EVALUATION OF TEMPERATURE FIELD COMPOSITE TUBE SHEET GEOMETRIES WITH COMPLEX BOUNDARY CONDITIONS

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INTRODUCTION

Knowledge of temperature field in composite tube shet geometries is important from suitable and effective thermal design aspect. In several situations a number of unknowns may be present at boundaries such as convective heat transfer coefficient, and fluid bulk temperature. Since convective heat transfer coefficient is a function of surface temperature for natural convection, it is desirable to correct the heat transfer coefficient and surface temperature literatively. In tube sheet problems one has to obtain three dimensional temperature field for complex heat load and internal heat generation. At times an equipment is required to operate with only partial cooling water level due to either nonavailability of cooling pumps in a system or due to failure of power supply to cooling pumps. The designer must ensure that the temperature in the equipment is within permissible limits. In this problem the temperature of cover gas trapped above the water level becomes one additional unknown.

In the present paper the above problem has been analysed at two stages. At first a simplified two dimensional model of composite tube sheet geometry is analysed by a finite element computer code AXITEMP [1]. The heat transfer coefficients are corrected iteratively and the trapped cover gas temperature is obtained by ensuring heat balance. A number of cases are analysed which include effect of water level fluctuation in the equipment, and effect of low flow or no flow from the cooling pumps. In second stage a local path of tube sheet with lattice tube is used for study with a three dimensional finite element computer code HEAT 5 [2]. In this analysis all the input such as surface tempera-ture at the patch edge, convective heat transfer coefficients and trapped cover gas bulk temperature is taken from simplified two dimensional analysis.

MODELLING

In the simplified two dimen-sional analysis the tube sheets and the central slab with buffle is first converted into equivalent blocks with same conduction volume and convection surface as shown in figure 1. In these models the lattice tubes and annular gap in baffle slab have been replaced suitably to obtain overall temperature and the cover gas temperature. At right end of equipment the air temperature is 271^0C while at the left end air temperature is 82.8^0C. The water is upto a level of G. Forced convection condition is assumed in water portion. For an assumed cover gas temperature the temperature distribution in

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two tube sheet sand the central slab is obtained after iteratively correcting the free convection heat transfer coefficients in cover gas and air portion. A heat balance as made for the assumed temperature of cover gas as follows:

$$Q_{TSL} + Q_{SLAB} + Q_{TSR} = 0 \qquad (1)$$

where Q_{TSL} = heat from left tube sheet to cover gas

Q_{TSR} = heat from right tube sheet to cover gas

Q_{SLAB} = heat from two slab faces

The cover gas temperature is changed till the above equation is satisfied .....(3).

The analysis was carried out for two cases in which water level in the equipment was changed from G row to level between F and G row (FG) and level between G and H row (FH). Outer cases which were studied by this method were shut down case with normal cooling water flow in the equipment. In this case the internal heat generation is reduced to 30%. Finally temperature distribution is obtained for a case when pumps stop due to power failure. In this case the water temperature is taken to be 99^{0}C with natural convection conditions. In phase 2 analysis the heat transfer coefficients in air and cover gas portion and the cover gas temperature obtained above are used as input for a detailed three dimensional temperature distribution study. Here a patch of tube sheet and certain length of lattice tube is modelled near water cover gas interface portion.

RESULTS

Fig. 2 shows temperature distribution in left and right tube sheet and the baffle slab with water level at GG with normal cooling water flow. The cover gas temperature is found to be 124.4^{0}C. The maximum temperature on left tube sheet is 31. ^{0}C, (in cover gas portion) while the maximum temperature in right tube sheet is 195^{0}C. In case of power supply failure to cooling pumps the water side temperature on left tube sheet is 141. ^{0}C. In cover gas portion the maximum temperature on left tube sheet is 11 ^{0}Cwhile on right side tube sheet it is 200.6^{0}C. Table 1 represents the detail results for various cases. Fig.3 shows temperature in tube sheet by two and three dimensional analysis. It may be noted that temperature of different locations matches well.

CONCLUSION

The temperature distribution in a complex geometry such as composite tube sheet can be obtained by simplified two dimensional and detailed three dimensional finite element analysis. The effect of heat transfer coefficient on temperature distribution can be iteratively corrected. Simplified analysis helps to arrive at various boundary conditions in terms of temperature bulk fluid bulk fluid temperature and heat transfer coefficients for detailed three dimensional analysis.

REFERENCES

1. H.S. Kushwaha, .K.Singh, B.Murali 'AXITEMP' A finite element computer code for two dimensional and asimsymmetric structures thermal analysis - RED, BARC, Bombay .

2. H.S. Kushwaha 'HEA 5 - A finite element computer code for three dimensional thermal analysis - RED, BARC

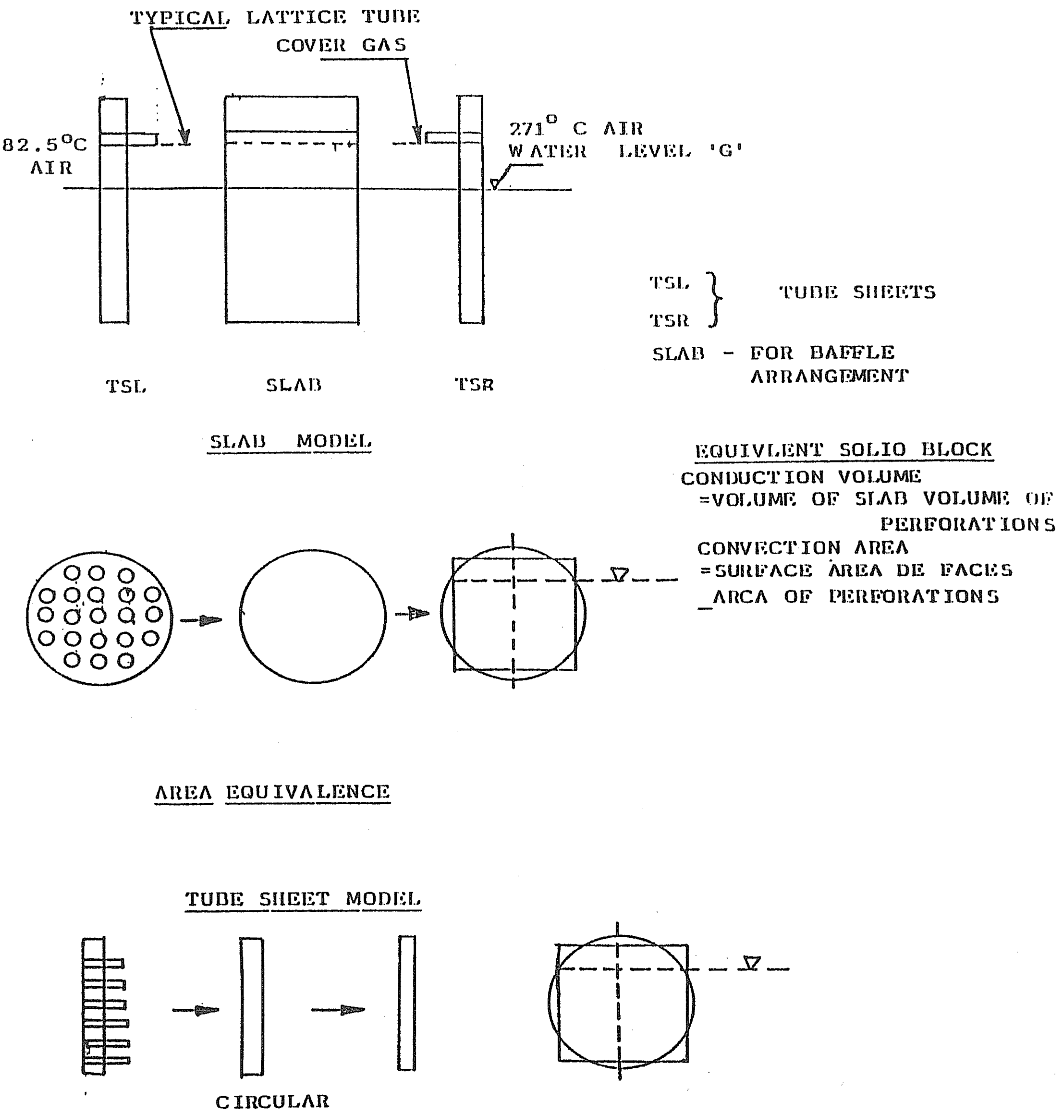
3. Heat transfer and fluid flow data book by General Electric Company.

Table - 1

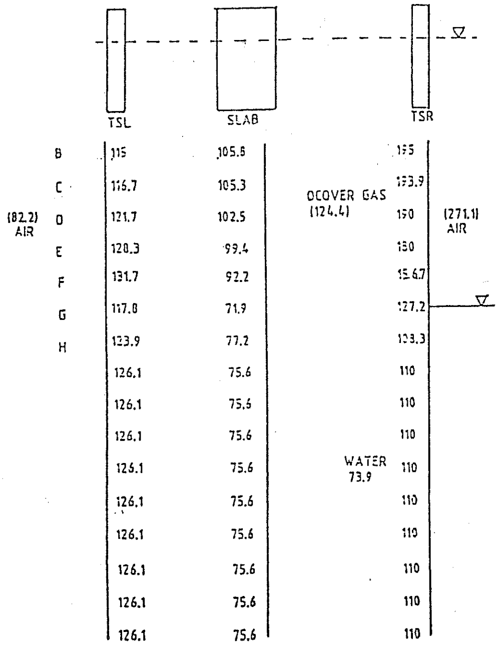
SR NO.	CASE	COVER GAS TEMP. (^{0}C)	MAX. TSR TEMP. (^{0}C) *(1,2)	MAX. TSR TEMP. (^{0}C) *(1,2)	MAX. BAFFLER SLAB TEMP. (^{0}C) *(1,2)
1.	Water level FG normal flow	118.3	120 (E) 127.8	191.1 (B) 111.7	98.9(B) 73.9
2.	Water level GG normal flow	124.4	127.8 127.8	111.7 111.7	73.9 73.9
3.	Water level GH normal flow	132.4	148.3 127.8	200(B) 111.7	115.6(B) 73.9
4.	Shut down water level GG normal flow	113.1	103.3(E) 110	190(B) 111.7	90.6(B) 73.9
5.	Shut down water level GG low due to power supply failure to pumps	135.2	118.9(F) 141.7	200.6(B) 140	119.4(B) 103.3

Legend *1 First temp.in cover gas portion Second temp. in water portion.

*2 Letters in bracket show location of the tube sheet.



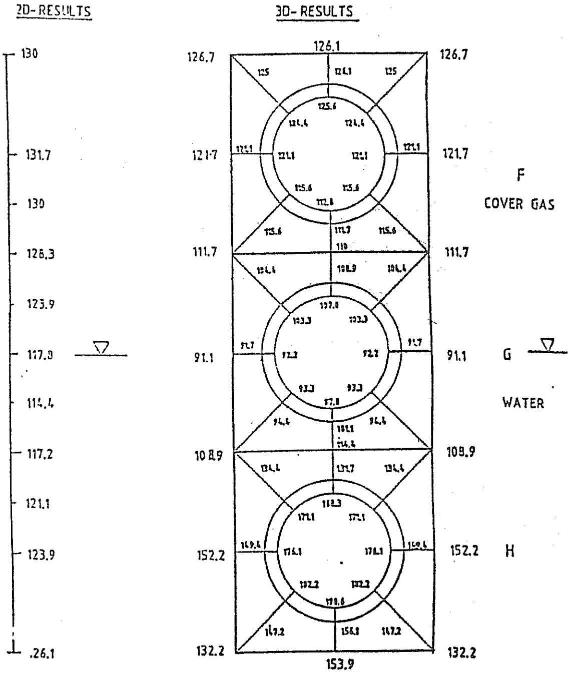
FOR ALL MODELS
h MODEL A MODEL hA
FIG.1



CENTRAL TEMPERATURE OF TUBE SHEETS AND SLAB (°C)

CASE - WATER LEVEL GG
NORMAL FLOW

FIG. 2



TEMPERATURE DISTRIBUTION AT WATER COVER GAS INTERFACE (°C)

CASE - WATER LEVEL GG
NORMAL FLOW

FIG. 3

TRANSIENT TEMPERATURE COMPUTATIONS IN DIFFERENT SIZES OF C-COUPLINGS DUE TO REACTOR START-UP AND SHUT-DOWN

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Abstract

The procedure for computing temperature transients in two different sizes of C-cuplings, used in nuclear reactors is described. Finite element numerical solution technique is used for this purpose. Imposed transient flux is due to fuelling machine operation as well as reactor startup and shutdown. Consideration of various convective boundary conditions and calculation of associated h values are shown.

INTRODUCTION

C-couplings are becoming more and more popular components in nuclear power plants and are used in place of conventional flanges because of their compactness, easy maintenance and more reliability. They are used in large numbers in Pressurised Heavy Water Reactors (PHWR) such as at the joint between feeder pipes and End-fiting, in F/M housing etc. Integrity of these clamps have direct effect on overall safety of the nuclear power plants.

This necessitates proper design, fabrication, installation and maintenance of these components.

The temperature transient computation of these couplings during reactor start-up and shut-down are found to be necessary to check whether maximum thermal stresses are within codal limit and also to compute allowable fatigue cycles. The irregular outer profile of the coupling necessitates the use of a powerful numerical technique such as finite elements for temperature computational purposes. The coupling with its hub may very well be simulated as an axisymmetric body when mounted, from heat transfer point of view. The inner surface of the coupling is in contact with its hubs, which is exposed to channel flowing water. The temperature of the water changes during various reactor operations. Hence heat transfer coefficient of this surface changes. Heat loss through outer surface of the coupling is due to natural convection and hence again a function of varying surface temperature.

In the present work transient temperatures are computed in two different sizes of C-couplings. The next Sec-

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Table 1: Numerical constants in Eq (4) based on Teja and Rice Method for viscosities of liquid mixtures

	R21-DMF	R21-DMETEG	R22-DMF	R22-DMETEG
a0	0.3878E+01	0.4396E+01	0.3270E+01	0.3773E+01
a1	-0.1122E+04	-0.1777E+04	-0.1033E+04	-0.1672E+04
a2	0.9738E+03			
a3	0.1391E+03	0.1371E+03	0.1430E+03	0.1538E+03
a4	0.4348E+03	0.1210E-02	0.1333E+02	0.2134E-02
a5	-0.1727E+02	-0.3294E-02	-0.3561E-02	-0.5240E-02
a6	0.1220E-02	0.1216E-02	0.1257E-02	0.1355E-02

Table 2: Numerical constants in Eq (5) based on Ely and Hanley Method for Thermal conductivities of liquid mixtures

	R21-DMF	R21-DMETEG	R22-DMF	R22-DMETEG
b0	-0.3647E+00	-0.3201E-01	-0.2018E+00	-0.8961E-01
b1	-0.2043E+03	-0.2077E+03	-0.2009E+03	-0.1881E+03
b2	-0.6911E+02	-0.4568E+02	-0.1460E+01	-0.2560E+02
b3	-0.3943E+02	0.9777E+02	0.1263E+03	0.1117E+03
b4	-0.3257E-02	-0.2623E-02	-0.3539E-02	-0.3201E+02
b5	-0.6224E-03	-0.8038E-03	-0.3880E-03	-0.1416E-02
b6	-0.1032E-02	-0.2048E-02	-0.3126E-02	-0.2058E-02

R21 = CHCI F; R22 = CHCIF2 ; DMF = Dimethyl formamide;
DMETEG = Dimethyl ether of tetraethylene glycol.

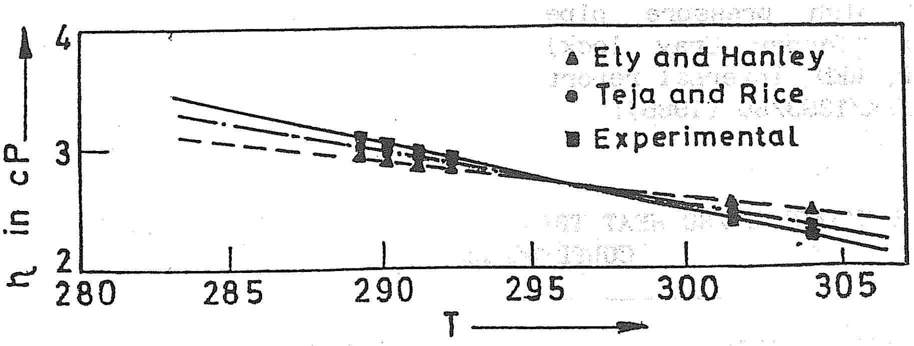

FIG. 1

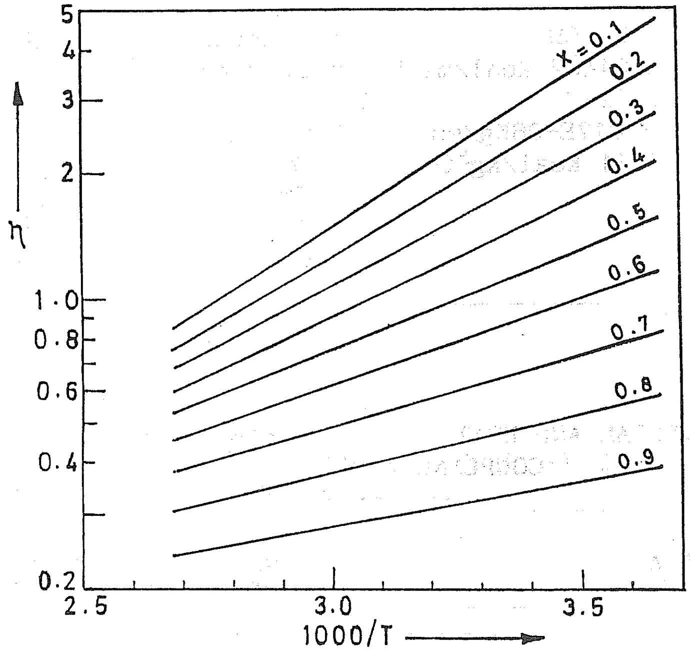

FIG. 2

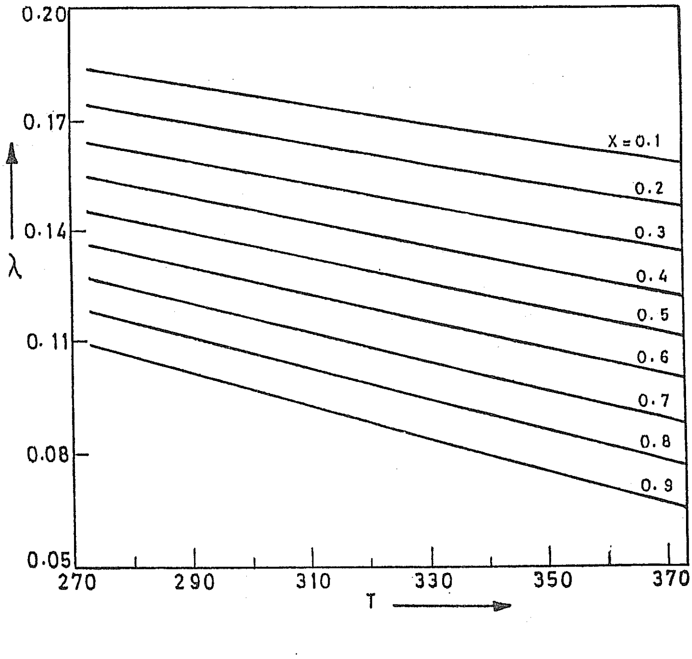

FIG. 3

sis of high pressure pipe coupling (feeder Gray lock) for KAPP, RED internal report no. RED/AK/1393/86 (1986).

TABLE-1 MATERIAL AND HEAT TRANSFER DATA FOR FUELLING MACHINE C-COUPLING ANALYSIS

MATERIAL DATA		HEAT TRANSFER COEFFICIENT DATA	
Material	- 403 SS	Inner Surface-525 Kcal/mm^2 Hr°C	
Av.Conductivity	- 0.01462 Kcal/mm Hr°C	Outer Surface -	
Density	- 7.817E-06Kg/mm^2	Surface temp.(°C)	h(kcal/mm^{2}HroC)
Sp.Heat	- 0.11 Kcal/Kg°C	38	0.0
		50	5.4668
		70	7.643
		100	9.1897

TABLE -2 MATERIAL AND HEAT TRANSFER DATA FOR FEEDER PIPE C - COUPLING ANALYSIS

MATERIAL DATA		HEAT TRANSFER COEFFICIENT DATA	
Material	- 403 SS	Inner Surface	
Av. Conductivity	- 0.01542Kcal/ mm Hr°C	Surface temp.(°C)	h(kcal/mm^2 Hr°C)
Sp.Heat	- 0.11Kcal/Kg°C	50	0.0111724
		70	0.01322
		100	0.016108
		200	0.021642
		250	0.021642
		316	0.019479
		Outer surface-assumed insulated	

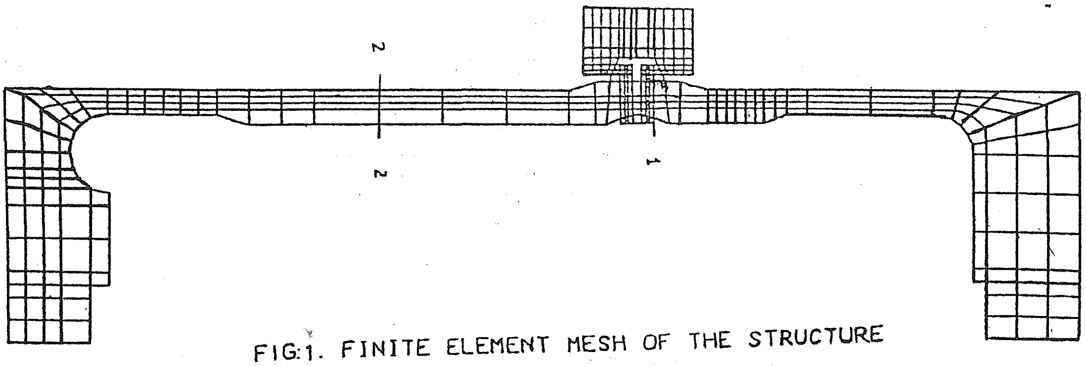

FIG:1. FINITE ELEMENT MESH OF THE STRUCTURE

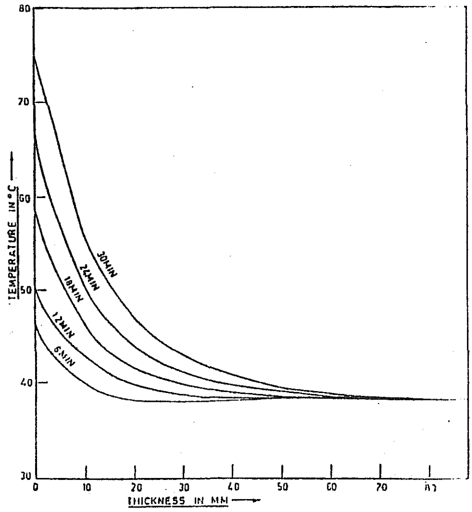

FIG.2A TEMPERATURE TRANSIENT ALONG THE THICKNESS AT SECTION1-1

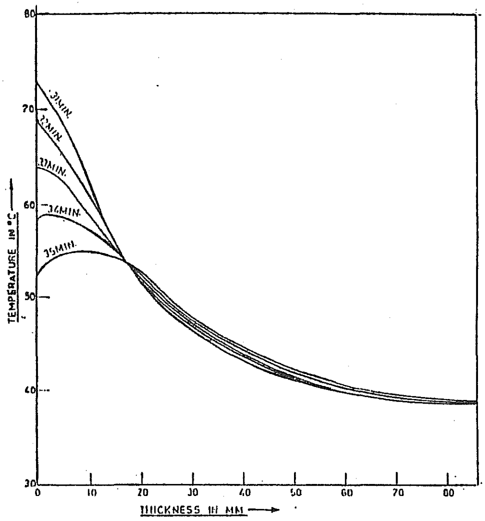

FIG.2B TEMPERATURE TRANSIENT ALONG THE THICKNESS AT SECTION1-1

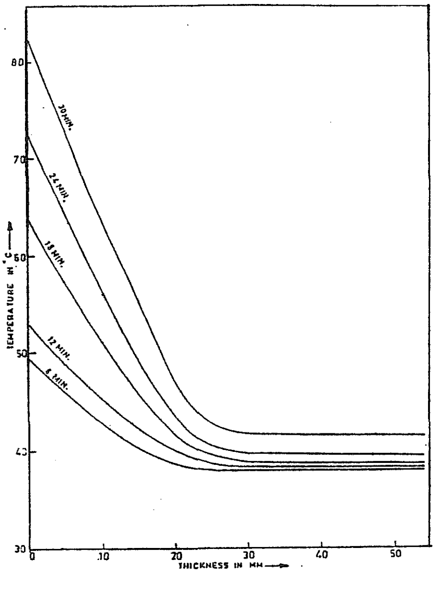

FIG.3A TEMPERATURE TRANSIENT ALONG THE THICKNESS AT SECTION2-2

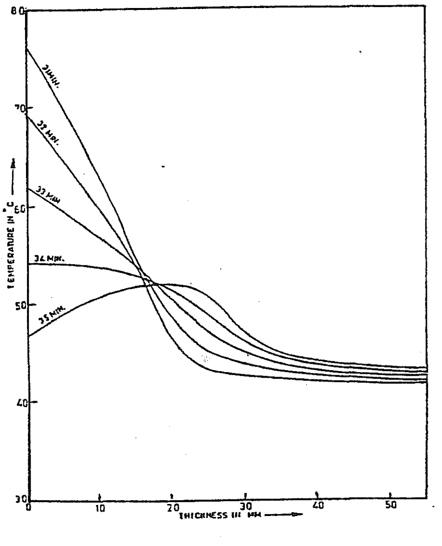

FIG.3B TEMPERATURE TRANSIENT ALONG THE THICKNESS AT SECTION2-2

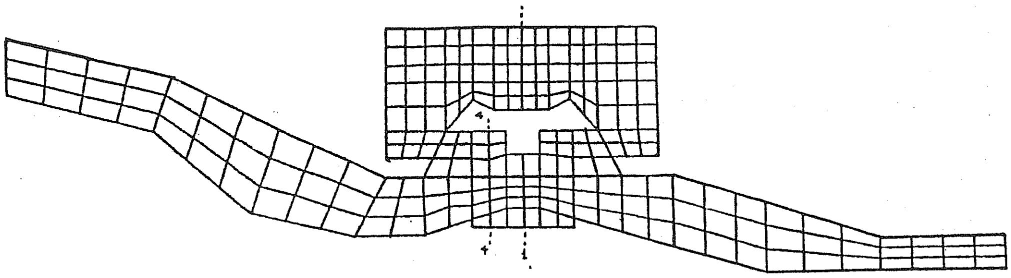

FIG. 4 DISCRETIZATION OF KAPP FEEDER PIPE COUPLING

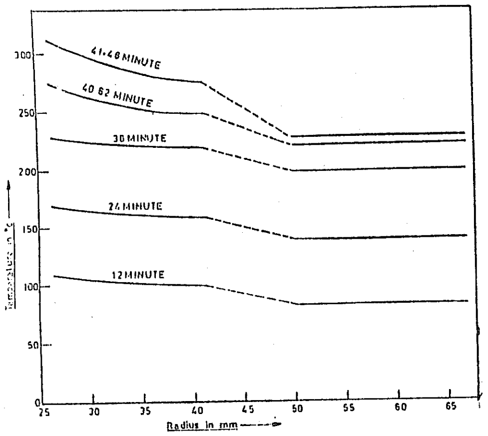

FIG.5A TEMPERATURE TRANSIENT IN KAPP PIPE FEEDER COUPLING AT SECTION1-1 DURING HEATING.

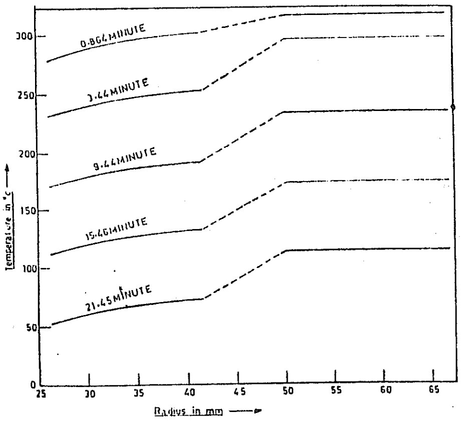

FIG.5B TEMPERATURE TRANSIENT IN KAPP PIPE FEEDER COUPLING AT SECTION1-1 DURING COOLING.

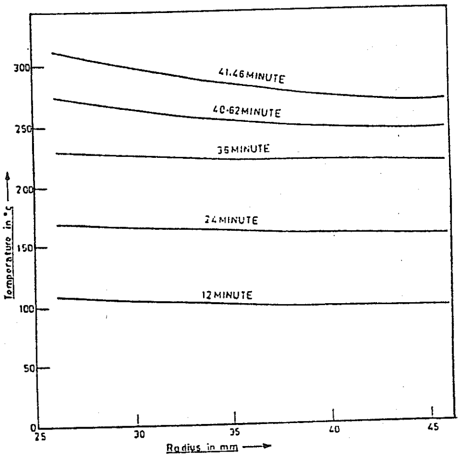

FIG.6A TEMPERATURE TRANSIENT IN KAPP PIPE FEEDER COUPLING AT SECTION2-2 DURING HEATING.

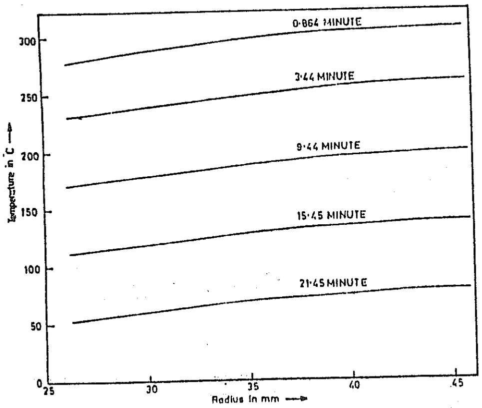

FIG.6B TEMPERATURE TRANSIENT IN KAPP PIPE FEEDER COUPLING AT SECTION2-2 DURING COOLING.