TEXAS UTILITIES GENERATING COMPANY

P. O. BOX 1002 · GLEN ROSE, TEXAS 76043

November 16, 1984

50-445

Ms. N. H. Williams
Project Manager
CYGNA Energy Services
101 California Street, Suite 1000
San Francisco, California 94111-5894

COMANCHE PEAK STEAM ELECTRIC STATION
Independent Assessment Program Phase 3
Cinched U-Bolt Testing & Analyses Program
Additional Information

REF: 1) J. B. George (TUGCO) letter to N. H. Williams (CYGNA), dated November 1, 1984 - same subject

2) N. H. Williams (CYGNA) letter to J. B. George (TUGCO), "Status of Cinched U-Bolt Testing and Analyses Program", 84042.018 dated October 1, 1984

Dear Ms. Williams:

Reference 1 provided in its attachment the information requested by Reference 2. Included in the attachment as part of the answer provided to Item 2 of Reference 2 were results of a finite difference heat transfer analysis conducted for an uninsulated and an insulated U-bolt configuration on a 10-inch pipe.

A rechecking of the modelling of the contact areas between the U-bolt and the pipe and the pipe and the crosspiece has indicated that the contact between the pipe and crosspiece was overestimated and that the contact between the pipe and the U-bolt had been incorrectly assumed to extend for an arc of 180°. Accordingly, we are providing in the attachment to this letter the results obtained for the uninsulated case of the pipe at 250° F and the insulated case with the pipe at 350° F, where the boundary conditions of the model are changed to reflect the more realistic contact areas. We will be glad to discuss the details of the model, if CYGNA so desires.

Please call if you have any questions.

Very truly yours,

TEXAS UTILITIES GENERATING COMPANY

11/16/84

J. B. George
Vice President/Project General Manager

JBG/RCI/gh

cc: S. Burwell — R. Iotti
J. Van Amerongen — D. Wade

2222 1/1 See Attached

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A DIVISION OF TEXAS UTILITIES ELECTRIC COMPANY

ATTACHMENT 1

Revision to Item 2 of Reference 1.

Please replace Item 2 response with the following:

A. The answer to this question is best worded by first restating that the choice of 250°F for the 10-inch pipe temperature is a compromise choice which bounds the majority of the systems in the plant, and where used with an uninsulated U-bolt configuration is also representative of the case where the pipe temperature may be 350°F but the U-bolt configuration is insulated.

Second, it is important to point out that there is a single cinched-up U-bolt which is used on the 10-inch portion of the RHR system. This is support RH-1-024-007-S22R which is on line 10-RH-1-24-601-R-2, which is connected to the outlet line of the RHR heat exchanger. The maximum normal temperature seen by the line is 280°F during initiation of RHR operation. Only under upset conditions, where component water cooling may be lost, can the maximum temperature of this line reach 350°F. There are no cinched-up U-bolts on the inlet side of the RHR heat exchangers.

Third, it is germane to point out that the tests conducted on the 10-inch pipe specimens had a corresponding average temperature of the U-bolt equal to approximately 150°F. For the particular configuration examined here, i.e., stainless steel pipe and carbon steel U-bolt, the approximate 150°F represents the equilibrium temperature of the U-bolt. The following describes the temperature history during the thermal cycling test and the creep test for both the U-bolt and the crosspiece.

Thermal Cycle 1:

The pipe reached the test temperature of 250°F at 30 minutes, but then continued to climb to over 280°F before settling back down ot 258°F. The U-bolt radius and leg stabilized around 195°F and 150°F, respectively, near the end of the cycle. See Figure 3.

Thermocouples 2, 9 and 10 on the crosspiece reached temperatures of 129°F, 136°F and 144°F, respectively, at the end of Cycle 1. These are less than the equilibrium temperatures reached during the creep test. Figure 4 shows that temperatures had not leveled off. Refer to Figure 9 for location of thermocouples.

Thermal Cycle 6:

The pipe reached an equilibrium temperature of 250°F within 20 minutes. The U-bolt radius and leg reached 183°F and 144°F, respectively, around 1 hour. See Figure 5.

Thermcouples 2, 9 and 10 on the crosspiece reached temperatures of 125°F, 132°F and 139°F, respectively, at the end of Cycle 6. These are less than the equilibrium temperatures reached during the creep test. Figure 6 shows that temperatures had not leveled off.

Creep Test:

The pipe reached an equilibrium temperature of 250°F in less than 1 hour. The U-bolt radius stabilized at 185°F within 1 hour. The U-bolt leg stabilized at 148°F within 2 hours. See Figure 7.

Thermocouples 2, 9 and 10 on the crosspiece reached equilibrium temperatures of 138°F, 146°F and 154°F, respectively, around 3 hours. See Figure 8.

10" Specimen Summary:

With a pipe test temperature of 250°F, the U-bolt reached thermal equilibrium during each cycle of the thermal cycling test, but the crosspiece didn't. The entire assembly reached thermal equilibrium shortly into the creep test. A summary is provided in Table 1.

Results of finite difference thermal analyses are very sensitive to the assumed area of contact between the pipe and the U-bolt and the pipe and the crosspiece. When the U-bolt is cinched, the line contact between the pipe and the U-bolt extends for an arc which is less than 180°, and the precise extent of which depends on the cinching force and the spacing of the bolt holes in the crosspiece. Similarly the cinching process tends to produce a loss of contact at some points between the crosspiece and the pipe due to either bending of the crosspiece or local deformation of the pipe. This loss of contact, however small, profoundly affects the heat transferred from the pipe to the crosspiece.

A heat transfer model has been executed for the uninsulated U-bolt configuration with the following assumptions. Heat transfer from the pipe to the U-bolt is along an arc near the apex of the U-bolt. At the diametral location there is a small gap (less than 1/16") between the pipe and U-bolt. No gaps are assumed between the U-bolt and the crosspiece (the assumption is believed to be inconsequential since both elements are roughly at the same temperature at that location). Heat transfer between the pipe and the crosspiece takes place through a line contact extending 2 inches along the pipe, and via gap conductance, along the circumference of the pipe and through a gap increasing from zero to 1/128" linearly from the end of the contact area to the end of the plate. Likewise, the heat transfer between the pipe and the U-bolt also considers the gap conductance with areas immediately adjacent to the line of contact and extending out to the U-bolt radius. This model produced results which more closely match the results of the test.

Results of the analyses are shown in Figure 1 for the uninsulated case. In Figure 2 similar results are shown for the insulated case. The only difference between the latter analyses and that of the uninsulated configuration are the pipe temperature, which in the latter instance is 350°F, and the presence of insulation.

For the uninsulated case the average temperature of the U-bolt in the curved portion is 175-180°F, while the straight portion is at about 150°F. For the insulated case the corresponding temperatures are approximately 300°F and 260°F respectively.

The effect of the temperature rise on the clamping forces acting on the pipe and the U-bolt for the two cases of 250°F pipe, uninsulated U-bolt and 350°F pipe, insulated U-bolt, can be estimated by comparing the relative growth of the pipe to U-bolt for the two cases, neglecting any deformation of the pipe. Since only relative growth is pertinent here, the one-directional growth of the U-bolt due to thermal expansion given as Y_1 where

$$Y_1 = \alpha_1 \Delta TL$$

where L is the projected length of the U-bolt which is given as 2R and T is the temperature differential between the average U-bolt temperature and ambient (or a reference temperature), is compared to the diametral growth of the pipe, Y_2, which is given as

$$Y_2 = \alpha_2 \Delta TD$$

The worst case relative expansion will occur for the stainless steel pipe and the carbon steel U-bolt. For the 10-inch pipe (10.75 OD), coefficients of thermal expansions $\alpha_1 = 6.3 \times 10^{-6}$ in/in/°F at 150-180°F or 6.6×10^{-6} at 260-300°F and $\alpha_2 = 9.4 \times 10^{-6}$ at 250°F or 9.53×10^{-6} at 350°F and a reference ambient temperature of 70°F, the relative expansion for the two cases considered, i.e., 250°F pipe with bare U-bolt, and 350°F pipe with insulated U-bolt are as follows:

1. 250°F ΔY = 0.011755 inches

2. 350°F ΔY = 0.0137 inches

3. Finite Element Analysis ΔY = 0.0141*

(* Finite Element Analysis used 210°F.)

As seen from the above, theoretical, steadystate heat transfer analyses would predict that the case of 350°F pipe expanding against an insulated U-bolt could result in a differential pipe expansion which would be approximately 17% larger than could be expected for a 250°F pipe with uninsulated U-bolt. However, the finite element analysis has been conducted in a manner that would encompass the case of 350°F insulated U-bolt. As seen from the third row of relative expansion, the finite element analysis, which used a pipe temperature of 210°F but maintained the U-bolt temperature at 70°F, would yield a relative expansion which is comparable to the case of 350° insulated.

Another point to be discussed, is that the test has provided information on the transient thermal expansion differential between the pipe and the U-bolt. As seen from the data which is attached as Figures 3 and 5, the maximum temperature differential between the pipe and the U-bolt occurred when the U-bolt has reached a representative temperature of about 100-105° while the pipe had been heated to 250-255°, a difference in temperature of approximately 150°F. This difference is well simulated in the finite element analysis where there is a constant difference in temperature of 140°F. It should also be remembered that for these temperature differentials, the amount of stress caused by the thermal expansion is not very significant.

TABLE 1

U-BOLT THERMAL AND CREEP TEST
DATA EVALUATION

	EQUILIBRIUM TEMPERATURE, °F						TIME REQUIRED TO REACH EQUILIBRIUM TEMPERATURE, HOURS					
	PIPE	U-BOLT RADIUS	U-BOLT LEGS	T/C 2	T/C 9	T/C 10	PIPE	U-BOLT RADIUS	U-BOLT LEGS	T/C 2	T/C 9	T/C 10
" INSULATED SPECIMEN												
THERMAL CYCLE 1	559	498	451	*	*	*	2.5	2.5	2.5	*	*	*
THERMAL CYCLE 6	560	530	440	*	*	*	2.0	2.25	2.75	*	*	*
CREEP	564	495	451	322	340	365	2.0	2.0	2.0	3.0	3.0	3.0
10" UNINSULATED SPECIMEN												
THERMAL CYCLE 1	250	195	150	*	*	*	.50	1.5	1.5	*	*	*
THERMAL CYCLE 6	250	183	144	*	*	*	25	1.0	1.0	*	*	*
CREEP	250	185	148	138	146	154	1.0	2.0	2.0	3.0	3.0	3.0
32" INSULATED SPECIMEN												
THERMAL CYCLE 1	560	*	*	*	*	*	4.0	*	*	*	*	*
THERMAL CYCLE 6	560	*	*	*	*	*	5.0	*	*	*	*	*
CREEP	563	440	353	154	175	251	4.5	11.5	12.5	14.5	14.5	14.5

* THERMAL EQUILIBRIUM WAS NOT ACHIEVED.

PRELIMINARY

EBASCO SERVICES INCORPORATED

BY M. Zurosky DATE 10/22/84 SHEET ____ OF ____

CHKD. BY ________ DATE ________ OFS NO ________ DEPT. NO. ________

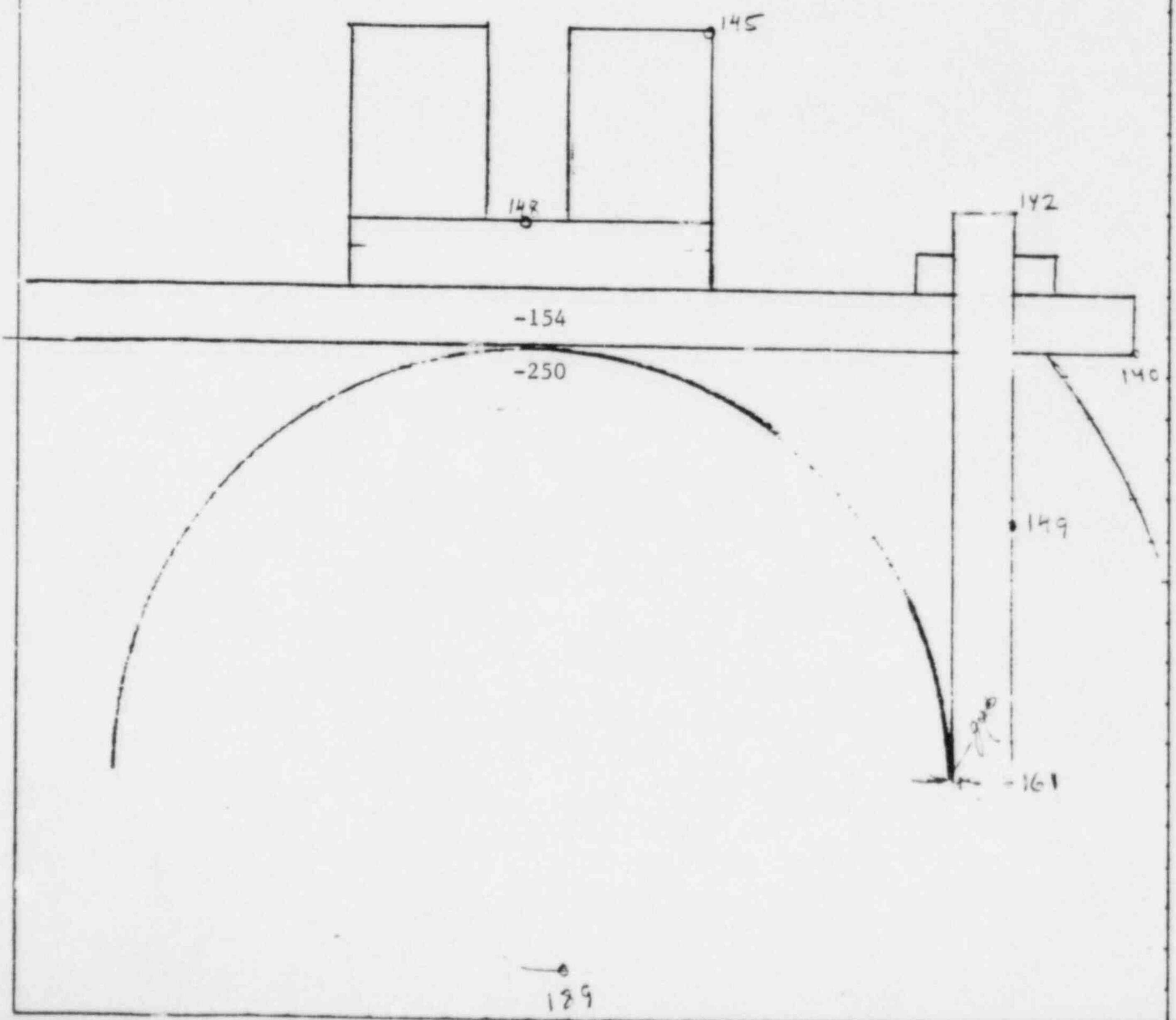
CLIENT TUGC

PROJECT Comanche Peak

SUBJECT Temperature in 10" carbon steel pipe U-BOLT Assembly

pipe at 250°F without insulation

FIGURE 1



EBASCO SERVICES INCORPORATED

BY M Zurosky DATE 10/22/84 SHEET ___ OF ___

CHKD. BY ______ DATE ______ OFS NO. ______ DEPT. NO. ______

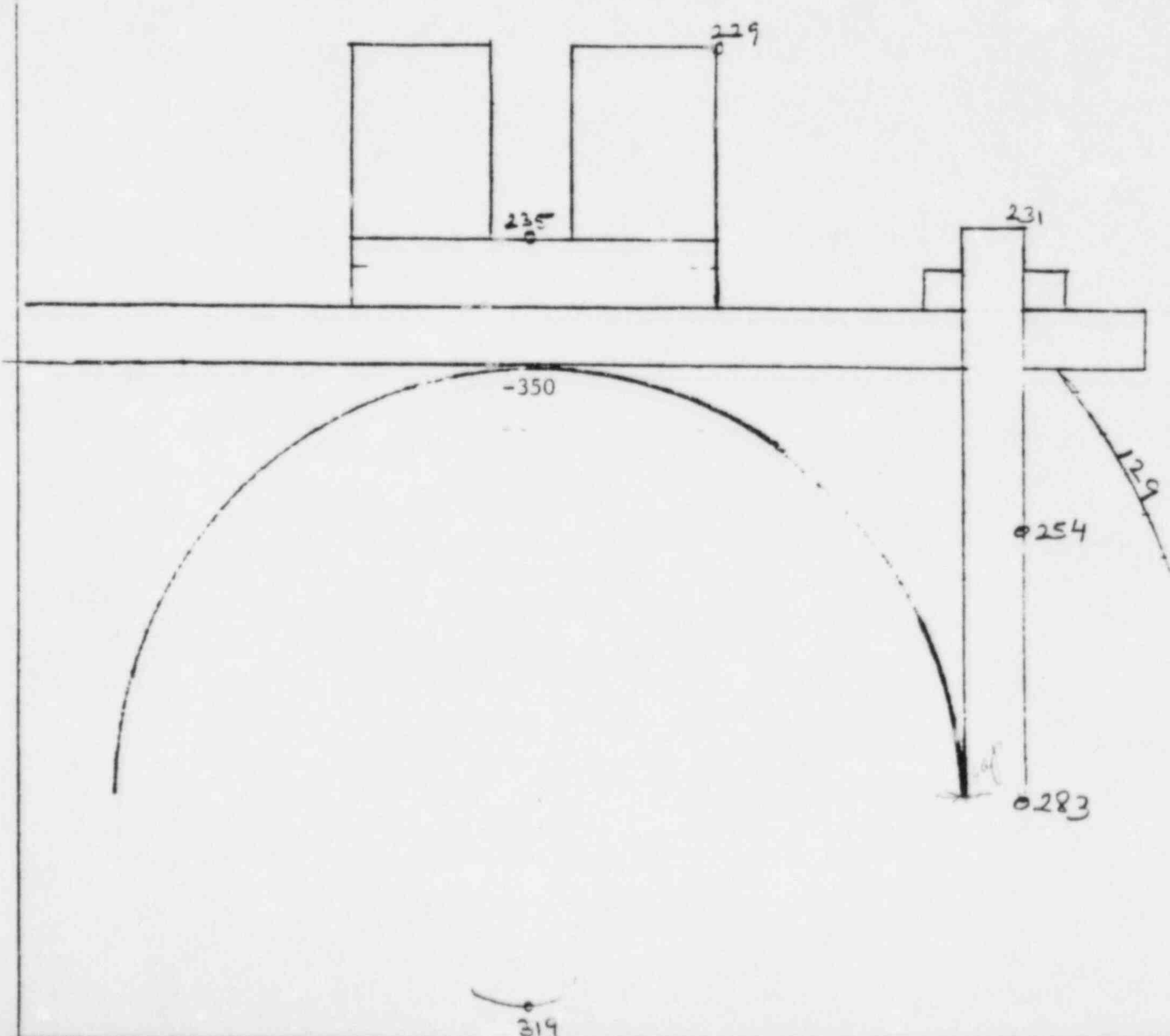
CLIENT TUGC

PROJECT Comanche Peak

SUBJECT Temperature in 10" carbon steel pipe U-BOLT Assembly

Pipe at 350°F with insulation

FIGURE 2



PRELIMINARY

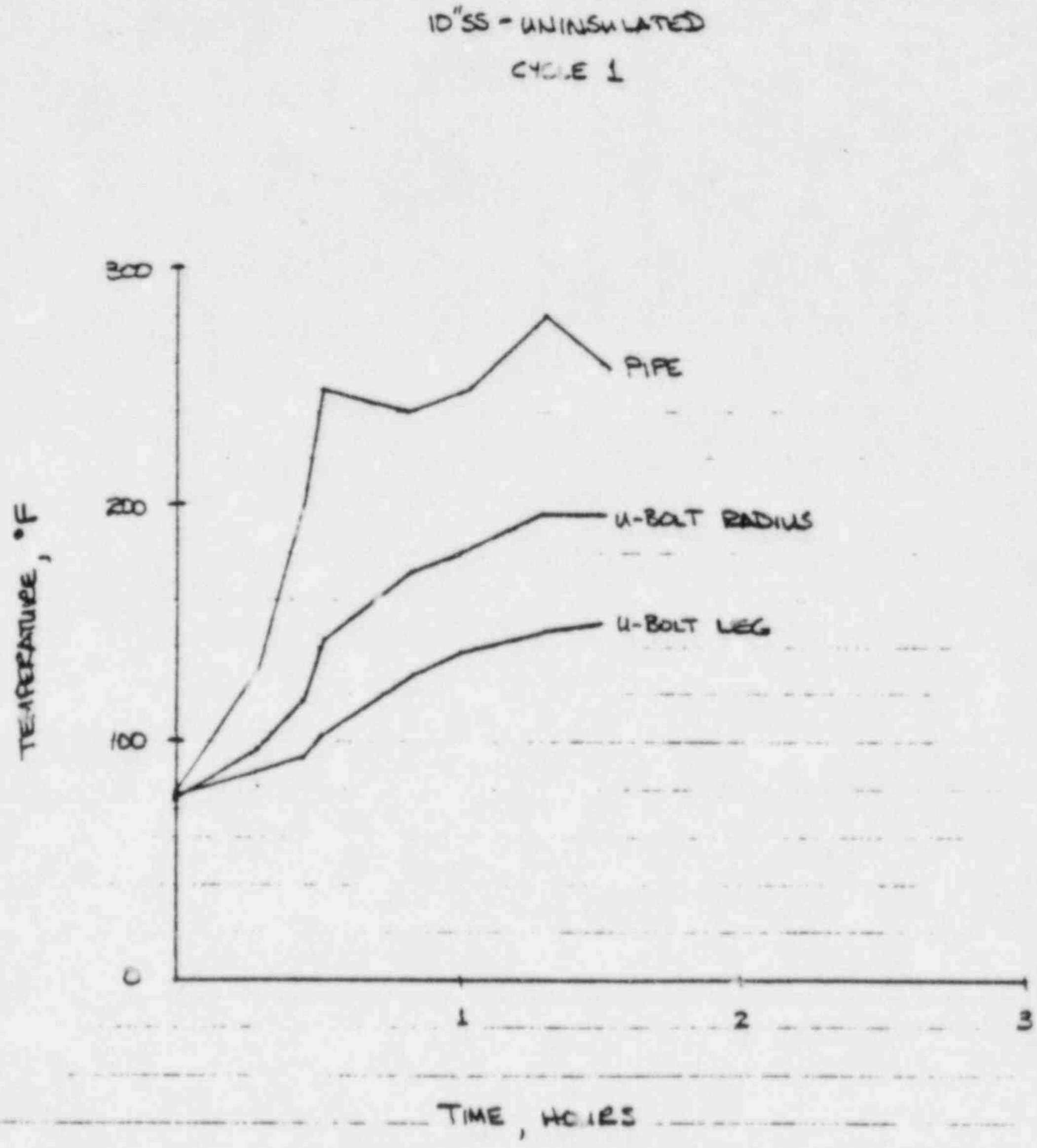


FIGURE 3

PRELIMINARY

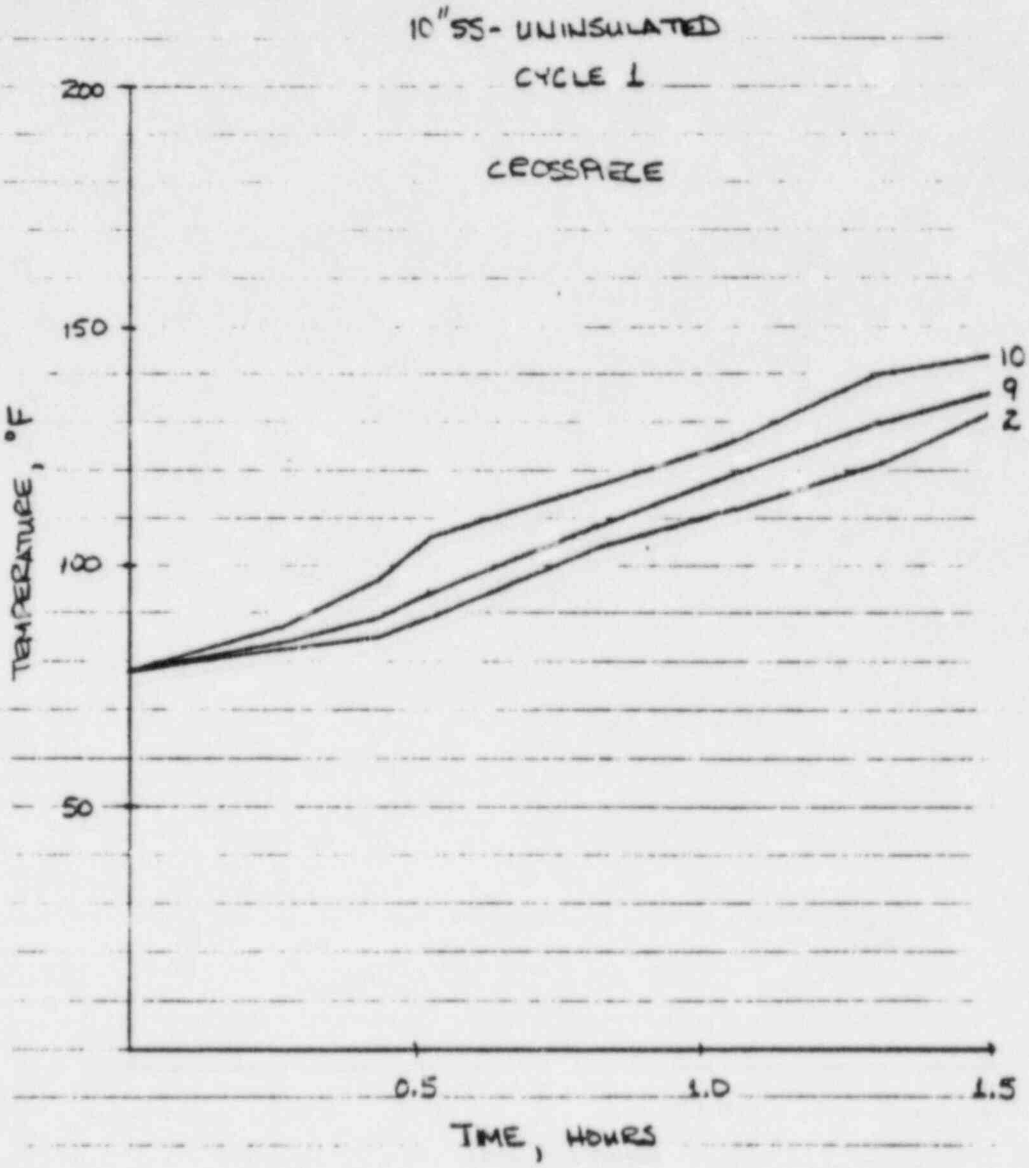


FIGURE 4

PRELIMINARY

D'SS - UNINSULATED
CYCLE 6

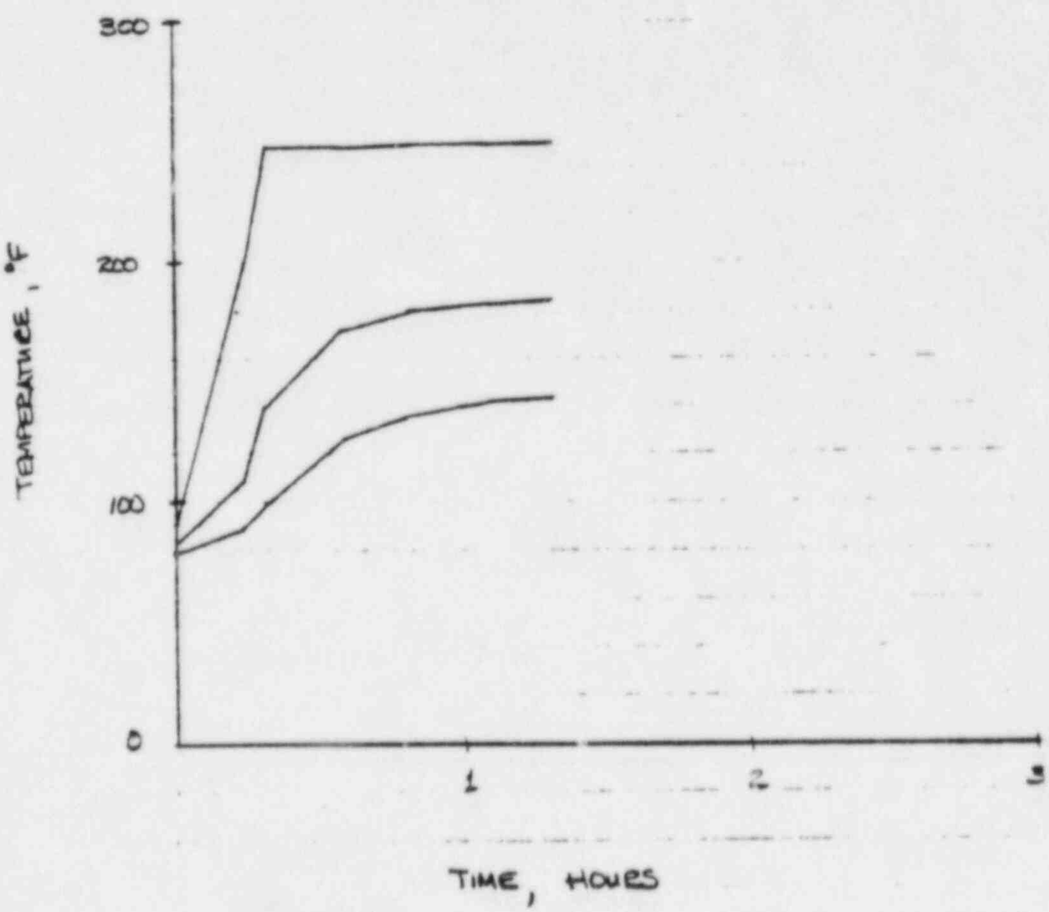


FIGURE 5

PRELIMINARY

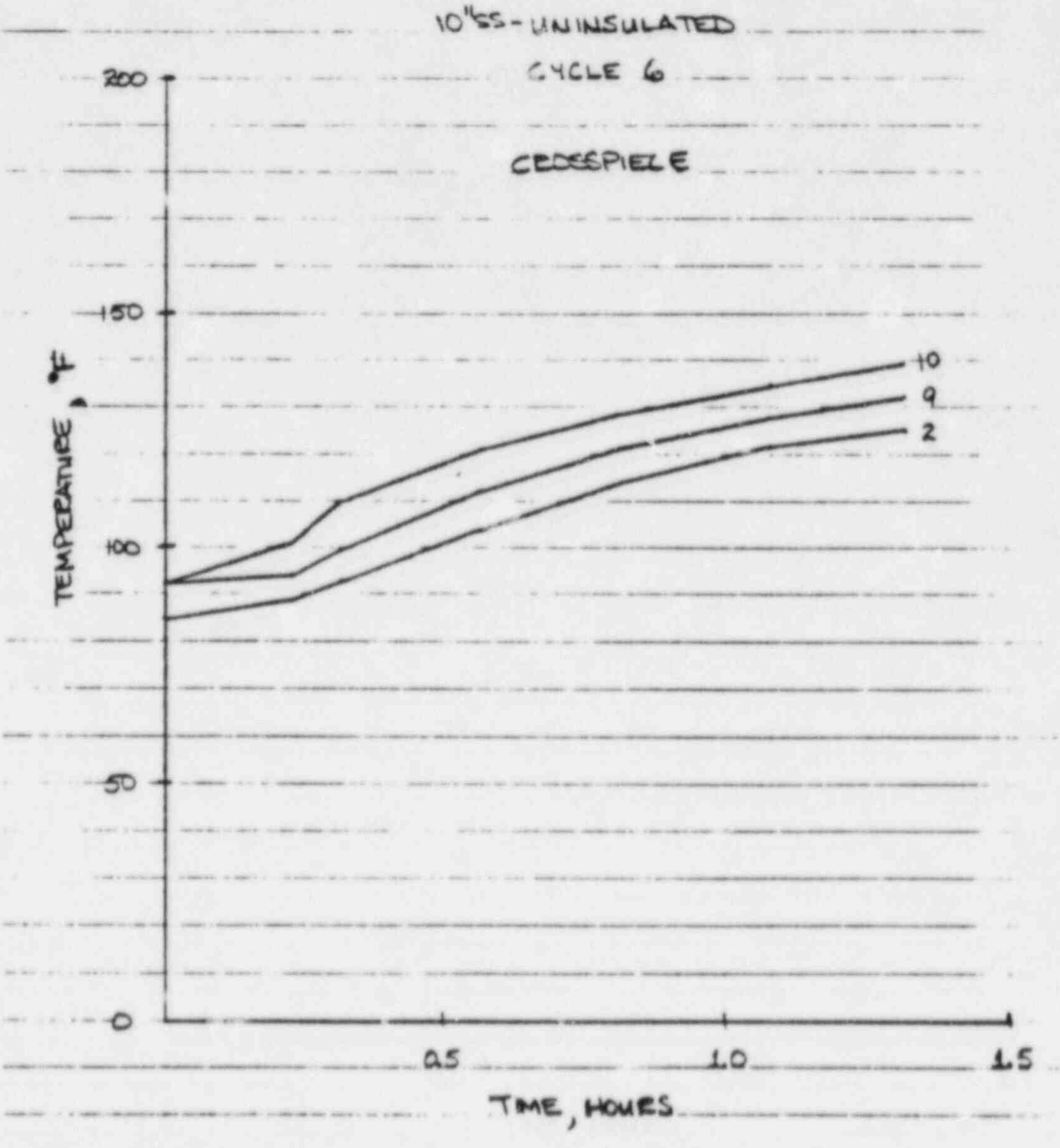


FIGURE 6

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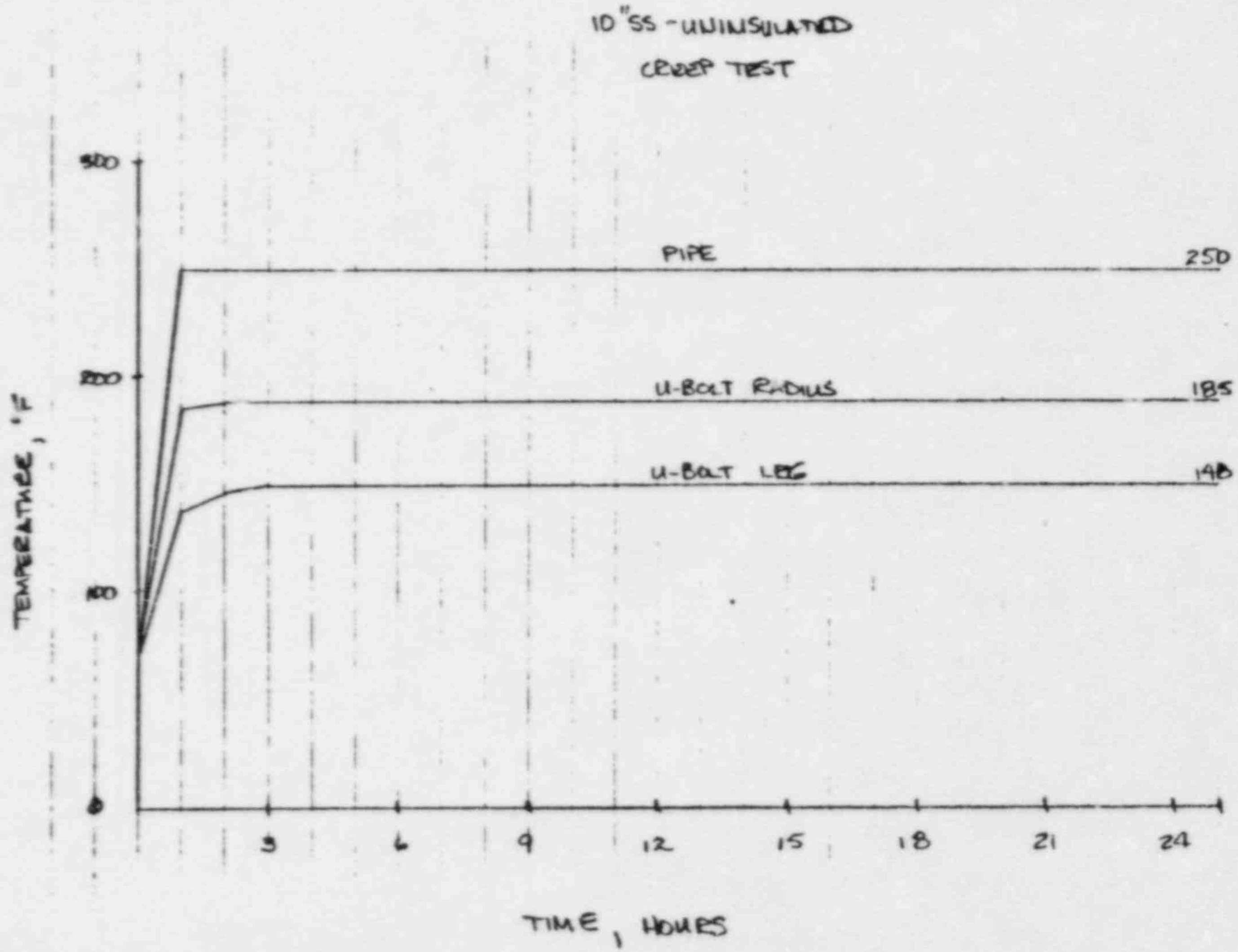


FIGURE 7

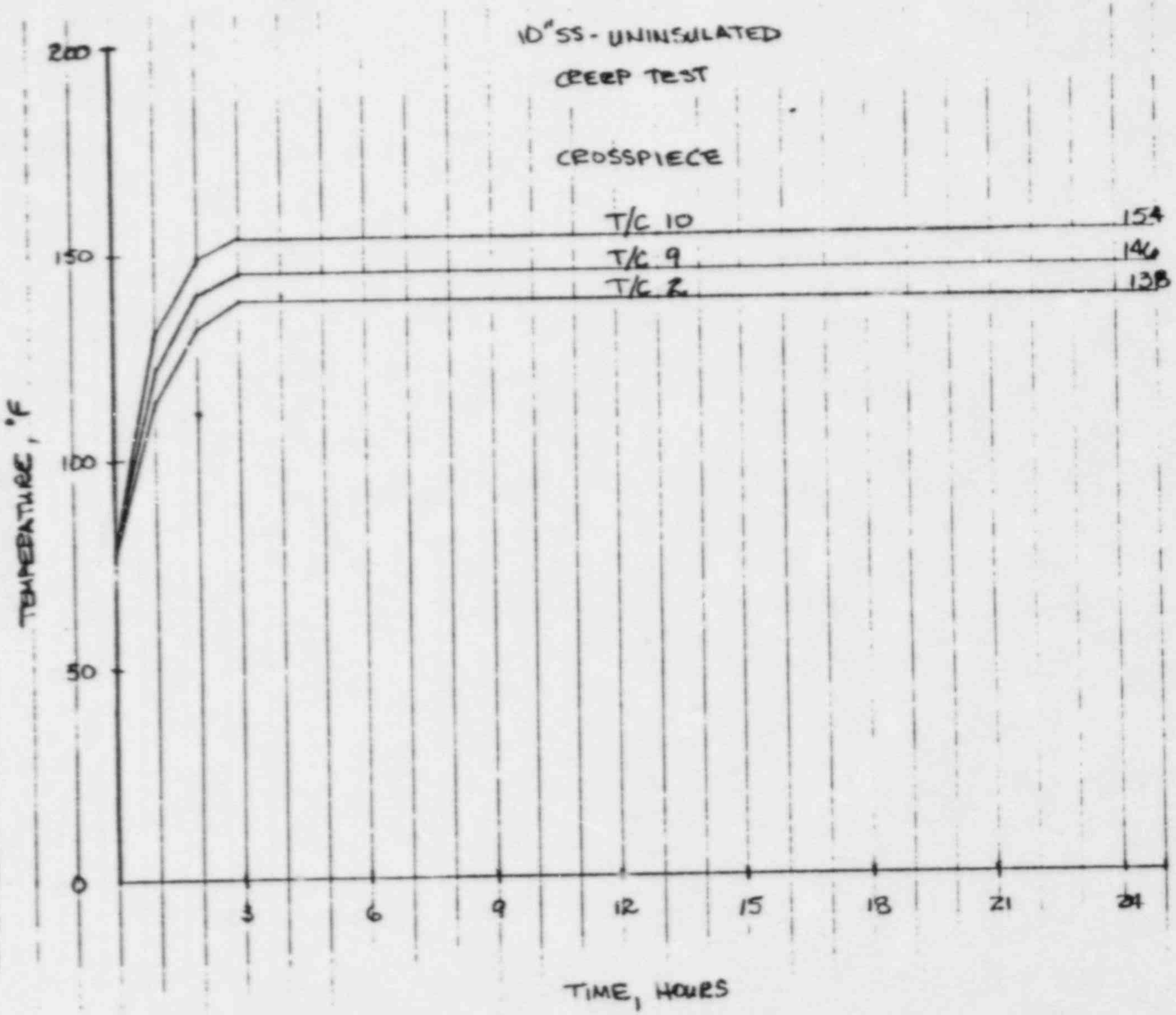
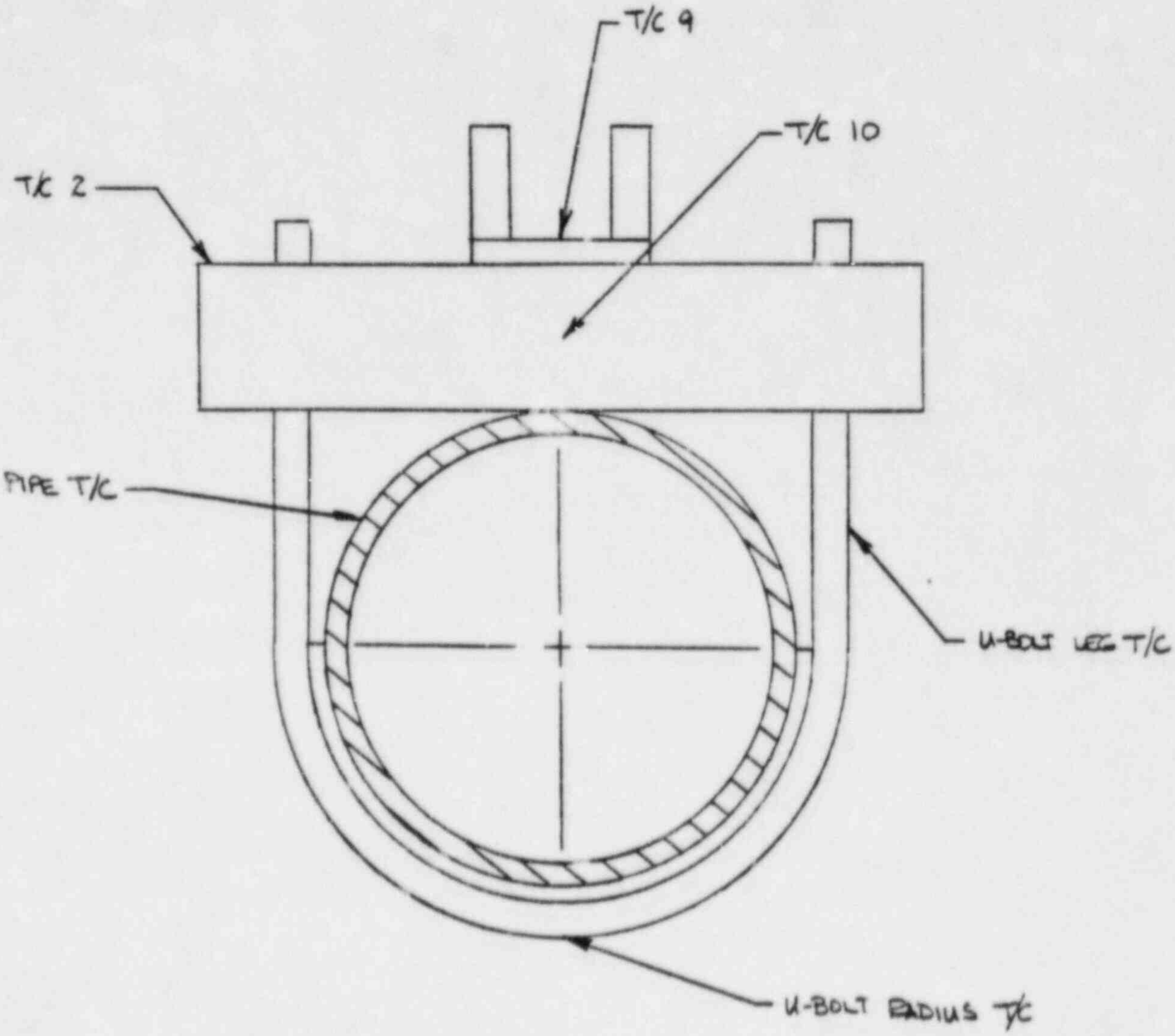


FIGURE 8

PRELIMINARY

PRELIMINARY



THERMAL AND CREEP TEST THERMOCOUPLE LOCATIONS

FIGURE 9