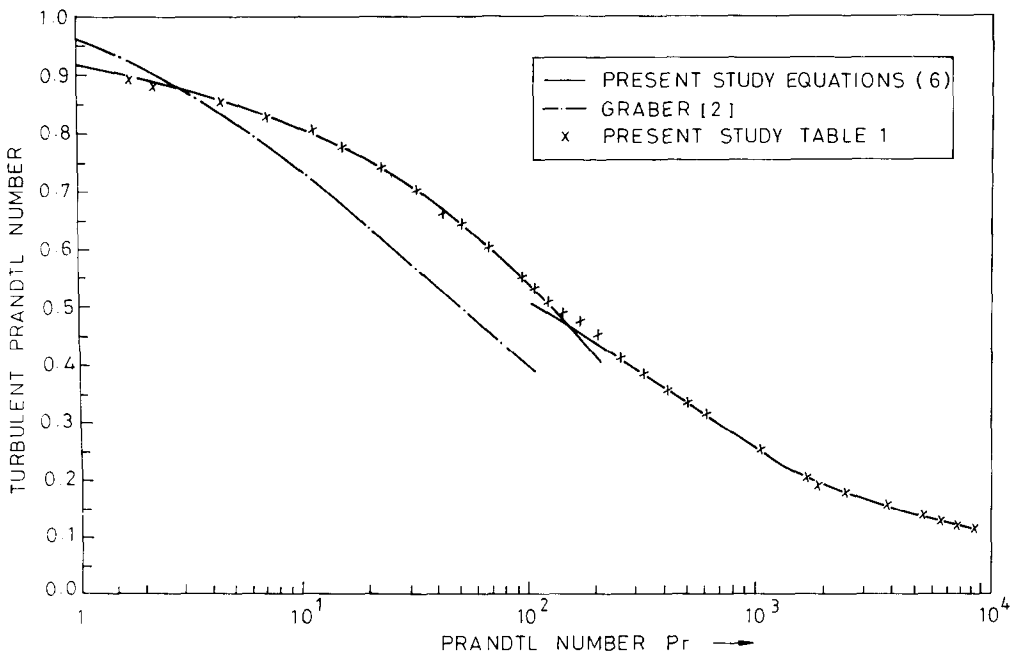

FIG. 2. Turbulent Prandtl number in the range $1 < Pr < 12\,500$.

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Determination of boiler furnace heat flux

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NOMENCLATURE

D	tube outside diameter [mm]
F	view factor
h	film conductance [kcal h^{-1} m^{-2} °C^{-1}]
p	pressure [kg cm^{-2}]
q	heat flux [kcal h^{-1} m^{-2}]
T	temperature [°C].

Greek symbols

β_1, β_2	view angles [rad]
θ	angle [rad].

Subscripts

o	tube outside
p	projected.

1. INTRODUCTION

THE DESIGN of a modern boiler furnace requires the computation of furnace wall metal temperatures for proper selection of tube material and thickness. The sizing of the furnace requires adequate knowledge of the heat flux distribution in the boiler furnace. The data required for these calculations can be obtained through experimental studies from operating furnaces. Since the direct measurement of furnace heat flux is difficult, it is normal practice to measure the furnace wall metal temperatures and use these for the evaluation of the furnace heat flux. This note describes an iterative procedure for the calculation of furnace heat flux from measured metal temperatures.

2. METHOD OF ANALYSIS

This study was made for a boiler furnace with a tangent tube construction. The furnace wall was formed of tubes 60.3 mm in diameter arranged at a pitch of 62 mm as indicated at the top of Fig. 1.

The major step involved in the analysis is the establishment of a relation between the metal temperatures and the furnace heat flux for various values of inside film conductance for the given geometry and arrangement of furnace wall tubes. This involves, among other things, the determination of the local heat flux over the tube circumference for a given value of furnace heat flux. The local heat flux is a function of the view factor F and is given by the relation

$$\dot{q}_o = \dot{q}_p F. \tag{1}$$

The view factor is dependent on the tube geometry and arrangement and its variation over the tube circumference with the angle from the tube crown is shown in Fig. 2. The view factor can be expressed as a function of the view angles β_1 and β_2 as [1]

$$F = (\sin \beta_1 + \sin \beta_2)/2. \tag{2}$$

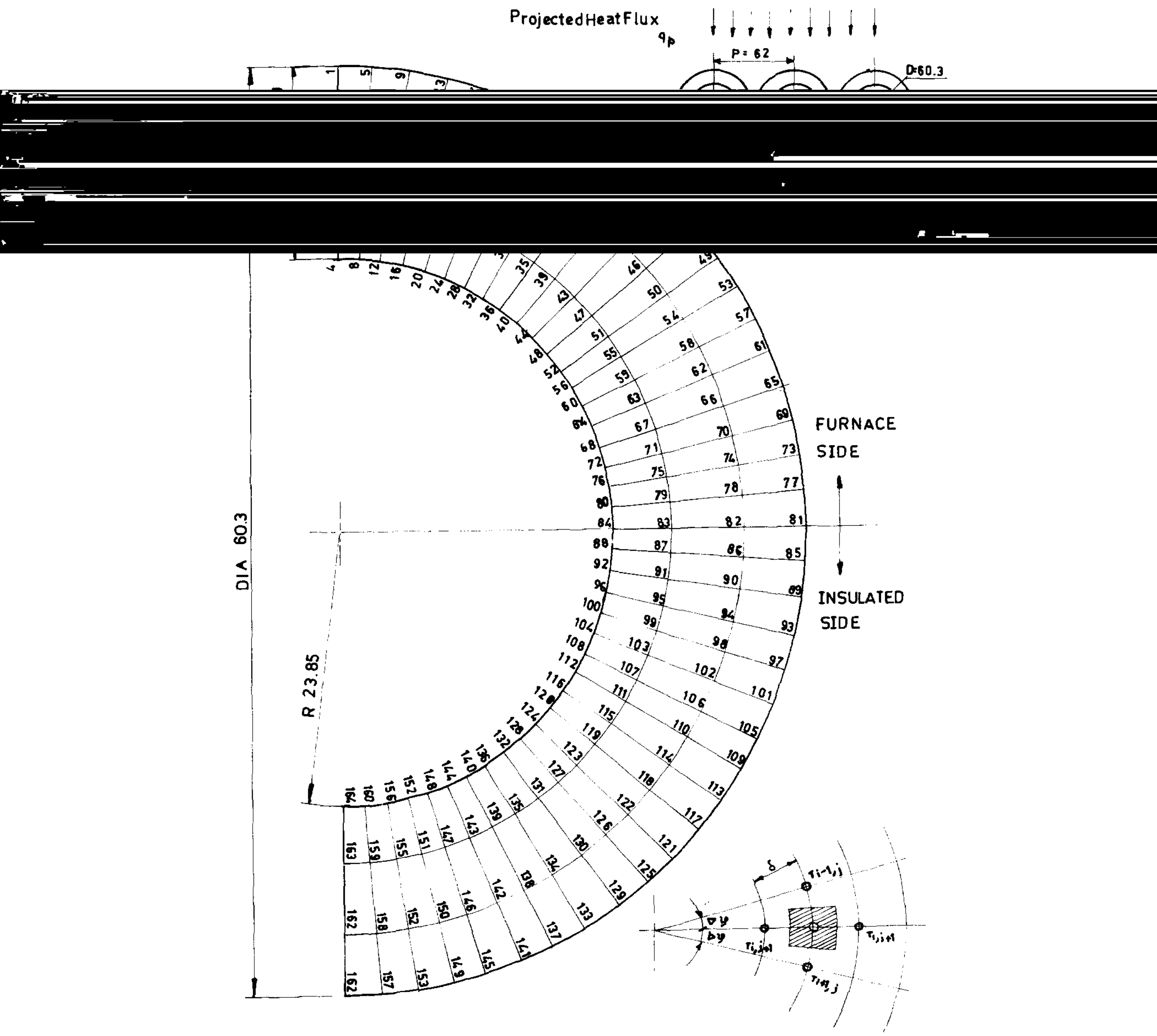

FIG. 1. Nodal representation. All dimensions in millimetres.

The view angles are indicated at the top of Fig. 2.

For the above analysis, the tube cross-section was divided into a number of nodes as shown in Fig. 1. Only one half of the tube was considered since the other half is thermally equivalent to the first half. For each node on the tube's outer circumference in the furnace side, the local heat flux was determined using the procedure explained earlier. For all the nodes on the tube's inner surface a constant convective heat transfer coefficient was applied.

Finite-difference equations were formulated for distinct nodes following the procedure given by Adam and Rogers [2] and these were solved using the relaxation method to establish the relation between the outside heat flux and the tube total temperature drop (differential of the tube crown metal temperature over the bulk temperature of the fluid inside the tube) as shown in Fig. 3. Figure 4 shows the relation between the heat flux ratio and the inside film conductance, which was also determined by the above procedure.

The relation between the inside heat flux and film conductance was obtained using a modified form of Jens and Lottes' correlation [3] for nucleate boiling, as shown in Fig. 5.

3. CONCLUSIONS

Having determined the above relationships, an iterative procedure, as shown in Fig. 6, was adopted to obtain the heat flux from the measured metal temperature. A typical plot of isotherms in the cross-section of a furnace wall tube, obtained using this procedure is shown in Fig. 7.

The calculation procedure discussed above was applied for the determination of the heat flux distribution in a boiler furnace. Good agreement was observed in the furnace average heat flux determined through measured metal temperatures (using the procedure outlined above) and through enthalpy pick-up in the furnace tubes of this unit [3].

The procedure outlined above for the determination of

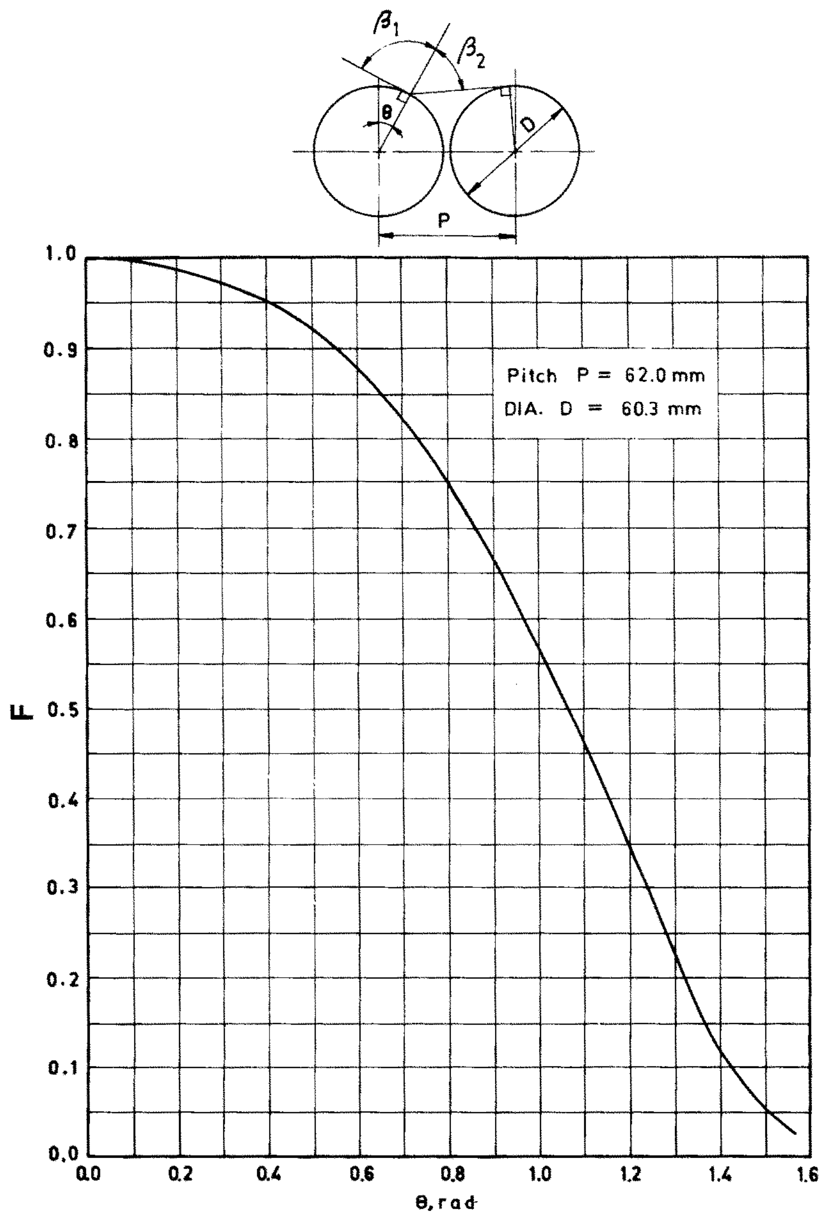

FIG. 2. Variation of view factor with tube crown angle.

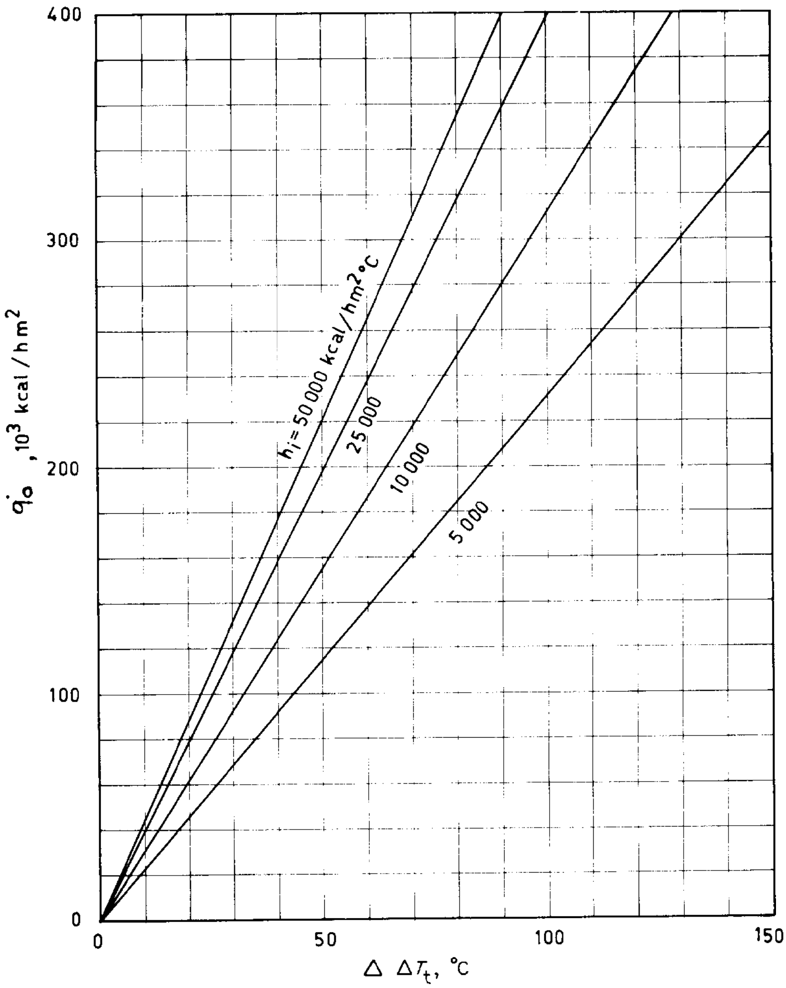

FIG. 3. Variation of outside heat flux with film conductance and total temperature drop.

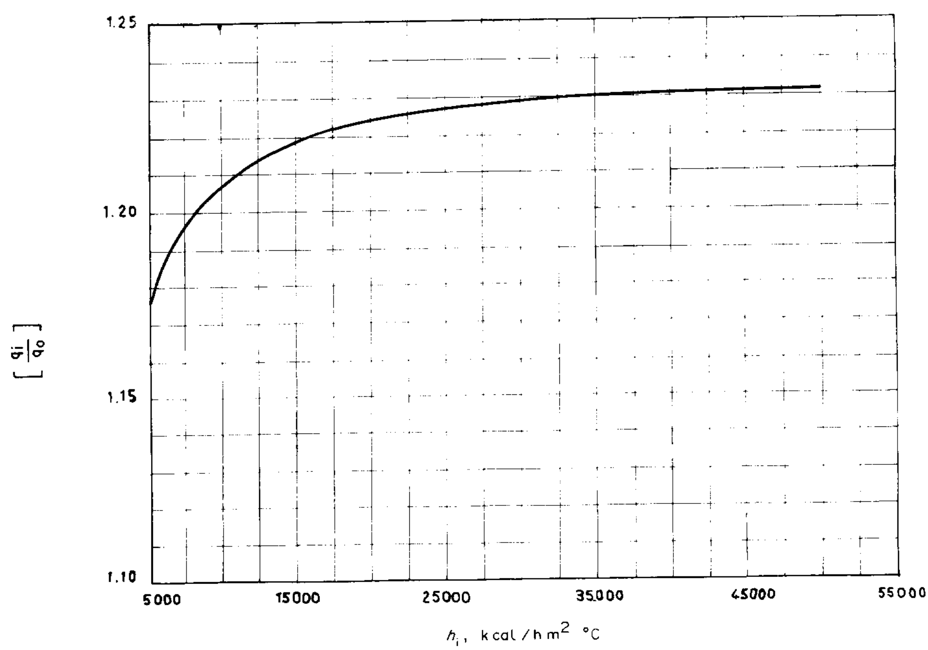

FIG. 4. Variation of heat flux ratio with inside film conductance.

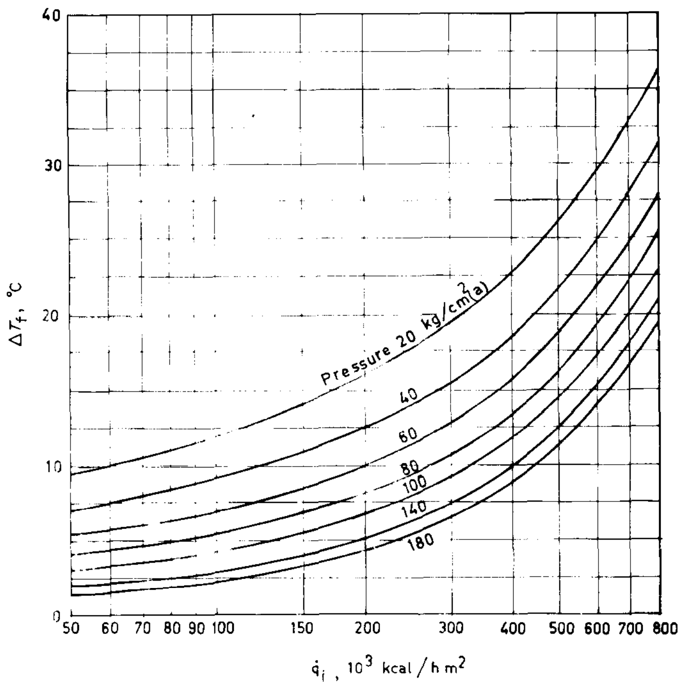

FIG. 5. Variation of film drop with inside heat flux.

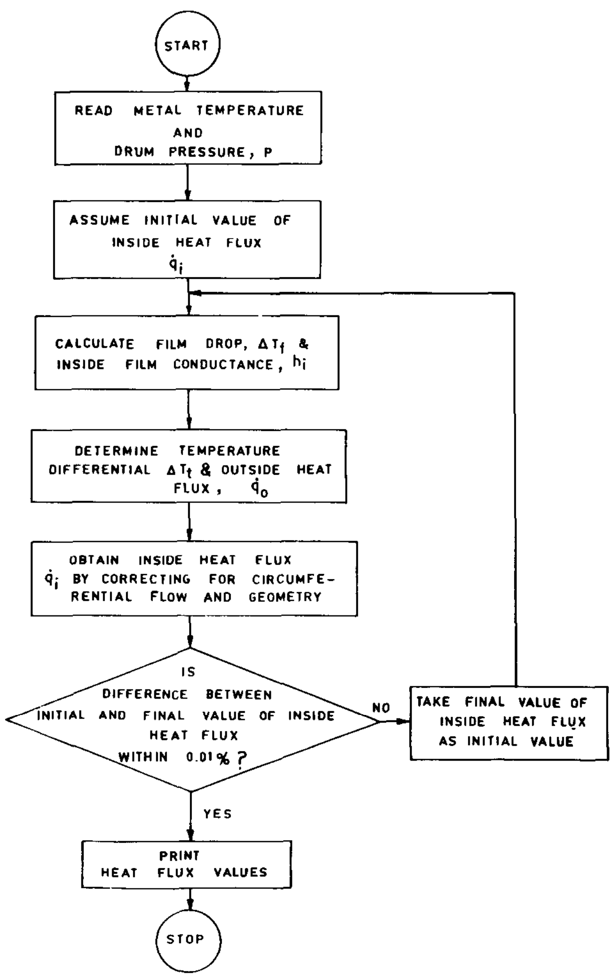

FIG. 6. Flow chart for calculation of heat flux.

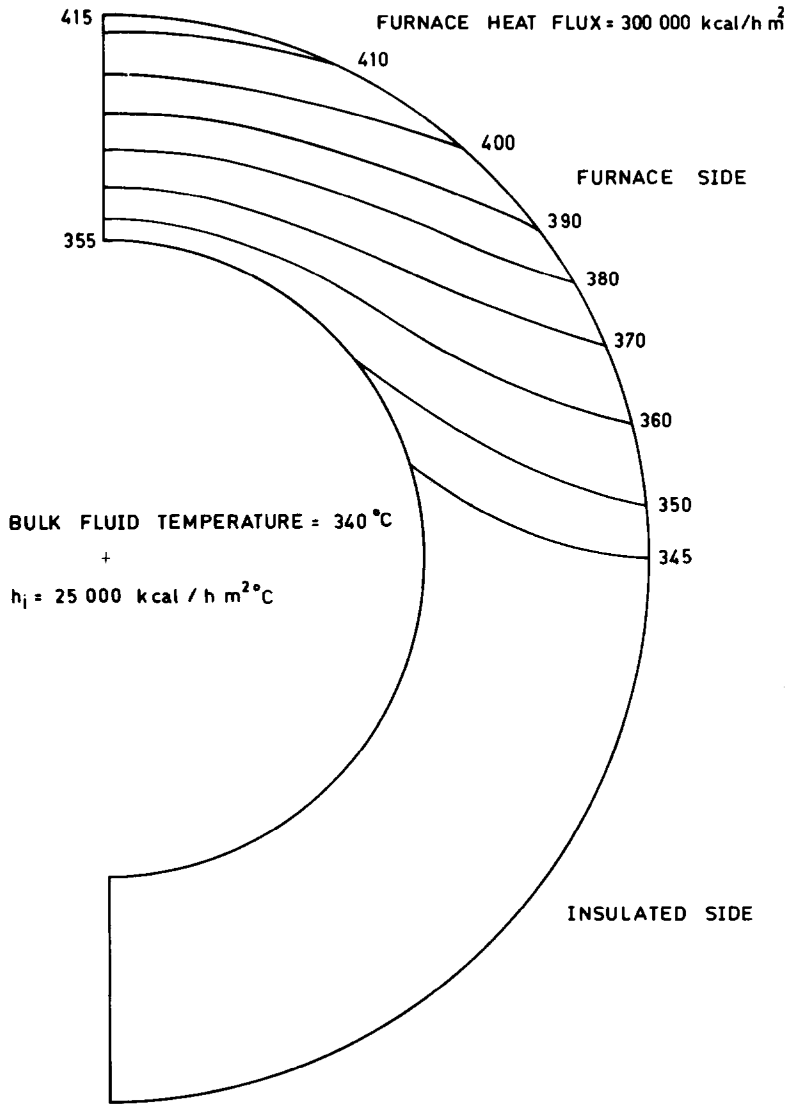

FIG. 7. Isotherms in tube wall.

furnace heat flux from measured metal temperatures can also be extended to other types of boiler furnace construction. Further, this can be used for the prediction of furnace wall metal temperature from design furnace heat flux values and hence be used as an effective tool for tube material selection and stress analysis of the furnace walls.

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