ANALYSIS OF NATURAL CIRCULATION COOLDOWN WITHOUT UPPER HEAD VOIDING FOR ST. LUCIE UNIT 1

DECEMBER 1980

NUCLEAR ANALYSIS DEPARTMENT
FLORIDA POWER AND LIGHT COMPANY

INTRODUCTION

An analytical evaluation of natural circulation cooldown to shutdown cooling system entry conditions without formation of voids was performed for the St. Lucie Unit 1 plant. The reactor coolant system pressure must be reduced to 275 psia for shutdown cooling initiation. Consequently to prevent the formation of voids, the upper head fluid must be cooled to a value less than the corresponding saturation temperature of 409.5°F. After that time de-pressurization to shutdown cooling system entry conditions can occur without void formation in the reactor coolant. Hot leg temperature cooldown rates of 30°F/hr and 50°F/hr to 325°F were investigated to determine the cooldown time required for the fluid temperature in the reactor vessel upper head to reach shutdown cooling entry conditions without void formation.

THERMAL-HYDRAULIC MODEL

The analysis was performed with a detailed thermal-hydraulic model utilizing the RETRAN (Reference 1) computer code. Figure 1 presents a schematic drawing of the fluid volumes, flow junctions, and heat conductors used in the model. Table 1 provides a description of these volumes, junctions, and conductors. Specific features of the model include: a detailed nodalization of the upper portion of the reactor vessel including a representation of the reactor vessel walls and internals; a number of automatic control systems including those for charging pumps, the letdown flow control valve and the pressurizer heaters; and a non-equilibrium thermal-hydraulic model for the pressurizer.

ANALYSIS RESULTS

An analysis of a St. Lucie Unit 1 natural circulation cooldown from full power for a hot leg temperature cooldown rate of about 30°F/hr to 325°F demonstrates that the reactor vessel upper head fluid cools to 409.5°F (shutdown cooling entry conditions) in 16.1 hours. The results are presented in Figure 2. The condensate supply required for this cooldown is 218,500 gallons.

The same analysis for a hot leg temperature cooldown rate of about 50°F/hr to 325°F demonstrates that the reactor vessel upper head fluid cools to 409.5°F (shutdown cooling entry conditions) in 14.2 hours. The results are presented in Figure 3. The condensate supply required for this cooldown is 193,000 gallons.

The analysis for a hot leg temperature cooldown rate of about 50°F/hr to 325°F was repeated using very conservative assumptions regarding fluid mixing in the upper reactor vessel in order to determine a bounding cooldown time for operating guidelines. The results demonstrate that the reactor vessel

upper head fluid cools to 409.5°F (shutdown cooling entry conditions) in 25.7 hours. The condensate supply required for this cooldown is 270,500 gallons.

RECOMMENDATION

The above results show that for a hot leg temperature cooldown rate of 50°F/hr to 325°F, the upper head fluid can be cooled to shutdown cooling system entry conditions without void formation in approximately 14.2 hours. In order to provide additional conservatism, it is recommended that for natural circulation cooldown to shutdown cooling system entry conditions without void formation, the hot leg temperature cooldown rate be about 50°F/hr to 325°F followed by a soak at 325°F for 20.4 hours for a total cooldown time of approximately 25.7 hours from cooldown initiation. Figure 4 shows the recommended plant cooldown rate. The condensate supply required for this cooldown is 270,500 gallons.

REFERENCE:

(1) RETRAN-A Program For One-Dimensional Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volumes 1,2,3&4, EPRI CCM-5, December 1978.

TABLE 1

MODEL GEOMETRY DESCRIPTION

FLUID VOLUME	DESCRIPTION
1	Combined hot leg volume.
2	Combined steam generator inlet plenum volume.
3	Combined steam generator tube volume from tube sheet to top of tube bundle.
4	Combined steam generator tube volume from top of tube bundle to tube sheet.
5	Combined steam generator outlet plenum volume.
6	Combined cold leg volume upstream of reactor coolant pump.
7	Combined reactor coolant pump volume.
8	Combined cold leg volume downstream of reactor coolant pump.
9	Reactor vessel downcomer volume.
10	Reactor vessel inlet plenum volume.
11	Core volume.
16	Volume from top of active core to fuel alignment plate.
12	Outlet plenum volume from fuel alignment plate to upper guide structure support plate.
13	CEA shroud volume.
17	Upper head volume from upper guide structure support plate to top of CEA shroud.
14	Upper head volume above top of CEA shroud.
32	Surge line volume.
34	Pressurizer volume.
51	Steam generator shell side volume.

TABLE 1 (continued)

MODEL GEOMETRY DESCRIPTION

FLOW JUNCTION	DESCRIPTION
1	Flow from volume 12 to volume 1.
2	Flow from volume 1 to volume 2.
3	Flow from volume 2 to volume 3.
4	Flow from volume 3 to volume 4.
5	Flow from volume 4 to volume 5.
6	Flow from volume 5 to volume 6.
7	Flow from volume 6 to volume 7.
8	Flow from volume 7 to volume 8.
9	Flow from volume 8 to volume 9.
10	Flow from volume 9 to volume 10.
11	Flow from volume 10 to volume 11.
17	Flow from volume 11 to volume 16.
12	Flow from volume 16 to volume 12.
13	Flow from volume 16 to volume 13.
14	Flow from volume 13 to volume 17.
15	Flow from volume 17 to volume 12.
18	Flow from volume 14 to volume 17.
35	Flow from volume 32 to volume 1.
36	Flow from volume 34 to volume 32.
37	Spray flow to volume 34.
38	Charging flow to volume 8.
39	Letdown flow from volume 6.

TABLE 1 (continued)

MODEL GEOMETRY DESCRIPTION

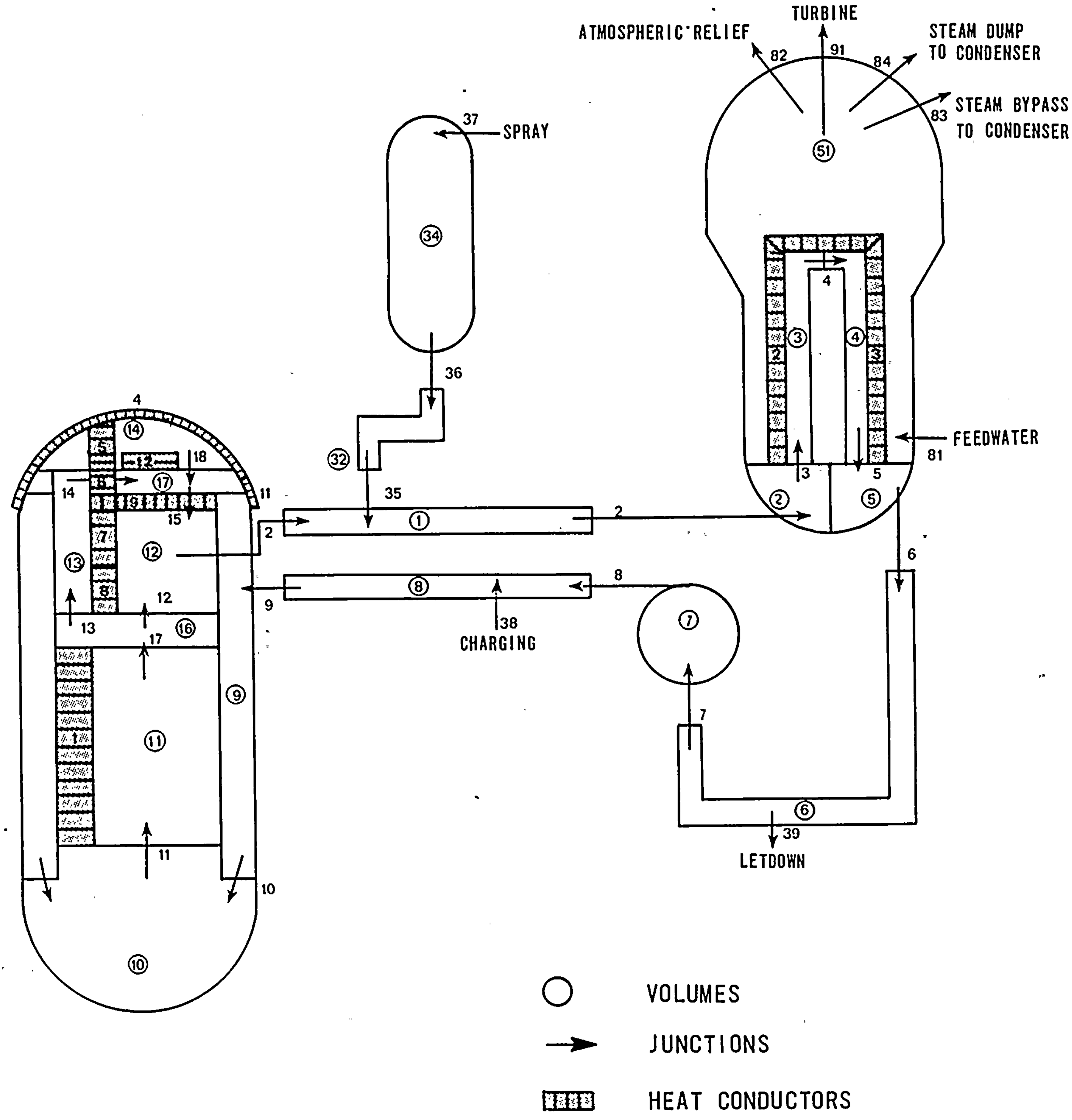
FLOW JUNCTION	DESCRIPTION
81	Feedwater flow to volume 51.
82	Atmospheric relief valve flow from volume 51.
83	Steam bypass valve flow to condenser from volume 51.
84	Steam dump valve flow to condenser from volume 51.
91	Steam flow to turbine from volume 51.

TABLE 1 (continued)

MODEL GEOMETRY DESCRIPTION

HEAT CONDUCTOR	DESCRIPTION
1	Fuel conductor connecting fuel to volume 11.
2	Steam generator tubes connecting volume 3 and volume 51.
3	Steam generator tubes connecting volume 4 and volume 51.
4	Metal in reactor vessel walls adjacent to volume 14.
5	Metal associated with upperhead drive shafts in volume 14.
6	Metal associated with CEA shrouds connecting volume 13 and volume 17.
7	Metal associated with CEA shrouds connecting volume 13 and volume 12.
8	Metal associated with CEA shrouds connecting volume 13 and volume 12.
9	Upper guide structure support plate connecting volume 17 and volume 12.
10	Metal associated with upper guide structure adjacent to volume 12.
11	Metal in reactor vessel wall adjacent to volume 17.
12	An effective conductor to allow axial heat conduction between volumes 14 and volume 17.

FIGURE I



MODEL VOLUME, JUNCTION, AND CONDUCTOR GEOMETRY

FIGURE 2
REACTOR COOLANT TEMPERATURE VS TIME
COOLDOWN AT 30° F/HR TO 325° F

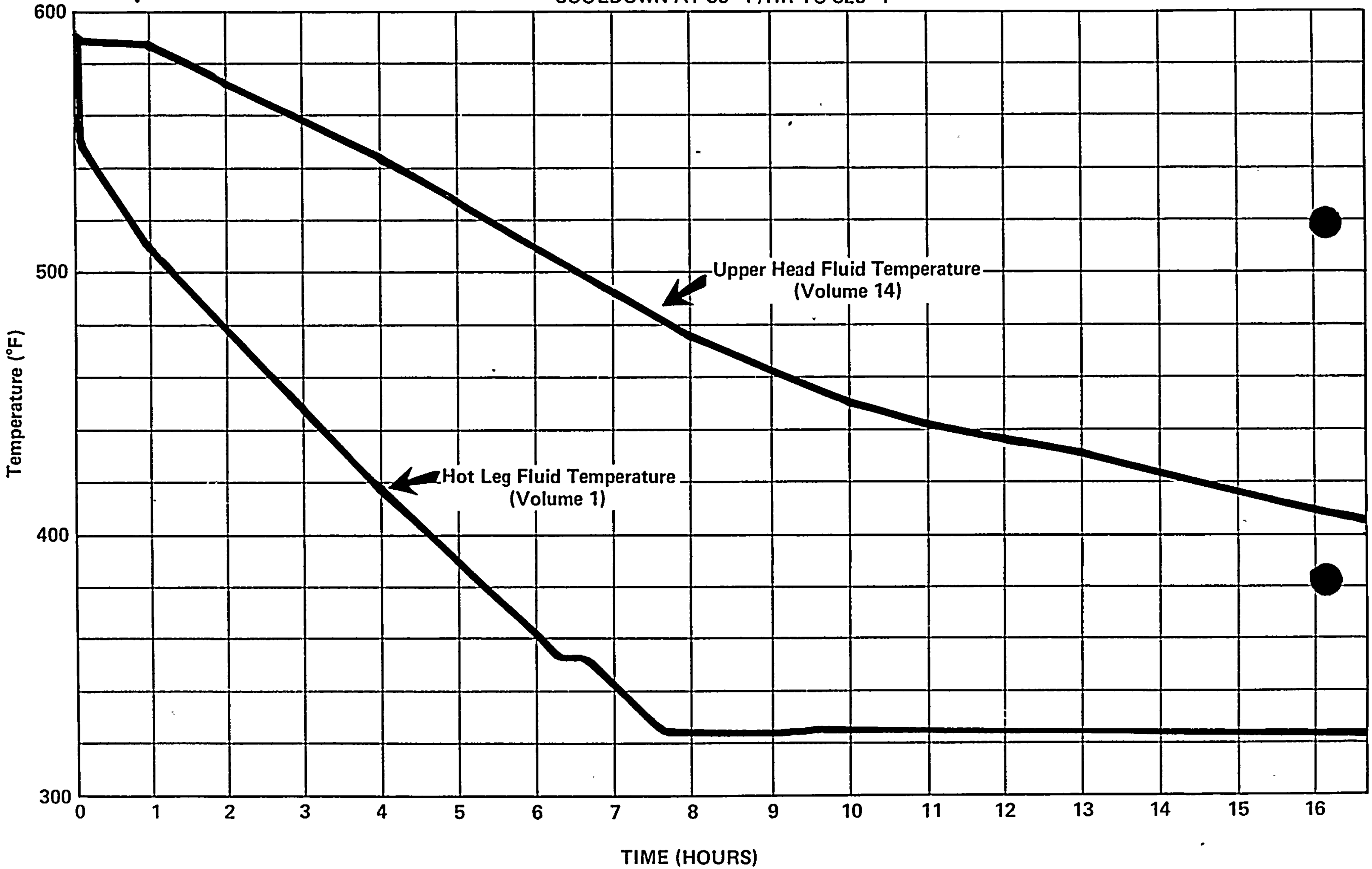


FIGURE 3
REACTOR COOLANT TEMPERATURE VS TIME
COOLDOWN AT 50° F/HR TO 325° F

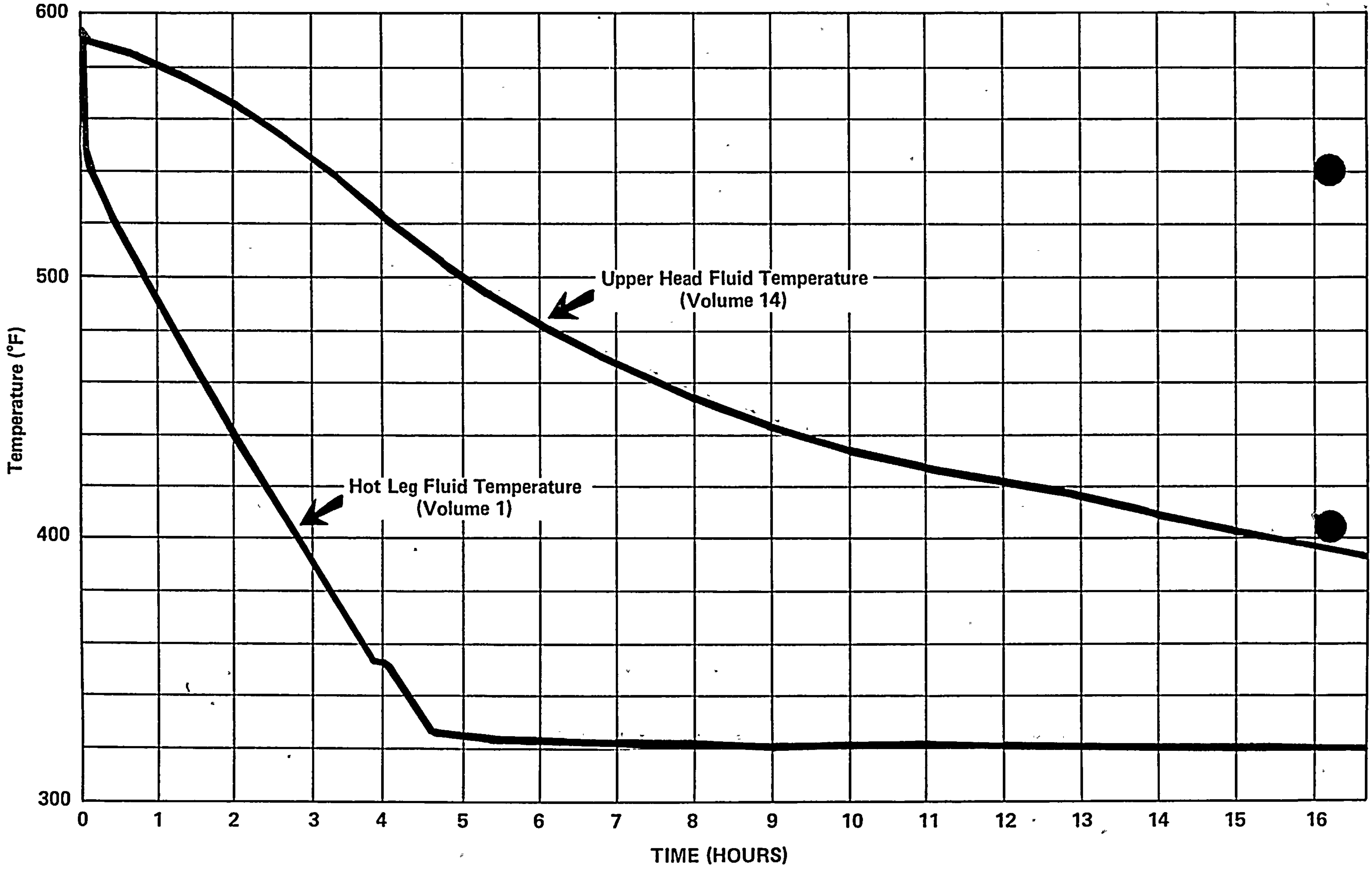


FIGURE 4

RECOMMENDED COOLDOWN GUIDELINE