EFFECTIVE ENERGY RECOVERY FROM WASTE ILLUSTRATED BY THE HAMBURG-STAPELFELD RESOURCE RECOVERY FACILITY

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Energy! Today, a key word. On the one hand, ways and means of saving energy are sought, and on the other hand, new possibilities are being explored to meet the ever-increasing demand for energy. The recovery of energy from waste is becoming increasingly important. Even if energy recovered from waste were to supply only a small portion of the entire energy demand, with little influence on the energy market, there are still enough economic reasons to justify the recovery of this energy source. Several applications are developed to efficiently integrate energy recovered from waste into existing energy systems. Today many existing resource recovery plants provide electric power and/or process steam for industries or district heating. The particular method of energy usage is often dependent upon the location of the plant.

The third resource recovery facility for the City of Hamburg, Germany was built in the Stapelfeld area. The facility receives solid waste from the northern section of Hamburg along with the bordering area of Stormarn and the dukedom of Lauenburg. This region produces nearly 287,000 tons (260,000 t) of municipal waste per year. The areas surrounding the plant are reserved for agricultural purposes. Originally the plant was planned to generate power only. During the course of the planning, it was decided to implement co-generation of power and steam so that later on heat for use in greenhouses could be provided along with electrical energy. The plant is equipped with two furnace-boiler units. The waste capacity per unit amounts to 21 tons/hr (19 t/h) at a lower heating value of between 1800 Btu/lb (4200 kJ/kg) and 4200 Btu/lb (9760 kJ/kg). The steam generated, 2 x 94,360 lb/hr (2 x 42,890 kg/h), is transformed into electric power in two extraction-condensing turbo-generators of 11,400 hp (8400 kW) each.

The thermal flow sheet (Fig. 1) of a plant with power generation indicates the main heat losses:

1. The flue gas losses: Due to fouling of the boiler tubes during the time of operation, the flue gas outlet temperature and the coherent stack losses will increase.
2. The condensation heat that is lost into the air through condensors.

During the planning phase of the facility, the task was to minimize the losses. The customers’ specification requested the following:

"To be able to recover the excess energy due to the unavoidable increase in the flue gas temperature, which occurs as the on-stream time progresses. The desired result had to be accomplished through the incorporation of a regulating heat exchange system".

In order to reduce the condensation loss, heat exchangers are installed additionally for the heating of greenhouses.

THE REGULATING BOILER

The task of the regulating boiler is to recover the excess energy due to the flue gas temperature increase during the on-stream time period, so that the temperature of the flue gas will remain approximately constant at the boiler outlet.
This boiler forms the continuation of the horizontal pass boiler, and is designed as a natural circulation boiler. The heating surfaces are divided into separate bundles that can be connected or disconnected manually.

The flue gas temperature at the regulating boiler inlet is approximately 545°F (285°C) at the beginning of the on-stream time. The heat surfaces are designed to cool the flue gasses from 590°F (310°C) to 410°F (210°C). At the beginning of the on-stream time a part of the heat surfaces are not in operation, that is, there is no water circulation. The bundles will be activated, one after the other, according to the increased fouling of the main boiler. The quantity of saturated steam that is generated in the regulating boiler, with an operating pressure of 72.5 psig (500 kPa), is utilized in the low pressure system of the plant for internal purposes (feed
water de-aeration, air preheating, building heating). The amount of produced steam can reach up to 17,640 lb/hr (8020 kg/h).

WASTE HEAT UTILIZATION

Under normal condensation conditions in the Stapelfeld plant, 90,600 lb/hr (41,100 kg/h) steam at 1.74 psi (12 kPa) and 121 F (49.5 C) is condensed in the air condensers. This amount of heat can be used for a low temperature heater in greenhouse businesses. In a cooperative effort between the customer, the Stapelfeld GmbH, the manufacturer of the power plant and a greenhouse specialist, the process for heating greenhouses with low temperature heat was worked out.

The heat supply from the steam leaving the turbine, after subtraction of the minimal needed steam quantity to the air condenser, is:

1. Eighty-five million Btu/hr (25.0 MW) at ambient temperatures over 32 F (0 C).
2. Seventy-three million Btu/hr (21.4 MW) at lower temperatures.

This heat value is sufficient for the heating of greenhouses with a ground surface area of 30 acres (120,000 m²). It is used in a heating-condenser in order to bring the hot water to a temperature of 113 F (45 C). Special heating surfaces and heating surface systems have been developed for the purpose of utilizing this heat in the greenhouses. This enables the greenhouses to be heated at ambient temperatures from 23 F to 59 F (-5 C to +15 C).

If the ambient temperature drop below 23 F (-5 C), the heating surfaces are no longer sufficient to cover the heating demand. Due to reasons dealing with greenhouse technology, the heating surfaces cannot be enlarged and therefore the hot water temperature must be raised. The heat demand has been computed using statistical data of mean daily temperatures in Hamburg. Heat supply and heat demand are presented in the following diagram in relation to the ambient temperature.

The heat requirement cannot be met during 13 days of the year when the outside temperature is between 23 F and 5 F (-5 C and -15 C). During this time the additional heat requirement is supplied by a supplementary source.

During the course of the project development other possibilities to meet the peak load were explored, concentrating on performance reliability and operation economy.

Two options are presented and discussed in the following:

A. SERVICING OF THE PEAK LOAD REQUIREMENT BY STEAM EXTRACTION

The exhaust steam of the first turbine is condensed in a heating condenser and pumped to the existing condensate tank. The heating water returns with a temperature of 86 F (30 C), is heated up to a temperature of 113 F (45 C) in the heating cond-

![FIG. 3 ENERGY RECOVERY IN THE FACILITY HAMBURG GERMANY](image)
After drying, the product is transported to the storage silo. The hot water then flows with a temperature of up to 126.5 °F (52.5 °C) in the direction of the greenhouses. At ambient temperatures the additionally required heat is generated in the reheat exchanger. The electrical power requirement of the air condensor unit for the first turbine will be reduced by a yearly rate of about 450,000 kWh. Conversely, the second turbine, as a result of the extraction process, will generate about 130,000 kWh less per year.

**B. SERVICING THE PEAK LOAD REQUIREMENT BY MEANS OF AN OIL-FIRED AUXILIARY BOILER**

The hot water will, as in option A, be heated to the necessary temperature, first in the heating condensor and secondly in the reheat exchanger. Unlike option A, the supplementary heat in the reheat exchanger will be supplied by an oil-fired boiler having a capacity of about 39.7 million Btu/hr (11.6 MW). With this option the electrical power for the air condensation system will be reduced by about 450,000 kWh per year, but the cost of fuel for the oil-fired boiler to supply the required 4.4 million Btu/year (1284 MW) during the cold period, must be considered.

**OPERATING ECONOMY**

The following operating cost comparison is based on debt service and maintenance costs for the supplementary installations in the resource facility of 13.2 percent total, the electrical power cost at approx. 22 mils/kWh (4.12 pf/kWh), and fuel costs at approximately $135.00/ton (DM220/t). The supplementary installations in the Resource Recovery Facility include:

1. Installing a steam extraction on the turbines
2. The heating condensors and reheaters
3. The pumps for condensate and hot water
4. The necessary internal piping
5. The hot water lines to the site limits
6. The installation of electrical measuring and control system
7. The oil-fired boiler (for option B)
FIG. 5 FLOW SHEET ALTERNATIVE B: HEAT RECOVERY WITH AUXILIARY BOILER.

Addition to waste processing plant.
Greenhouse operation costs
Total:

Fuel costs for oil-fired boiler
to cover the energy need.
Total:

FIG. 6 YEARLY COSTS PER GREENHOUSE SURFACE: $/ft² AND (DM/m²)

8. The related civil construction.

Based on a greenhouse surface area of 1 ft² resp. 1 m² (the ground surface area is about 30 acres (120,000 m²)), the following yearly costs are derived:

In order to ultimately cover the heat requirement with oil, given the same oil costs, the fuel costs alone would run about $0.67/ft² (DM 13.09/m²). Through the utilization of the condensation heat of one turbine, approximately 98 percent of the heating requirement for greenhouses can be met. The remaining 2 percent will be supplied most economically by installing an auxiliary boiler.
Boiler outlet temperature 285°C/545°F
Regulating boiler outlet temperature 210°C/545°F

FIG. 7 ENERGY BALANCE: HOT WATER PRODUCTION

SUMMARY

In the Resource Recovery Facility in Hamburg-Stapelfeld, a regulating boiler was installed in order to reduce the flue gas losses, and at the same time to hold the flue gas temperature at the precipitator inlet constant over an extended period. The steam generated by installing this boiler will be used for inplant purposes such as feedwater deaeration, combustion air preheating, and building heating.

The condensation heat from the turbines, which is usually lost into the atmosphere, will be put to beneficial use in connection with a low temperature heating system.

Through the practical application of these two solutions, a modified and improved energy flow results, with less heat losses and recovery of more valuable energy!

Key Words
Combustion
Cost Reduction
Energy
Europe
Germany
Waste Heat
Waterwall