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July 29, 1980

United States Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. Dennis M. Crutchfield, Chief
Operating Reactors Branch #5
Division of Licensing

Reference: (a) License No. DPR-3 (Docket 50-29)
(b) USNRC Letter to YAEC dated March 28, 1980

Subject: Additional Information for Calculating Containment Pressure and Temperature for Equipment Qualification Purposes.

Dear Sir:

Per our discussion of July 23, 1980 with the SEP staff, we are enclosing a summary comparison of our August 1970 LOCA analysis (P.C. 96) to current day practice. Included in this enclosure is a tabulation of the mass and energy release data for the primary coolant system double-ended rupture and main steam line double-ended rupture used in the 1970 analysis. Additionally, we have plotted, in Figure 1, the blowdown data produced by the LOCTIC code (1970 version) and the RELAP4 - MOD3/EM code used for our current large LOCA/ECCS performance calculations. From this curve, it is demonstrated that the final integral blowdown energy to containment, calculated by the RELAP4 Code, agrees quite well with the data generated in the 1970 analysis. Neither the LOCTIC or RELAP4 data in Figure 1, contain the S.G. secondary energy portion (approx. 9 MBTU's). Furthermore, the RELAP4 data reflects current plant operating parameters (ex. Tavg = approx. 540°F vs. 520°F in LOCTIC).

In the Notes to Enclosure 1 of Reference (b), the staff indicated that in cases where a new plant specific analysis would have to be performed, a best estimate of the conditions that could eventually be justified should be provided along with a schedule to provide the new analysis results. In Reference (c) we provided a discussion of the analysis that defined the service conditions used for equipment qualification. Although this analysis is ten years old, it does represent our best estimate.

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The complexity of assessing the differences in analysis methodologies do not easily permit us to accurately quantify the bounding containment conditions. It is our engineering judgment, however, that the containment pressure curve will not change by more than several psi. We do not expect the temperature curve to change by more than 20^{o}F.

We are still in the process of obtaining proposals for reanalysis of the containment accidents. We will inform you of our schedule to redo our containment analyses as soon as it is finalized.

If you have any questions or desire additional information, please contact us.

Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

J. A. Kay

J. A. Kay
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ATTACHMENT 1

Review of Yankee Rowe Containment Analysis

The containment analysis performed for Yankee Rowe in August 1970 was done with the Stone & Webster computer program, LOCTIC. The accident analyzed was a primary coolant system double-ended rupture concurrent with a main steam line break inside containment. The important features of the analysis are described below.

A. Mass and Energy Release Data

1. Primary Coolant System

Primary coolant system (PCS) mass and energy release data were calculated with LOCTIC. The break diameter, 19.3 in ID is close to the cold leg pump suction line size. The mass and energy release transients are given in Table 1.

The PCS was modeled as two volumes: the pressurizer, and the remainder of the system. During the initial blowdown phase, energy was added to the contents of the main volume from decay heat, core sensible heat, and hot metal sources, and energy from hot metal sources was added to the contents of the pressurizer. Energy was also transferred from the PCS to secondary water in the steam generators during this period. Flow out the break was calculated with the general equation for compressible flow through a pipe of constant area with friction. Flow from the pressurizer to the main volume was also determined.

As the PCS water level dropped below the steam generator tubes, heat transfer to secondary side water stopped. As the liquid level dropped below the reactor vessel nozzles, at around 9 seconds, the blowdown changed from subcooled liquid to steam. Blowdown continued until the PCS depressurized to containment pressure, at around 20 seconds. The the core reflood period began with the PCS water level at the bottom of the core.

As the core region was being reflooded with safety injection water, there was no mass release from the break. Energy from the core and hot metal was absorbed by the entire liquid mass in the vessel. Since this energy was not sufficient to raise the entire mass to saturation temperature, there was no steam release from the core during reflood.

As the water level reached the nozzles, at around 65 seconds, hot liquid began to flow out the break. This continued during the entire period of safety injection from the demineralized water storage tank. At the initiation of the recirculation phase of safety injection, at around 2070 seconds, the containment sump water temperature was 165^{o}F.

Approximately 12 minutes later, the PCS temperature had increased to saturation. From this point on, the release was two phase.

The decay heat curve was based on data from Westinghouse. It compares quite closely to a curve generated from Branch Technical Position 9-2.

Table 3 provides the energy distribution in the PCS and containment at the beginning of the accident, and at 20 seconds and 1800 seconds after the accident.

2. Secondary System

Secondary system mass and energy release data were also calculated with LOCTIC. The release transients for the double-ended rupture of a main steam line are presented in Table 2.

It was assumed that the non-return valve in the ruptured main steam line functioned, preventing blowdown from the three intact steam generators and the turbine plant piping. Blowdown from the ruptured loop steam generator was determined by modeling the steam generator as a single reservoir. Flow out the break was calculated with the same general equation for compressible flow through a pipe as was used for the PCS, except since the exit nozzle was above the liquid-vapor interface, the flow was pure steam. Blowdown continued until the steam generator depressurized to containment pressure, at around 29 seconds. A small amount of additional blowdown was just a result of further containment depressurization. Approximately 12, 000 lbm remained in the steam generator since there was no source of heat to boil it off. Heat transfer from the PCS stopped when the level initially dropped out of the steam generators, and steam generator hot metal energy was not considered.

3. Other Energy Sources

The analysis assumed that 100% of the zirconium in the core reacted during the accident, with a reaction rate of 0.1 percent per second from 30 seconds to 1030 seconds. The net energy from the reaction, an average of 21,945 Btu/sec, was added to the energy of the PCS, and the resultant hydrogen was added directly to the containment. An instantaneous burn of the hydrogen in the containment was then assumed, producing 22,975 Btu/sec net energy.

Energy released from PCS hot metal sources which are not covered by liquid are added directly to the containment. This energy, which amounts to approximately ten million Btu's at 1800 sec is not included in the release rates in Table 1.

B. Safety Injection System

The safety injection flow history was:

1. 4200 gpm for 5 min

2. 2000 gpm until total of 77,000 gallons was removed frm the water tank

3. Switch to recirculation phase flow of 200 gpm (occurs at about 2070 sec - slightly more than 77,000 gallons removed from tank due to roundoff errors)

   It was also assumed that 30% of all injection spilled directly out the break to the containment sump water.

C. Containment Transients

The containment was divided into two regions: the containment atmosphere and the containment sump water. Mass and energy were added from the sources described above in Sections A and B.

Energy was removed from the containment by static heat sinks. The Uchida correlation was used to determine the condensing heat transfer coefficient. Heat transfer from the outside of the containment sphere to the environment was calculated assuming natural convection with a heat transfer coefficient of 2.0 Btu/hr - sq. ft - ^{o}F.

The containment pressure transient showed a peak pressure of 31.6 psig at 19.5 seconds as the PCS blowdown ended. During the core reflood period, when there was no PCS release, the pressure continually declined as the heat sinks removed energy from the atmosphere. A minimum of 22.0 psig at 583 sec was reached as the rate of energy removal by the heat sinks declined below the rate of energy addition. The pressure then increased to 24.2 psig at 1030 seconds, when the zirconium-water reaction and subsequent hydrogen burning ended. The pressure decreased rapidly until safety injection from the water tank ended, then stabiliized at around 17 psig. Finally, there was a very gradual decline to slightly over 16 psig at 24 hours. The decay heat rate at this time was still greater than the rate of heat transfer through the containment to the environment.

Mass and Energy Release Data
Primary Coolant System Double-Ended Rupture

Time (sec)	Mass Rate (lbm/sec)	Energy Rate (Btu/sec)	Integrated Mass (10^3 lbm)	Integrated Energy (10^6 Btu)
0.1	69.522	35,528,530	6.95	3.55
1.0	14,695	7,387,490	20.47	10.36
2.0	14,065	7,039,577	34.83	17.56
3.0	13,481	6,712,653	48.58	24.42
4.0	13,047	6,458,104	61.81	30.99
5.0	12,494	6,142,714	74.47	37.24
6.0	11,832	5,774,459	86.62	43.18
7.0	11,583	5,610,872	98.35	48.89
8.0	11,073	5,296,789	109.6	54.31
9.0	3,204	3.233,449	115.5	58.40
10.0	1,993	2,217,906	117.9	61.06
12.0	1,051	1,178,585	120.7	64.25
14.0	648.5	725,609	122.4	66.07
16.0	425.6	474,070	123.4	67.25
18.0	233.8	255,758	124.1	67.96
19.0	138.9	153,339	124.3	68.16
20.0	0.0	0.0	124.3	68.20
60.0	0.0	0.0	124.3	68.20
65.0	400.3	74,051	126.9	68.69
70.0	400.4	74,425	129.0	69.07
80.0	400.4	74,488	133.0	69.82
100.	400.7	74,178	141.1	71.32

TABLE

Mass and Energy Release Data
Primary Coolant System Double-Ended Rupture

Time (sec)	Mass Rate (lbm/sec)	Energy Rate (Btu/sec)	Integrated Mass (10^3 lbm)	Integrated Energy (10^6 Btu)
120.	401.2	73,961	149.2	72.81
150.	401.8	72,842	161.2	75.01
200.	402.2	71,170	181.3	78.61
320.	403.0	66,722	229.5	86.83
340.	191.4	31,931	235.9	87.89
400.	191.8	36,095	255.8	91.47
500.	210.0	42,133	267.6	93.78
600.	198.7	43,061	287.2	97.83
700.	192.8	42,276	306.7	102.04
800.	193.0	43,240	326.1	106.35
1000.	192.8	44,118	364.7	115.12
1500.	191.8	28,339	458.8	132.26
1800.	191.7	24,223	516.0	139.96
2190.	21.9	3,060	570.5	146.63
3030.	19.3	11,945	589.4	152.48
4230.	18.7	11,617	611.6	166.84
6630.	18.7	10,567	655.9	193.09
10230.	18.1	9,457	722.5	228.97
17430.	18.1	8,490	855.9	294.24
42630.	19.5	7,974	1323.2	495.39
133530.	19.1	6,580	3009.4	1115.26

Mass and Energy Release Data
Main Steam Line Double-Ended Rupture

Time (sec)	Mass Rate (lbm/sec)	Energy Rate (Btu/sec)	Integrated Mass (10^3 lbm)	Integrated Energ (10^6 Btu)
0.1	629.0	757,483	.0629	.0757
1.0	587.6	707,796	.607	.7319
2.0	550.7	663,376	1.174	1.415
3.0	521.5	628,177	1.709	2.058
4.0	497.3	599,020	2.217	2.670
5.0	475.7	572,840	2.702	3.254
6.0	456.4	549,522	3.167	3.814
7.0	438.5	527,869	3.613	4.352
8.0	421.2	506,969	4.042	4.868
9.0	399.0	480,101	4.453	5.362
10.0	355.9	427,896	4.829	5.813
12.0	266.6	319,702	5.441	6.550
14.0	204.6	244,623	5.903	7.103
16.0	163.3	194,575	6.267	7.537
18.0	133.9	159,159	6.561	7.887
20.0	111.8	132,498	6.805	8.177
25.0	76.6	90,135	7.266	8.721
28.0	62.9	73,878	7.473	8.965
29.0	0	0	7.522	9.022
300.0	0	0	7.735	9.272
133530.	0	0	7.957	9.530

TABLE 3

Energy Distribution

(Units of Millions of BTU's; Referenced to $32^{\circ}F$)

	Time (seconds)		
	0.0	20.0	1800.
Heat Sources			
Primary Coolant	71.02	6.77	8.34
Primary System Hot Metal	23.51	22.09	6.50
Steam Generator Metal	-	-	-
Steam Generator Secondary Water	38.14	35.50	34.33
Pressurizer Water	3.32	0.04	0.00
Core Sensible Heat	5.11	1.93	0.64
Accumulator Water	2.52	2.07	0.00
External Water Tank	37.08	37.08	15.11
Total	180.70	105.48	64.92
Heat Sinks			
Containment Atmosphere Water	0.91	60.57	38.69
Containment Atmosphere Air	0.78	2.42	2.02
Containment Floor Water	0.0	12.23	92.51
Concrete Structures	0.0	2.17	26.97
Liner and Misc. Steel	0.0	1.38	22.31
Neutron Shield Tank	0.0	0.04	3.33
Total	1.69	78.81	185.83

TABLE 3 (Continued)

Energy Distribution

(Units of Millions of BTU's; Referenced to 32°F)

	Time (seconds)		
	0.0	20.0	1800.
Heat Inputs			
Delayed Fissions	0.0	0.0	0.0
Decay Heat	0.0	0.72	27.58
Pump Heat	-	-	-
Zirc-Water Reaction	0.0	0.0	21.95
Hydrogen Burning	0.0	0.0	22.98
Feedwater Addition	0.0	1.33	1.33
Total	0.0	2.05	73.84
Heat Outputs			
To Environment through Containment	0.0	0.00	5.09
Total	0.0	0.0	5.09
Heat Balance			
Decrease in Heat Sources Plus Heat Inputs	-	77.27	189.62
Increase in Heat Sinks Plus Heat Outputs	-	77.12	189.23
Difference	-	0.15	0.39
Percent Error	-	0.2%	0.2%

ATTACHMENT 2

EVALUATION OF THE YANKEE ROWE CONTAINMENT ANALYSIS

Since the last Yankee Rowe containment analysis in 1970, there have been many changes to the methods and requirements for containment analyses. Current acceptance criteria are specified in the NRC Standard Review Plans for Section 6.2, published in 1975. This evaluation will discuss the major differences between the 1970 analysis and an analysis performed with current methods.

The accident analyzed in 1970, was a primary coolant system double-ended rupture (DER) concurrent with a main steam line DER inside containment. Today these accidents are not taken together; a primary coolant system DER and a main steam line DER are evaluated independently. Analyzing both ruptures together produced an intial peak containment pressure somewhat higher (roughly 2 spi) than what would result from just a primary coolant system DER.

The primary coolant system break analyzed in 1970 was apparently a pump suction line break. The model used to calculate mass and energy release data after the initial blowdown period did not consider the core reflood phenomenon and the subsequent removal of energy from the steam generators (post-reflood froth). Consideration of these effects would increase the mass and energy release to the containment, and cause another peak containment pressure several psi higher than the initial peak.

The 1970 analysis assumed 100 percent of the zirconium in the core reacted to release hydrogen which was instantaneously burned inside containment. Current guidelines require reaction of only a small fraction (typically 5 percent) of the zirconium. Decreasing the amount of zirconium assumed to react from 100 percent to 5 percent would have little or no effecton the peak containment pressure since the reaction was assumed to occur over a relatively long period of time.

Long-term mass and energy releases depend on the decay heat. Since the values for decay heat used in 1970 are similar to current standards (BTP9-2, for example), there would be little change in long-term releases, and, therefore, little change in long-term containment transients.

There are several other differences which would have a much smaller effect than the items just discussed. The Tagami correlation for condensation heat transfer to the heat sinks would be used rather than the Uchida correlation. This would increase heat transfer to the sinks early in the transient, and slightly decrease the containment pressure. Pump heat would be considered, providing a small long-term increase in energy added to the containment.

In summary, a current containment analysis for a primary coolant system DER would result in a higher peak containment pressure (by several psi) than that calculated in 1970. The long-term transient would not be significantly different.

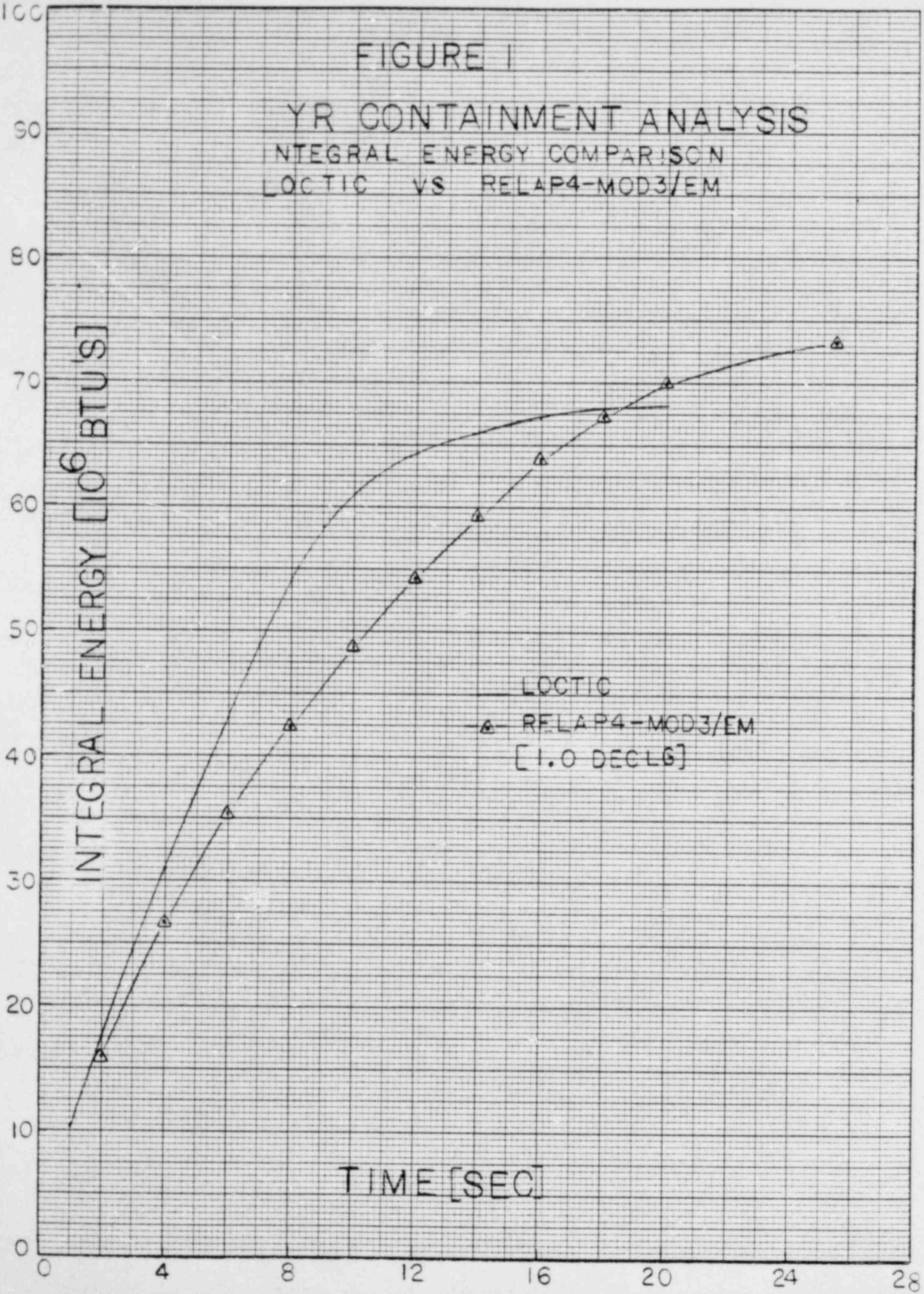
FIGURE 1
YR CONTAINMENT ANALYSIS
INTEGRAL ENERGY COMPARISON
LOCTIC VS RELAP4-MOD3/EM
INTEGRAL ENERGY [10^6 BTU'S]
TIME [SEC]
LOCTIC
RELAP4-MOD3/EM
[1.0 DECLG]
0
10
20
30
40
50
60
70
80
90
100
0
4
8
12
16
20
24
28