Latest experiences with newly developed sugar drying and cooling systems

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Introduction

An increasing number of sugar producers prefer to supply their customers from current production batches. Freshly produced sugar that is not stored in silos and allowed to mature for some time before it is loaded on trucks has to be dry and conditioned to such an extent when leaving the sugar dryer / cooler that unloading the transport trucks does not pose any problems.
The authors propose a concept for sugar drying using a process and equipment that ensures that the sugar produced has the required properties, while providing for low energy consumption.

1. Required sugar properties

Sugar that is to be loaded immediately after leaving the production process should have a residual moisture of less than 0.03 % and a temperature of no more than +/- 5°K above/below the mean ambient temperature at which it will be transported.
In addition to these easily quantified properties, it is also the way in which the sugar is dried which has an important role to play. If the syrup clinging to the sugar crystals is dried very rapidly, a layer of amorphous sugar tends to form on the surface. This amorphous sugar normally crystallizes while the sugar is stored and thus encourages bridges to form between the crystals. The result is sugar lumps.
Measuring the so-called AW-value (the relative moisture in the bulk sugar) can help assess the storage life of the sugar. When starting from the same residual moisture, a low AW-value is indicative of an elevated percentage of amorphous sugar.
Fig. 1 shows two typical curves produced when measuring the AW-value. The residual moisture for both samples was nearly identical.

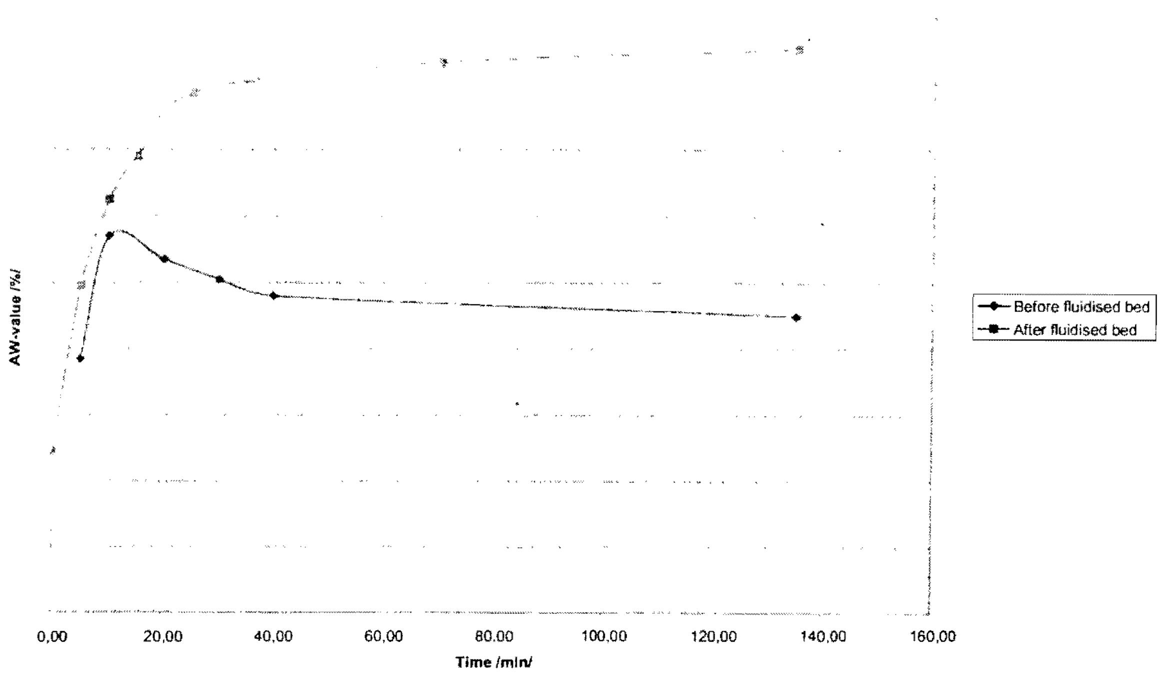


Fig. 1: **AW-values as a function of time**

The above properties also prove to be an advantage for conventional storage of the sugar in silos, because low storage temperatures reduce the problem of sugar coloration as well as the conditioning requirements in the silos.

2. The plant concept

2.1. Drying the sugar

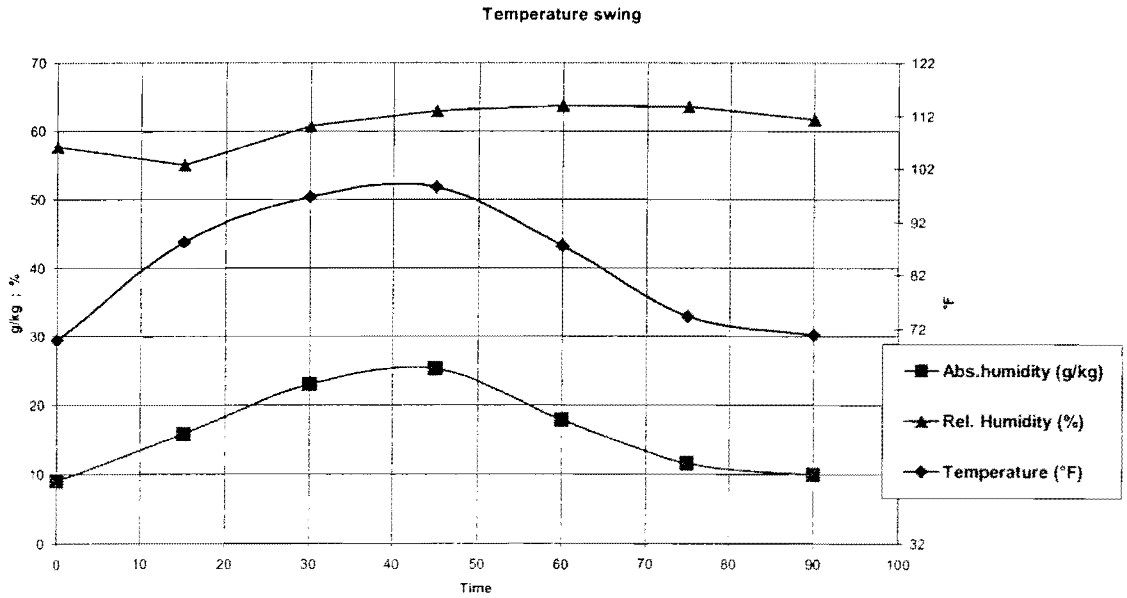
Once the syrup has been separated in the centrifugal, the sugar moisture content is normally still as high as 0.3-1.0 %. Although this is a rather low level when compared to other products, the difficulties encountered in the drying process result from the fact that the moisture is contained in a saturated sugar solution.
Since the sugar may have temperatures of between 122 °F and 158°F when leaving the centrifugals, this means that up to 4.5 % sugar syrup (based on the total mass) have to be dried. Evaporation of the water in the drying process increases the syrup concentration.
One of the requirements of sugar drying is to set off a crystallization process which ensures that a maximum of the remaining syrup is transformed into sugar crystals. This crystallization process takes time, and it has to start from seed crystals. If either the required time or the seed crystals are missing, the syrup will dry into an amorphous body favoring the entrapment of moisture, a process which the literature refers to as "case hardening" or "skin effect".
Seed crystals are the result of a mechanical interaction at the crystal surface between the dried syrup and syrup that is still liquid.
Sugar factories primarily use drum (rotary) or fluidized-bed dryers for sugar drying.
When the sugar is dried in a fluidized bed, the mechanical design has to provide for drying velocities that remain below the crystallization rate, while at the same time subjecting the moist sugar crystals to a mechanical treatment. If the formation of the aforementioned

amorphous structures is to be prevented, this presupposes adequate distribution and homogenization of the sugar mass and also a well adjusted measuring and control system. Since in drum dryers the drying air is not used as a sugar transport medium, the required mechanical treatment of the crystal surface can fairly easily be combined with low drying velocities. The required homogenization is achieved with the drum volume available for drying.
Countercurrent drying drums offer ideal conditions for effective sugar drying, since they do not only favor relative crystal motion, but also provide for an optimum temperature profile.
A new type of drying drum incorporates a central pipe that allows the temperature to be controlled as required within the drum drying section. Because it uses the countercurrent principle, the internal heat of the sugar is in this case put to efficient use for sugar drying. Sugar drying in a drying drum offers the added benefit that because of the sturdy design fluctuations in throughput and fairly large sugar lumps, but also temporary high sugar moisture contents are tolerated without causing any major problems.

2.2. Cooling the sugar

It is important that the sugar is cooled as it leaves the dryer. This is due to the fact that high sugar temperatures favor high moisture loads of the air contained in the bulk volume voids. This high moisture load is a potential driving force behind a diffusion process that makes the moisture travel to the colder storage tank periphery, where it is absorbed by the sugar. This process will take place even if the sugar stored has a low moisture content, because in view of the sugar-to-air ratio in the bulk volume, the air will always reach a state of equilibrium with the sugar. The graph in Fig. 2 shows the changes recorded for sugar of a moisture of 0.0282 %

Fig. 2: State variables plotted against time



In the past, sugar cooling primarily proceeded on air. To ensure an adequate cooling effect, cooling air of a low temperature has to be made available in sufficient quantities. Even though a rotary unit offers excellent drying properties, the cooling effect is limited, because only a limited volume of air can be used.
A fluidized bed improves the cooling effect as in this case there are no serious restrictions concerning the air rate. However in this system the temperature of the exiting sugar is very decisively influenced by the ambient air conditions.
In order to guarantee a constant sugar outlet temperature which is independent of these ambient air conditions, it is, therefore, indispensable that additional cooling energy is supplied.

The new sugar cooler concept (Fig. 3) integrates water-cooled cooling coils in a fluidized-bed cooler.
This combines efficient cooling with the necessary conditioning effect produced by air. The air rate required for sugar crystal fluidization at the same time provides for additional secondary sugar drying. This consequently eases the temperature load for the sugar in the drying drum and yields a sugar of improved storage stability.
It appears from Fig. 1 that cooling in the fluidized bed also helps reduce the percentage of amorphous sugar, without at the same time increasing the residual moisture content.

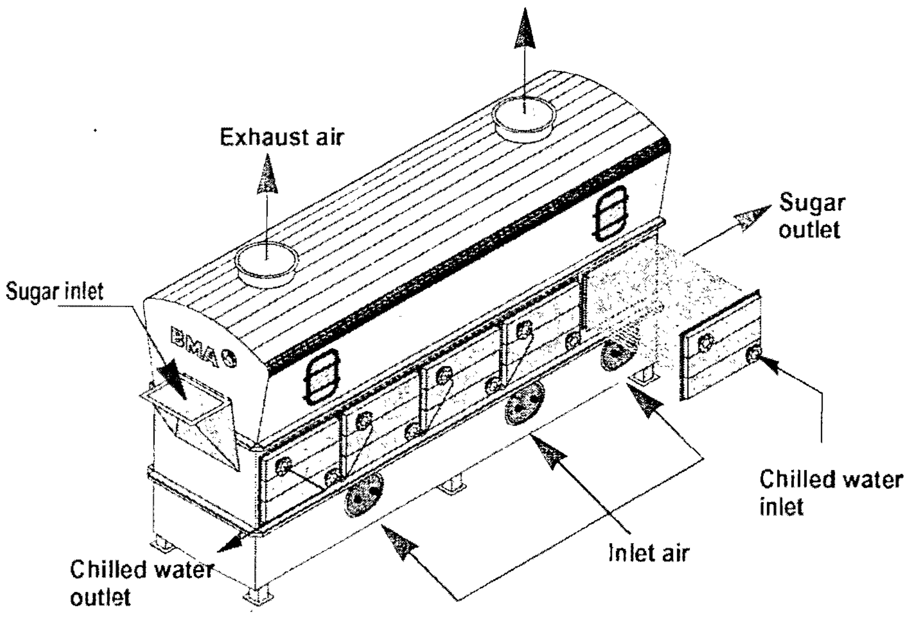


Fig. 3: Fluidized-bed cooler with internal cooling coils

An other relatively new sugar cooling method is the one used by the so-called moving-column cooler, which does not require any cooling air. In this system, the sugar loses its moisture by its contact with water-cooled plate heat exchangers as it travels under its own gravity through the plate units. More practical experience will have to show, however, in how much immediate contact of the freshly dried sugar with cooled surfaces has an effect on the residual moisture and the flow properties, if air flow is dispensed with altogether. What is certain at this stage is that the sugar already needs to have the required residual moisture when it enters the moving-column cooler.
All the heat discharged is lost in the water cooling system and is not available for energy saving purposes in the drying phase, which would be the case when using the combined effects of both process steps.

3. Experience with a combined system of drum dryer and fluidized-bed cooler

When combining drum dryer and fluidized-bed cooler within one system, the properties required for the freshly dried sugar can be achieved, while the energy requirements are reduced at the same time.
The first two combined systems of sugar drier and fluidized-bed cooler with integrated cooling coils were put into operation in the last beet sugar campaign.
The integrated cooling coils allow the air rate required for cooling to be reduced to such an extent that the entire exhaust air leaving the fluidized-bed cooler can be passed into the drying drums.

Fig. 4 shows a combined system with countercurrent drum and fluidized-bed cooler that has already been put to the test of practical operation.

Performance tests conducted during the past beet sugar campaign (autumn 2002) produced specific data that were used as a basis for the schematic representation in Fig. 4. These performance tests have demonstrated that the temperature of the drying air required in the drying drums can be reduced when the waste air from the fluidized-bed cooler is used again. In this case the energy saved corresponded by approximation to the amount of heat entering the system with the cooling air.

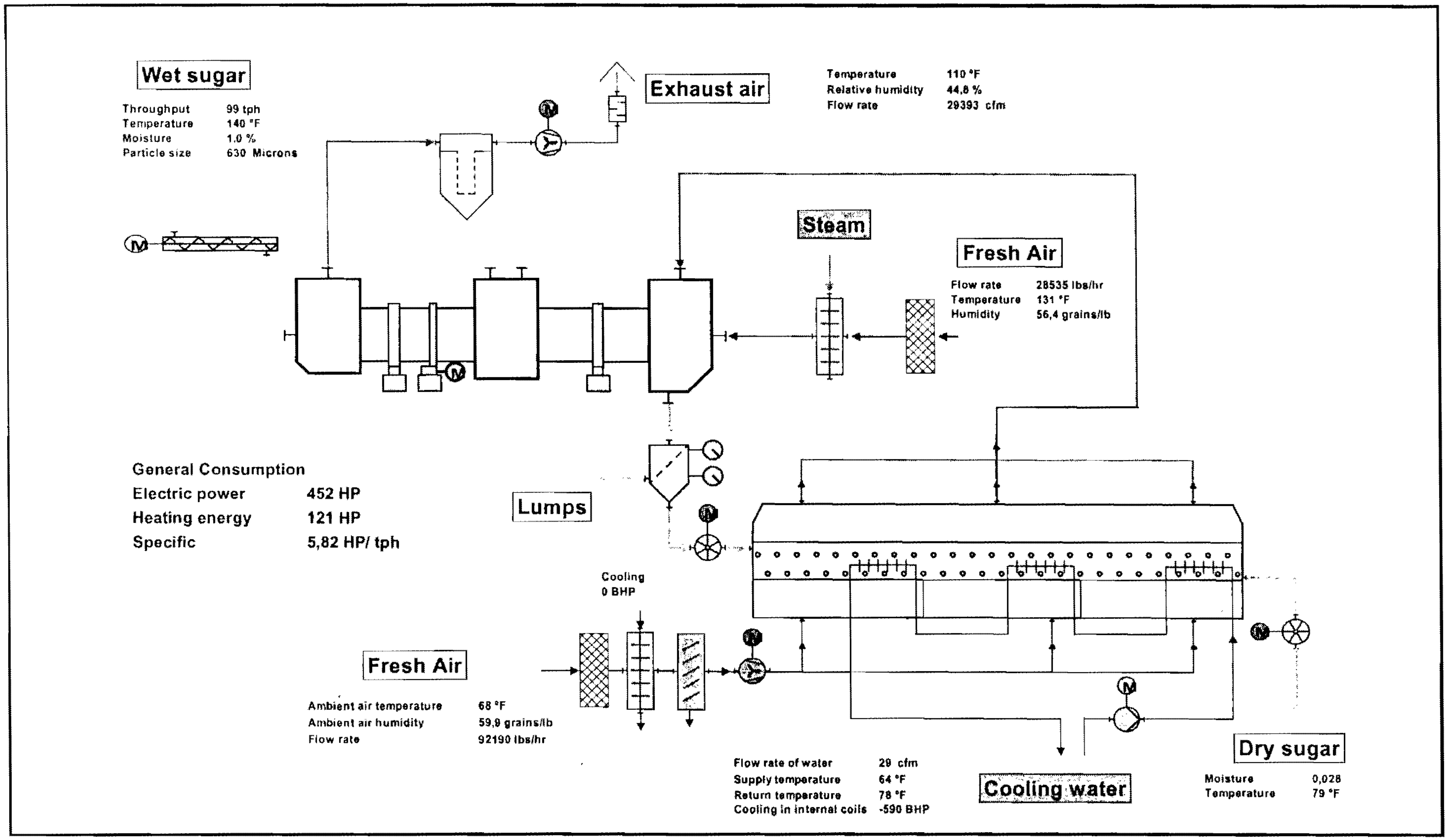


Fig. 4: Rotary dryer/cooler and fluidized bed cooler with internal cooling coils

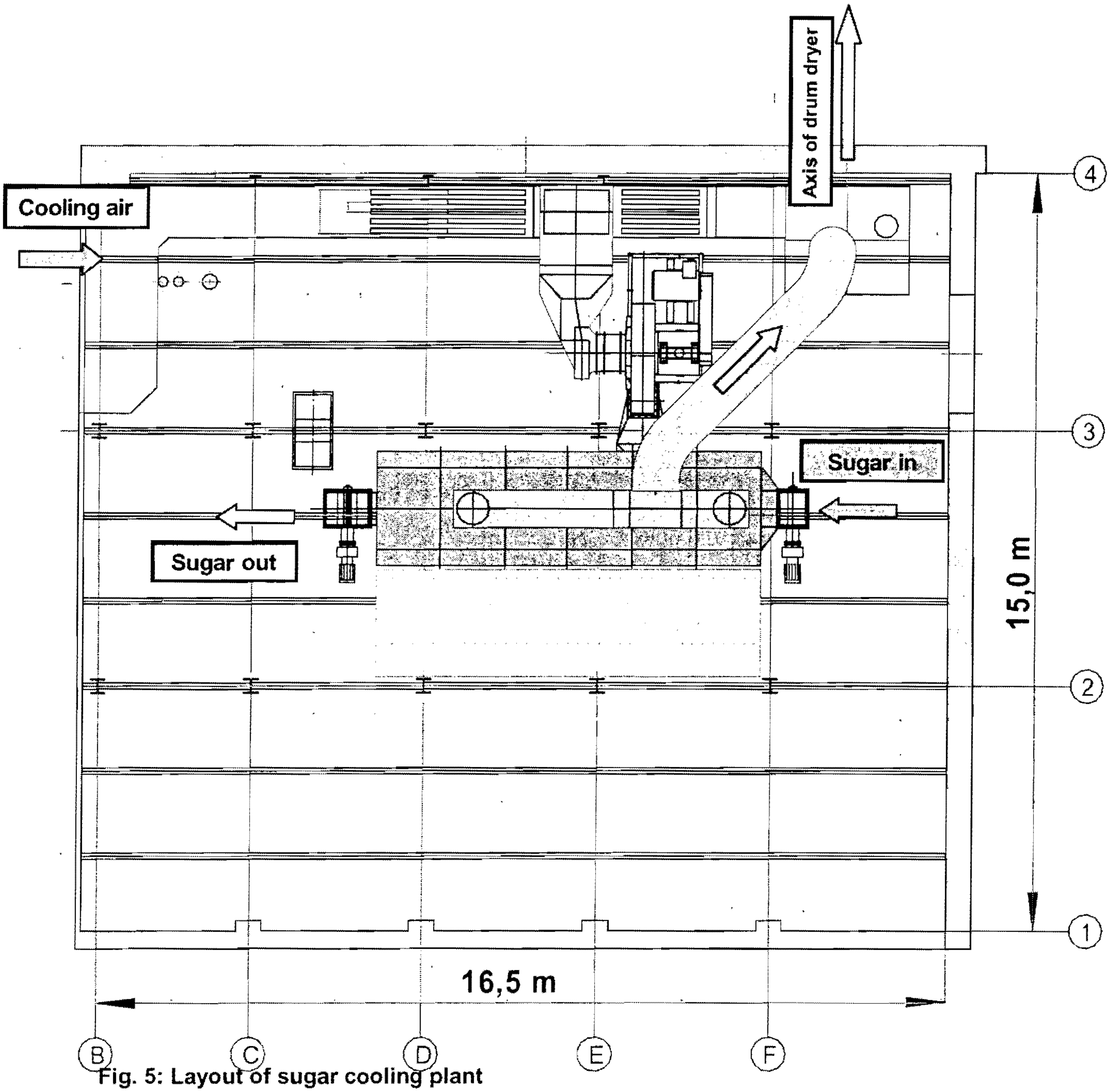


Fig. 5: Layout of sugar cooling plant

Figure 5 shows the layout situation for a sugar cooler with a rated throughput of 99 tph which was installed in the past beet sugar campaign in Germany. The existing ducting for the inlet air was used. The exhaust air was re-used in the drum dryer as cooling air. The sugar outlet temperature was reduced from 113°F- 122°F to constant 77°F during the campaign.

The technological parameters illustrated in Fig. 4 were used for a comparison of three different versions (which all start from the same ambient and sugar parameters as well as the same specific input for generation of the required cooling energy):

(1) Conventional drum for drying and cooling by means of a conventional fluidized bed with air conditioning system
(2) Countercurrent drum for drying and cooling in the fluidized-bed with internal cooling coils.
(3) Conventional drum for drying and cooling in the moving-column cooler

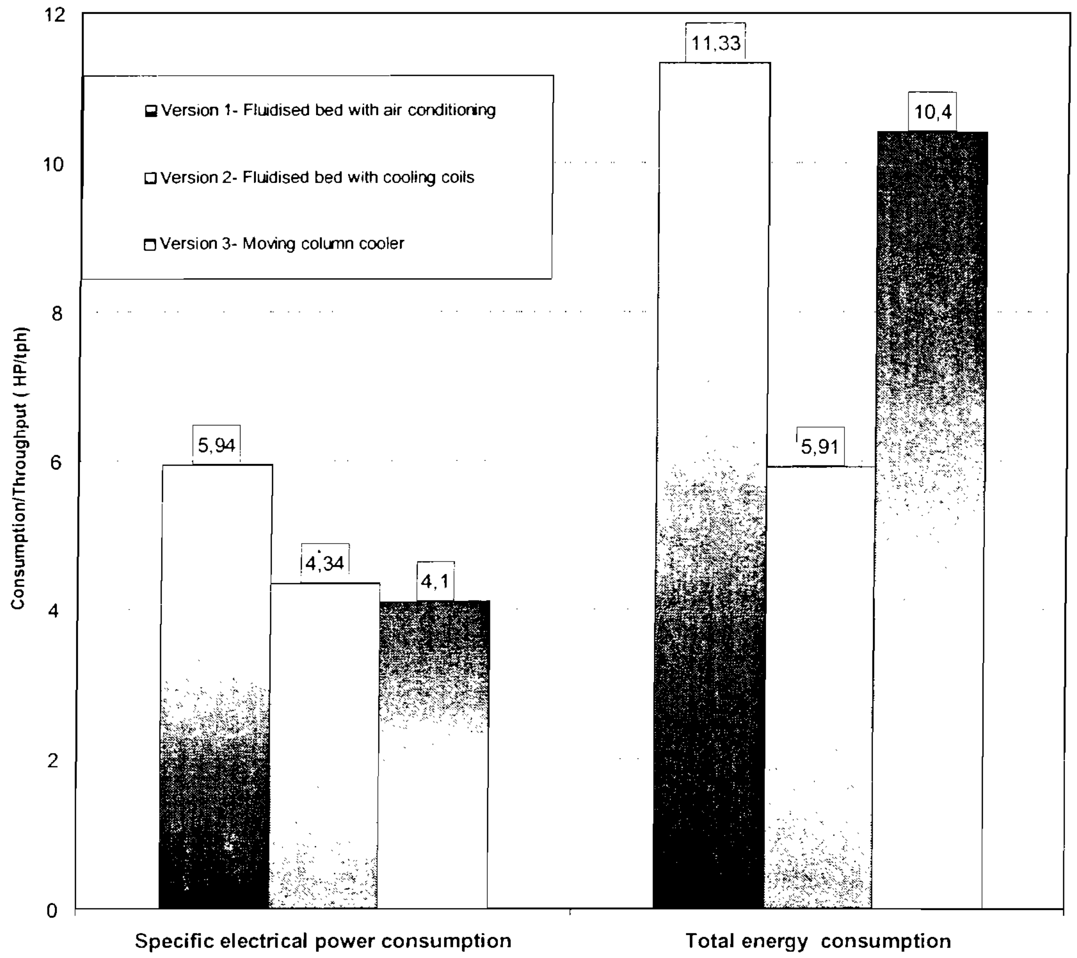


Fig. 6 : Specific power consumption of different types of sugar dryer/ coolers

It is evident from this comparison that respecting the electric power input the three versions produce similar results. When also considering the overall energy requirements, the fluidized-bed cooler with internal cooling coils offers a clear advantage.

The new concept of sugar drying and cooling makes sure that the storage properties required for freshly produced sugar are achieved at a lower input of energy. In principle, the concept is also available for capacity expansion programs in existing plants.

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