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For Efficient Dairy Plant Operation
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EFFICIENT STEAM GENERATION

This bulletin includes technical information, latest development on products, systems, techniques etc. reported in journals, companies' leaflets, books and based on experience. The technical information would be on different areas of plant operation in different issues. It is hoped that the information contained herein, if employed in the factory, will help in making dairy plant operations more efficient.

Your contributions and suggestions will make the bulletin more useful, and are welcomed.

*The theme of information in this issue is **Efficient Steam Generation.** It may be understood that the information given here is by no means complete.*

This issue on **Efficient Steam Generation** is being brought out at the requests of Dr. A.M. Shivakumar, Managing Director, Mandya District Cooperative Milk Producers Societies Union Ltd., Mandya, and Manager (Projects), Ernakulam Regional Cooperative Milk Producers' Union Ltd., Ernakulam.

In This Issue

1. INTRODUCTION

Steam is a very important source of energy required in pasteurization, evaporation, powder making, sterilization, equipment cleaning and many other dairy operations. Efficient steam system would, therefore, be a key to reduction of processing costs.

Steam system includes three elements : Steam generation, steam distribution and steam utilization. The 5th (November-December 1996) issue of Technews gave some useful tips on fuel handling, fuel combustion and some aspects of steam distribution. This issue gives some more useful information on efficient steam generation system.

Dairy factories use packaged, fire-tube boilers of capacities upto 10,000 kg steam per hour or higher. The boiler efficiency ranges from 60 to 85%, and depends on how complete the combustion is, and how best the boiler is operated. In addition to efficient combustion, other important factors are proper heat distribution, operating at the desired temperature, minimizing wall losses and losses through furnace openings, draft control, waste heat recovery and optimum capacity utilization. Some of them are mentioned here.

2. EFFICIENT COMBUSTION

One of the important factors responsible for efficient combustion is control of excess air. There is an optimum level of excess air required for each type of furnace design and fuel type (see Table 1).

Table 1
Optimum Excess Air

Fuel Type	Firing Method	Optimum Excess Air (%)	Equivalent Oxygen (% by volume)
Natural gas	—	5-10	1-2
Butane/Propane	—	5-10	1 - 2
Furnace oil/ LSHS	Steam atomized	10-15	2 - 3
	Pressure-nozzle	20-25	3.5 - 4.5
Coal	Pulverized	15-20	3 - 3.5
	Stoker	20-30	3.5 - 5

More than this amount increases the heat lost through the stack, resulting in higher fuel consumption. Important indicators of combustion efficiency are excess air in the flue gas and stack temperature.

Excess Air Control : Continuous measurement of the excess air (or excess oxygen) is necessary to accomplish optimal control over avoidable losses. There are two types of equipment employed to measure flue-gas oxygen and hence corresponding excess air : (I) portable equipment — an Orsat flue-gas analyzer or the like, and (2) permanent-type installations — probe-type continuous oxygen analyzer for the on-line measurement.

These equipment measure oxygen percent in the flue gas, which establishes operating/combustion efficiency. Accordingly, the excess air quantity can be controlled manually or automatically.

In certain situations, like when air and fuel are not well mixed, fuel calorific value has changed, burner and tip are worn, load changes, burner is dirty etc., the combustion will be incomplete. Consequently, there can be elements of both oxygen and combustible (Carbon mono-oxide) in the flue gas. **Thus, while excess oxygen measurement in flue gas will still be an index of excess air, it would be necessary to periodically check flue gas CO levels** to ensure complete combustion. With complete combustion, **only a trace amount of CO — 100 to 250 ppm** — is found in the exhaust gases. Hence, to obtain the maximum operating efficiency, the boiler should be operated with an excess air to keep this level of CO. A portable Flue Gas Monitor with dual analyzer will measure both oxygen and CO.

The following are the guidelines to assure peak boiler efficiency and minimum permissible excess air operation.

1) Check the calibration of the O_2 analyzer frequently and check the zero point daily.
2) Check to assure proper operation of the sampling system, if it is employed.
3) Check casing leakage, and stop it if taking place.
4) Check the forced draft damper to ensure that it is not broken or damaged.
5) Check control drives and instruments routinely.
6) If O_2 analyzer is used, check the excess air daily, and control it.
7) The fuel flow/air flow charts should be carefully checked to ensure that the fuel follows the air on increasing load and that the fuel leads the air on decreasing load on daily basis.
8) Periodically check flue gas CO levels to ensure complete combustion.

Stack Temperature Control : Boiler flue gases are rejected to the stack at temperatures at least 40 to 65°C higher than the temperature of the generated steam. Recovering a portion of this heat will result in higher boiler efficiencies (See Figs 1 & 2). Heat recovery can be accomplished by using either economizer to heat the feed water or an air preheater for the combustion air.

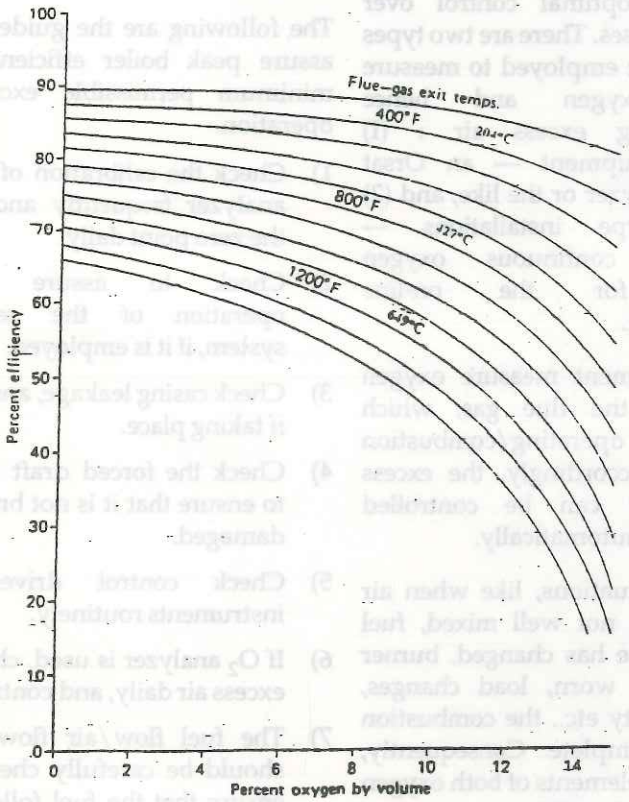

Fig. 1. Fuel oil unit efficiency

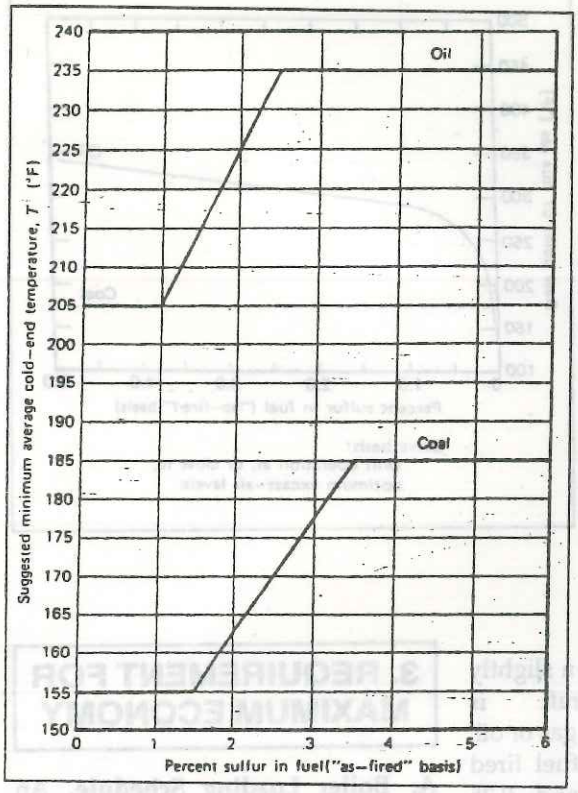

Fig. 2. Guide for selecting flue-gas air preheaters

The lowest temperature to which the flue gases can be cooled is set by the flue gas dew point. The dew point increases as the sulphur content of the fuel increases (Fig 3): 120°C for natural gas, 150°C for coal and low-sulphur-content fuel oils, and 180°C for high-sulphur-content fuel oils.

Temperature of the flue gas is measured by mercury or bimetallic thermometers, optical pyrometers or thermocouple probe.

Draft Control : Draft is an indicator of how quickly flue gases leave the boiler as compared to how quickly combustion air and fuel are put in. For proper combustion to occur, the proper overfire draft must be maintained in the firebox of the boiler.

When burning solid fuels, it is desirable to have a slightly negative draft in the firebox to prevent soot and flyash from blowing out through the fire door or its opening.

As most modern flame retention burners can easily fire against

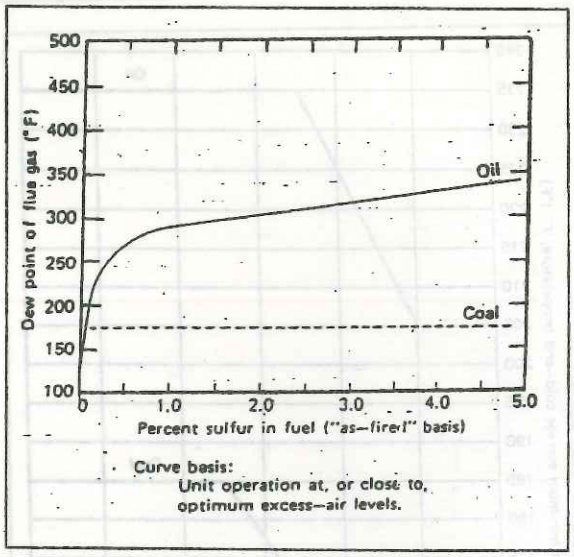

Fig. 3. Flue-gas dew point. Curve basis: unit operation at, or close to, "optimum excess-air" levels.

positive firebox pressures, a slightly positive overfire draft is recommended when firing gas or oil. The ideal draft for soild fuel fired boilers is between -0.125 and -0.25 cm water gauge (wg), and 0.25 cm wg for those fired with oil or gas.

Usually this draft is controlled by an adjustable damper located between the boiler and its smoke outlet. A manometer connected to the rear smokebox of the boiler indicates the draft. Draft can also be controlled automatically.

Draft gauge can also be used to measure the draft. The gauge can be located at a distance from the test point and can remain connected for a continuous reading.

3. REQUIREMENT FOR MAXIMUM ECONOMY

A. Boiler Loading Schedule. An optimized loading schedule allows plant steam demand to be met with the minimum energy input.

1) Boilers generally operate most efficiently at 65 to 85% full-load rating, centrifugal fans at 80 to 90% design rating. Equipment efficiencies fall off at higher or lower load points, with decrease most pronounced at low-load conditions.

2) It is usually more efficient to operate a lesser number of

boilers at higher loads than a larger number at lower loads.

3) The most efficient unit should be put into service first, than in order of decreasing efficiency.

4) Newer units and units with higher capacity are generally more efficient than are older small capacity units.

5) Generally, steam plant load swings should be taken in the smallest and least efficient unit.

B. Optimize the Use of High-Pressure Units. Usually the higher pressure boilers are more efficient. It is, therefore, desirable to supply as much of the plant demand as possible with these units **provided** that the high-grade energy in the steam can be effectively used. Otherwise, degrading high-pressure steam through a pressure reducing and desuperheating station is the least efficient method of supplying low-pressure steam demands. Direct generation at the required pressure is usually more efficient by comparison.

4. BOILER GIVES OUT BLACK SMOKE?

Black smoke indicates incomplete combustion and hence loss of fuel. Check up as follows :

1) **Poor air-oil mixture.** Open air regulator to the correct setting.

2) **Too high oil pressure.** Redue it to the correct value.

3) **Too low oil temperature.** Check preheater and correct it.

4) **Dirty blower fan.** Clean it.

5) **Burner nozzle dirty or worn out.** Clean or replace it.

6) **Air passage blockage.** Correct it.

7) **Copper asbestos joint ring in sprayer head leaking.** Replace it.

8) **Damper closed too much.** Reset it.

5. STACK TEMPERATURE TOO HIGH?

1) **Tubes are dirty.** Clean them.

2) **Boiler overloaded.** Reset back pressure.

3) **Too much excess air.** Adjust air-oil ratio.

4) **Refractory baffle damaged.** Repair it.

5) **External fouling.** Can be detected by use of draft loss gauges or water manometers. Clean dirty surfaces.

6) **Excessive negative draft at chimney outlet.** Adjust damper.

6. SAFE BOILER OPERATION

For safe boiler operation, amongst other, attention must be paid to the following :

Stack Temperature. Should not be high. Causes should be investigated immediately and rectified.

Scale Formation on Water Side. Take remedial action. Use soft, treated water.

Excessive Firing Rate. Control the firing rate within the limits as prescribed by the manufacturer.

Care should be taken as follows :

1) When the accumulated flue gases in combustion spaces of boiler reach ignition point, flare back or minor combustion explosion occurs. Such accumulation may occur due to the obstruction in stack or failure of oil to ignite due to inadequate oil temperature or leakage.

   Once a flare back occurs, stop the burner immediately, close oil valve & check the boiler thoroughly for any damage. Clean combustion tubes thoroughly of oil accumulated, if any, and purge the combustion tubes for about 10 minutes to ensure all gases are blown out. This can be done by keeping primary blower running. Then only fire the boiler again.

2) Ensure that the water is always above the low water level. If no water is visible in the gauge glass, stop boiler firing, leave main steam stop valve open and allow the boiler to cool before attempting to restore water, because cold water may cause serious damage due to contraction of tube metal.

3) Check for clinker formation in the boiler. If found in excess, stop it to avoid serious backfire and/or accidents, and take necessary action.

4) Avoid raw oil accumulation in the furnace during starting, as this may lead to explosion, specially with light diesel oil (LDO), which is very dangerous.

5) **With LDO firing, do not use preheater at all, as this may result in explosion.**

6) Always make a practice to run only blowers manually for about 5 minutes before starting the boiler to purge accumulated gases, if any. This is for additional safety.

7. SOME MORE USEFUL INFORMATION

1) About 5% improvement in excess air that can be attained, the fuel saving will be 1%.

2) Every 21°C rise in combustion air temperature in air heater results in 1% fuel saving.

3) Boiler efficiency increases by 1% for every 22°C reduction in stack temperature.

4) Heating of the feedwater by 1°C in economizer reduces the temperature of the flue gases by 2-3°C.

5) In air heaters, cooling of the flue gases by 1°C raises the temperature of air by 1.2 - 1.5°C.

6) Quantity of air required for theoretical combustion of a solid or liquid fuel is : Calorific value (kcal/kg) x 0.00138 kg/kg fuel

For furnace oil or low sulphur heavy stock theoretical air quantity required is 14.4 kg per kg fuel.

7) Volume of flue gas produced is cu m. per kg of fuel is : Calorific value (kcal/kg) x 0.001124

For furnace oil and LSHS, flue produced is 14.3 kg or 11.6 cu.m per kg of fuel.

8) One kg of fuel oil will produce about 15.6 kg steam.

8. SOME PROPERTIES OF FUEL

A. Specifications (IS 1593 - 1982)

Specifications	Furnace Oil	Low Sulphur Heavy Stock (LSHS)
Density at 15°C, g/ml	0.958	0.92
Flash point, min., °C	66	95
Pour point, max., °C	27	72
Kinematic viscosity, max., centistokes, at 50°C	170	—
100°C	23	100
Water content, max., (% vol.)	1	1
Sediment, max., (% weight)	0.1	0.1
Ash, max., (% weight)	0.1	0.1
Total sulphur, max., (% weight)	4	1.2
Acidity, inorganic	Nil	Nil
Gross calorific value, kcal/kg.	10280	10556

B. Calorific Values

Fuel	Gross Calorific Value kcal/kg	Ignition Temp °C
Coal, anthracite	7777	480-510
bituminous	4400	450
Fuel oil	10200-10700	750
Natural gas	8900	185

1 kcal = 4 Btu, 1 kcal/kg = 1.8 Btu/lb
1 kcal/cu m = 0.112 Btu/cu ft
1 Boiler horse power (Bhp) = 15.69 kg steam/hr = 8450 kcal/hr
= 9.8 kw

REFERENCES

1) Houghtaling, T.P. (1994). Boiler draft and its control, **AHRAE Journal,** May

2) Moran, W.G. & Hoyos, G.H. (1982). Boiler heat recovery, in **Process Heat Conservation,** Ed. R. Greene, Chemical Engg., McGraw-Hill, New York.

3) PCRA, **Fuel Economy in Furnaces and Waste Heat Recovery,** Petroleum Conservation Res. Assoc., New Delhi.

4) Scollon, R.B. and Smith, R.D. (1982). Boilers and fired systems, in **Energy Management Handbook,** Ed. W.C. Turner, John Wiley, New York.

5) Soni, D.K. (1993). Oxygen and CO control for improvement of combustion efficiency and quality, **Active Conservation Techniques,** PCRA bulletin, 8 (3).

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