

## Drying of Beet Pulp in Superheated Steam

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## CONTENTS

1. Introduction
2. How it works
3. The DDS steam dryer  
at Stege Sugar Factory
4. Nangis Sugar Factory, France
5. No pollution
6. Improved product
7. Energy saving by integrating steam  
pulp drying in a sugar factory
8. Mixing molasses in pellets
9. Special features of the DDS steam dryer

## 1. Introduction

The high energy prices in the beginning of the 80'es have been an incentive to develop new and less energy-consuming processes. The intensified requirements for reducing the air pollution have also encouraged the development of new technologies.

Traditional drum driers for drying beet pulp require about one third of the energy needed by a sugar factory if it has to dry all the beet pulp. The air pollution from drum driers is quite considerable with regard to emission of solids and foul smelling gases.

In 1981 DDS (the Danish Sugar Corporation) started the development of a new drying method on a laboratory scale. In 1983 a pilot plant was erected, and after two seasons enough data was gathered to build a full-scale plant at Stege Sugar factory. This plant was further developed in the following years.

1987-88 was nominated the European year of the Environment by the European Council of Ministers. In this connection the drier was awarded a prize presented by His Royal Highness Prince Henrik of Denmark.

In 1990 a dryer with an evaporative capacity of 25 t/h was erected at Nangis Sugar Factory in France.

The new drying method offers three major advantages:

- \* energy saving
- \* no pollution of the environment
- \* improved product quality

## 2. How it works

The pulp is dried in a cell-divided fluid bed carried by a vertical flow of superheated steam circulated within a vessel under pressure.

Fig. 1 shows an open view of the drier. By the screw conveyer (1) the pulp is introduced into the first of the 16 cells placed around the superheater (7) in the centre. The impeller (8), which is the only moving part of the drier, blows the superheated steam up through the perforated plates at the bottom of the cells.

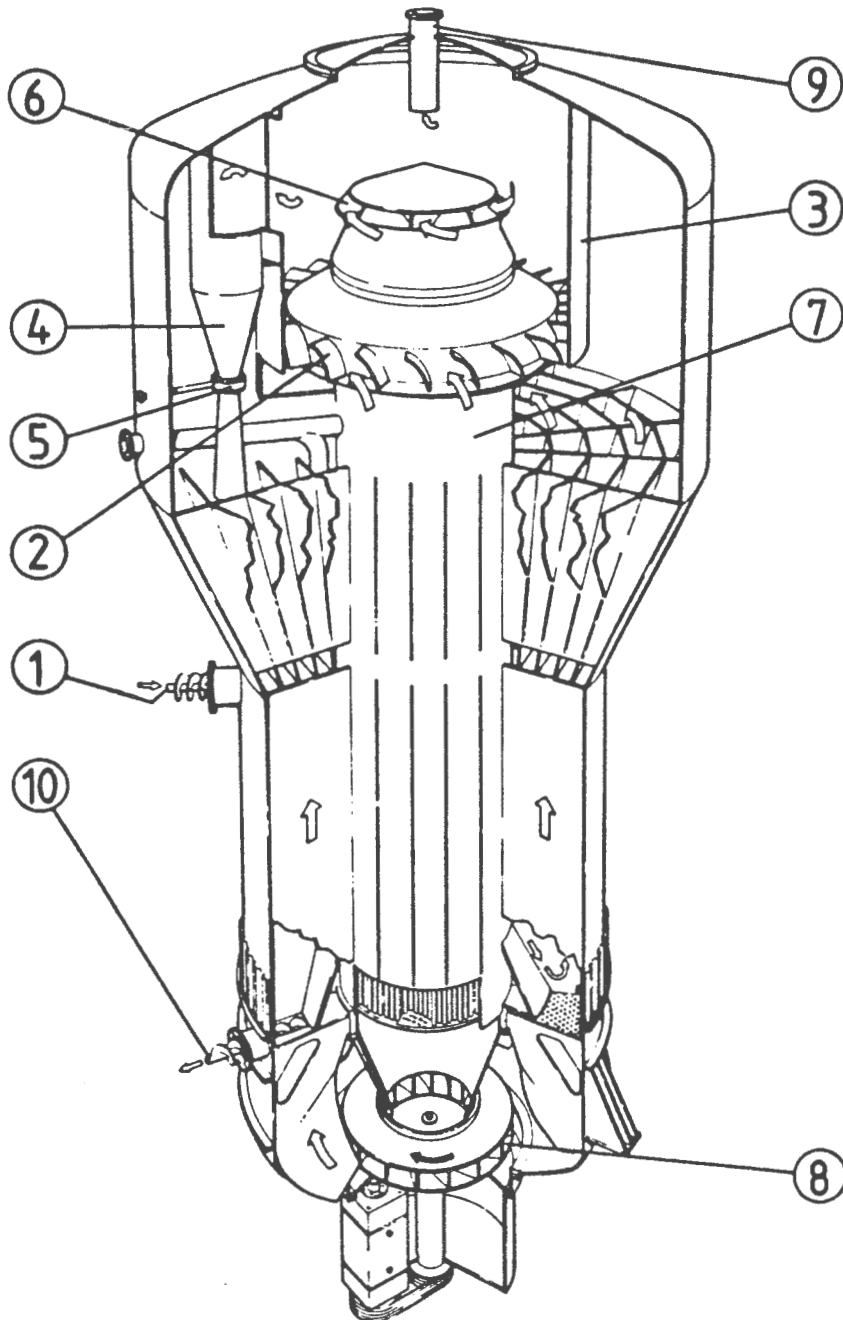
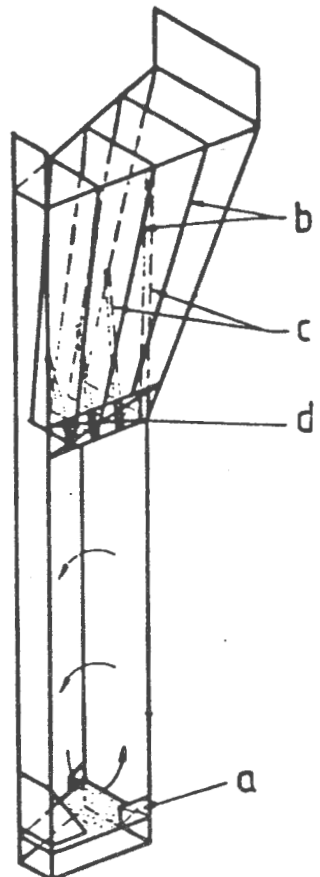


Figure 1  
574

Fig. 2 shows one of the cells. The beet pulp is kept moving by the flow of superheated steam coming from below. In the lower part of the cell, the horizontal cross-sectional area has been reduced by filling in the triangular body shown. This results in higher average velocity of the steam; in this way large particles will also be kept moving. The triangle also creates a rotating movement of the material, and all large particles will thus find their way to the opening (a) of the next cell. The light particles will be lifted to the upper part of the cell, where the inclined plates (b) distribute the flow of steam in the large cross-sectional area. The pulp particles will fall down on the upper sides of the plates and slide downwards on them. Some of the particles will be guided by the rails (c) towards the opening (d) to the next cell. In this way, the pulp particles will finally reach cell 16, from where they are carried away by the screw conveyor (10). A proper design of the rails (c) and the bottom part of the cells results in a prolonged retention time of the large particles compared to that of the small ones, corresponding to the difference in drying time.



575 Figure 2

The steam that passes up through the cells to the top of the drier will contain some dust particles (smaller than 1 mm). This dust-filled steam passes between the stationary blades (2) creating a vortex in the cylinder limited by the wall (3). The dust collects on the wall and passes through a slot into the side cyclone (4), from where it is sucked into cell 16 by the ejector (5).

The dustfree steam passes between the stationary set of blades (6), which form some channels in which the kinetic energy of the vortex is transformed into elevated pressure, whereby the steam is distributed on all the tubes of the superheater (7). During its passage down through the tubes the steam is superheated by steam of higher pressure condensing on the outer surface of the tubes. From the bottom of the apparatus the steam is again blown through the cells by a blower wheel (8), and the big circuit is closed. The steam evaporated from the beet pulp is discharged through the pipe (9) at the top. Since the steam is taken out at the centre of a vortex, the steam contains less than 10 ppm dust, which means it can be used in the juice evaporator without any risk of dust accumulation.

The energy supplied to the dryer is consequently recovered, and the air pollution known from drum dryers does not exist.

### 3. The DDS steam dryer at Stege Sugar Factory

The first full-scale plant was erected at Stege Sugar Factory in Denmark in 1985. In the first years the dryer was further developed and optimized, and its capacity increased from 6 to almost 9 t/h water evaporation. Typical data from the 1989 season was as follows:

Pulp supplied	12.2 t/h	25.8% DS
Dried pulp	3.5 t/h	90% DS
Evaporation	8.7 t/h	
Steam supplied	10.2 t/h	12.5 bar g
Steam produced	9.8 t/h	2.9 bar g
Electric power supply	285 kW	

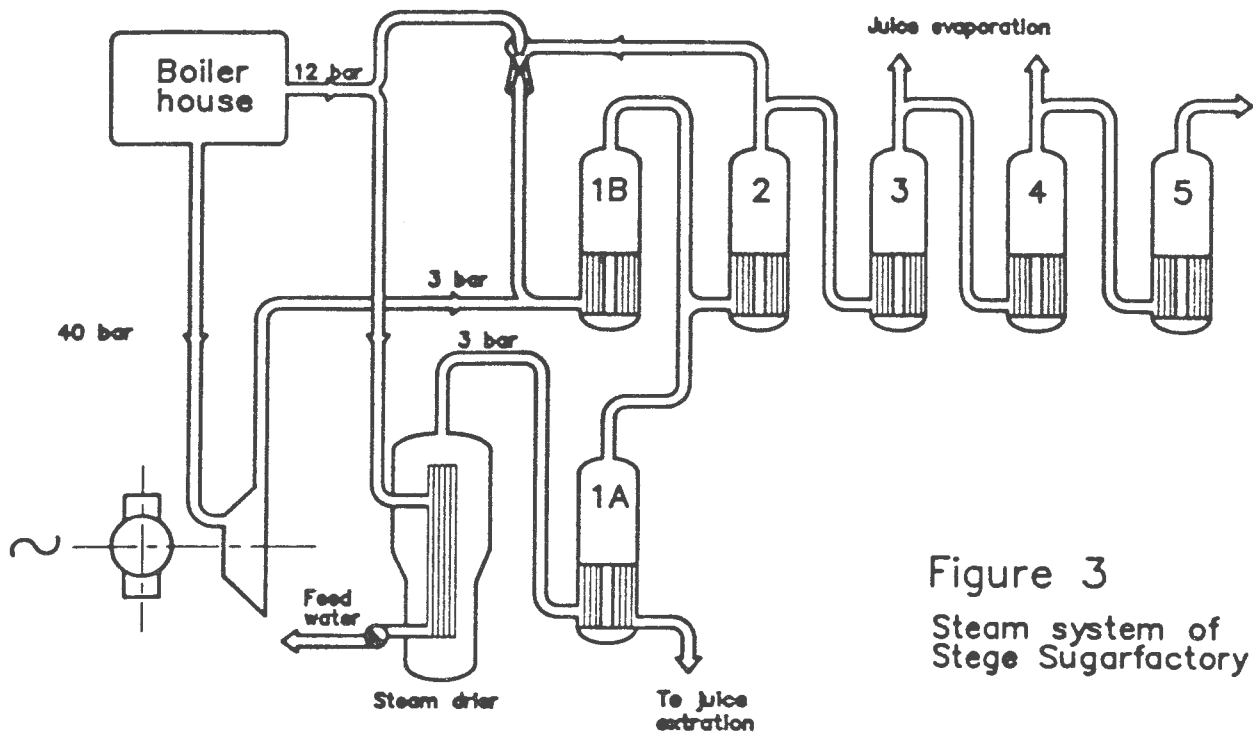


Figure 3  
Steam system of  
Stege Sugarfactory

The steam system at Stege Sugar Factory is shown in figure 3 in a simplified form. The dryer is supplied with 12 bar g steam from boilers already in operation before installation of the dryer. The first effect of the evaporator is divided in two parallel vessels. One (A) is supplied with steam from the dryer and the other (B) with exhaust steam from the turbine. The boiler house is supplied with feed water from the superheater in the dryer and from effect 1B. The condensate from 1A is used as fresh water in the diffuser.

At Stege only 12 bar g steam was available for the dryer. If the same dryer is supplied with steam of a higher pressure, the steam circulating in the dryer will be further superheated and thereby increase its capacity. This will be demonstrated in 1991 as the dryer from Stege will be moved to Gørlev Sugar Factory, where it will be supplied with 25 bar g steam. Gørlev Sugar Factory, which has not till now had any pulp drying is planning to install another and bigger DDS dryer. The dryer size is determined by the top diameter. The Stege dryer is a 6 m dia dryer. The additional dryer planned in Gørlev is a 8 m dia dryer. The evaporative capacity of the two dryers as function of the steam pressure is illustrated in figure 4.

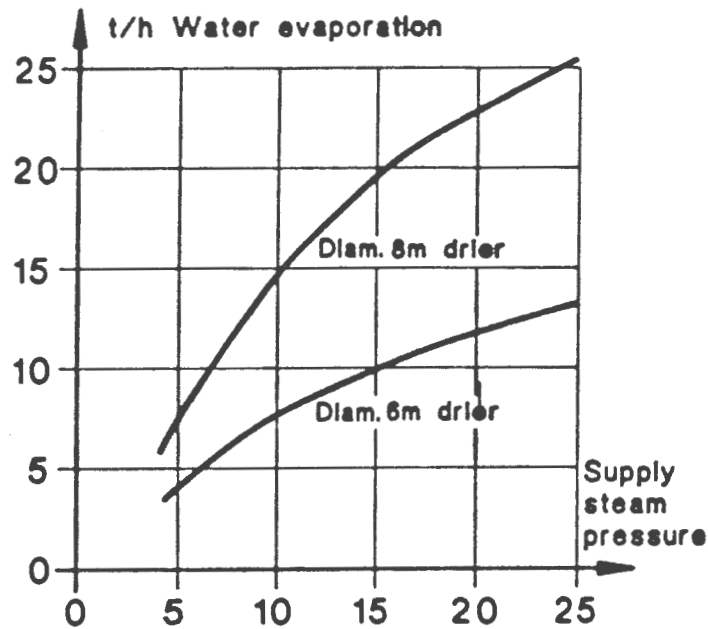


Figure 4  
Evaporation capacity with  
2.9 bar gauge in drier.

#### 4. Nangis Sugar Factory, France

After a visit at Stege Sugar Factory in the season of 1989, the factory management of Nangis Sugar Factory, owned by Lesaffre Frères S.A., decided to have a steam dryer installed for the 1990 season. Nangis had not previously dried its pulp, so the project included not only the dryer, but a complete plant with transport system, granulation, pellet cooling, silo for temporary storing and a new building. The evaporator was extended with one extra effect placed in front of the existing six effects. The time for implementing this comprehensive project was very short, but the plant was ready for the start of the season.

The dryer erected at Nangis is a 8 m dia DDS dryer with an evaporative capacity of 25 t/h and supplied with 25 bar g steam. The mass and energy balance is shown in figure 5.



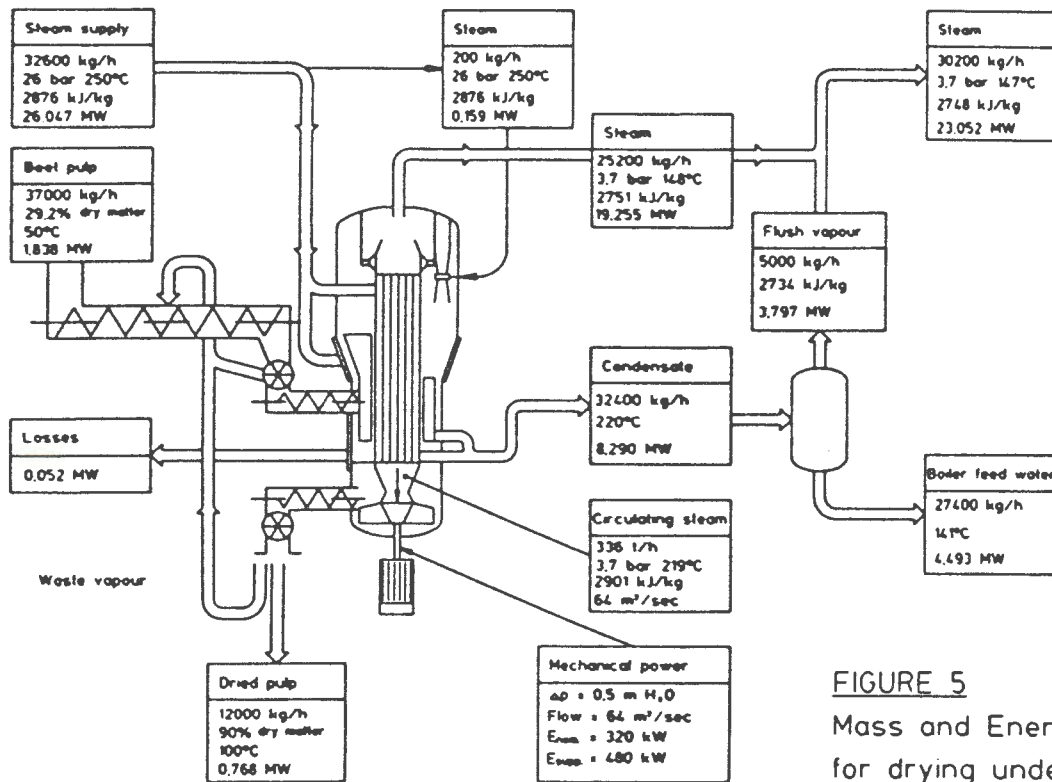
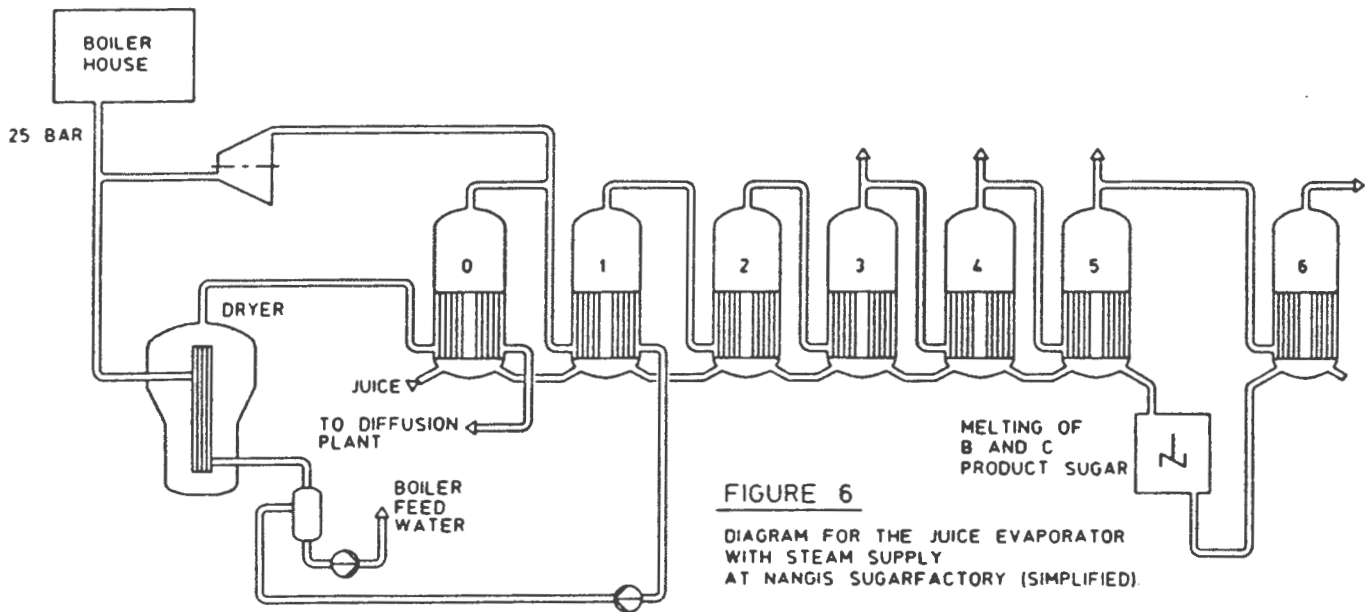


FIGURE 5  
Mass and Energy balance  
for drying under pressure

At Nangis some tests were made with alkaline diffusion, during which the dry substance in the pulp went up to 38%. Under other conditions the dry substance content was only 22%. These tests provided the opportunity to prove that the dryer's evaporative capacity does not depend on the dry substance in the wet pulp even within that wide range.

As mentioned before, the juice evaporator was extended from 6 to 7 effects. In figure 6 a simplified diagram shows the steam system. After installation of the DDS dryer, Nangis obtained an extremely low fuel consumption of only 12 kg heavy fuel oil per 100 kg white sugar including steam drying. This is probably a world record, which the factory expects to improve even more in the coming season. But as only 25 bar g steam is available at Nangis, and part of the steam to the evaporator comes from the dryer, the factory cannot produce all the electric power necessary by itself. Some power has to be bought from the public grid. In spite of this cost, the energy costs are still reduced taking into consideration the great fuel saving. This will also be the case outside France, even if electric power is more expensive than in France.



### 5. No pollution

One of the greatest advantages of steam drying is that there is no environmental impact on the surroundings as is the case with drum drying. The steam from the dryer is condensed, so there is no emission to the atmosphere and consequently no pollution with dust or smell. The condensate formed by condensing the steam is suitable as fresh water in the diffuser after cooling in a heat exchanger with thin juice. It contains a little acetic acid (100-200 ppm) and a little dissolved ammonia ( $\text{NH}_3$ ), both of which are evaporated from the pulp in the drier. The pH varies according to the content of ammonia. In Stege the pH fluctuated between 7 and 8 and in Nangis between 7.5 and 8.5.

## 6. Improved product

When pulp is dried in its own superheated steam, no impurities from flue gas will be admixed, such as heavy metals and sulphur dioxide.

As there is no oxygen in the dryer, no oxydation of the product occurs, which means no loss of dry substance and no half burnt particles in the dried product. In drum dryers the loss of dry substance is between 3 and 10% depending on the load of the drum dryer (inlet temperature 600 to 1050°C).

In addition the feed value is improved by up to 20% according to tests made in the following way:

Samples of steam dried and drum dried beet pulp in nylon nets have been injected direct into the paunch of cows at the Royal Danish Institute of Cattle. After various retention times the samples were taken out again, and the degradation of the solids as a function of the time was determined for pulp dried in the two different ways. Based on this information the recovery of the product was calculated. Especially dairy cattle with a short transition time through the digestive organs will have a higher efficient yield of the feed which is steam dried (+20%).

## 7. Energy saving by integrating steam pulp drying in a sugar factory

A steam drying plant does not consume energy. The energy supplied to the dryer as for instance 25 bar g steam leaves the dryer in a usable form as 3 bar g steam and hot condensate. But as the pressure of the steam has been reduced, the possibility of transforming part of the energy into electric power is not utilized.

Any thermal drying means transformation of energy.

In drum dryers none of the energy supplied as fuel leaves the plant in a usable form. This means that it is neither possible to recover the energy nor produce power. In order to evaporate 32 t/h in a drum dryer, you would have a fuel consumption of 26 MW, which is all lost, including the 6 to 10 MW that could have been transformed into electric power.

Almost the same amount of energy is consumed by a steam dryer, and more than 90% leaves the dryer in a usable form, mainly as 3 bar g steam. If a dryer with a capacity of 32 t/h is supplied with 16 bar g steam, the possibility of producing electric power is reduced by 2 MW as the steam pressure reduction could have been done in a turbogenerator producing said 2 MW.

When integrating steam drying in an existing sugar factory, you must take into consideration the operational conditions of the factory in question. If the sugar factory reduces the pressure of live steam expressly for the first effect in the evaporator, this pressure reduction could instead be effected in the DDS steam dryer with only an initial rise in fuel consumption. The live steam used for steam compression if any could instead be used for steam drying. This would cause an increase in condensate loss and fuel consumption of the boiler house, which would, however, constitute only a small part of the amount of fuel needed for drum drying.

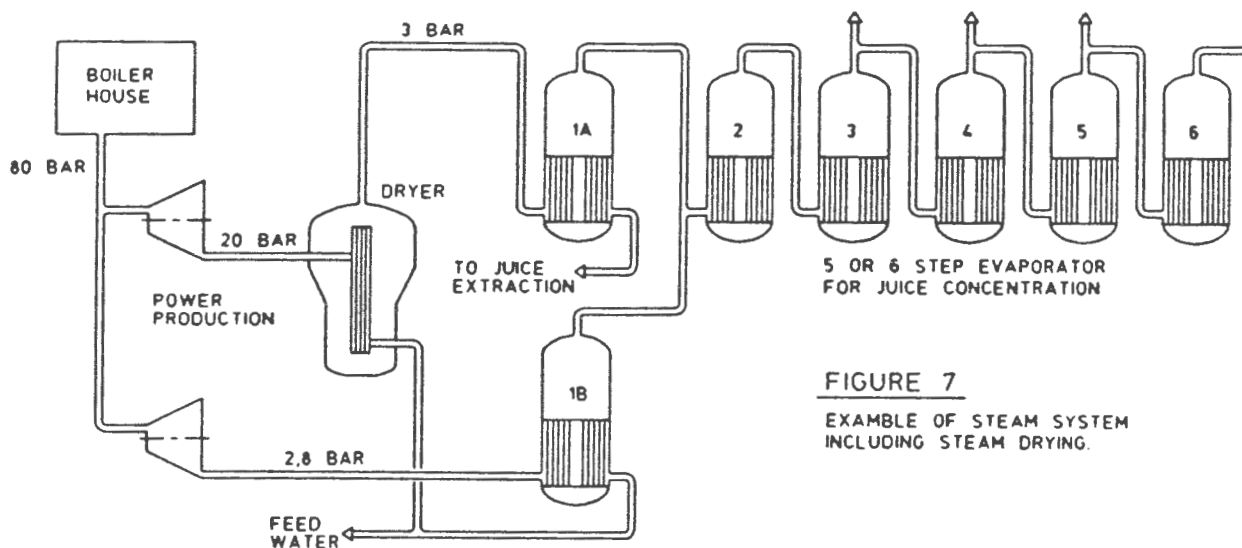


FIGURE 7  
 EXAMPLE OF STEAM SYSTEM  
 INCLUDING STEAM DRYING.

If a high power production as well as a low fuel consumption is required, the layout could be as shown in figure 7. The turbine shown has an outtake of 20 bar g steam going to the dryer. There could also be two separate turbines, one with a 20 bar g back pressure and another with a 2.8 bar g back pressure. Please note that the evaporator has six effects and no steam compression.

With this set-up you will have a very low fuel consumption and a power production which depends on the live steam pressure. Figure 8 indicates the power production as a function of the live steam pressure for a sugar factory processing 6,000 t beets per day. It is assumed that the pulp is pressed to 28 % dry substance. If, for instance, you take a sugar factory with 60 bar g live steam, where the DDS dryer is supplied with 20 bar g steam, the power production will be 5.7 MW and the fuel consumption 2.48 % standard coal on beet corresponding to 1.8 % heavy fuel oil on beet.

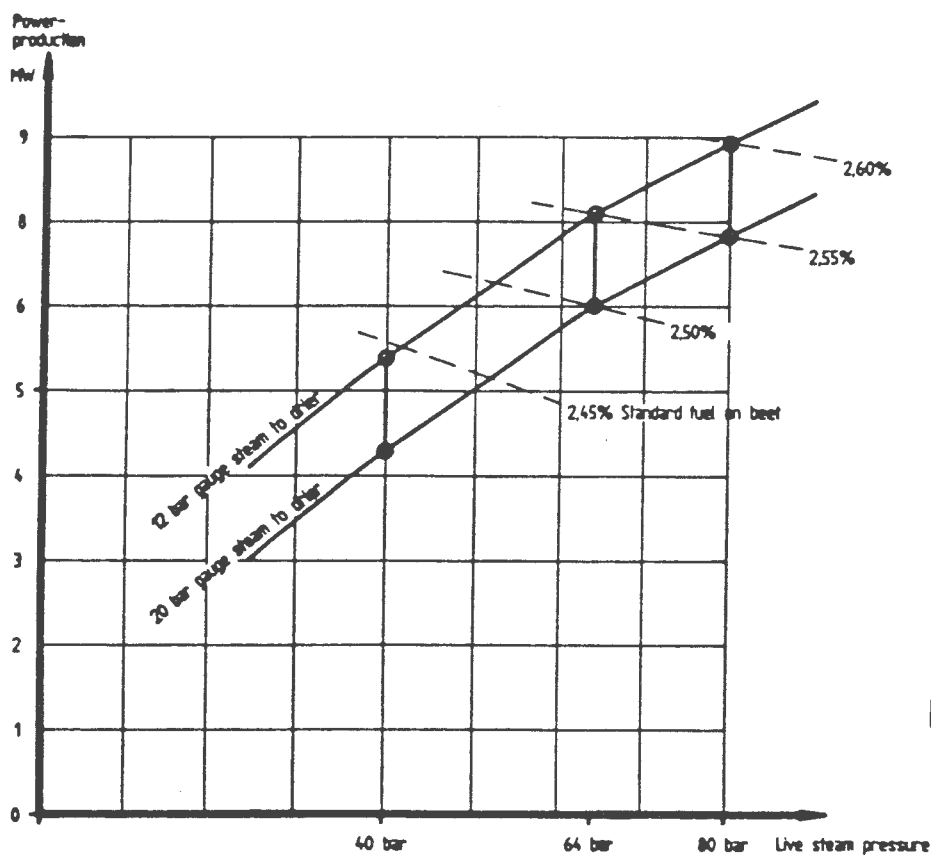


Figure 8

### 8. Mixing molasses in pellets

It is possible to admix molasses into the pulp before drying it in a DDS dryer. But furthermore and contrary to drum dried pulp, you can admix large quantities of molasses into the steam dried pulp at the very moment the pulp is discharged from the dryer. The following three conditions must be present:

1. The product is very porous after having just been depressurized
2. All pores are filled with steam
3. The product has a temperature of 100°C

As an example you can mix 50 kg 77 Brix 110°C hot molasses into 100 kg pulp dried to 91% dry substance. The molasses must be admixed at the very moment the pulp leaves the dryer and before air is admitted. After some seconds of intensive mixing, the pulp is slowly stirred for 10 minutes. During these 10 minutes the pulp is cooled by air at 70°C, pressed to pellets and then cooled again. The remaining heat will evaporate so much that the final product will have a DS content of 90%.

Pellets made in this way are especially attractive to horses which often refuse to eat drum dried pellets.

## 9. Special features of the DDS steam dryer

The DDS steam dryer is today fully developed and has proved its capability to dry beet pulp in a way which has many advantages compared to the conventional drying processes.

### \* HIGH RELIABILITY

The DDS steam dryer has demonstrated its ability to run a whole season without production stops caused by the dryer.

### \* AUTOMATIC OPERATION

The DDS steam dryer is easy to control, and the operator can be placed in a central control room away from the dryer.

### \* COMPACTNESS

The DDS steam dryer requires very little space. Three DDS steam dryers, type 8, need no more space than a drum dryer with 20 t/h evaporation.

### \* NO FIRE RISK

As drying takes place without admission of air, there is no risk of fire.

### \* LOW MAINTENANCE COSTS

There is only one moving part - the impeller - in the DDS steam dryer. In the cells there is measurable wear only after 5 years.

### \* LOW NOISE LEVEL

About 70 dBA

### \* NO DUST IN THE DRYING PLANT

As drying takes place in a closed system, the drying plant is totally free from dust in the screw conveyors.

THE THREE MAIN CHARACTERISTICS ARE HOWEVER THE FOLLOWING:

1. NO POLLUTION

No emission of dust or odour, because the product is dried in a closed system. The condensate arising from condensation of steam is suitable for juice extraction.

2. ENERGY SAVING

More than 90% energy saving is possible by recovering the steam leaving the dryer and using it in the evaporation plant.

3. IMPROVED PRODUCT

As the product is dried without admission of air, you avoid any oxidation and loss of dry substance. In addition the product is not contaminated with flue gas impurities, and the heat treatment increases its digestibility.

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