Causes for Failures of Cast Iron Tubes in Air Heaters

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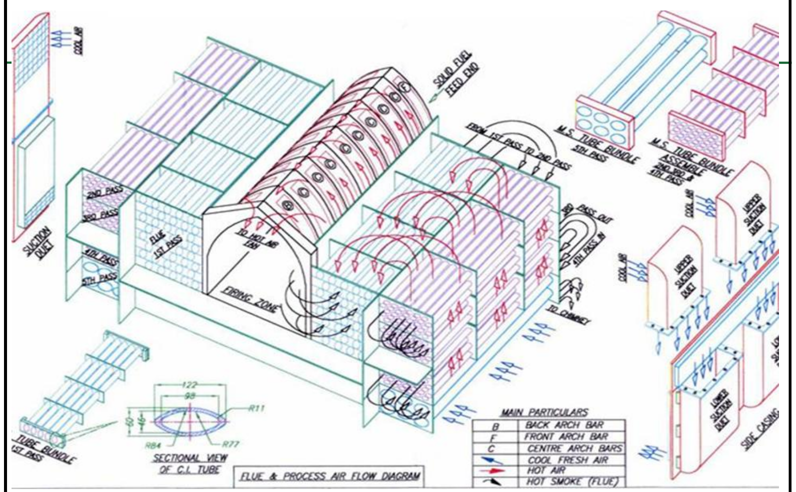
Air heaters

- Furnaces : Heat transferred from hot flue gasses to clean air via cast iron and/or steel tubes. Single, 2, 3 & 5 pass heaters
- Hot Water Generators : Heat transferred from hot flue gasses to water in closed loop, then to clean air via radiators
- Boilers: Heat transferred from hot flue gasses to water to make steam in closed loop and then to clean air via radiators

Nearly all Tea Processing factories in Sri Lanka use Firewood as the source of fuel



5-pass air heater

Problem & Objective

- **Problem: Failure of Cast Iron tubes of Firewood Fired Furnaces**
- **Objective: To investigate the extent of the problem and likely causes and also look for possible solutions**

Study approach

- Visiting factories which experienced the problem and discussing with Superintendents / Factory Staff and Workers
- Collecting data and photographic evidence
- Analyzing samples to determine chemical composition of Cast Iron taken from failed components
- Measuring temperature regimes inside the furnace [Trials done at St Joachim factory - 5 pass heater].

Identified causes of failures

Main failure is at the hot end of the first cast iron tube bank
- need to replace

Note: This is the extreme situation where tube flange has got cracked. ***It has got separated after removing from the furnace, Otherwise sure***

Identified causes of failures

- Shortcomings in operation of furnaces
- Shortcomings in maintenance of furnaces
- Lack of quality assurance in the process of casting of tubes
- Unsuitability of the chemical composition of Cast Iron

Shortcomings in operation

- Failures are mainly due to over straining of the furnaces,

  by long hours of work, thus allowing inadequate time for maintenance

  - Cropping months
  - using for drying & withering
  - Heavy crop after festivals

- Targeting temperatures higher than design levels

  - inlet temperature above 120 °C

Shortcomings in operation

- Having a very large heap of firewood within the combustion area
  - Live flame impinging on the tube bank
  - Flame entering the tubes

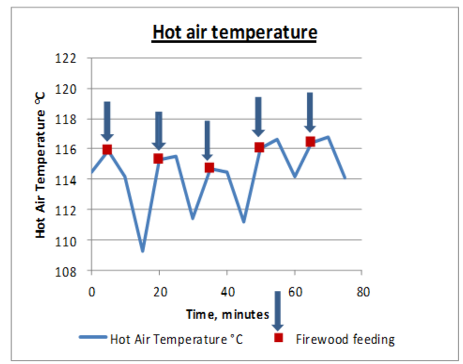
Shortcomings in operation

Excessive air for combustion

Shortcomings in operation

Shortcomings in operation

Fluctuations in temperature due to firewood feeding



Note: Here firewood is fed every 15 minutes.

This fluctuation is acceptable.
To facilitate feeding in a short period, worker must have firewood at arm's length.

These fluctuations can be lot larger in cold / humid conditions.

Shortcomings in operation

Poor firewood management

Firewood moisture content	Dry/Split FW at 15% moisture	Not so dry/Split FW at 40% moisture
Target Temperature, ^{0}C	115	115
Firewood feeding frequency, minutes →	15	10
Firewood , kg/hr	187	300
Achieved average air temperature, ^{0}C →	115	103
Achieved maximum air temperature, ^{0}C	120	108
Flue Gas Temperature, ^{0}C	131	133

Use cut, split and dry firewood

- stack after cut and split

- maintain three month stock

Shortcomings in operation

Ignorance in maintaining ID temperature

Steel tubes developing simple corrosion caused by low Flue gas temperature

Faulty ID temperature indicator

Note: Also inadequate space for cleaning of tubes

Shortcomings in operation

Another unwise practice

- Switching OFF of main fan for a short period to get the required temperature where tubes can get extremely hot

Shortcomings in maintenance

Allowing build up of ash inside tubes - Huge collection of ash over long hours of work

Continuous use of the furnace
- no time to do proper cleaning of tubes and removal of ash.

Shortcomings in maintenance

Badly maintained

- **Fire bars,**
- **ID & FD fans,**
- **Combustion air controls**
- **Dryer itself and**
- **Surroundings - Untidy**

–makes the furnace less efficient and

–machine is strained further to overcome effects of these lapses

Shortcomings in maintenance

Flame entering the tube due to badly balanced air flow

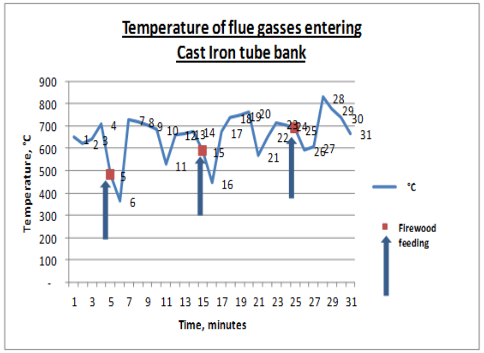
Shortcomings in maintenance

Blocked tubes – Other tubes under excessive heat load

Lack of quality assurance

Thickness of oval tube is not uniform – Early failure is very likely.

Measuring temperature inside the furnace



5 - Firewood fed

6 - Temperature drop - large quantity of ambient air entered

7 - Temperature increase -door closed

8 – Temperature fairly constant – slight drop due to ash coating on firewood

9 - Doors opened – firewood stoked to dislodge ash

10 - Temperature drop - large quantity of ambient air entered

11 - Temperature increase -door closed

12 ,13 - Temperature steady

14 - Door opened- firewood fed

Flue gas temperature > 600 °C .Chemical composition of cast iron tube banks should be suitable to tolerate this temperature.

Chemical composition of Cast Iron

- **Cast iron is primarily an alloy of Iron and Carbon [around 3 to 4%].**
- **Next in importance to carbon (C) is Silicon (Si). Carbon and Silicon contents together determine most properties.**
- **Manganese (Mn), Sulfur (S) and Phosphorus (P) which always present in small quantities also influence the properties .**
- **Such Cast Irons are normally termed as "Unalloyed Cast Iron".**
- **Standards on Cast Iron such as BS 1452:1977, IS 210: 1993 etc. refer to mechanical strength only. These standards do not refer to suitability for use in high temperature environment.**

Chemical composition of Cast Iron – Contd.

- FOSECO Foundryman's Handbook is a very informative reference book on Cast Iron. It states that "Unalloyed Cast Iron" are recommended for applications up to a maximum of 600 ºC only.
- It is to be noted that quality of cast iron depends not only on the composition but on casting techniques also.

Chemical composition of Cast Iron

Chemical composition (%) of Cast Iron samples collected from failed tubes

Elements	Sample 1	Sample 2	Sample 3
Total Carbon	3.04	2.91	3.21
Silicon	1.17	1.35	1.16
Manganese	0.33	0.25	0.23
Sulfur	0.094	0.113	0.105
Phosphorus	0.045	0.051	0.047
Chromium	0.02	0.09	0.02

Chemical composition of Cast Iron

Compositions (%) suitable for higher temperatures

Element	[A] Suitable for up to 700 °C	[B] Suitable for up to 850 °C
Total Carbon	3.4 - 3.7	3.4 - 3.7
Silicon	About 2.3	About 2.3
Manganese	About 1.0	About 1.0
Sulfur	<0.12	<0.12
Phosphorus	0.3 Max	0.3 Max
Chromium	0.6	0.6
Aluminium		1.0

Reference – The FOSECO Foundryman's handbook – Eighth revised and enlarged edition-1975

Note: Composition [A] is same as to what was used in Sri Lankan made castings many decades ago.
Caution must be exercised in addition of Aluminium [in Composition [B] as the level is very critical.

Conclusions

- **Main failure is at the hot end of the first cast iron tube bank. This is due to flue gas entering at high temperature. In worst case is entering of flame.**
- **Other failures experienced are crack and corrosion in tube banks.**
- **Frequency of failure of tubes could be reduced to a great extent through proper operational practices of furnace.**
- **Allowing adequate time for attending to routine maintenance is equally important to minimize failures.**
- **Measured flue gas temperature at the hot end of the tubes was often between 650 to 700 °C.**
- **Chemical composition of collected cast iron samples shows those compositions are not suitable to temperatures higher than 600 °C according to Cast Iron Handbook.**

Conclusions – Contd.

- **For working temperatures up to 700 °C, Composition [A], where there is 0.6% Chromium is recommended.**
- **For working temperatures up to 850 °C, Composition[B], where in addition to 0.6% Chromium, 1% Aluminium is recommended. The Handbook states that Aluminium content is very critical as it has other adverse effects.**
- **Generating sizeable volume of demand with suggested composition of Cast Iron tubes to cope up with much higher temperatures up to about 850 °C needs industry-wide commitment.**

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Thank You