Oil Mill Energy Sources and Power Balances in a Palm Oil Operation

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ABSTRACT

Equipment needs for using waste materials to supply steam and electricity in palm oil mills are discussed. Energy balances are considered for mills of varying capacity.

INTRODUCTION

Power supply in palm oil mills is a field that has developed considerably since the construction of large scale oil mills with consistent oil quality and yield standards.

In preindustrial mills and the first mechanized mills set up just after the Second World War, steam was produced to operate a single reciprocating engine that simply transmitted its power to a few machines by means of a drive shaft and belts.

In modern large scale mills, there is a much greater number of machines in operation; they are more powerful and must be dependable. As a result, the single drive shaft principle has proven inadequate and it has become apparent that each machine and pump requires an individual electric motor. Instead of the rudimentary boiler plant of the past, it has become necessary to equip each mill with a veritable power station including a steam source and an installation to convert steam into electrical power. A complete power plant is not just a technical need but an economic one as well. Palm oil mills are always located in the middle of a producing zone far from electrical distribution networks, but even if it were possible to connect up with a distribution system, the production costs would rise sharply. The only advantage would be lower capital investments.

To produce the required electrical power, at least two solutions are possible:

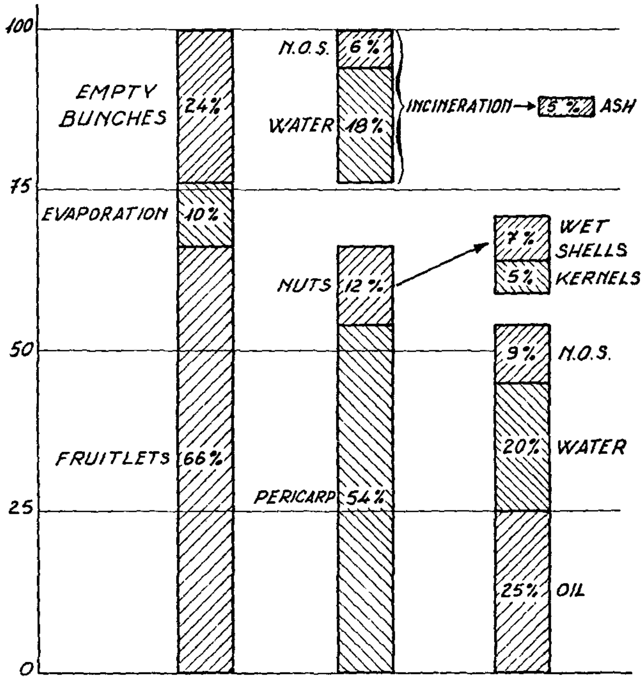

FIG. 1. Composition of Tenera FFB.

1. Make no changes in the steam production system in old mills (i.e., keep the steam pressure relatively low) and produce electrical power with a diesel generator.
2. Improve the boilerworks to produce enough pressure to drive a turbogenerator.

The second solution is used in modern palm oil mills.

Electrical power production by steam has a number of advantages in palm oil plants since the oil extraction generates waste materials of no food value which can only be used as fuel or hauled away. Most palm plantations have the Tenera variety palm, a hybrid that gives today's best yields per acre. The average composition of a Tenera fresh fruit bunch (FFB) is shown in Figure 1. After oil extraction, waste materials consist of 24% empty bunches containing 75% water, 11% fibers containing 40% water, and 7% shells containing 10% water. The empty bunches are not used for fuel because of their high water content, which gives them a very low heating value. Only the fibers and shells are used as fuel: NHV of the fibers is ca. 2,760 kcal, and of the shells, ca. 4,250 kcal.

The fibers and shells from 1 ton of Tenera FFB (Fig. 2) provide a potential heat supply of

110 kg of fibers at 2,760 kcal	303,600 kcal
70 kg of shells at 4,250 kcal	297,500 kcal
Total	601,100 kcal

The mean efficiency of the boilers employed is ca. 70%, which brings us to

601,100 x 0.70 . . . . 421,000 kcal

The useful heat provided by the fibers and shells is capable of producing

421,000 ÷ 620 . . . . ca. 680 kg of steam

For a medium-size palm oil mill processing 20-25 t/h of FFB, power requirements are

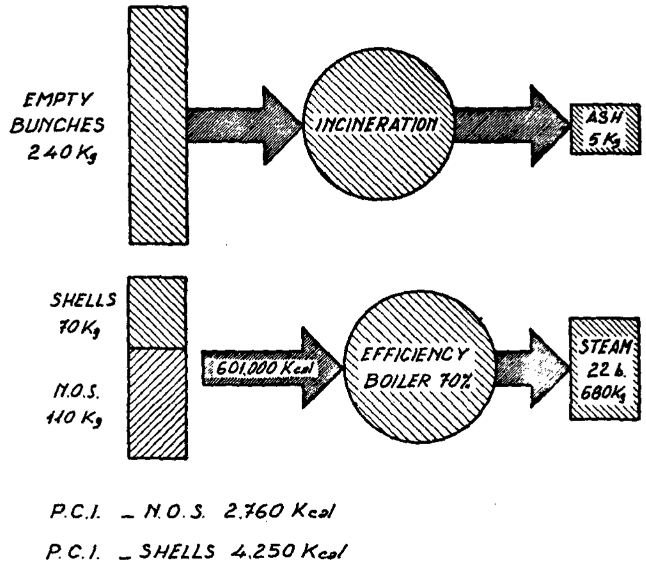

FIG. 2. Palm waste for 1 ton of FFB. b = bar.

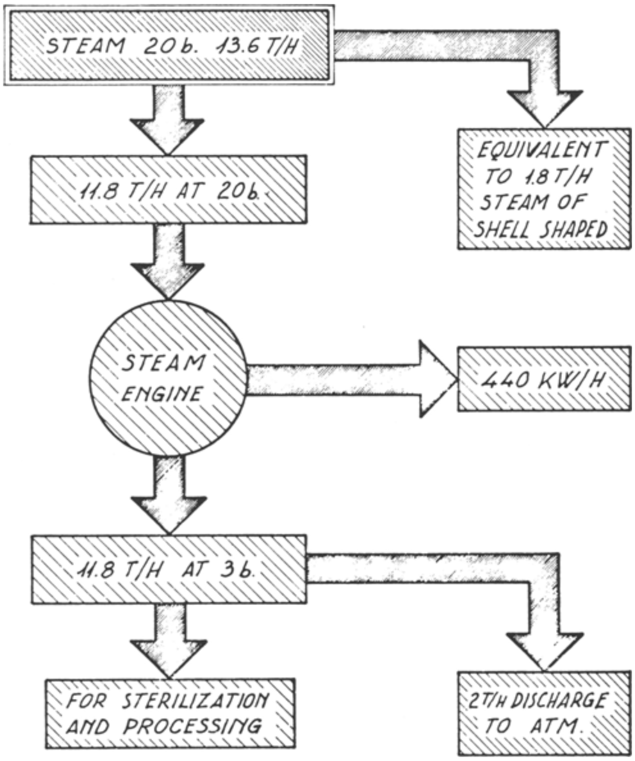

FIG. 3. Steam balance, 20 t/h of FFB. b = bar.

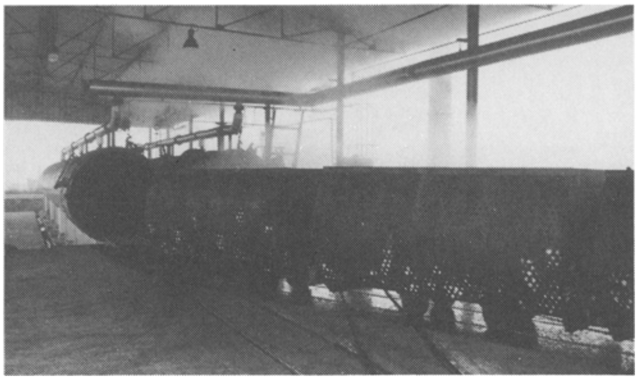

FIG. 4. Sterilization cookers.

1. *Steam at three bars:* For 1 ton of FFB, sterilization requires 250 kg and processing requires 240 kg, i.e., a total of 490 kg of steam at three bars.
2. *Electricity:* The average electrical power requirement for the mills with which we are familiar is 440 kWh for 20 t/h of bunches.

The steam pressure required for processing is very low, which allows for the use of the exhaust pressure from a turbine or a reciprocating steam engine.

To remain within a relatively unsophisticated equipment range, the pressure upstream of the turbines is set at 18-20 bars. This permits the use of medium pressure boilers of 20-22 bars with relatively trouble-free operation and simplified water treatment standards.

The pressure differential between the turbine inlet and exhaust is relatively slight, which means rather high steam consumption–ca. 27 kg per kW. However, this is not particularly important because the steam is practically cost-free.

If we draw up the balance of energy resources and demands in a 20 t/h oil mill (Fig. 3), we arrive at the following:

1. Potential steam production of 680 x 20 = 13,600 tons.

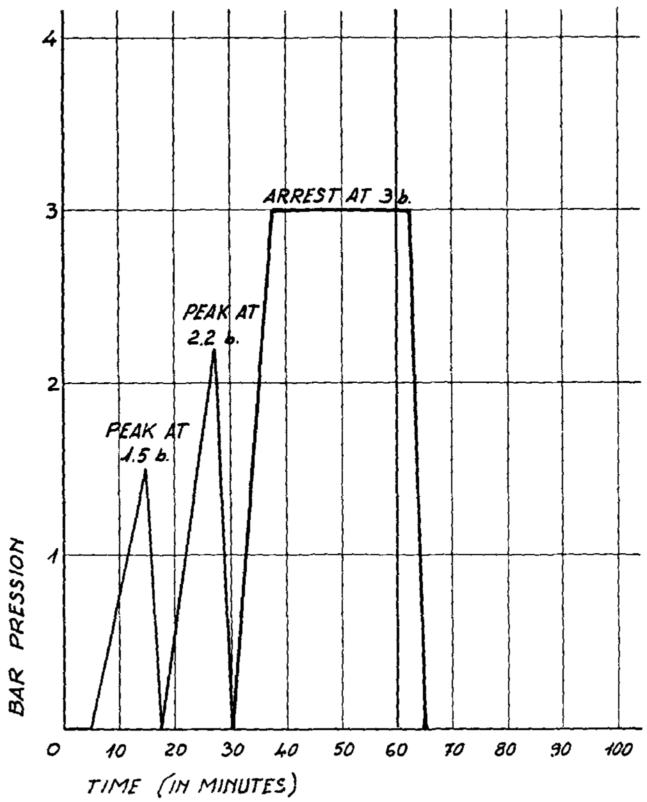

FIG. 5. Sterilization cycle. b = bar.

2. To generate 440 KWH, we need 27 x 440 = 11,800 tons of steam at 20 bars.
3. For sterilization and processing, we need (250 + 240) x 20 = 9,800 tons of steam at three bars.

The balance is therefore positive. Wastes can supply 13,600 tons of steam at 20 bars whereas the turbine requires only 11,800 tons to produce the necessary power, and it returns 11,800 tons of steam at three bars whereas sterilization and processing represent a demand of only 9,800 tons.

According to these figures, the problem appears to be solved since it is proven that we have enough fuel to produce the electrical power and meet all processing demands. However, this is not quite the case in practice because we have, at stabilized operating rates, a steam supply that may be considered regular combined with certain demands, such as steam required for sterilization, that are irregular.

Sterilization is carried out in horizontal cylinders into which cages each containing 2.5 tons of palm FFB are pushed. Depending on the size of the mill, the sterilizers may hold 3-9 cages and as many as 12 in exceptional cases (Fig. 4).

The sterilization cycle is ca. 80-85 min and consists of several phases in order to drive out the air in the sterilizer and within the bunches so that the heat is evenly transmitted to all the fruits (Fig. 5):

1. Scavenging for 5 min
2. Pressure buildup to 1.5 bars
3. Sudden letdown
4. Buildup to 2.2 bars
5. Sudden letdown
6. Buildup to 3.0 bars and hold for ca. 25 min
7. Sudden letdown and unloading of sterilizers

Corresponding heat demands at each stage are shown in Figure 6 for a total of 1,912,000 kcal or 3,750 kg of steam.

If this amount of steam is added to the quantity required for processing, we see that the steam is used in a

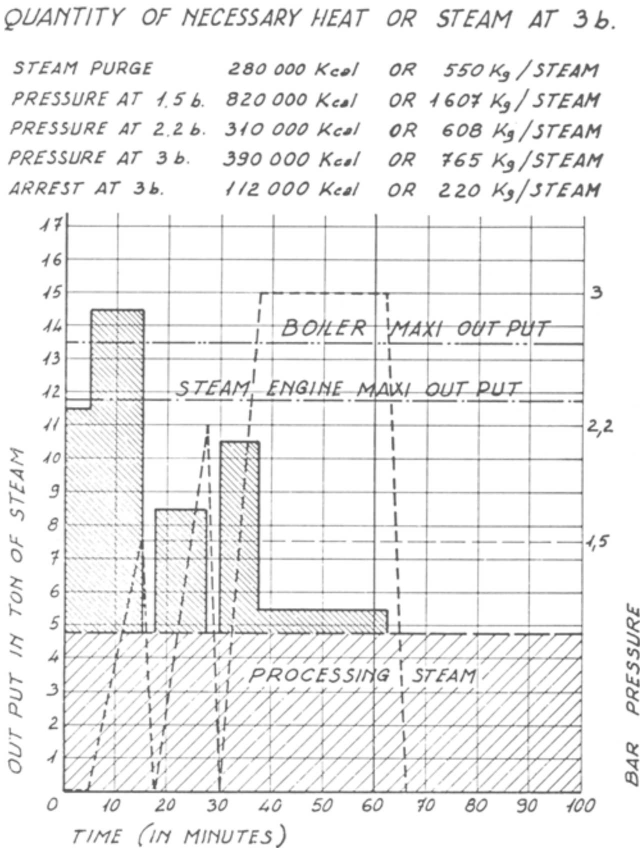

FIG. 6. Steam consumption of one 12-cage sterilizer. b = bar.

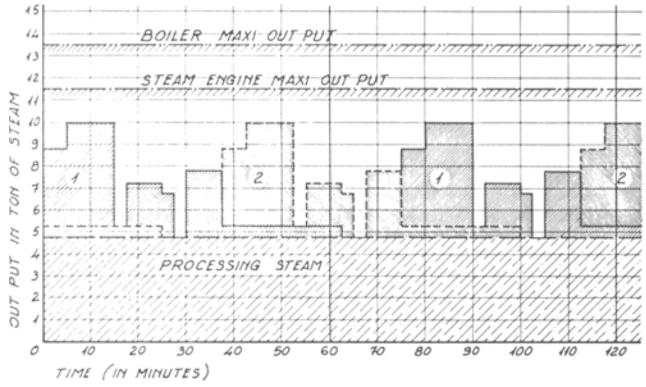

FIG. 7. Steam consumption of two 6-cage sterilizers.

very inefficient manner. The demand is high for 10 min, normal for 40 min, and low for 30 min. To overcome this drawback, the number of sterilizing cylinders is increased. In the case of a 20 t/h oil mill, two sterilizers of six cages each are generally used and the sterilizing cycles are staggered. This results in the flow sheet shown in Figure 7.

As this diagram shows, the steam discharged by the turbine is not always entirely used; to avoid upsetting the turbine operation, a regulating element is brought into play. This element is a steam distribution station that can provide a makeup directly from the boiler plant in the event that the electrical power demand is not high enough to exhaust steam at three bars (e.g., when the mill is started up) or blow off unused three-bar turbine exhaust steam when a few motors or large machines are briefly shut down during processing.

This steam supply goes through a buffer tank that varies from 1 to 12 m^3 depending on the manufacturer (Fig. 8). This tank receives exhaust steam from the turbine as well as direct feed from the boiler via a pressure reducer that functions only when the tank pressure is below 2.5 bars. It

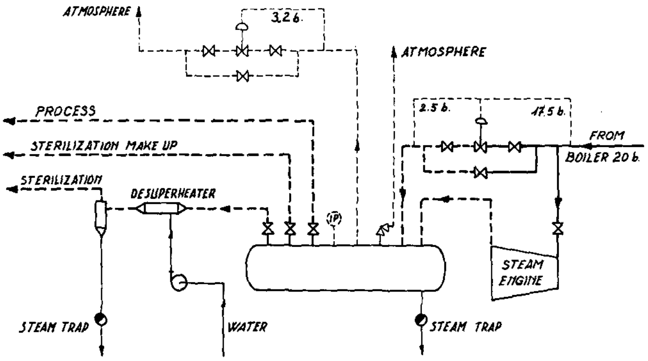

FIG. 8. Steam distribution diagram.

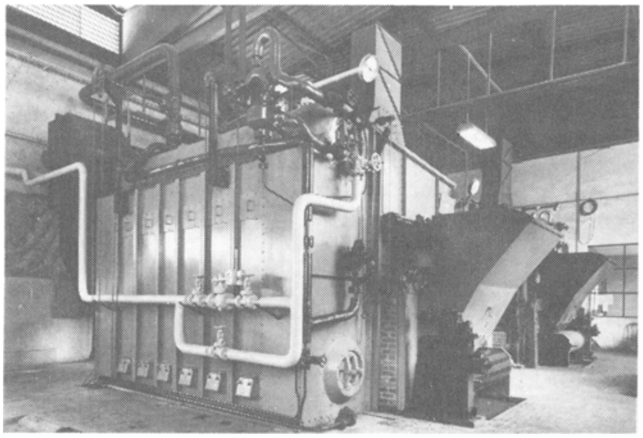

FIG. 9. Babcock boiler.

feeds the sterilizers and has an automatic discharge that blows off excess turbine exhaust to the atmosphere. This relief valve functions as soon as the tank pressure exceeds 3.2 bars.

EQUIPMENT

Following is a discussion of the equipment used in palm oil mill boiler plants and electrical power plants.

Boilers

Theoretically, any boiler built to burn vegetation wastes is suitable. However, experience has shown that the furnace or forehearth has to be modified because the fuel, which is a mixture of shells and fibers, is not always homogeneous. In fact, there is a great difference in NHV between the fibers and shells, and it has been found that shell feed alone can damage the boiler flue system. This is the reason for the general practice of burning fibers first and making up with shells. Any surplus fuel is in the form of shells, which are very hard and imputrescible. They can be used to replace gravel in access roadworks.

Palm wastes often contain flue-damaging silica.

A few manufacturers have tackled this problem and succeded in turning out boilers that are well adapted to palm oil mills. Among such manufacturers, we mention the following: Babcock (Fig. 9), Frazer & Frazer (England), Wickers Hoskins (Australia), and Duray (Belgium) (Fig. 10). We name these four manufacturers because their techniques are relatively diverse and their boilers have proven themselves in the palm oil mill industry. We leave it to the manufacturers themselves to describe their equipment in detail and point out the advantages of their respective designs.

Turbines and Steam Engines

Turbines for palm oil mills must have one quality in particular–simplicity and reliability. Efficiency is second-

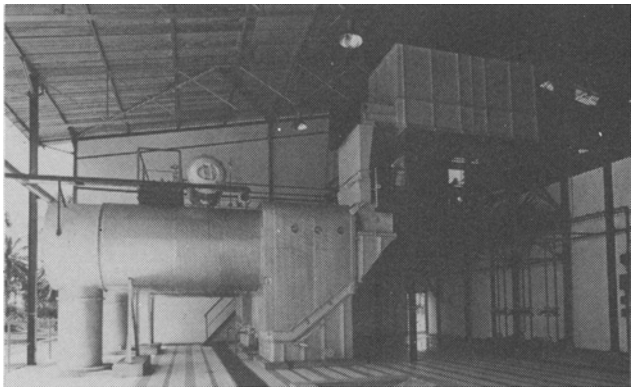

FIG. 10. Duray boiler.

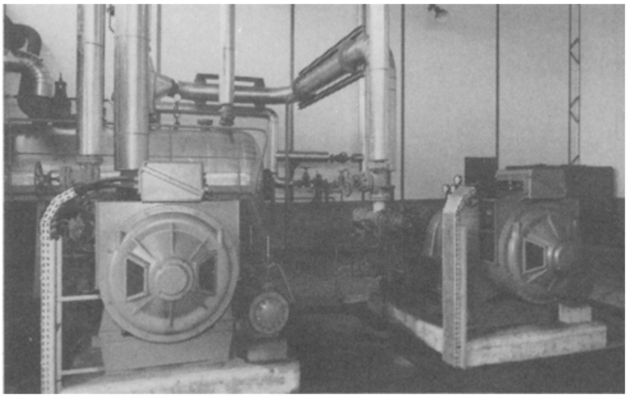

FIG. 11. KKK turbines.

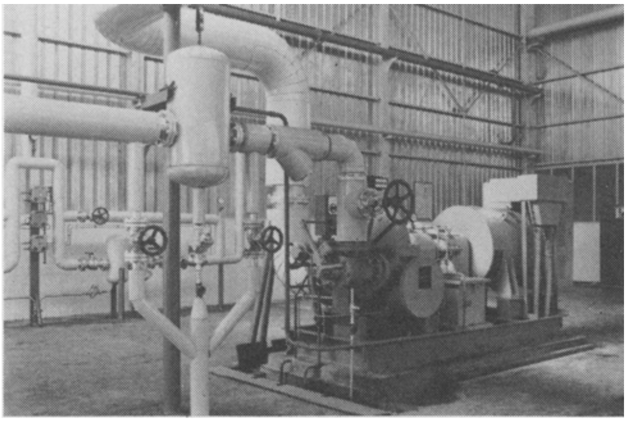

FIG. 12. Worthington turbine.

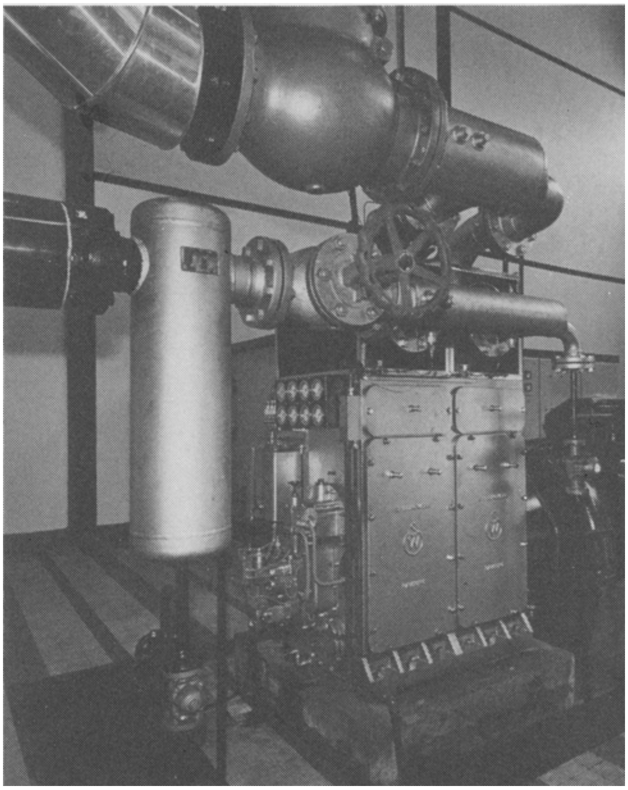

FIG. 13. Steam motor by Spieling.

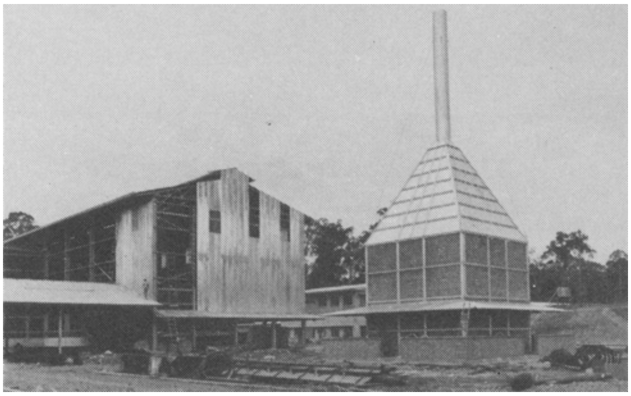

FIG. 14. Incinerator for empty bunches.

ary. As we have seen in the requirement calculations, the electrical energy demand is relatively low—it varies from 400 to 600 kVA. However, the market unfortunately offers very little equipment to meet such needs. The lack of competitors is perpetuated by the reaction of the operator, who tends to buy equipment that has proven its reliability—a natural reaction considering the location of the palm oil mills in the center of plantations far from any industrial center. Breakdowns must be avoided at all costs.

To our knowledge, the turbine manufacturers that have really penetrated the palm oil mill market are KKK (Germany) (Fig. 11), Worthington (France) (Fig. 12), and Manubat (France).

After dealing with turbines, we cannot entirely ignore the fact that there are nonetheless reciprocating steam engines still in use in palm oil mills (but used to drive AC generators rather than belt transmission shafts). The advantage of these engines is that they are more efficient than turbines, they do not require superheated steam, and they can run with less pronounced pressure differentials. On the other hand, for equal power ratings their price is higher and their maintenance more complex. They are mainly used in small palm oil mills processing < 10 t/h as they are the only means of balancing fuel supply with energy demands in such cases. The locomotive type boiler and reciprocating steam engine tandem is best for small mills. It is the only system permitting processing with mill wastes as the only fuel. As far as we know, there is only one steam engine manufacturer, Spieling in Germany, left in the palm oil mill market (Fig. 13).

We hope that if we are wrong, numerous manufacturers in this field will make themselves known. As with the boilers, we leave it to the manufacturers to demonstrate the value of their equipment.

Emergency Generators

The power plant is completed by diesel emergency generators. The installed power for emergency purposes is generally equal to half the total power. These emergency units make it possible to start up the mill and run the extraction section in the event of turbogenerator troubles. There is a great variety of equipment available, and since we cannot name all, we will name none.

The emergency units and turbogenerators can be coupled together. This means a large control and distribution station requiring personnel well trained in electrical power production and distribution.

DISCUSSION

Mainly because of the introduction of electrical power supply, palm oil mills have become very complete industrial installations.

As we have seen, energy-producing equipment in palm oil mills is not particularly efficient. It is even very inefficient in many cases. From the technical viewpoint, it is obvious that efficiency improvements are possible, but in economic terms such improvements are unnecessary since the wastes cannot be used for anything but fuel and their quantity has been proven amply sufficient to run a mill. All savings in waste consumption would create additional operating costs as it would become necessary to haul the wastes quite a distance from the mill and destroy them by unexploited combustion (which is not entirely free of risk). The problem has already arisen with respect to the empty bunches; costly incinerators (Fig. 14) must be installed to dispose of them.

The palm oil industry is one of the rare fields in which no attempt is made to save energy and the reliability of the equipment prevails over efficiency. A palm oil mill cannot afford serious breakdowns because it is usually isolated from the breakdown services of industrial centers and, with a perishable feedstock, long shutdowns are out of the question. Palm FFB that are not processed within 48 hr after cutting will yield a low grade oil, which means considerable operating losses.

Such are the methods used in the modern palm oil mill power supply. It has taken a big step forward to permit processing of the large palm FFB production of today's vast industrial plantations.