EFFECT OF CIRCULATION RATIO IN BOILER DESIGN

Any Boiler design starts with the calculation of circulation ratio based on the drum working / operating pressure. The circulation ratio is immensely important for providing safe cooling of the heated tubes. Any adjustment & efforts for cost cutting & value engineering will leave a huge impact on boiler maximum operating life. A wrong calculation of circulation ratio (CR) OR reduction of desired circulation ratio shall start pressure parts failure after few months of operations in the forms of bulging, sagging, cracks, tube / pipe inside grooving, wrinkles, overheating rupture etc.

If steam generation is exceeded w.r.t. design consideration, fluid looses contact with tube wall and heat transfer impacted. When tubes are positioned horizontally and inclined, then fluid flow will stratified and water flows along the bottom and steam along the top of the tube /pipe and flow pattern is rippled - wavy type, hence the top of the tube is alternately wet and dry.

A lower circulation ratio selection against the actual requirements will lead to less supply of water due to inappropriate sizing of downcomer, riser and other supply feeder pipes. This scarcity of water supply will start steam film formation leading to overheating and failures.

There is only one solution i.e. increase circulation ratio by correcting engineering faults OR reduce input heat absorption to pressure parts and reduce boiler steam generation capacity. Other preventive measures taken to avoid engineering correction & witness faulty design are refractory application to reduce heat absorption by pressure parts, rifle tubes in place of plane tubes.

Avoid boiler low steam load operation at rated pressure in case of faulty CR as the water & steam do not move at the same velocity in circuit.

Circulation Ratio CR:

Higher circulation ratio means less steam formation in tubes and Lower CR means high steam formation in tubes. A circulation ratio varies in a wide range in natural circulation boilers. A lower circulation ratio i.e. more percentage of steam is acceptable for boilers operating at higher pressure as the difference between properties of steam and water reduces with increase in pressure and ultimately vanishes at the critical point.

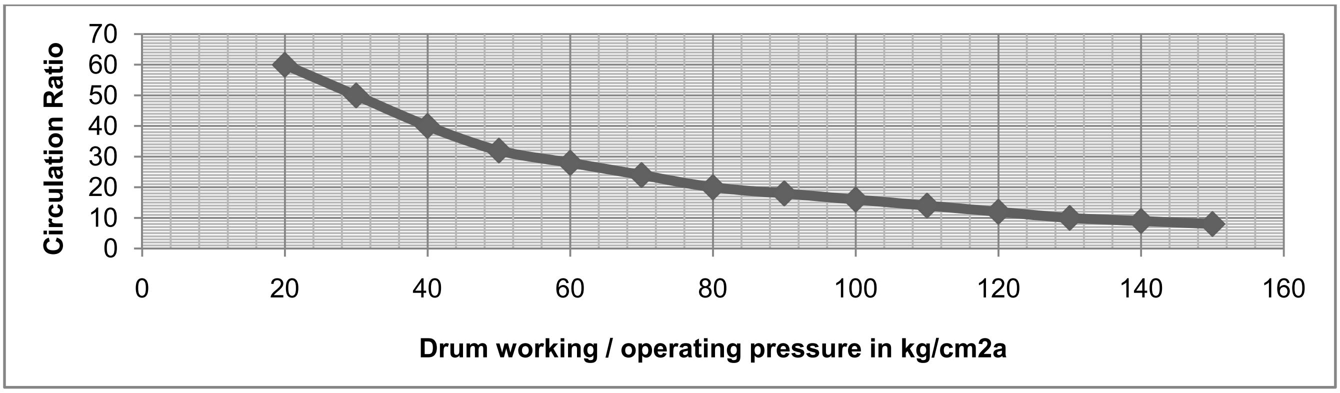
CR = 100 / (percentage of steam in steam & water mixture)

Circulation Ratio is the percentage of steam formed which reduces the density of a column of water against the density of water in downcomers and hence propels circulation due to this thermal head, however steam has also high specific volume and hence produces more frictional loss and other several losses in the system.

The circulation in each tube is dependent on heat gain. A non-uniform heating among tubes means non-uniform fluid flow. Entry of sub cooled water into the downcomer should be free from steam bubbles entry & Vortex breaker is required to avoid it. Any obstruction in downcomer OR mix up of steam water mixture from riser to downcomer, will create the poor circulation in tubes.

Circulation Ratio CR Calculation:

Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Steam Drum Working / Operating Pressure in kg/cm2a	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Circulation Ration - CR	**60**	**50**	**40**	**32**	**28**	**24**	**20**	**18**	**16**	**14**	**12**	**10**	**9**	**8**



<u>Basic concept of CR calculation</u> at drum working / operating pressure = (Saturated Water Density / Saturated Steam Density)

Steam drum length calculation is mainly dependent on Circulation Ratio, drum operating pressure, steam-flow, number of steam separator cyclones, high steam load variations, steam purity and steam space loading.

The head produced by downcomer fluid column (height x density of liquid column) & the head produced by riser column should be equal to all pressure drops in the downcomer & riser pipes. At low steam loading, the water & steam do not move at the same velocity & frictional head loss will be high as compared to calculated pressure drops, hence need to be taken care. It is essential to reduce friction head loss in the system.

In any riser section, the heat flux & incoming percentage of steam in mixture is known then the outgoing percentage of steam can be determined. In riser, the fluid mixture density is
Dnmix = Dnw - (Dnw - Dns) x (percentage of steam by volume) /100
Where: Dnmix is density of mixture, Dnw is density of saturated water and Dns is density of saturated steam.

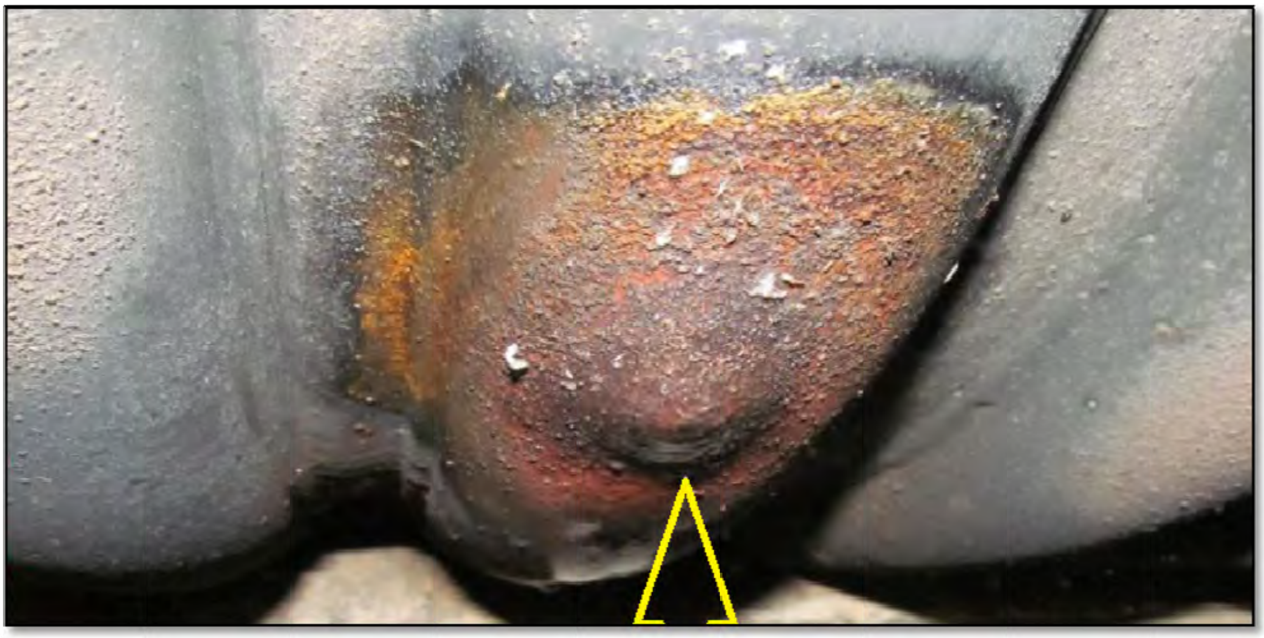
To determine head produced by riser for the complete circuit, then the average density of mixture should be calculated using density at riser inlet and density at riser outlet from above method. If there are several parallel circuits for the steam water mixture then each boiling circuit has its own CR depending on the steam generated and frictional head loss.

OTHER CHECKS FOR CR

1. The cross section area of Risers should be more than that of supplies / feeder pipes for each panel.
2. Top Header of panel to be kept of same OR bigger size than Bottom header of panel.
3. Velocities in m/s:
   a. Non-Heated Down comer from steam drum velocity ≤ 4
   b. Heated Down comer velocity > 1.0 (like Rear tubes of Boiler Bank)
   c. Supply pipes velocity ≤ 6
   d. Riser velocity ≤ 8

TYPES OF CIRCULATION IN BOILERS:

1. Natural circulation - operating on thermo-siphon principle
2. Forced circulation - normally in super-critical boiler
3. Assisted circulation – By employing circulation pump that draws water from drum and discharges into tubes/pipes to avoid steam film formation, where inclination of evaporative tube is low OR tube friction loss is very high



Finally, Downcomer, Feeder pipes & Riser Velocities is directly proportional to Circulation Ratio, if flow & area is constant. Further each waterwall panel & evaporator panel has their own circulation ratio.

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Regards

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