NSTX CALCULATION

TITLE Integrated Thermal Analysis, Normal Operations

CALC. NO. NSTX-CALC-13-9 DATE 2/14/97

ORIGINATOR A Brooks CHECKER ______ Rev. 0

PURPOSE:

This calculation describes heat flows and temperature rise expected during normal operations.

REFERENCES:

See attached.

ASSUMPTIONS:

See attached.

CALCULATION:

See attached.

CONCLUSION:

See attached.

NSTX

13-970214-AWB-02

TO: DISTRIBUTION
FROM: A Brooks
DATE: 14 February 1997
SUBJECT: Thermal Analysis VV/CS during Normal Operation
Ref: 1) Memo from S. Kaye Dated Oct 24,1996, "NSTX Divertor Heat Flux Estimates"
2) Memo 13-970214-AWB-01 from A Brooks dated Feb 14,1997, "Bakeout of Vacuum Vessel and Internals"

This memo documents the thermal analysis of Vacuum Vessel , Center Stack and Plasma Facing Components as it affects the Center Stack. As the VV and PFC designs evolve, they will need to be addressed in more detail.

Requirements

Normal operation of the NSTX device will result in heat fluxes from the plasma impinging on the surfaces of PFCs and VV. Reference 1 provides guidance on the magnitude and distribution of these heat fluxes under various modes of operation, specifically Natural Divertor (ND), Double Null Divertor (DN) and Single Null Divertor (SN) Plasma Configurations. For the Center Stack, the most significant of these is the Natural Divertor Configuration during which, for a 6 MW plasma, half of the non-core-radiated power or 2.1 MW is deposited on the center stack giving average heat fluxes of ~ 1 MW/m2 with a peaking of 1.6 MW/m2. The other half is deposited on the outer divertor plates, split between the top and bottom.

The radiative power which accounts for the remaining 1.8 MW or 30 % of the total plasma power is assumed to be distributed uniformly over all plasma view surfaces. Using approximately 35 m2 of viewing surface area, the average radiative flux is 0.051 MW/m2.

The device is being designed for a pulse duration of 5 seconds when operating at 6 MW. The repetition rate is once every 300 seconds (5 minutes) for OH single swing operation where the heating in the OH is minimal (~ 50 C) For OH double swing operation, during which the OH Coil reaches 95 C in a single pulse, the rep rate is reduced to once every 600 seconds (10 minutes) to eliminate thermal ratcheting.

One of the prime concerns is to demonstate adequate protection of the center stack coils by limiting heat flow and resultant temperatures at the OH groundwrap insulation.

Design Overview

The Center Stack Casing and Tiles are radiatively cooled to the outer PFCs and VV. To provide an adequate radiative sink, the outer PFCs (Inboard Divertor, Outboard Divertor and Passive Plates) and the Vacuum Vessel will be actively cooled. The system will also provide heating and cooling during Bakeout. (see reference 2).

Table I below summarizes the bulk temperature distribution found after fully ratcheting for the Natural Divertor Plasma. The data is based on averaged heat loads (due to the coarseness of the model) and does not include peaking.

Table I

	Bulk Temperature Distribution following 8 hours of 6MW pulsing every 300 s	
	Min Temperature, C	Max Temperature, C
CS Tiles	211	520
CS Casing	35	460
VV	25	34
PP	33	36
Outboard Divertor	60	70
Inboard Divertor	39	49

Table II below shows the resulting heat flows to the various components for 6MW of total heating for 5 secs every 300 secs (average 100 KW)

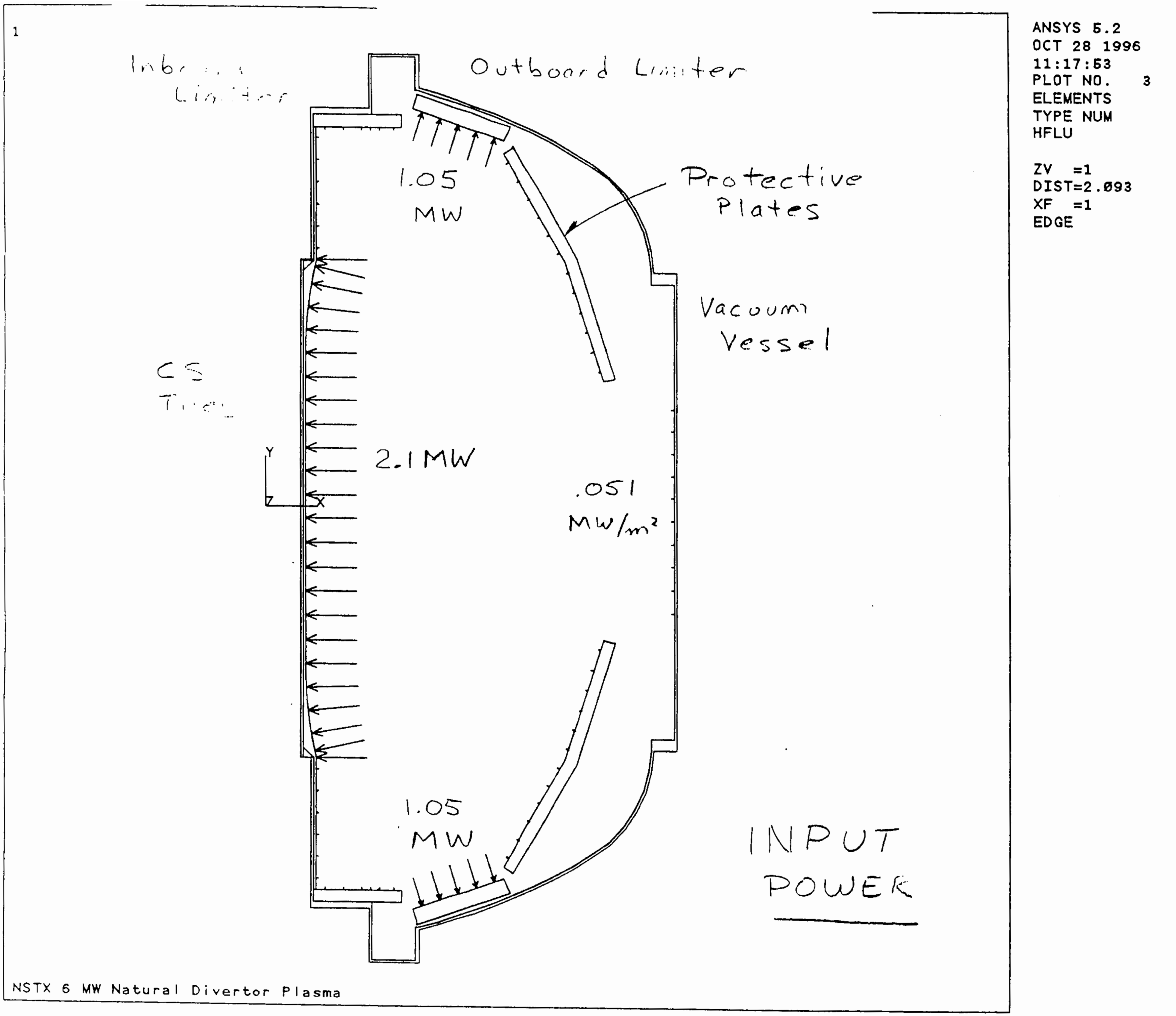
Table II

	Heat Flows, KW
Heat Loss to CS OH Coil	2.8
Heat Loss to CS PF1a Coils	0.4
Vacuum Vessel	16.6
Protective Plates	36.3
Divertors	44.3
Total	100.4

Using a 50 C radiative sink and the peak heat flux of 1.6 MW/m2 in the 1-D model, figures 4 and 5 shows the transient response at the surface of the CS tiles, the Inconel Casing and the OH groundwrap Insulation temperatures. Figure 4 is for the OH single swing operation where the OH conductor is at 50 C and pulsing is every 300 sec. Figure 5 is for OH double swing operation where the OH conductor is at 95 C but pulsing is only every 600 s.

The curves for the tiles show approximately 320 C rise in the surface temperature of the tile at the end of a pulse, equilibrating shortly thereafter for a bulk temperature rise of 200 C.

The Center Stack fully ratchets in less than 2 hours. At that point there is only about a 60-70 C difference on average between the bulk temperature of the tile and the hot Inconel casing (peak temperature 568 C).. Earlier analyses using poorer thermal insulation showed much lower casing temperature and slightly lower tile temperatures, with a larger difference between the two, indicative of much larger heat losses to the CS coils. While the casing temperature has gone up significantly, the heat loss and corresponding temperature gradient from the OH conductor to the OH groundwrap has gone down offering better protection to the CS coils.


1
Outboard Limiter
1.05
MW
Protective
Plates
Vacuum
Vessel
CS
2.1MW
Y
Z
X
.051
MW/m²
1.05
MW
INPUT
POWER
NSTX 6 MW Natural Divertor Plasma
ANSYS 5.2
OCT 28 1996
11:17:53
PLOT NO. 3
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HFLU
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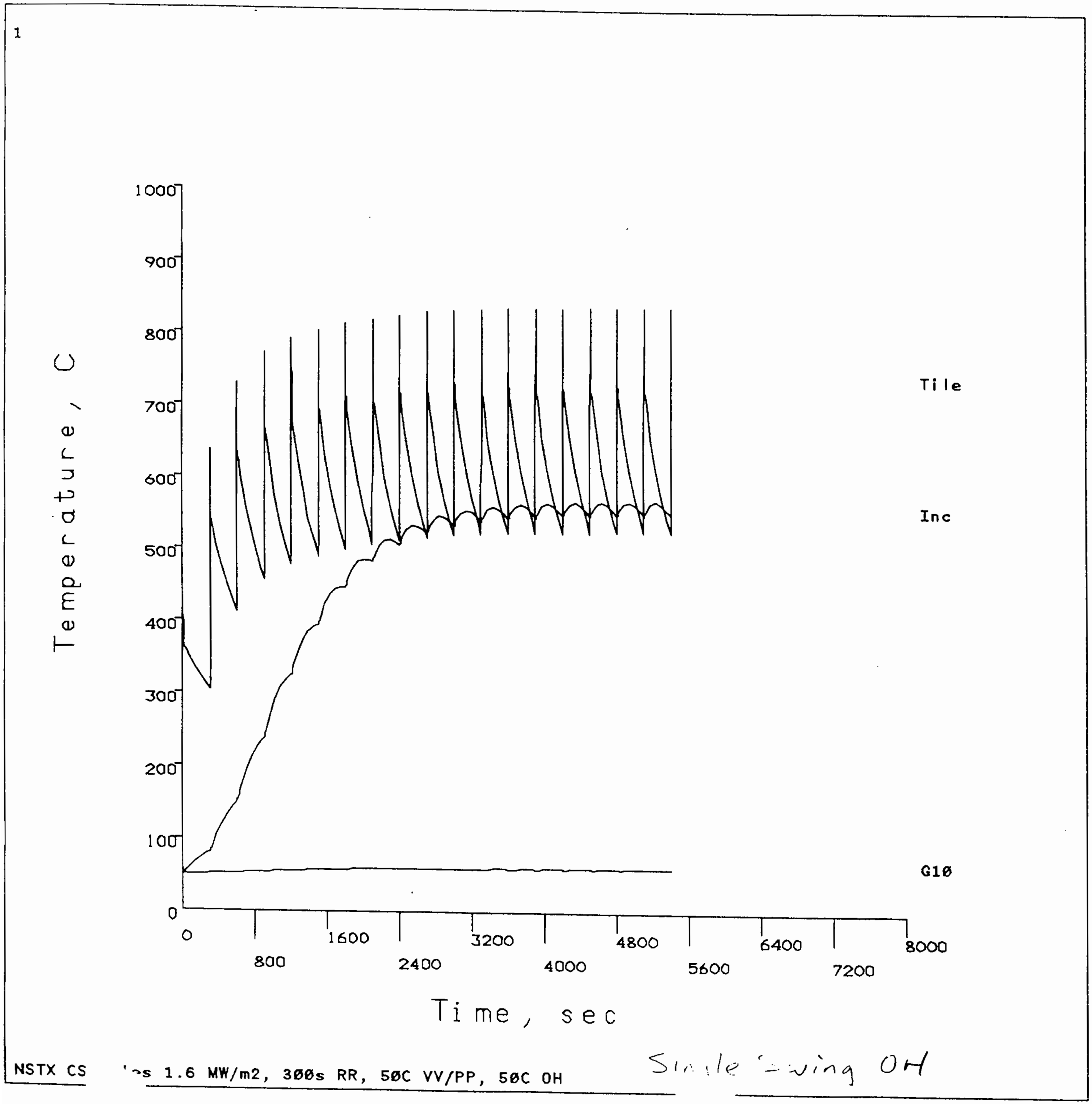
XF =1
EDGE


1
ANSYS 5.2
FEB 16 1997
10:55:54
PLOT NO. 1
POST26
ZV =1
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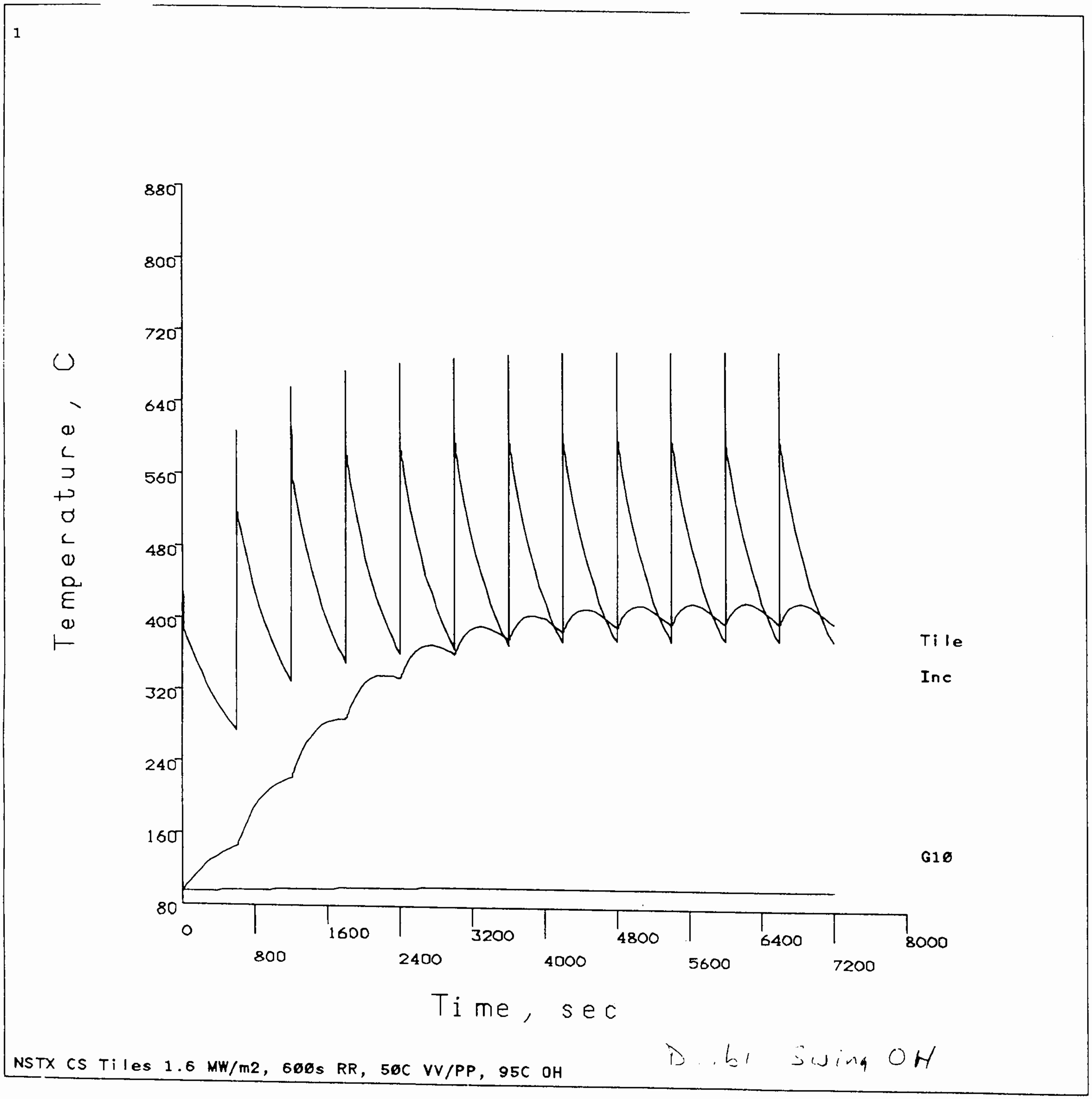
XF =.5
YF =.5
ZF =.5
Temperature, C
0
100
200
300
400
500
600
700
800
900
1000
Tile
Inc
G10
0
800
1600
2400
3200
4000
4800
5600
6400
7200
8000
Time, sec
NSTX CS
1.6 MW/m2, 300s RR, 50C VV/PP, 50C OH
Single Swing OH

Figure 4



ANSYS 5.2
FEB 16 1997
11:Ø2:Ø2
PLOT NO. 1
POST26

ZV =1
DIST=.75
XF =.5
YF =.5
ZF =.5

NSTX CS Tiles 1.6 MW/m2, 6ØØs RR, 5ØC VV/PP, 95C OH

Double Swing OH

Figure 5