Introduction
It has always required much more energy to remove a ton of water from beet pulp than from thin
juice. This no longer holds true. Now, just imagine if what the following diagram shows was possible.

![Figure 1 The Dream](image1)

This is but still a dream. Beet pulp is not fluid, and the heat transfer coefficient to pulp is
different from that to juice. Nevertheless, the dream is not that far out of reach, even though
some difficulties still need to be solved.
Now, however, these difficulties can be overcome. The pulp can fluidise in a fluid bed, and the
transfer of energy to the pulp can be achieved by superheated steam. Thus the following
becomes possible.

![Figure 2 The Possible](image2)

The new alternative is to dry pulp in a pressurised fluid bed with energy supplied in the form of
steam at 16 bar. This steam leaves the dryer as a pure condensate to be returned to the boiler as
feed water. All the energy supplied leaves the dryer as steam at a suitable pressure for the first
step of the evaporator. The steam, in fact, is the water, that has evaporated from the pulp. By
using the steam in the first step of the evaporator, a full energy recovery is achieved and air
pollution from dust and smell is fully avoided.
The evaporation from the pulp at most sugar factories is about half of the evaporation of the first
step of the juice evaporation. This step is split in two parallel bodies - A and B. Variations in the
evaporation from the pulp is compensated by a opposite variation on the evaporation from 1B.
That gives a steady flow from the boiler house, and the control of the thick juice brix is not disturbed.
 Feed water for the boiler is recovered from the dryer and 1B.
 Drying in a closed vessel solves all air pollution problems for good.
 Furthermore the product is not oxidised, so the product losses well known from drum-drying no longer occur.

The first pressurised fluidbed steamdryer was developed from 1981 to 1990 at the Danish Sugar Corporation (Danisco A/S). This was published at CITS 1987 (1), and further described in International Sugar Journal 1992 (2) and Zuckerindustrie 1995 (3).

Now a new pressurised fluid bed steamdryer is available. It is based on a new independent patent pending world-wide. This new steamdryer offers 40% more capacity for the same cost.

**How it works**

The pulp is fed through the rotary valve (1) to the screw (2) that brings the pulp into the pressure vessel (3) filled with superheated steam. The only moving part in the dryer is the impeller (4) circulating this steam up through the perforated curved bottom (5) into a low ring shaped fluid bed (6) where the pulp is kept “fluid” swirling around as the arrows indicate. Guiding plates (not shown) make the pulp move forward all the ring around to the discharge screw (8) and subsequently out through the rotary valve (9). The lighter particles are blown up between the plates (7) radiating from the heat exchanger (12) outwards towards the conical vessel wall without reaching this. Due to the reduced velocity the particles fall onto the forward inclined plates, slide down on those, and pass the gap between the plates and the conical vessel wall. In this way also the lighter particles pass forward around the dryer and arrive at the discharge.

Figure 3. A look into the dryer.

The circulating steam arrives into the upper part of the dryer where dust is separated in the main cyclone (10). By means of an ejector the dust passes out through the pipe (11) and goes out with the dried product.

The dust-free steam moves downwards inside the tubes in the heat exchanger (12) where it is reheated, as steam at elevated pressure is supplied through the pipe (13). The supply steam is condensed and leaves the dryer through the pipe (14). With a higher supply steam pressure, a higher temperature of the circulating steam is achieved, and this again increases the drying potential of the steam. Thus, the capacity of the dryer is dependent upon supplied steam pressure as illustrated by the curves in figure 4.
The steam evaporated from the pulp leaves the dryer through the pipe (15) right in the center of the vortex. That gives a steam so dustfree, that it can be condensed between pipes in a tube bundle. The small quantity of dust (2 to 10 ppm) will be flushed out with the condensate. Using this steam, and the energy in the hot condensate leaving the dryer through the pipe (14) almost a 100% energy recovery is achieved.

Drying under pressure requires pulp to be fed into the pressure system and out again. This is done through rotary valves. They have a design originally developed 40 years ago in the Swedish paper pulp industry, where they were used for feeding wood chips into the cookers having 7 to 12 bars (103 psig. to 176 psig.). That was also feeding into steam under pressure. Beet pulp compared to wood chips has a larger surface area, on which the steam condenses so fast already in the rotor, that it causes feeding problems. This has made modifications on the valves necessary. In the paper (3) is this problem closer described, as well as solutions, that make the valves operate well today.

This new dryer is different from the existing pressurised fluid bed dryer, by having a low ring shaped fluid bed with a curved bottom. The “old” type has high vertical cells. This has demonstrated the disadvantage of causing medium and smaller particles to be overdried, while the coarse particles are not yet dried. That reduces the product quality and in serious cases it is difficult to reach the wanted average dry substance. This problem becomes more severe with a wide variation on the particle size.

The new dryer has a different upper part, which allows a larger circulation of steam in the dryer without having too much pulp blown up in the dust separation cyclone. Thereby 20 to 25% more capacity for the same diameter of the dryer is obtained. The new dryer is lower, and the costs are reduced by 10 to 15%. Related to price the capacity is thereby increased 40%.

Most of the new ideas have already been successfully tested on plants in operation.

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![Figure 4. Dryer Capacity Related to Supply Pressure](image-url)
Mass and Energy Balances.

Figure 5 illustrates the energy and mass flow for a size G dryer supplied by 22 bar abs. (323 psig.) As seen is the evaporation 30.6 tons water per hour. The highest capacity unit is 50 tons water evaporated per hour by a size H supplied by 28 bar abs. (397 psig.)

Figure 6 shows an example, where the steam dryer size G is working as shown on figure 5 supplied directly from a boiler. The hot condensate is fed back into the boiler. It is seen, that the effect supplied by the fuel (23918 kW) is about the same as the effect passing on to the evaporation (23689 kW) though 10% is lost in the boiler. The explanation is, that the wet pulp brings in more enthalpy than the dried pulp takes out, and the energy supplied by the fan also contributes to the enthalpy, that ends up in the steam.

Figure 5. Mass and Energy Balance.

Figure 6. Mass and Energy Balance for a Dryer and a Boiler.
Fuel saving and power production.

Any thermal drying takes energy. After the drying is the energy still there. By conventional drying the used energy is lost in the gas going out the stack. This is a mixture of water vapour, gas from the combustion, air and dust. The temperature could be 120 °C and the dewpoint 80 °C. A recovery of the energy from this is not practically possible. All the energy is therefore lost along with the part, that could have been converted into electric power.

<table>
<thead>
<tr>
<th>Energy consumption by drying</th>
<th>Energy as heat supplied</th>
<th>Energy recovered</th>
<th>Net energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drum drying</td>
<td>700 kcal/kg water evap.</td>
<td>0</td>
<td>700 kcal/kg</td>
</tr>
<tr>
<td>Steam drying</td>
<td>600 kcal/kg water evap.</td>
<td>540 kcal/kg water evap.</td>
<td>60 kcal/kg</td>
</tr>
</tbody>
</table>

*Figure 7. Energy consumption for drying.*

Steam drying takes about 15% less energy than drum drying. The consumption is smaller because no air is heated and released hot. But the most important is, that the energy supplied leaves the steam dryer as a steam that the sugar factory can recover because the pressure and temperature fits for the supply to the evaporators. Therefore the almost 100% of the energy needed for drum drying can be saved when changing to steam drying. But there is a trade-off.

The steam dryer requires a supply of steam with a pressure in the range 12 to 25 bar (176 to 368 psi). This steam should either come directly from a boiler or from an outtake on the turbine as shown on figure 2. That means that the electric power production is reduced. That part of the energy that could have been converted from heat to electric power is not lost. It is still there as heat, but the possibility to convert it to electricity is lost.

If you practice energy saving in the sugar factory in general you should hopefully be able to see this saving as a reduced need for steam. This does also result in less steam through the turbine and thereby reduced power production.

Figure 8A shows an example of the energy flow through a sugar factory. In this case the factory has a fair fuel consumption the flow of steam to the first effect is 28% on beet. The width of the flow shown is proportional to the energy flow, which also is indicated in MW. The numbers on figure 8 is based on:

- 6000 metric t beet per day
- Boiler Pressure 40 bar = 588 psi
- Standard fuel has 7000 kcal/kg
- All pulp pressed to 28% DS and dried
- Evaporation in dryer: 31000 kg/h
- Supply steam to dryer has 16 bar = 235 psi

Starting from the situation shown on 8A fuel saving could either be done in the sugar factory itself (figure 8B) or by introducing steam drying of the beet pulp (figure 8C).
In the case on figure 8B the consumption in the sugar house is reduced by 25%. This is only possible through two stage panboiling, which is an expensive installation and further the number of evaporator stages must be adjusted by one step more. It brings the needed amount of fuel down from 4.21 to 3.5% standard fuel on beet, which is a reduction of 17%. But the power production is reduced by 1.7 MW.

In the case shown on figure 8C steamdrying of all pulp has been introduced. There are no modifications in sugar house and evaporation. It is seen, that all the fuel needed for the drum drying is fully saved, but the power production is also in this case reduced by 1.7 MW. The saving on the total fuel is over 31%.

Comparing B and C it is seen that C gives a much higher fuel saving. They both cost the same on power production. The investement from factory to factory will be very individual, but both B and C will be a few millions US dollar. C solves the biggest air pollution problem for good.

**Pulp pressing.**

The dry substance of pulp pressed in screwpresses has a well known dependence on the rpm. of the spindle and so the capacity. The dry substance can be in the range 22% to 34%. A demand for a high dry substance will require many presses turning slowly. Thereby the press station will be expensive. But the demand for drying capacity will be reduced. What is the right DS to aim for? The trend in Europe has so far been to aim for a DS on 30% to 34% in order to save fuel in the drumdrying or in order to reduce the investment in steamdrying.

The investment in presses as a function of the achieved DS is calculated for an installation of Stord 3500 presses. A price of 1,60 Mill US $ per press fully installed inclusive all conveyors, piping etc. is used. Addition of gypsum, pH < 5 and normal cossettes quality is assumed. Then the investment for the next ton of water per hour removed by pressing is calculated. The result is shown on the curve figure 9. Take an example. Starting from 28% DS there must be invested
$120 000$ for one extra ton of water pressed out. As presses are not available in whatever size wanted it will only be possible to make larger steps than just $1$ ton water per h.

When pressing to higher DS the torque on the press spindle goes up. The number of presses goes up, and the rpm down. That all balances out to approx. the same power consumption in the actual range. So removing more water does not demand any more energy.

The new steam dryer size H costs approx. $5.5$ mill $\$ \text{ fully installed with conveyors, piping, civil works, electric installations. It can evaporate up to 50 t/h for this investment. That gives a price of 110 000$ per ton/h evaporation. By smaller sizes of dryers or by a lower steam supply pressure will increase the investment per ton/h evaporated. The range will be 110 000 to 150 000$. When this price is compared to figure 9 it shows, that it will be reasonable to aim for a pulp pressing to 28 to 29% DS.

Environment and product loss.

By drum drying an essential part of the product is burned away. Therefore product losses from 5 to 8% is to be considered as normal, but as high as 12% or more does also occur. That has a big influence on the economy, that must be taken in account when considering steam drying, that has no product loss.

The main air pollutant created by drum drying consist of the ashes and half burned small particles. They are very fine and sticky. Therefore they are difficult to remove. Only wet scrubbing can bring the dust content down to the legal level in most countries, but the smell remains.

By steam drying there is no outlet to the air. The energy is recovered by condensing the vapour from the dryer. This condensate may be used as freshwater for juice extraction, or for the last cleaning of the beets by spraying through nozzles just before the beets leaves the washing plant. The condensate contains organic acids and ammonia. It has a BOD from 500 to 1000 ppm and is easily decomposed in the water treatment plant of the sugar factory.
Conclusion
The new pressurised steamdryer from EnerDry offer some 40% more capacity for the same price compared to the existing steamdryers. The price level of this dryer drives the optimal dry substance of pulp from the screw presses down to 28 – 29%. It is possible to press to a higher dry substance, but it is cheaper to install more steamdrying capacity.

A sugar factory might be able to save fuel in the sugar factory itself or it could make savings by introducing steamdrying of the beet pulp. A comparison of the two possibilities shows that a sugar factory having drum drying and a reasonably fuel consumption in the factory itself should rather consider steamdrying of beet pulp than try to reduce the fuel consumption in the sugar factory itself.

The steamdryer offers:

- Almost 100% energy recovery
- No air pollution
- No product loss
- Compactness
- No fire risk
- Automatic operation from a central control room
- Low maintenance
- Low noise level

Literature:

Authors Address:
Arne Sloth Jensen
EnerDry ApS
Moelleaaparken 50
2800 Lyngby
Denmark.