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Thermal & Hydraulic Simulation of Natural Circulation Single Drum Boiler

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Abstract: *Circulation in the industrial boiler is the continuous supply of water to the boiler heated tubes in order to sustain steady steam output without overheating tubes. Adequate circulation occurs when there is sufficient flow of water into tubes for adequate cooling. In the natural circulation industrial boiler system the rate of flow in the circulation system is governed by flow resistances and differences in density between downcomer tube circuits and heated riser circuits. Control of these resistances allows adequate flow of water to parallel circuits. Adequate water flow through the boiler's heat-absorbing circuits is necessary to cool the tubes. To insure proper boiler circulation, a simple, clear, and comprehensive approach is described in this article covering all aspects in boiler circulation analysis. The analysis details all boiler circulation circuits, explaining all forces imposed on them, including thermosyphon as well as friction forces.*

Keywords: *Circulation, thermal simulation, natural circulation, boiler.*

1. INTRODUCTION

The role of boilers [1] in the industrial economy has been profound. Boilers form the backbone of power plants, cogeneration systems, and combined cycle plants. Steam is the most convenient working fluid for industrial processing, heating, chilling, and power generation applications. A boiler [2] is described as a conversion device for producing steam from fuel. Its basic features are decided by the fuels and the size by the amount of steam demanded by the turbine or plant it feeds. Over the decades, fuels used in boilers as well as the sizes of plants have steadily increased, making modern boilers far smarter and more complex than they were before.

2. BOILING PROCESS

When thermal energy is applied to furnace tubes, the process of boiling is initiated. However, the fluid leaving the furnace tubes and going back to the steam drum is not 100% steam but is a mixture of water and steam. The ratio of the mixture flow to steam generated is known as the circulation ratio, CR. Typically the steam quality in the furnace tubes is 5–8%, which means that it is mostly water, which translates into a CR in the range from about 20 to 12. CR is the inverse of steam quality. CR depends on the resistance of the various circuits and energy absorbed in each of them.

Nucleate boiling is the process generally preferred in boilers. In this process, the steam bubbles generated by the thermal energy are removed by the flow of the mixture inside the tubes at the same rate, so the tubes are kept cool. Boiling heat transfer coefficients are very high, on the order of 25,000–40,000 W/m^{2}K. When the intensity of thermal energy or heat flux exceeds a value known as the critical heat flux (CHF), then the process of nucleate boiling is disrupted. The bubbles formed inside the tubes are not removed adequately by the cooler water; the bubbles interfere with the flow of water and form a film of superheated steam inside the tubes, which has a lower heat transfer coefficient and can therefore increase the tube wall temperatures significantly as illustrated in Figure 3. It is the designer's job to ensure that we are never close to critical heat flux conditions.

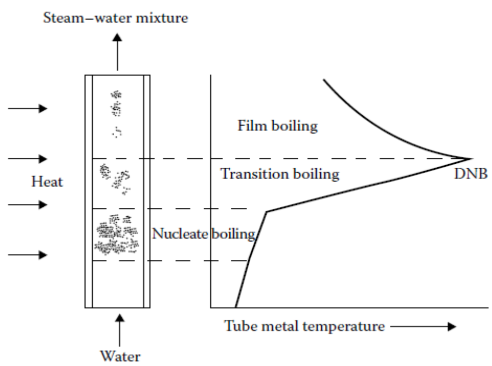

Fig 1: *Boiling process and DNB in boiler tube [6]*

Generally, packaged boilers operate at low pressures compared to utility boilers and therefore DNB is generally not a concern. The actual heat fluxes range from 126 -222 kW/m^2, while critical heat flux could be in excess of 790 kW/m^2 at the CR and steam pressures seen in package boilers. Rifled tubes are used in high-pressure boilers to ensure that tube inner surfaces are wetted by the water film. They have spiral grooves cut into their inner wall surface. The swirl flow induced by the rifled tubes not only forces more water outward on to the wall surfaces but also promotes mixing between the phases to counteract the gravitational stratification effects in a non-vertical tube. Horizontal tubes have a lower limit for CHF values as stratification of flow is a possibility compared to vertical tubes. Rifled tubes can handle a much higher heat flux about 50% more than plain tubes. As they are expensive, large utility high-pressure steam generators use them in high heat flux areas only.

At DNB conditions, the bubbles of steam forming on the hot tube surface begin to interfere with the flow of water to the tube surface and eventually coalesce to form a film of steam that blankets the hot tube inner surface. The transition from nucleate boiling to steady-state film boiling is unstable because of the sweeping away of the coalescing bubbles. As this unsteady transition approaches full film boiling, the tube wall temperature fluctuates significantly, and large temperature increases on the order of 30°C–60°C are seen as shown in Figure 1.

A. Understanding Boiler Circulation

A large percentage of boilers operating today are of natural circulation design (Figure 2). The difference in density between the colder water entering the boiler through the downcomers and the hotter mixture of steam and water flowing through the riser tubes drives the circulation process. Figure 5 shows a typical evaporator and the downcomers, risers associated with it. The cold feed water from the economizer or from a deaerator enters the drum, mixes with the riser steam and water flow, and part of it flows out of the drum as saturated steam while the rest returns through the downcomers to restart the process of circulation.

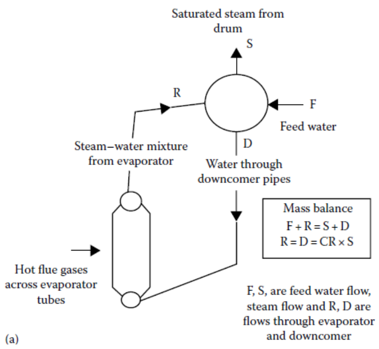

Fig 2: *Natural Circulation System [6]*

CR is the term used to indicate the ratio of the mixture flowing through the downcomer evaporator system (or riser system) to that of saturated steam generated. A CR (circulation ratio) of 10 in a boiler of capacity 12 tph of steam means that 120 tph of steam water mixture is circulating through the downcomer and evaporator–riser system. This is only an average value. Depending on the energy absorbed in a particular circuit, the CR may vary row by row or section by section.

In elevated drum packaged boiler, downcomers are connected to the bottom drum, and steam is generated in several parallel circuits such as the front wall, side wall, rear wall tubes, and evaporator bank tubes and finally through the riser pipes goes back to the steam drum. Each evaporator path may have a different tube size and equivalent length, which determines its resistance to flow and hence CR. When engineers talk about CR, they mean an average value, but one has to do the calculations to find out the CR in each parallel path. The first few rows or, say, 15% of the bank tubes, which face hot flue gases, may be generating more than 70% of the steam in the boiler banks, and hence, there is a need to do a section-by-section analysis.

In many packaged boilers, the drum is integral as shown in Figure 2. Here, external downcomers are not used, but part of the bank tubes, serve as downcomers. These are typically located at the cooler end of the bank tubes, where the energy transfer to the tubes is minimal, and hence, the water enthalpy pickup is not much. The number of heated downcomers is obtained through circulation calculations Evaporator tubes have failed through overheating due to poor circulation even though the heat flux was low. It is also likely that stagnation of flow can occur as these tubes can neither act as risers. Hence, over a period of time, these tubes reach the flue gas temperatures and can get overheated and fail. Correction may be implemented through proper baffling inside the drum to ensure that only the tubes located in the cool gas region act as downcomers. If downcomers are properly selected, the cool water flowing down the tubes will have a higher density than the hotter steam–water mixture in the riser tubes, which ensures good circulation.

The quality of steam at the exit of the riser for a CR of 10 will be 0.1, or 10% is the wetness of steam in the mixture. Low-pressure boilers (up to 40 bar (g)) may have a CR ranging from 15 to 40, while higher-pressure units may have a CR ranging from 5 to 15. This is determined by the balance between the available head and the losses in the circulation system. In a forced circulation system, a circulating pump takes water from the drum and forces it through the evaporator tubes. In these types of boilers (Figure 3), one may predetermine the CR, depending on experience. Since pumps assure that circulation will occur, a low value of 3–8 may be used depending on the cost of pump and electricity. Note that the operating costs are higher if circulating pumps are used.

Circulation calculations or determination of CR in each circuit is not the end in itself. A CR of 10 or 15 does not mean much unless factors such as heat flux inside the tubes, mass flow inside the tubes, steam pressure, and orientation of evaporator tubes whether horizontal or vertical are considered. In evaporator tube as shown in Figure 1, bubbles start forming as the water gets heated in the risers. If the heat flux is below the DNB limits, bubble formation is not intense, and tubes will be wetted by the water film ensuring cool tubes. The tube wall temperature in a normal riser tube is expected to be 5°C–15°C above saturation temperature. If tube-side deposits are present due to poor water chemistry, then this temperature can shoot up.

If the heat flux suddenly increases to critical limits, then the vapour formation is so intense that the film of of vapour forms around the periphery of the tubes increasing the tube temperature significantly causing it to fail. As the vapour film has a much lower heat transfer coefficient compared to water, it will not be able to cool the tubes effectively, and hence, the temperature rise will be significant. Hence, CR has to be looked at along with the several other variables discussed to find out if the possibility of overheating exists.

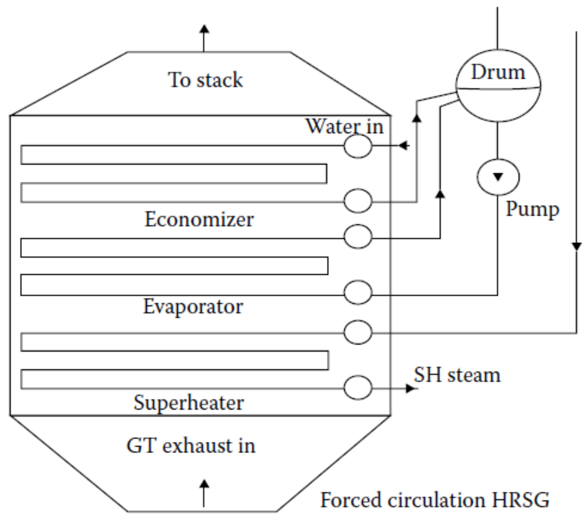

Fig 3: *Forced Circulation System [6]*

As part of circulation study, one has to check the actual heat flux inside the tubes with the allowable heat flux for which correlations are available in the literature. There must be sufficient margin between the two to avoid what is called DNB condition. The heat flux inside the tubes at DNB conditions is called the CHF. DNB checks are initiated when heat fluxes exceed 600–700 kW/m^2 for steam pressures less than140 bar(g). There are correlations in the literature for CHF depending tube diameter, mass flow inside the tubes, pressure, and tube orientation. Note that heat flux in a plain tube is much lower than in a finned tube.

It may be noted that a circulation pump is not always required with horizontal tube evaporators. This evaporator had plain tubes, and hence, the heat flux inside the tubes was not high. The streams and the location of the drum should be selected with care, and circulations should be done to ensure that the fluid velocity inside the tubes is reasonably high and will not cause stagnation or separation of flow. The heat flux also is an important variable. With finned tubes, the heat flux inside the tubes particularly if the boiler is fired will be high, and hence, circulation pumps provide some safety factor.

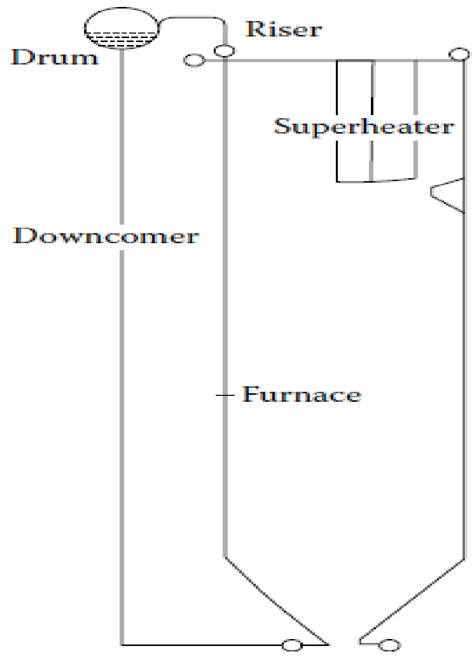

Fig 4: *High-pressure boiler with external downcomers and risers [6].*

While designing a steam generator, the sizing calculations are first performed followed by off-design calculations. The maximum load conditions or the highest furnace heat flux cases are generally chosen for circulation study. The energy absorbed in each section

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of the boiler such as furnace front and rear walls, side walls, and bank tubes is evaluated along with steam generation in each section. For example, the furnace duty may be estimated first. Then based on the average heat flux in the furnace and considering variations in heat flux along the flame length, one can assign duty to each section from which the steam flow is estimated. Oil-fired boilers have a higher operating heat flux in the furnace compared to gas-fired boilers as discussed earlier. As one can see, the distribution is subject to many variables, and no clear formula or empirical equation can provide this information. It is generally based on the experience of the boiler supplier and field data of operating units. Losses from two-phase flow must be estimated for performing circulation studies.

B. Thom's Method of Estimating Losses

The circulation calculations balance the static head available with the losses occurring in the steam loop. The downcomer flow is single phase, and hence, the following equation may be used for estimating the pressure loss as discussed in Appendix B.

$\Delta P = 810 \times 10^{-6} f L_e v w^2/d_i^5$ .... (1)

where, w is the flow in each pipe in kg/s.

i. The *friction loss* ΔP_f in kPa in the heated riser tube is estimated by the following equation:

$\Delta P_f = 38 \times 10^{-12} f L_e v_f G_i^2 r_3/d_i$ .... (2)

where

f is 4× Fanning's friction factor = Moody's friction factor;

L is the total effective length over which two-phase friction loss occurs, m;

v_f is the specific volume of saturated water, m³/kg;

G_i is the tube-side mass velocity, kg/m²h;

d_i is the tube ID, m;

r_3 is Thom's friction loss factor (Figure 5b)

ii. The *gravity loss* in the heated riser section in kPa is given by:

$\Delta P_g = 0.00981 L r_4 / v_f$ .... (3)

where

L is the length of the boiling section, m;

v_f is the specific volume of saturated water, m³/kg;

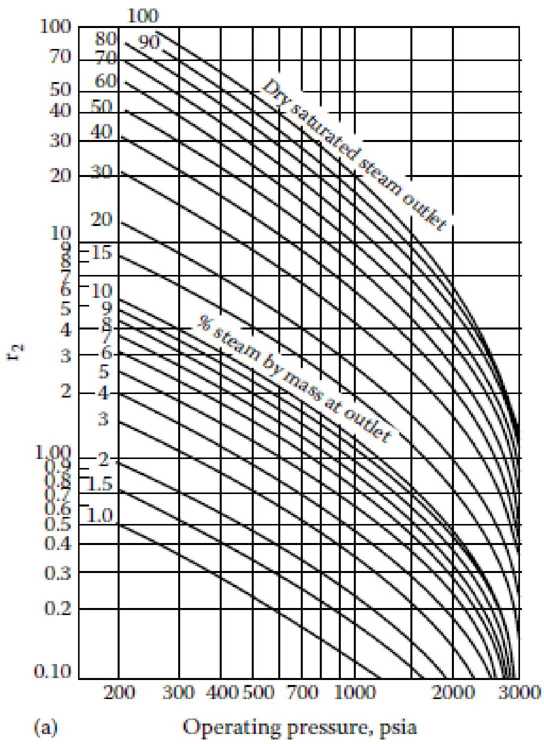
r_4 is the multiplication factor for gravity loss (Figure 5c).

iii. The *acceleration loss* (ΔP_a) is in kPa due to change of phase, which is significant at low steam pressures and high mass velocities and is given by:

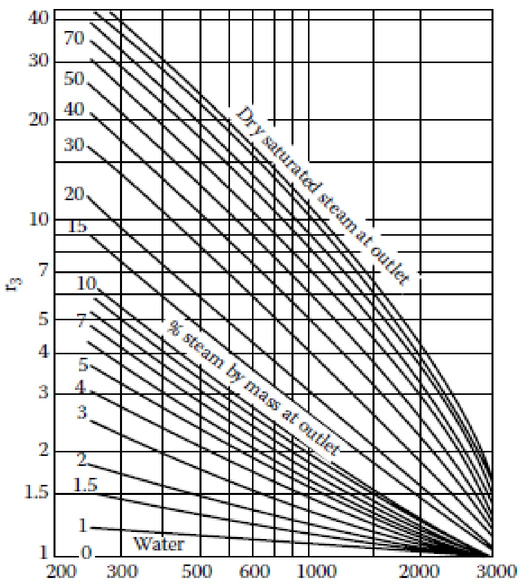
$\Delta P_a = 7.65 \times 10^{-11} v_f G_i^2 r_2$ .... (4)

where

r_2 is the acceleration loss multiplication factor as shown in Figure 5(a).



(a)



(b)

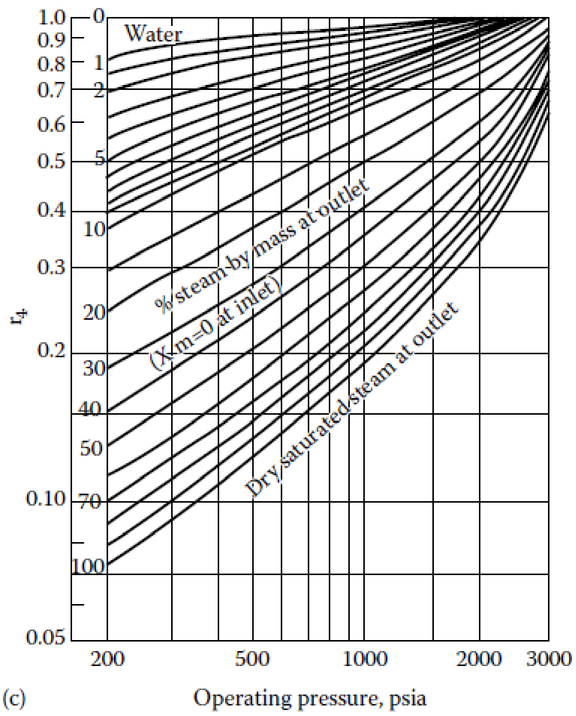


Fig 5: *Thom's multiplication factor for (a) acceleration loss, (b) friction loss, and (c) Thom's two-phase multiplication factor for gravity loss.*

C. Circulation Calculations

Circulation calculation [8] in a natural circulation boiler is an iterative process. For proper boiler operation, one has to ensure that there is adequate flow of the steam-water mixture inside the evaporator tubes to keep their tube-wall temperatures within metallurgical limits. If for some reason the flow is absent or inadequate or stagnation of flow has occurred, then the tubes can become overheated and fail. Users must carry out circulation calculations to ensure that there is proper circulation of the steam-water mixture through the evaporator.

The correlations are shown in Table 1 in all three systems of units.

Table 1: *Two phase pressure drop correlations*

British	Metric
$1.664 \times 10^{-11}\ v_f G^2 r_2$	$\Delta P_a = 7.8 \times 10^{-13}\ v_f G i^2 r_2$
$4 \times 10^{-10}\ f v_f L G^2 r_3/d_i$	$\Delta P_f = 0.388 \times 10^{-12}\ f v_f L G_i^2 r_3/d_i$
$0.00695\ L r_4/v_f$	$\Delta P_g = 0.0001\ L r_4/v_f$
lb/ft²h	G, kg/m²h
lb/h	w, kg/s
ft	L, m
Fanning friction factor = Moody's friction factor/4	f, Moody's friction factor
In	di, m
ft³/lb	m³/kg
psi	kg/cm²

Ref. 1 describes the calculation procedure for determining CR in a natural-circulation boiler, and provides illustrative examples. Briefly, the basic steps are as follows:

Step-1: First, a CR is assumed based on experience and type of steam generator and pressure. For low-pressure boilers (<70 barg), CR could range from 12 to 35, while for higher-pressure units, it can range from 5 to 15.

$$CR = \frac{1}{x}$$

where x is the steam quality or dryness fraction.

Flow through the downcomers, evaporators, and risers is *CR* x *steam generated*.

Step-2: The feed water temperature entering the drum should be known from thermal calculations, which should have already been done. This includes the complete boiler performance, furnace calculations, and estimation of energy absorbed in each parallel path such as front wall, rear wall, and side walls. The resistance of each path must also be

known. Mixture enthalpy entering the downcomers is calculated through an energy balance around the drum, Figure 5.

$h_{fw} + \text{CR} \times h_e \times CR = h_g + CR \times h_m$ (1)

where:

h_{fw} = enthalpy of the feedwater, kJ/kg

h_e = the enthalpy of steam-water mixture leaving the evaporator, kJ/kg

h_m = the enthalpy of the steam-water mixture entering the downcomers, kJ/kg

h_g = enthalpy of saturated steam leaving the drum, kJ/kg

It should be noted that cool water entering the downcomer aids better circulation. If h_m is close to or at saturation, then bubbles will be formed in the region near the entry of downcomer pipes, and circulation will be hindered. There may be several downcomers in a boiler each with a different length and pipe size. A flow and pressure balance calculation is done to arrive at the flow in each downcomer and riser. As the downcomer flow enters the evaporator, it gets heated, and boiling starts after a distance from the bottom of the furnace. This is called the boiling height, L_b.

$L_b = L \text{ x } CR \text{ x } W_s\ (h_f - h_m)/Q$

where,

h_f is the enthalpy of saturated liquid, kJ/kg

Q is the energy absorbed in the furnace, kW

L is the furnace height, m

W_s is the steam generated by the boiler, kg/s

1. The static head available is first estimated. It is typically the distance from the drum water level to the bottom of the furnace; then the following losses are estimated.
2. Losses in the downcomers including entry and exit losses.
3. Losses in the boiling height and two-phase losses such as friction, acceleration, and gravity using Thom's method or similar well-known two-phase correlations.
4. If there are unheated risers, their losses are estimated. Again there may be several parallel paths with different pipe sizes and lengths. Flow in each parallel path is evaluated by estimating the pressure drop in each path for different flows and ensuring that the pressure drop is the same. This is an iterative process. These calculations are preferably done using a computer program.
5. Loss in drum internals. This is impacted by the presence of cyclones inside the drum for steam separation.

The static head is balanced with various losses, and if they match, the *CR* assumed is fine; else, another *CR* is assumed and the calculations are repeated. If there are multiple parallel paths (boiler has front wall, rear wall, side wall, and boiler bank tubes), then flow and pressure balance calculations are carried out to ensure that the total losses in each parallel path are the same. *CR* in each parallel path may differ depending on its energy absorbed, tube size used, and resistance to flow.

Once the circulation calculations are done, the flow in each evaporator tube will be known along with the steam quality at its exit. Checks for heat flux in each path and *DNB* based on exit quality are then done. The variation of heat flux along flame length and view factors based on tube spacing enter into these calculations. If there is a potential for *DNB*, then efforts are taken to revise the downcomer and riser system pipe sizes to improve the *CR* in the boiler; else, the heat flux in the furnace has to be reduced, and the boiler design is redone. Based on experience and field data, one should be able to arrive at a good system considering these concerns.

D. Circulation Flow Vs Head

The amount of flow circulated through a steam generator typically shows a trend shown in Figure 6. As the load increases, the heat flux in various parts of the evaporator increases, and hence, the difference in density between the cooler downcomer water mixture and the flow in the evaporator tubes increases increasing the circulation flow through the system. However, beyond the maximum load, the resistance offered by the riser circuits and drum internals dominates and reduces the flow circulating through the system. If the CR at 100% load is, say, 15, then at 80% load, it could be 17, and at

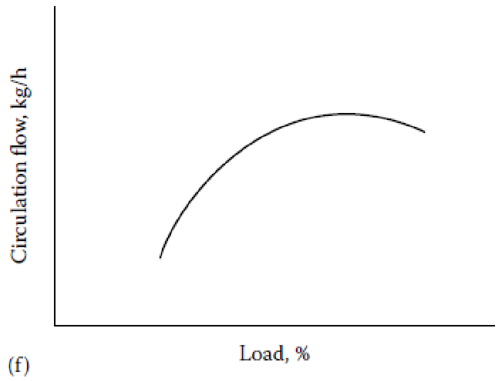


Fig 6: *Load versus circulation rate [6]*

120% load, it could be 11. At 100% load, the mixture flow = 15 × 100 = 1500. At 80% load, 80 × 17 = 1360, and at 120% load, 120 × 11 = 1320. Overloading a steam generator is not recommended for this reason, and critical circuits must be evaluated for DNB concerns.

Flow Stratification in Horizontal Tubes

With horizontal tubes in two-phase flow, one has to also check if flow stagnation is likely. Froude number is an indicator of inertial forces to gravity forces, and if it is above 0.04, flow separation is unlikely.

Froude number $F = G^2/\rho^2 gd$

where

G = mass flow inside the tubes (liquid only), kg/m^2 s,

ρ = density of liquid, kg/m^3,

g = acceleration due to gravity (9.81 m/s^2), and

d = tube inner diameter, m.

E. Correlations For CHF and Allowable Steam Quality

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One may obtain the heat flux given the steam quality, mass flow inside tubes, steam pressure, and tube inner diameter or conversely obtain the allowable steam quality given a heat flux. There are several correlations for CHF, and the Kastner correlation [7] is one of them. It gives the allowable quality at any mass flow and heat flux and steam pressure.

For 0.49 < P < 2.94 MPa [9]

$$x_c = 25.6(1000q)^{-0.125} G^{-0.33} (1000\, d_i)^{-0.07} e^{0.1715P}$$

For 2.94 < P < 9.8 MPa

$$x_c = 46(1000q)^{-0.125} G^{-0.33} (1000 d_i)^{-0.07} e^{-0.0255P}$$

For 9.8 < P < 19.6 MPa

$$x_c = 76.6(1000q)^{-0.125} G^{-0.33} (1000\, d_i)^{-0.07} e^{-0.0795P}$$

(Steam pressure P in MPa, d_i in m, q in kW/m^2, G in kg/m^{2}s)

Macbeth correlation gives the CHF, given the other variables, and takes the following form:

$$q_c = 0.5025\, h_{fg}\, d_i^{-0.1} (G_i)^{0.51} (1-x)$$

where

q_c = CHF, kW/m^2

x is the steam quality, fraction

d_i is the tube ID, m

G_i is the mass velocity, kg/m^{2}s

This being a theoretical correlation does not account for tube-side fouling, and the actual value of CHF

could be 20%–30% of this. Groeneveld's lookup tables are also used to check for CHF. Table 2 shows an extract from 1996 tables.

Table 2: *Groeneveld's Lookup Tables for CHF in kW/m² for 8 mm Tubes [10]*

Pressure, kPa	G, kg/m²s	X = 0.2	0.4	0.6	0.8
3000	500	5660	3392	2745	1320
	1000	5620	3079	1925	830
	1500	5043	2691	1080	499
	2000	4507	2279	608	330
5000	500	5178	3975	3040	1769
	1000	4957	3447	2066	1034
	1500	4530	2983	1194	899
	2000	3984	2557	668	650

Note: *P in kPa, G in kg/m²s, CHF in kW/m². Use a correction factor of 0.79 for tube ID > 16 mm. This table is based on a tube ID of 8 mm. For diameter above 16 mm, use a correction factor of 0.79.*

Though there are several correlations for CHF, many have been developed in laboratories under controlled conditions. They may show different CHF values for the same steam parameters and tube geometry. Hence, charts such as Figure 2.15 developed by boiler firms have more practical value as the results are backed by operation of steam generators [11].

3. CIRCULATION PROBLEMS [15]

The common problem in boiler circulation system is that the downcomer tubes are not properly located or shielded from hot flue gas. If located in the hot gas zone, steam bubbles are likely to be formed at the downcomer inlet preventing the flow of cold water to the bottom of the boiler for circulation. This generally happens through improper baffling inside the drum. The boiler designer may think that the tubes are acting as downcomers, while due to improper baffling; they may be acting as risers. Sometimes, the head is inadequate to ensure flow as downcomers, and hence, stratification occurs with steam bubble formation at downcomer inlet resulting in the stagnation of flow. The tubes can then reach the flue gas temperature and fail even though they may be in 500°C–600°C gas temperature region and the average heat flux in the convection bank is very low, well below the DNB limits. So DNB is not the problem but vapour formation, stratification, and overheating of tubes, which are neither capable of acting as downcomers or risers.

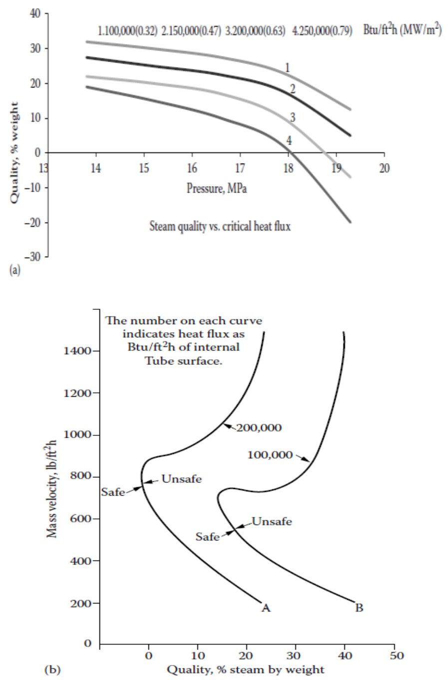

Fig. 10(a): *Allowable steam quality as a function of heat flux Btu/ft² h (MW/m²) and steam pressure; (b): Allowable quality for nucleate boiling at 2700 psia*

High feed water temperature close to saturation temperature or steaming water entering the drum from the economizer is also a concern. If one computes the mixture enthalpy entering the downcomers, he may find it above saturated water enthalpy or above saturation temperature. The bubble formation at the downcomer inlet prevents water flow to the bottom of the boiler for creating a circulation pattern.

F. Guidelines For Good Circulation System Design [16]

The following are the guidelines used while designing the downcomer system in a package boiler:

1. The designated downcomer tubes should be located at the coolest gas temperature region. If they are located in a high gas temperature region, the enthalpy absorbed by these tubes can be high, resulting in steam bubble formation inside the tubes, which can hinder downward flow of water and hence the circulation process. Formation of steam decreases the density of the water in the downcomer, which in turn reduces the available head for circulation and also physically prevents the free flow of downcomer water. If inevitable, then the downcomers must be insulated.

2. The gas temperature entering the downcomers should be as low as possible to ensure that even if stagnation occurs, the tubes will not be overheated. A good value is less than 450°C at full load.

3. Belly pans are used to collect steam from risers and all the water for circulation is allowed to flow from drum normal level through the downcomer tubes. Design velocity chosen for downcomer flow is generally in the range of 1–3 m/s at full load.

4. Proper baffling to be done inside the drum to ensure that tubes, which are supposed to be risers, are inside the belly pan area. This provides these tubes an additional head for circulation. So riser tubes should be under the belly pan. Tubes acting as risers in the water-filled region will have difficulty in circulating as this additional head is not available.

5. It is very important that downcomers do not take suction from locations in drum where vaporization or heat flux is intense resulting in sucking of bubbles into downcomers. This will interfere with circulation and also prevent a normal downcomer from acting as a downcomer. In large boilers, a vortex breaker is provided at the suction line to break up these bubbles.

6. Swaging of tubes inside drums is better avoided as it adds to the flow resistance and impacts circulation. Resistance to flow at the riser end should be avoided, while resistance at downcomer inlet or feed water inlet in once-through boilers improves the stability of two-phase flow.

G. Boiler Simulation

The Boiler simulation [17] is a rigorous and high-fidelity mathematical process model that provides a realistic dynamic response for a forced draft drum-type steam utility boiler. It is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output. The boiler simulation consists of thermal and hydraulic simulation of boiler components. To understand reality and all of its complexity, we must build artificial objects and dynamically act out roles with them. Boiler simulation serves to drive synthetic environments and virtual worlds. Within the overall task of simulation, there are three primary sub-fields: model design, model execution and model analysis.

Steps for Boiler Simulation:

1. *Preparation of Boiler Thermal Model:* The boiler thermal model is prepared using PPSD Software. All boiler components like superheater, economiser, water wall, steam drum, preheating coils, etc. are created as 1-D model in the program and geometric parameters are assigned to it.

2. *Assignment of Boundary Conditions and Control Loops:* In this process, the inlet and outlet boundary conditions such as properties of fuel, water, steam, flue gases like flow rate, pressure, temperature, fouling factors, usage factors etc. are assigned at required locations. Interconnections and various control logic loops are assigned at appropriate locations.

3. *Execution of Simulation:* Once model is prepared it is checked for errors. Once errors are removed simulation run is carried out for varying inlet / outlet conditions and behaviour of various boiler components is observed. Corrections are done if necessary to approach to required solutions.

4. *Presentation and interpretation of results:* Once the simulation is completed the results are shown either in graphical form, tabular form as the need be. The results are interpreted to draw suitable conclusion.

4. CONCLUSIONS

Detailed thermal and hydraulic analysis of natural circulation provides the overall idea about the various resistances available in the boiler. Circulation calculation ensures the proper flow distributions and thermal balancing in between different boiler sections.

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