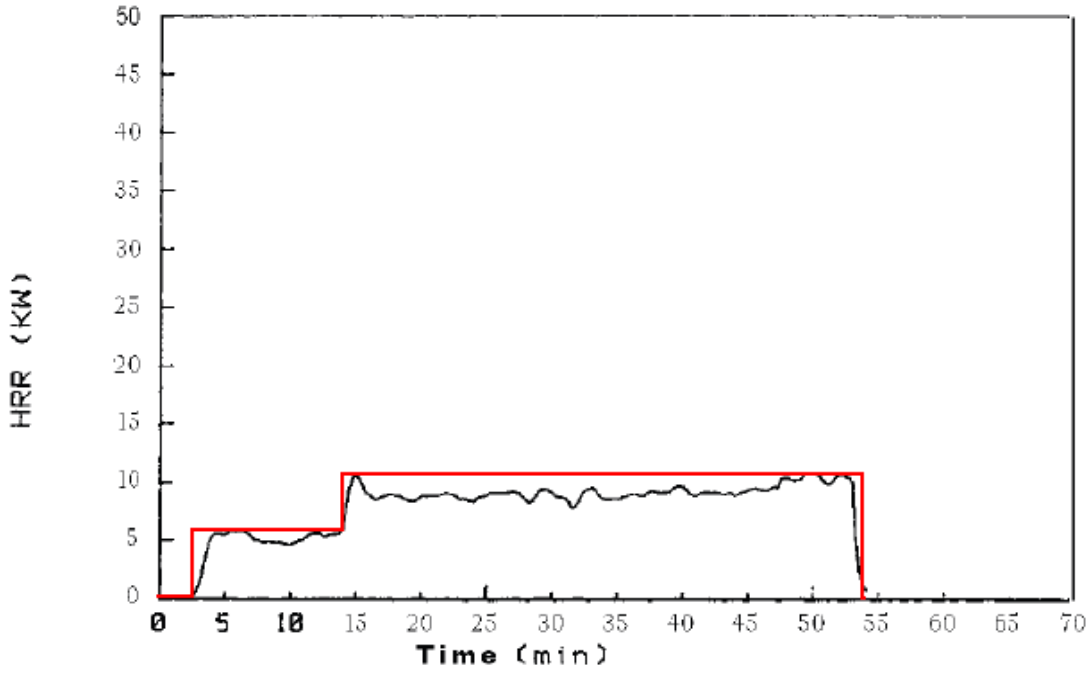
Attachment 1

The total MJs released for each of the tests contained in NUREG/CR-6850 Supplement 1 Appendices A and B is estimated by discretized 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 for each discretized step is changing by multiplying the seconds for each step by the average HRR for the endpoint of the step (i.e. linear ramp). The kJ for all the steps are 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

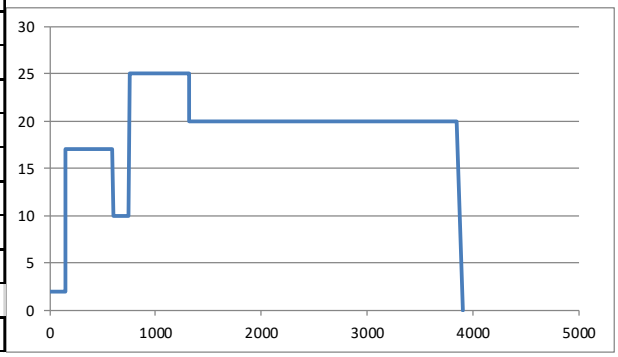


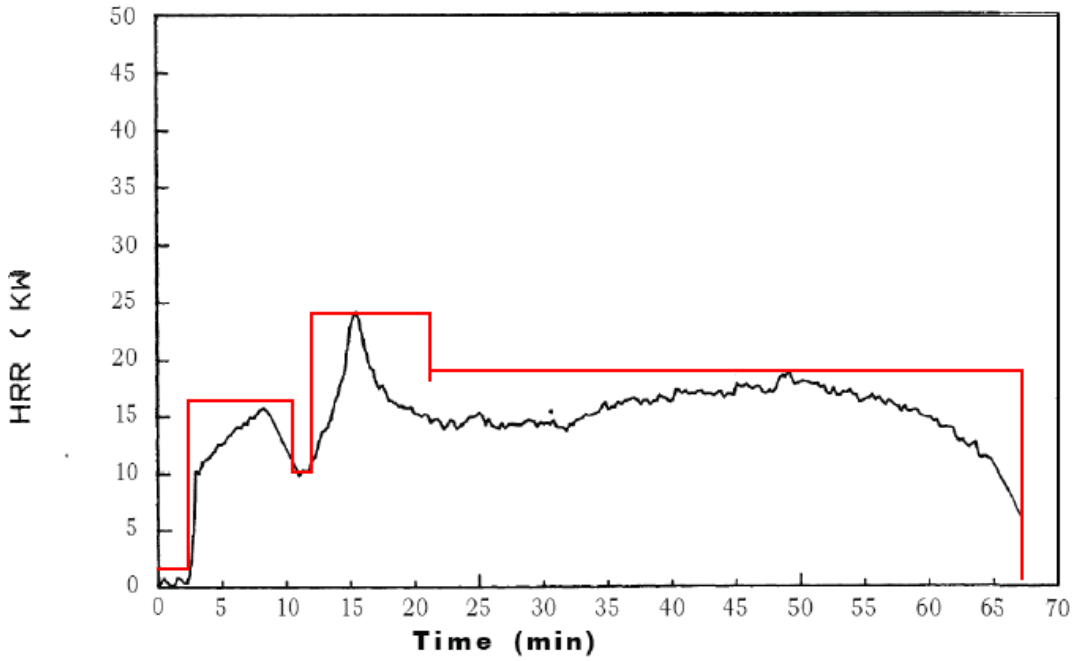


Attachment 1

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

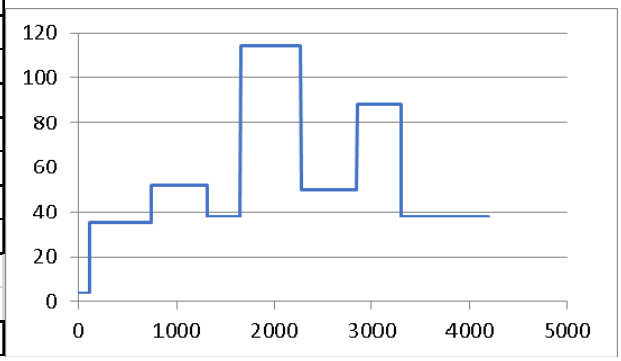


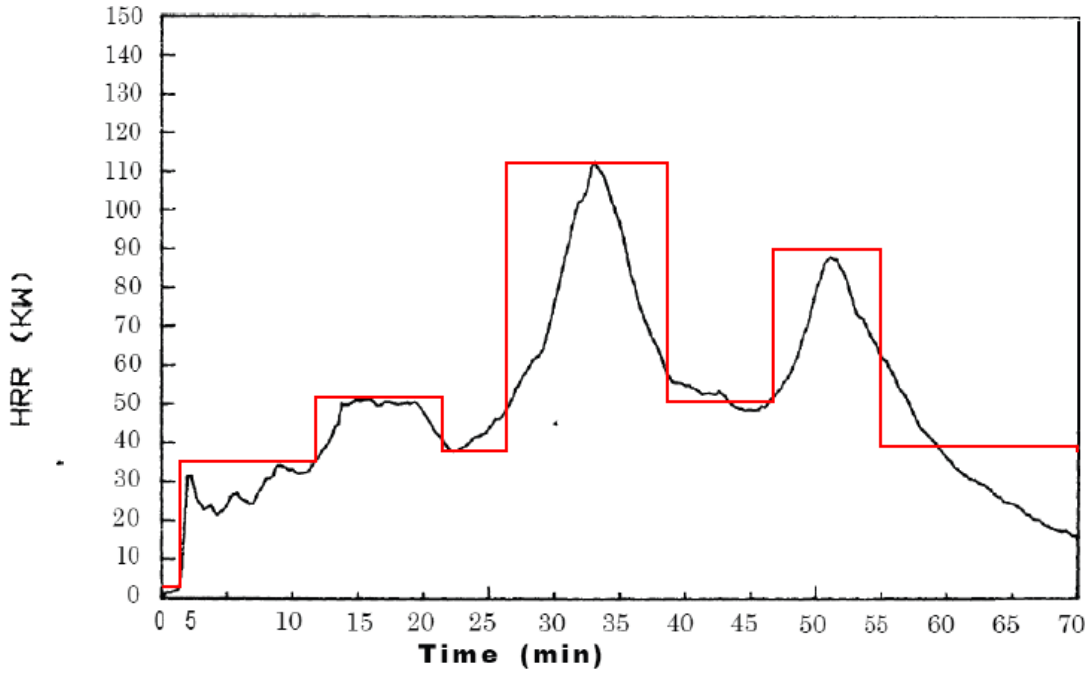


Attachment 1

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