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Energy efficiency improvement in air heater of a tea unit - A case approach

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This paper evaluates efficiency of air heater and discusses system modifications carried out in air heater used in one of the tea units. Field trials indicate that these driers are operating at very low efficiency due to age-old design and improper selection of materials. Operational system changes have improved performance of heater and firewood consumption has dropped to about 100 kg/h from 160 kg/h resulting in a saving (38%) with little or no investment.

Keywords: CO_2%, Air heater efficiency, Excess air, Firewood, Flue gas, Flue gas temperature

Introduction

Heater furnace efficiency (HFE) improvement is important to determine overall specific energy consumption in tea industry. This study presents improvements in HFE of a tea unit.

Materials and Methods

Air heater, a multipurpose heat exchanger where flue gases pass, is a cellular multitubular heater (capacity, 10.5 million kcal/h or 12212 kW). It has five passes, of which front pass is made of cast iron and rest of mild steel. It has following specifications[1]: hot air fan capacity, 4500 cfm (2.1238 m^3/s); ambient air temperature, 20°C; hot air temperature, 120°C; flue gas outlet temperature, 115°C; and fuelwood calorific value, 2500 kcal/kg.

Field Study

A field trial was conducted to look into furnace design. Heater in a furnace is provided with duplex air heaters (multi pass heat exchanger). Initially, air heaters though identical in design did not show equal temperature pick up (Table 1). Flue gas was analysed using flue gas analyzer (Fyrite). Initially, CO_2 in flue gas was only 4%. ID fan was heavily part-loaded and its pulley size was reduced to reduce rpm so that output air from ID fan can be reduced. This resulted in marked improvement in loading of ID fan and CO_2 in flue gas was found to be 8%. Also, there was no increase in furnace temperature. The deposit on first pass was high and this resulted in bulging of tube due to overheating.

After cleaning tubes, CO_2 was found to be 8% only. Dampers might have become choked and non-functional due to erosion and corrosion. Therefore an FD fan (2 HP) was put up to control FD dampers for optimum airflow. Flue gas was analysed and CO_2 went up to 18%. Firewood feed rate got reduced from 160 kg/h to 100 kg/h, because flue gas temperature at the first pass increased from 400°C to 790°C. Thus, combustion efficiency got improved due to placement of FD fan and adjusting dampers afterwards. Outlet hot air temperature was maintained by controlling dampers in FD fan.

Because of poor material of construction (cast iron) on pass tube, material has to be changed to higher quality materials like SS, hastealloy etc. Analysis of air heater furnace with above modifications in heater system indicated that unit is able to achieve a saving (38%) in fuel consumption[2,3].

Energy Efficiency Evaluation Method

Energy efficiency of furnace cum air heater is calculated as

$$\eta_{(F/AH)} = \frac{m_{air} \times C_{Pair} \times \Delta T_{air}}{m_{fuel} \times G.C.V_{firewood}} \quad \ldots(1)$$

where, $\eta_{(F/AH)}$ = energy efficiency of furnace-cum-air heater, %; m_{air} = mass flow rate of air, kg/h; Cp_{air} = specific heat capacity of air at constant pressure, kJ/

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Table 1—Field trials of air heaters performance

S No	Fuel kg/h	Flue gas		Flue gas temperature, °C						Fresh air temperature, °C				
		CO_2%	O_2%	1PASS	2PASS	3PASS	4PASS	5PASS	STACK	1PASS	2PASS	3PASS	4PASS	Parameters
1	160	3	13	300	263	225	212	140	125	30	-	-	140	80 % flue gas damper open 730 RPM (ID- fan)
2	160	5	11	420	380	300	240	130	115	30	78	-	116	50 % flue gas damper open730 RPM
3	140	66	88	420	L398	251	214	165/ 138	104	28	83	102	107	50 % damper open 538 RPM
				R318		221	195	149/ 121		28	81	96	107	
4	140	8	>8	L489	344	224	165	137	104	28	62	78	97	50 % damper
				R489	300	186	153	117		28	60	75	97	open 538 RPM
5	100	18	3	L790	390	230	191	133/ 126	8080	2525	10288	138138	128	FD placed
				R790	370	230	161	129/ 113						Both ID & FD fan working

Note: L = Left side air heater; R = Right side air heater

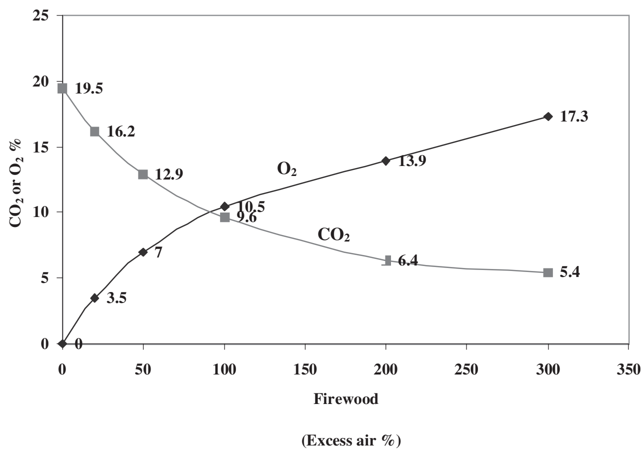

Fig. 1—CO_2% / O_2% vs excess air curve for firewood

kgK; T = temperature, °C; $GCV_{firewood}$ = gross calorific value of firewood, kcal/kg; m_{fuel} = mass of firewood loaded, kg/h.

In Eq. (1), amount of air supplied through furnace was calculated using graphical relation between CO_2 percentage in flue gas and excess air. From CO_2 percentage, it is possible to calculate actual combustion air supplied to furnace by knowing theoretical air requirements, which was calculated based on the composition of fuelwood[4] (Fig. 1).

Theoretical air/fuel ratio
= 5 kg/kg of firewood
Amount of flue gas per kg of fuel at 225% excess air
= 1 + (5 × 3.25) = 17.25 kg/h
Amount of flue gas per kg of fuel at 50% excess air
= 1 + (5 × 1.5) = 8.5 kg/h
Amount of dry flue gas (before improvement)
= 17.25 × 160 = 2760 kg/h
Amount of dry flue gas (after improvement)
= 8.5 × 100 = 850 kg/h
Based on Eq. (1), air heater efficiency under old system [$\eta_{(F/AH)}$] = 55%
Under improved system, air heater efficiency [$\eta_{(F/AH)}$] = 88%

Results and Discussion

Presently, excess air level maintained is very high (225%), which has been brought down to 50% by installing a FD fan (3 HP) and maintaining a balanced draught by adjusting dampers in FD and ID fan ducts. Under these conditions, CO_2 in flue gas is kept around 14-15%. Moist fuelwood was dried using hot flue gas and low moisture was maintained in fuelwood fed to the furnace. Also, fuelwood was cut into small pieces before feeding to furnace in order to minimize unburnt matter in ash.

During modification stage, it was observed that old CI tubes of present air heater can withstand temperature upto 400°C and were not able to withstand flame temperature of 800°C. Hence, high temperature material like SS and alloy steels has to be used. It was also observed that temperature difference (ΔT) in each pass of heat exchanger was different probably due to high ash deposits in flue gas side. Further, cleaning of tubes has become difficult because of locations of baffles in the passes. Hence, design should use lesser number of passes and lesser cleaning requirements.

After improvements, a higher flame temperature was achieved under same hot air conditions (same flow) and firewood consumption was reduced (100 kg/h). Thus, a saving of 60 kg/h was possible by making small design changes and operational improvements. By reducing fuel consumption, it is thus possible to reduce CO_2 emission to a considerable extent.

Conclusions

A considerable fuelwood saving (60 kg/h) has been observed due to operational improvements and small modifications. Similar benefit can be achieved in almost all the tea units located in India due to similarity of design and operation of the air heater in these units.

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