QUALITY AND CHARACTERISTICS OF STEAM PRODUCED FROM WASTES

by

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Overview

Waste is a fuel characterized by physical and chemical properties somewhat less desirable than solid fossil fuels. Solid fossil fuels are used commercially for a variety of steam-energy systems. Some solid fuels, especially the lower grades, are troublesome and require special considerations. Waste is certainly a fuel available for commercial application. The thrust of this presentation is to assess the quality and characteristics of the energy output from steam systems fired in whole or in part with waste. Such an assessment is intended to be useful in evaluating various waste-firing methods, combined firing systems for various energy systems, and also other thermal processes.

Fuel Characteristics

It is generally agreed that an apt description of waste is that it is nonhomogeneous. Physical and chemical properties vary from year to year, season to season, month to month, day to day, and minute to minute. It is appropriate then to consider the quality of the energy output in terms of fuel homogeneity. In a steam-producing unit, the quality of the energy output can be monitored in terms of pressure, temperature, and flow. Pressure and temperature are relatively amenable to control. Therefore, flow is the major variable. Homogeneity is the consistency of the properties of waste fuel as delivered to the steam-producing device. Lest this oversimplified definition offend anyone, it will be expanded later.

Firing Methods

Firing methods commercially used include mass-burning, semi-suspension, and suspension systems. Each system requires a certain amount of fuel preparation. In mass-burning systems, bulky refuse is usually excluded.

The collection systems can often provide a degree of classification. An extreme example of preparation is the removal of magnetic metals prior to burning. Examples of mass-burning systems (thick fuel bed) include the Norfolk, Braintree, Oceanside, Harrisburg, Chicago Northwest, Nashville, and Saugus units. There are numerous examples of such systems in Canada, South America, Europe, and Japan. One such system is the Düsseldorf units. In general "as received" waste is delivered to the steam generator. For a semi-suspension system, shredding to a nominal 10-cm (4-inch) size is required. Although the semi-suspension system (air-swept spouts with spreader stoker-thin fuel bed) is used commercially with wood fuels, to date the only example is the units at Hamilton in Canada. For a full-suspension system, shredding and classification to a nominal 2.5-cm (1-inch) size are required. The closest example of this system is the Eastman Kodak unit.

Now that three different firing methods have been illustrated, perhaps it is possible to qualify the energy output in terms of energy output varation. To visualize this, it is convenient to visualize an energy-conversion device directly connected to the waste-fired steam generator, e.g., a turbo-generator. A typical example of a mass-burning system with essentially a constant volume waste-fed system and constant airflow is shown in Figure 1. Shown is the variation in CO_2, temperature in the combustion chamber, and steam flow. An example of a recorder chart from Düsseldorf (August 16, 1966) is shown in Figure 2. Included on this chart is waste table feeder amperage (Mülaufgabe) and the airflow (Luftmenge), both of which are fairly uniform, O_2 (O_2-Gehalt), furnace exit temperature (Feuerraumtemperatur), and steam flow (Dampfmenge), which are quite variable.

Those familiar with such units will immediately agree that's the way it is. The turbogenerator supplier will reel in shock and balk at having a steam line from such a unit connected to his steam turbine. Others will say "An individual unit behaves like that, but we've improved the system so the turbine doesn't receive that steam." Before reviewing the latter, secondary effects, let's consider how the energy output variations can be related to homogeneity. If homogeneity can be visualized as a function of fuel sizing with pulverized coal as a base, then there will be an increase in homogeneity from "as received" to 10-cm (4-inch) to 2.5-cm (1-inch) to the pulverized coal base. With all of the above variables constant, the energy output variation will decrease with increased homogeneity -- or the better the homogeneity, the better the quality of the energy output. Norfolk-type, Hamilton, and Eastman Kodak units, respectively representing mass, semi-suspension and suspension systems, are shown in Figure 3. Will energy from waste ever be as good as energy from solid fossil fuel? Before attempting that answer, some more examples of homogeneity will be cited.

Combined Firing

The Europeans have led the way with utilization of waste for energy. Their achievements include the evolution of the Munich designs. Munich is an appropriate example because the steam conditions (2400/1004/1004) and much of the equipment are similar, the differences being mainly in design. The design features are summarized in Table 1.

Table 1

Munich Designs

Unit	MW	No. of Furnaces	Furnace Type	Fossil Fuel	Waste Heat Input (%)
North 1A & B	68	2	Separate	Coal	50
North 2	124	1	Combined	Coal	30
South 5 or 4	124	1	Separate Economizer	Oil/Gas (Future Coal)	20

These units were designed and are operated as "block" units; that is, the turbogenerator is directly connected to the steam generator. One way of minimizing the energy output variation is to manifold the steam lines from one or more units. This is done at Norfolk, Saugus, Düsseldorf, Stuttgart, and other plants. Munich North 1 has two identical steam generators connected to the 68-MW turbogenerator. Visual observation of the generator charts indicates a reduction in energy output variation from North 1 to North 2 to the identical South units. If these units were plotted with a constant homogeneity value, they would appear as shown in Figure 4. Admittedly, this is a qualitative assessment, but it is in agreement with observation of traces and also interviews and published documentation that indicate each succeeding design was better than the previous one.

Another combined-firing method examined in detail in design studies included a semi-suspension steam generator providing saturated steam which is then superheated in a separately fossil-fuel-fired superheater. In comparison with a unit like Hamilton, there would be the reduction in energy output variation shown in Figure 5.

Yet another combined-firing method tested in demonstration is the suspension system in which shredded and classified refuse is burned with pulverized coal. This demonstration was performed at Union Electric on both tangentially fired units and, on a trial basis, on a front-wall-fired unit. Similar commercial installations are in service at Ames and in planning by Union Electric. The variation in energy output of such a system is very similar to that of a fossil-fuel-fired unit. Operators at

Union Electric have indicated it is difficult to determine from their recorders when waste is being fired. For such a system, the energy output variation is as shown in Figure 6.

Now that a number of examples have been identified, it is possible to generalize. The heat input from refuse for the different firing methods can be correlated as shown in Figure 7. A more difficult assessment is to limit energy output variations for specific steam applications. However, such an attempt has been made. Obviously, 20 percent full suspension, Munich North 2 and the South units can be used for power generation. Based on the design studies, the 50 percent semi-suspension system can also be used for power generation. Munich North 1 is used for power generation, but recall, the actual energy output variation is somewhat dampened by the parallel furnace arrangement of the steam lines. Even though this is an existing unit, the variations are substantial, and this 68-MW power is distributed into the 600-MW grid with other fossil-fuel-fired units synchronized to minimize variations. Therefore, this type of unit is excluded from power-generation service as shown in Figure 8. The Hamilton unit presently provides no steam services, but based on similar units firing wood bark, such systems can be used for process applications. Some process applications include back-pressure turbogenerators or a small amount of steam sent to a condensing turbine. Units that generate steam for distribution may have slight superheating (Nashville) or deliver steam at saturated conditions (Norfolk). The limit for steam distribution is a mass-burning system with slight superheat as shown in Figure 8. Process applications are, therefore, systems with greater homogeneity or lower energy output variation.

Refinements

Obviously, the material presented so far is somewhat simplified, and there are many refinements that can be made. The Düsseldorf mass-burning units are used in combination with turbogenerators, but the steam lines of each unit are manifolded and delivered to a conventional fossil-fuel-fired plant some distance away. The total heat input from refuse for the entire system is below 20 percent, and the long steam lines dampen flow variations. Steam accumulators, such as used in Quebec, serve to reduce energy output variations. The three Stuttgart units combine mass-burning with oil-firing in separate furnaces along with steam manifolds, so that the refuse heat input for the system again is quite low. Even at Stuttgart the variations were recognized, and a sophisticated control system was installed to minimize flow variations, as shown in Figure 9. Such systems are also employed on units firing only refuse, such as the Hamburg-Stellinger Moor units shown in Figure 10.

Applications

The concept of correlating energy output variation as a function of a property such as homogeneity can be a useful design tool in decision making on waste-to-steam applications, depending on the use of the steam and total waste available, the fossil fuel available, the type of energy recovery, and also the type of firing method.

Further Development

This concept has merely been introduced and judged by a qualitative evaluation. What yet remains is the further step of quantitative evaluation, utilizing operating records of existing plants and tolerances in energy output variations for various equipment. For example, it may well be that a high-pressure superheat steam turbine may require steam flow control with less than 5 percent/minute variation. In Figure 2 larger variations are not uncommon. It would appear that the greater the homogeneity, the less the variation in energy output. However, sophisticated control systems may well achieve greater homogeneity externally. The designer may choose a system in which the superheater elements are not exposed to refuse flue gases in a 100 percent heat-input system and may elect to choose a system requiring some waste preparation.

This concept has been reviewed by the ASME Research Committee on Industrial and Municipal Waste through its Research Needs Subcommittee and the Energy Recovery Subcommittee. Hopefully, some funding can be solicited. However, the success of such a project will depend greatly on the cooperation of many operators. Perhaps this explanation of the concept will encourage support of the project.

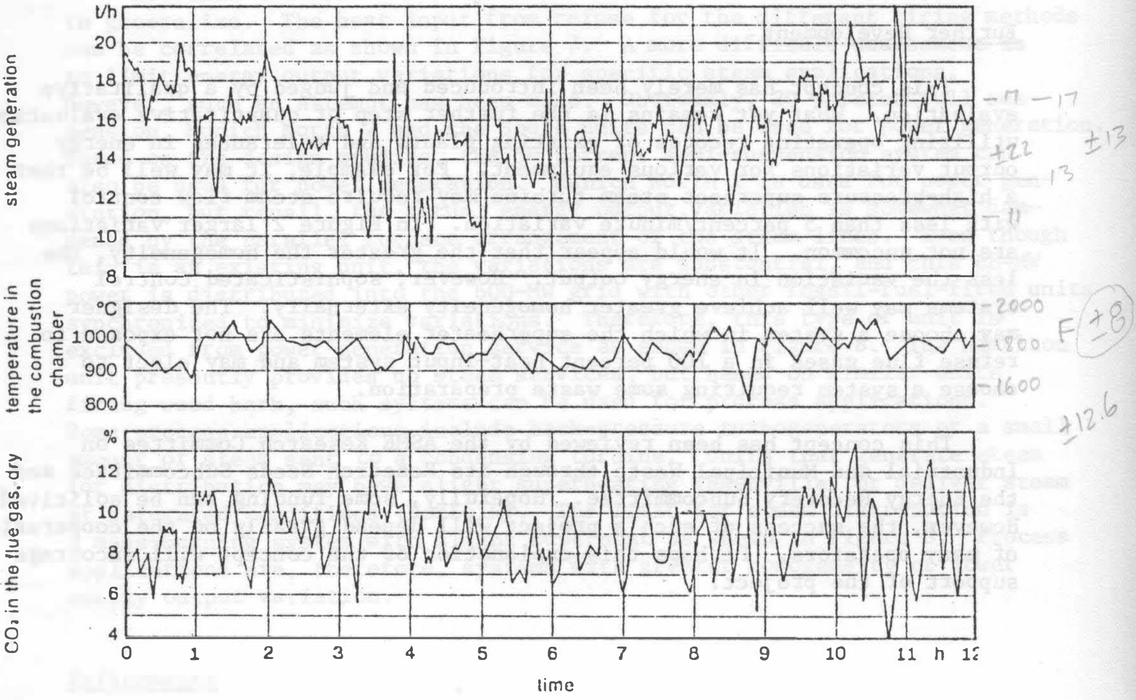
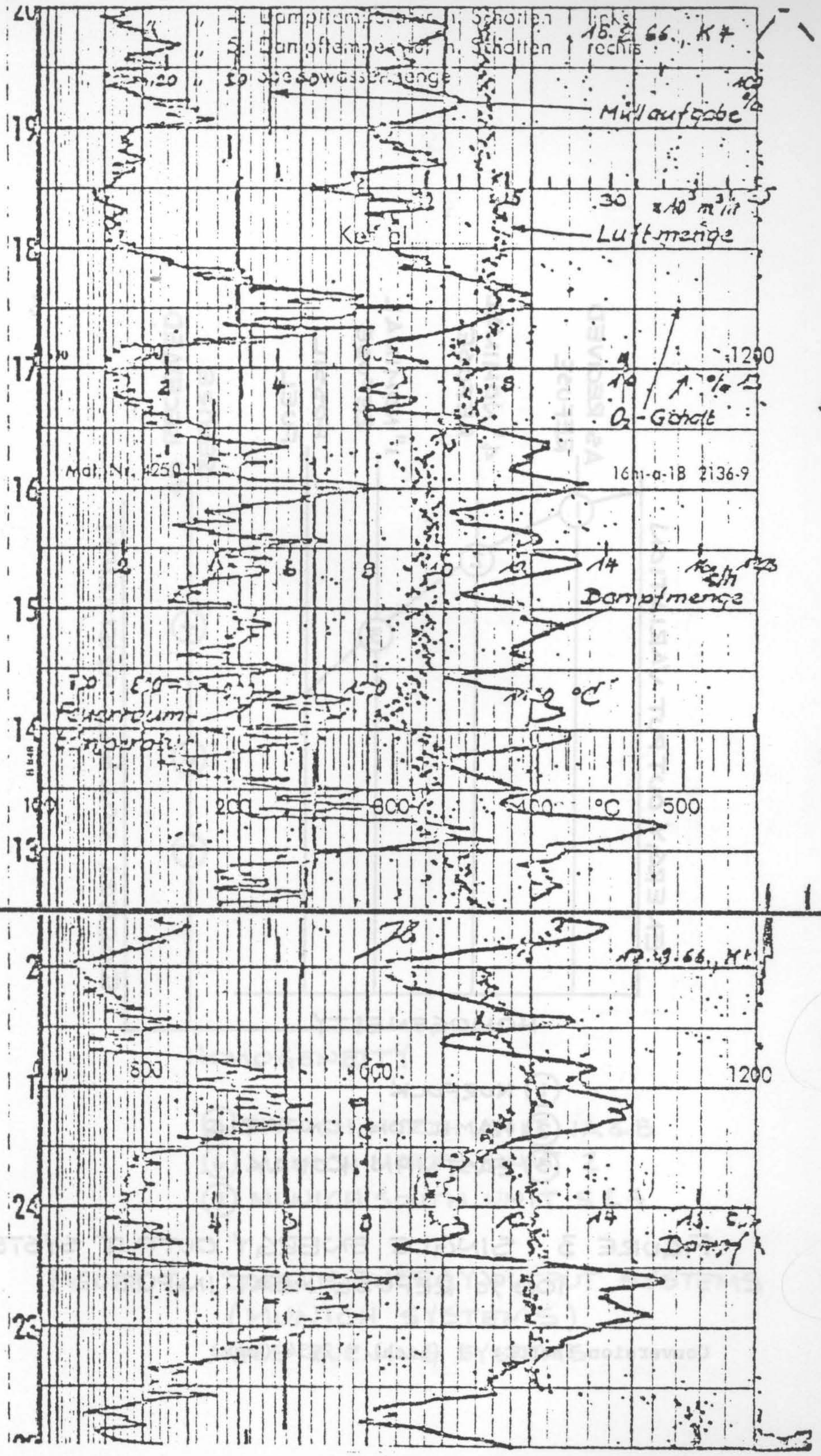


FIGURE 1. Conditions in the Combustion Chamber of Grate Furnaces

1700–1900 °F

10 – 13 ±13%



3,2% /min

2,4% /min

5% /min

2,3% /min

FIGURE 2 UNIT RECORDER CHARTS FROM NORMAL DAY AND NIGHT OPERATION DÜSSELDORF MVA

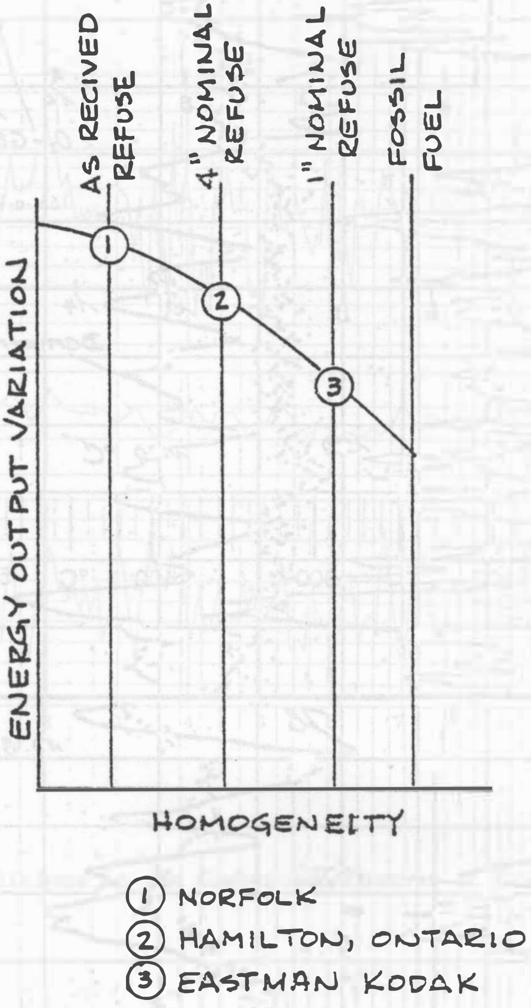
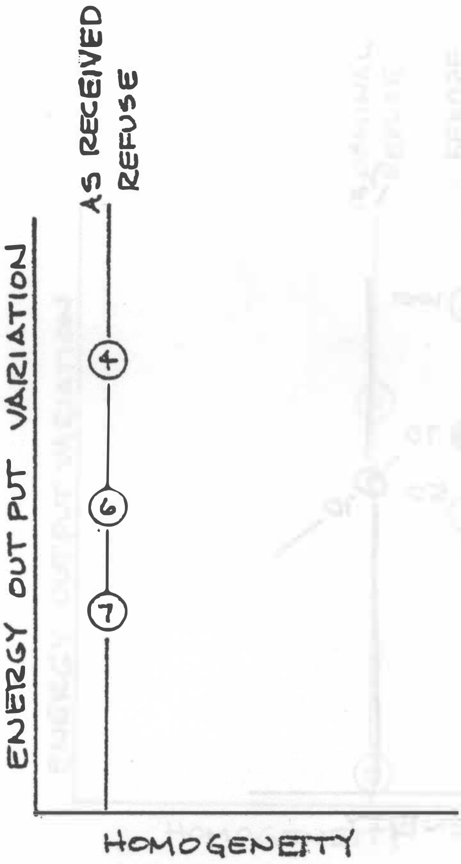


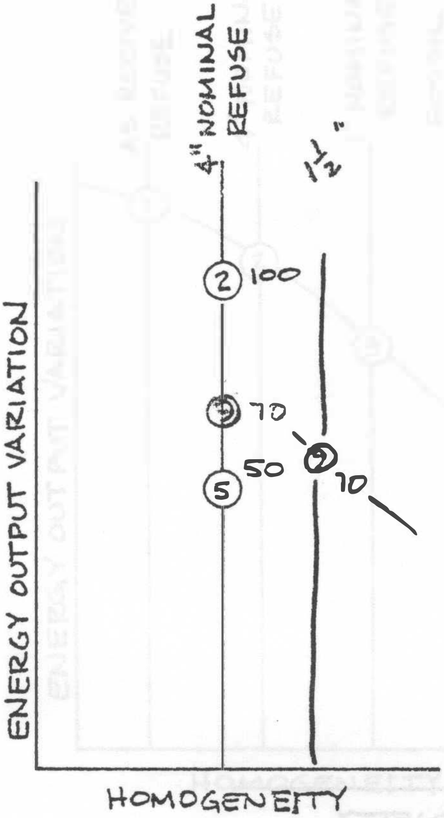
FIGURE 3 SINGLE ENERGY OUTPUT SYSTEMS
100% REFUSE HEAT INPUT

Conversion factor: 1 (inch) = 2.54 (cm)



④ MUNICH NORTH, UNIT 1A & B
⑥ MUNICH NORTH, UNIT 2
⑦ MUNICH SOUTH, UNIT 5 & 4

FIGURE 4 SINGLE ENERGY OUTPUT SYSTEMS
(MUNICH SYSTEMS)
MASS BURNING SYSTEMS



② HAMILTON, ONTARIO
⑤ SEPARATELY FIRED SUPERHEATER
⑨ AMES

FIGURE 5 SINGLE ENERGY OUTPUT SYSTEMS
SEMI SUSPENSION SYSTEMS

Conversion factor: 1 (inch) = 2.54 (cm)

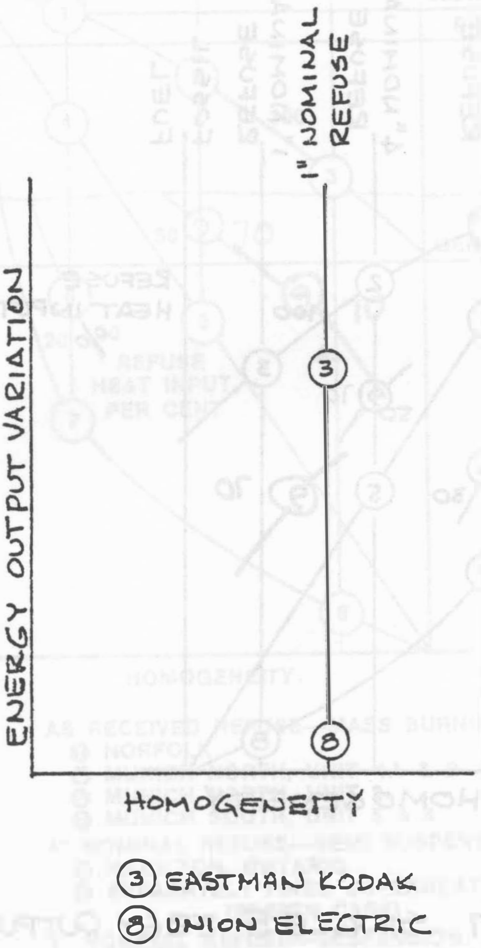


FIGURE 6 SINGLE ENERGY OUTPUT SYSTEMS
SUSPENSION SYSTEMS

Conversion factor: 1 (inch) = 2.54 (cm)

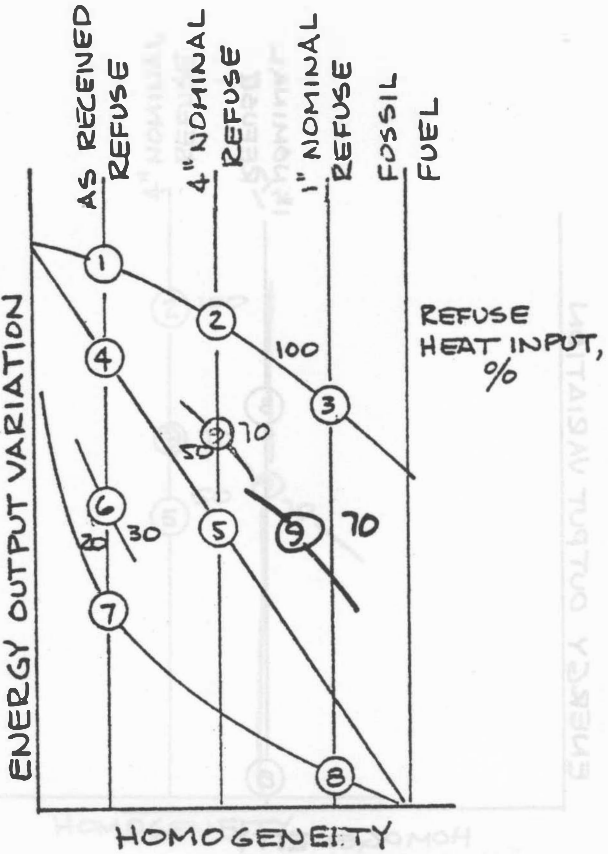


FIGURE 7 SINGLE ENERGY OUTPUT SYSTEMS (VARIOUS REFUSE HEAT INPUT)

Conversion factor: 1 (inch) = 2.54 (cm)

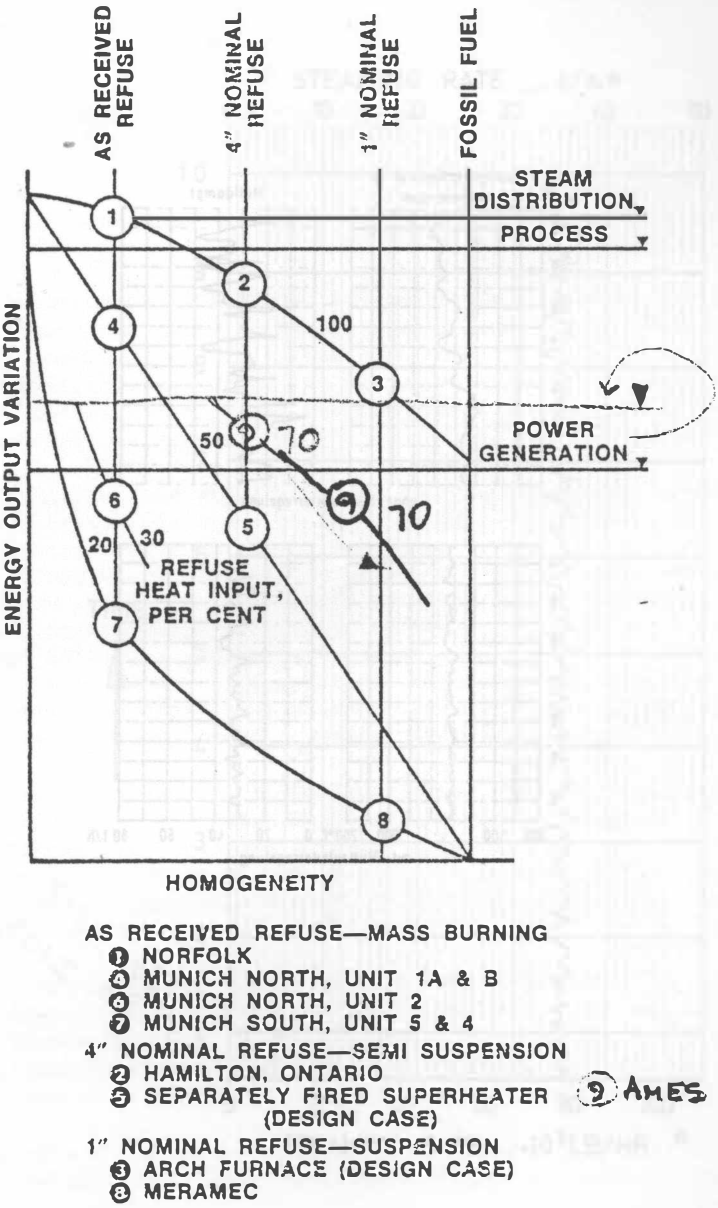
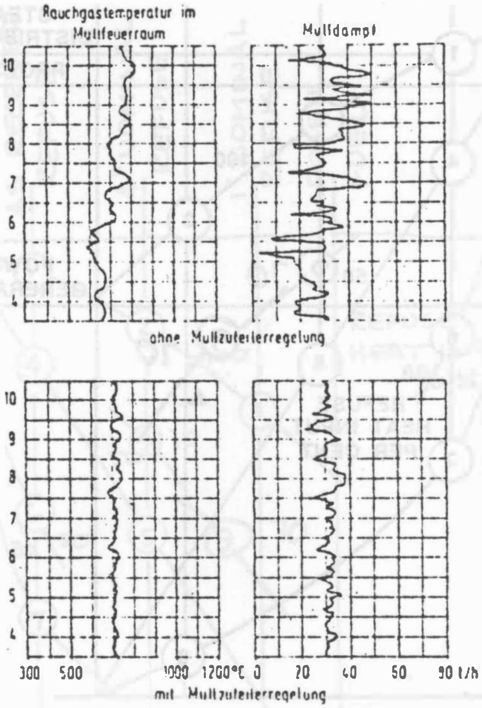


FIGURE 8 SINGLE ENERGY OUTPUT SYSTEMS (VARIOUS ENERGY USES)

Conversion factor: 1 (inch) = 2.54 (cm)

20 45

25/3 = ± 35%



25 - 38 ± 21%

25 - 20 ± 10%

FIGURE 9) FLUE GAS TEMPERATURE & STEAM FLOW STUTTGART MVA

33 37 ±6%

4/35 = 12

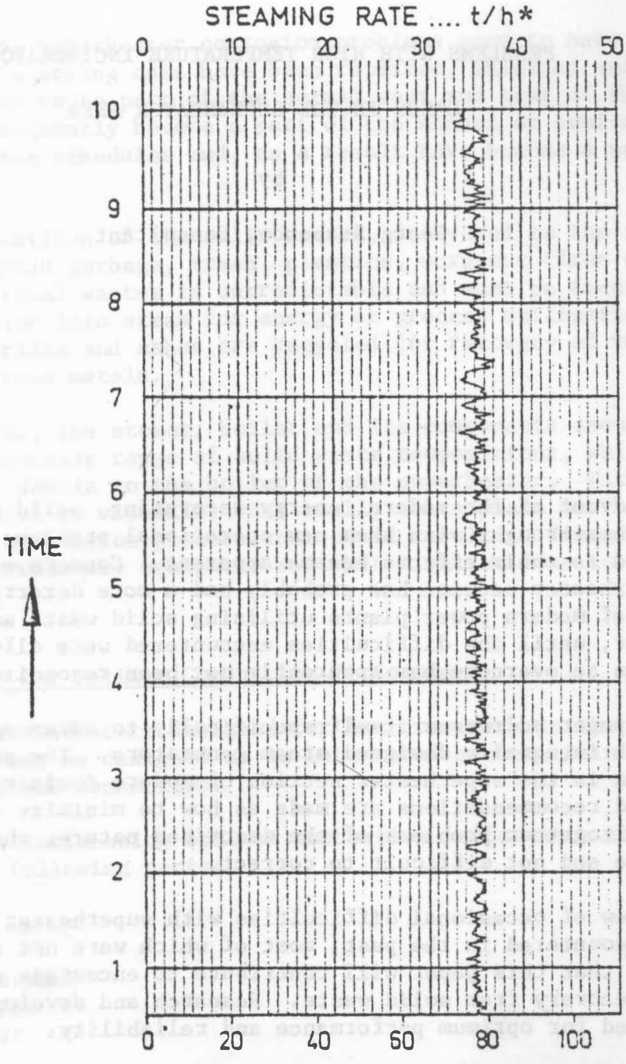


FIGURE 10 STEAM FLOW
HAMBURG-STELLINGER MOOR MVA

*Conversion factors: 1 (U.S. ton) = 0.907 (metric ton)
1 (lb/hr) = 0.454 (kg/hr)