► *Applications for drying & cooling sugar in respect of specific needs and ambient conditions*

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APPLICATIONS FOR DRYING & COOLING SUGAR IN RESPECT OF SPECIFIC NEEDS AND AMBIENT CONDITIONS

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1 Introduction

The properties of white sugar at the end of the production process have to meet requirements that become more and more stringent. This is evident from the wide range of different certification systems. In this connection, drying and cooling of the centrifuged sugar has a decisive role to play, and this phase in the production process is increasingly developing into a conditioning phase before the sugar is stored, graded and packed. For designing the required processing systems, the underlying physical conditions have to be known and adequately accounted for. Depending on the specific needs and ambient conditions, processes can be optimised in different ways as presented in this paper.

2 Importance of sugar drying and cooling

Cooling, and in particular conditioning, is the final step of white and refined sugar production. It transfers the sugar into a stable condition for storage, packaging and transportation.
The maximum residual moisture content depends on sugar quality and should be in the range of 0.03 % - 0.04 %, while the maximum temperature, which depends on the customer's specifications, climatic conditions, and available silo technology, has to be between 25 °C and 40 °C. The finished product must be free from sugar lumps.

Experience shows that freshly dried and cooled crystal sugar undergoes a conditioning phase during the first few days after production. Depending on ambient conditions, freshly produced sugar can lose its water-binding properties again within a relatively short time (within the first one to two days), i.e. it releases part of the bound water. In silos or in the packed sugar, this released water can cause lumps and caking. Our experience clearly shows that slow drying combined with a gentle movement has a positive effect on the storage properties of sugar.

3 Ideal solutions to suit different needs

Depending on the specific needs as well as on the ambient conditions, different ways lead to optimum sugar quality. In the following an example is given to present a set of alternatives for a sugar factory taking into account both cold and warm ambient conditions.

The alternatives are based on the following general assumptions:

- Throughput: 100 t/h
- Quality: EC1/EC2
- Coefficient of variation: 35%
- Temperature wet sugar: 60°C
- Crystal size: 0.6mm
- Moisture wet sugar: 0.7%
- Residual moisture: 0.03%

The two following situations are to serve as examples in order to illustrate the effects that different ambient conditions can have:

A) A factory in moderate or **cold climatic zones** as, for instance, in northern Europe, the CIS states or the northern parts of the United States:
Factories in these zones are primarily operated during the cold season, between September and January, when the ambient temperatures are generally low and the ambient air has a substantial, and at the same time low-cost, potential for absorbing and giving off both the moisture and the heat of the sugar that has to be dried.

Assumptions underlying the calculations for cold conditions:

- Air temperature (average): 15 °C
- Air humidity (average): 7.5 g/kg dry air
- Available surface water: 15 °C
- Requested dry sugar temperature: 30 °C

B) A factory that operates **in a warm climate or season**, where the prevailing ambient temperature and air humidity therefore creates much harsher conditions for the two process steps that are considered here.

Assumptions underlying the calculations for warm conditions:

- Air temperature (average): 39 °C
- Air humidity (average): 27 g/kg dry air
- Available surface water: 20 °C
- Requested dry sugar temperature: 35 °C

For both the cold and the warm ambient conditions, the following options are presented:

1. Drum dryer / cooler alone; with an additional air cooler / dehumidifier for warm ambient conditions

2. Drum dryer / cooler with downstream horizontal fluidised-bed cooler; with an additional air cooler / dehumidifier for warm ambient conditions

3. Drum dryer / cooler with downstream vertical fluidised-bed cooler; with an additional air cooler / dehumidifier for warm ambient conditions

In general, drying of sugar takes place in a drum dryer (Fig. 1). Gentle movement in between the crystals prevents the formation of amorphous crystal layers on the crystal surface and the countercurrent principle enables an easy and effective process. Furthermore, it always allows for a cooling effect.

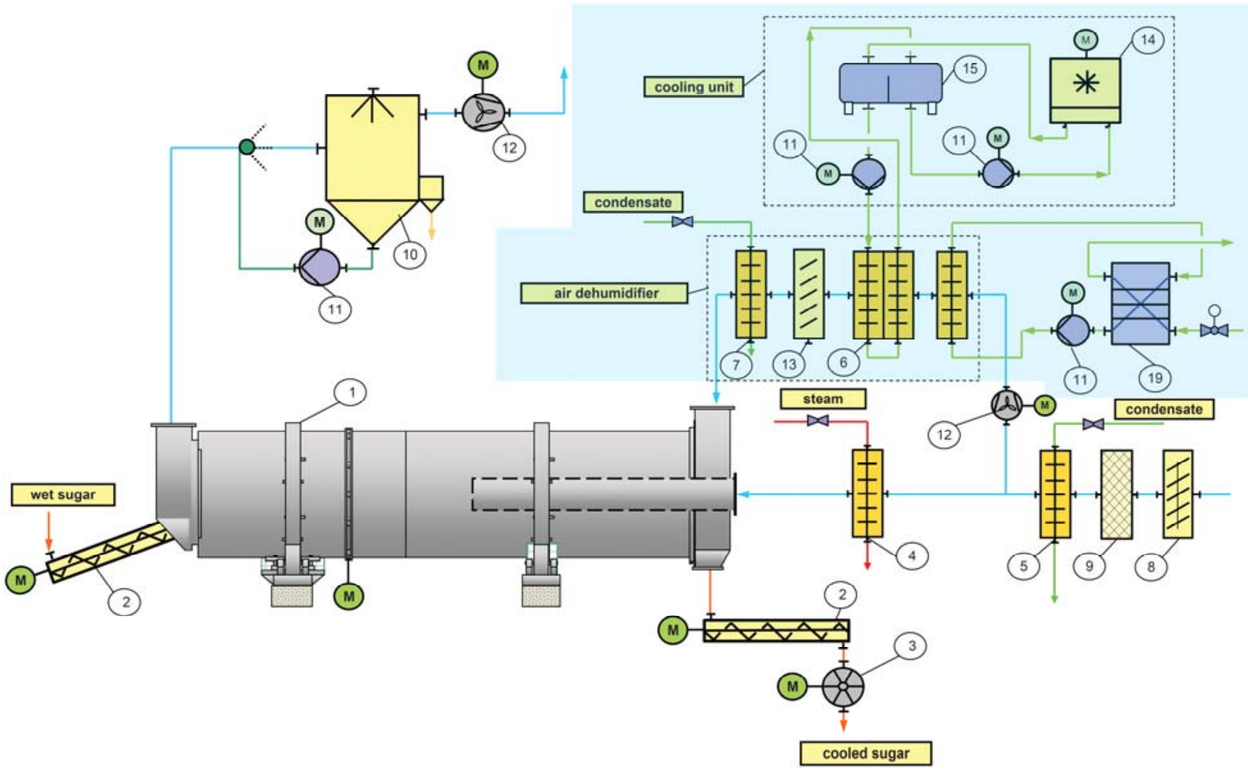

Fig. 1: Option 1 - Drum dryer

Fig.1 shows a drum dryer / cooler system. When this version is used under cold ambient conditions, the 100 t/h of sugar that are assumed for calculation purposes can be cooled with warm air of 15 °C to the intended sugar outlet temperature of 30 °C. However under these conditions, this system reaches its upper performance limit, and it has to be equipped with a large drum. If air with a temperature of 15 °C is not available, or if the plant is operated in a warm environment, the temperature of the exiting sugar will be higher when the throughput remains the same, or an additional cooling system has to be provided, which allows for combined air dehumidification and secondary heating of the cooling air. The ancillary equipment that is required for operation of the plant under warm ambient conditions is highlighted in light-blue in Fig.1.

The above option 1, in which only a drum dryer / cooler is used and which offers a maximum of simplicity and reliability, has successfully stood its test in numerous applications. Under cold ambient conditions, the energy requirements of this plant are very low; however they go up considerably, when it is operated under warm ambient conditions, because it then becomes necessary to cool and condition the air.

If lower sugar temperatures or higher throughput rates have to be reached, this system is no longer adequate. In these cases, the sugar stream either has to be divided across more than one line, or a downstream cooler has to be added. Systems with fluidised-bed units, as shown in Fig. 2 with a horizontal cooler, are good solutions under these conditions. This also applies to operation of the plant in a warm environment, because then the ambient air has to be cooled and possibly also dehumidified. The required equipment is highlighted in light-blue in Fig. 2.

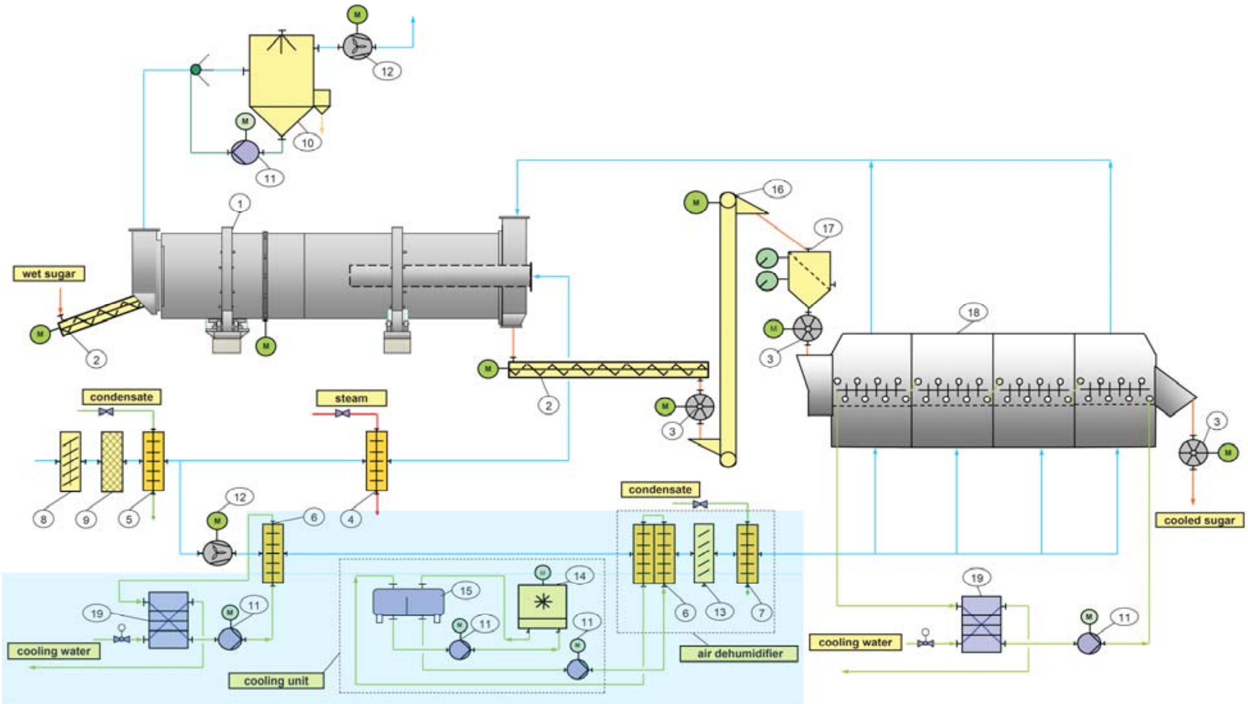

Fig. 2: Option 2 - Drum dryer with horizontal fluidised-bed cooler

The downstream fluidised-bed unit is not only operated with air; it also uses available cold water for removing the heat from the sugar.
Cold water flowing through pipes that are located within the bed of fluidised sugar absorb the heat contained in the sugar and discharge it to the outside. With this construction principle, the footprint of the fluidised-bed cooler becomes much smaller than that of a version without cooling pipes. A smaller cooler footprint automatically means that less air is required for fluidisation.

The air that leaves the fluidised-bed cooler is used again in the drum. It is very often possible to adapt these two units to each other so that the entire exhaust air can be put to further use. Much of the thermal energy that is contained in the sugar can, for instance, be utilised as drying energy in the drum. This is an important step towards enhancing the energy efficiency of the complete plant.

The efficiency of this dual use of the air becomes even more marked when the plant is operated under warm and humid ambient conditions, where the cooling air must be both cooled and dehumidified. When the amount of ingoing air is reduced, this automatically means that the energy required for cooling and dehumidifying the air can also be substantially reduced.

Despite its smaller size compared to conventional coolers, the BMA horizontal fluidised-bed cooler still requires a lot of space for installation. Especially when it comes to capacity expansions, this space is very often not available.
Furthermore, reducing the energy consumption is considered as a high priority in most factories.

With the vertical fluidised-bed conditioner VFC (Fig. 3) BMA now offers the sugar industry a suitable alternative to the horizontal fluidised-bed of compact build and with reduced air and energy consumption while keeping the advantages of a fluidised-bed compared to an airless moving column system.

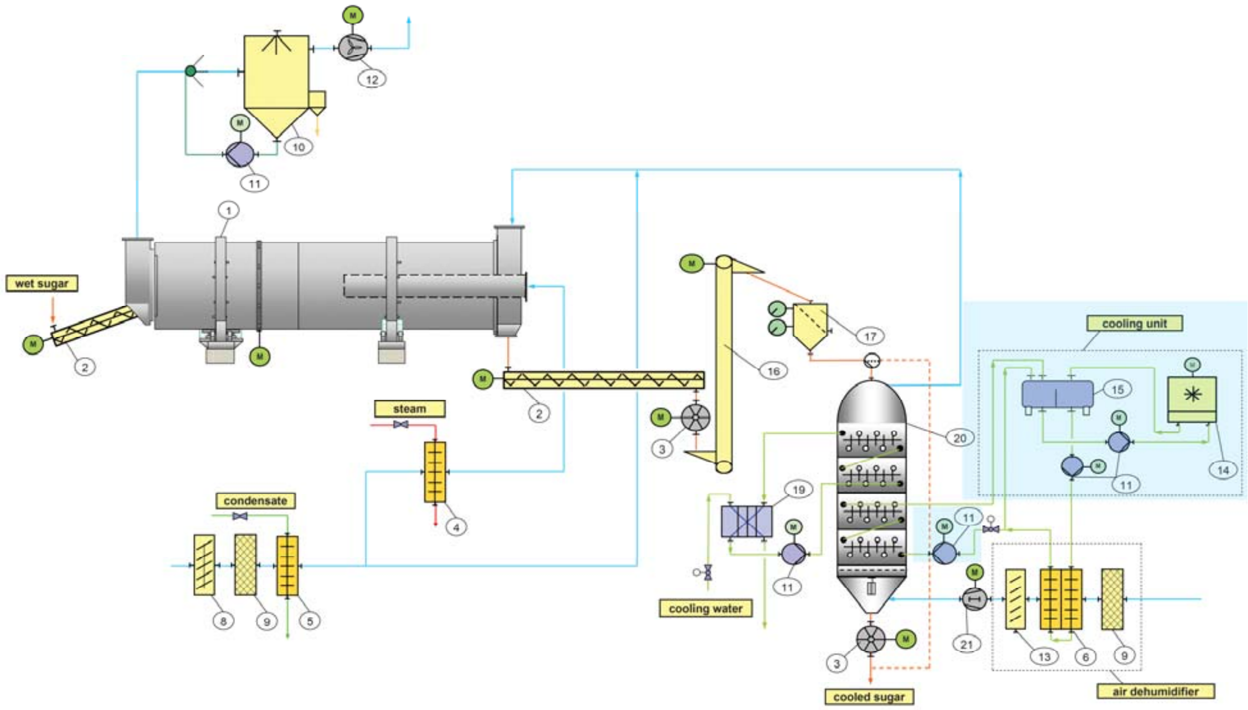

Fig. 3: Option 3 - Drum dryer with vertical fluidised-bed cooler & air conditioner

With this version, the ingoing air should always be conditioned. For operation in a warm environment, a larger water chiller is used for conditioning the ingoing air, so that this air can assume part of the cooling function for the cooling pipes.

Legend:

1	Drum dryer	12	Fan
2	Screw conveyor	13	Drop separator
3	Rotary air lock	14	Chiller
4	Heat exchanger for drying air	15	Buffer tank
5	Anti-freeze protection (optional)	16	Bucket elevator
6	Air cooler	17	Lump sifter
7	Heat exchanger for cooling air	18	Fluidised-bed cooler, horizontal design
8	Weather protection grid	19	Plate heat exchanger
9	Filter for ambient air	20	Fluidised-bed cooler, vertical design
10	Wet scrubber	21	Air blower
11	Pump		

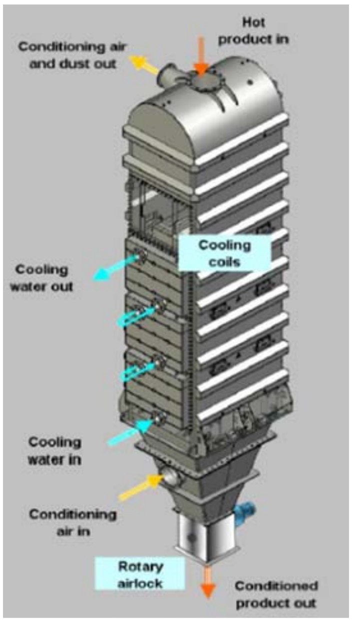

Fig. 4 Fluidised-bed conditioner

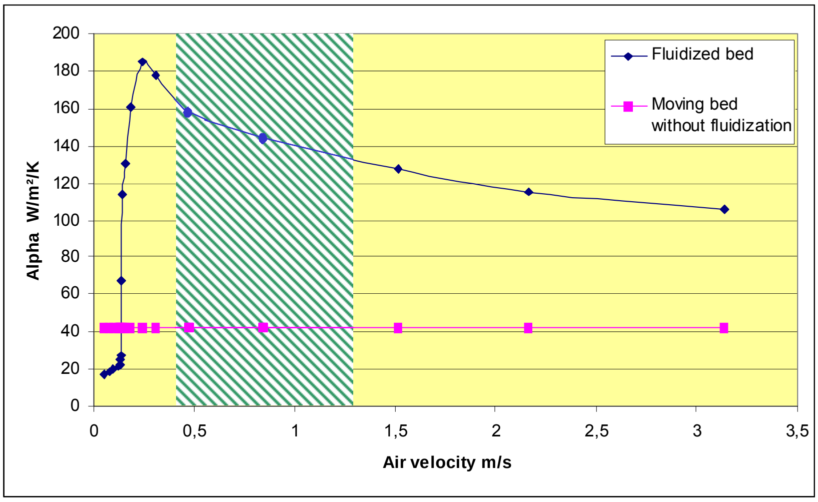

Fig. 5: Heat transfer rate in fluidised-bed coolers between Heat transfer surface and product

Figure 4 shows the design of the sugar conditioning unit. By opening and closing the air distribution plate in the lower part of the conditioner, the product is transported from the process area into the lower area of the unit, where it is discharged by a rotary air lock. The solid matter flow is controlled by periodical opening and closing of the distribution plate. This allows a uniform residence time of the product. Owing to the large free surface of the distribution plate, the pressure drop is very low. The sugar quantity inside the apparatus is controlled via the pressure drop across the fluidised bed.

Due to the fluidisation, vertical fluidised-bed conditioners have a three to four times higher heat transfer rate than the airless moving column system (Fig. 5) though they have equally compact dimensions.

In many technological respects, this option compares to the version with the horizontal fluidised-bed cooler. However it features the following advantages:

- Much lower air rate
- Very small footprint
- The amounts of ingoing and outgoing air are so small that the ingoing air can be conditioned with an extremely low energy input (only approx. 20 kW)
- In addition to direct applications downstream of drum dryers, this version can, for instance, also be used for secondary cooling downstream of conditioning silos
- Because of the small amount of air, the exhaust air can also be disposed of with central aspiration systems
- The sugar temperature that can be reached is primarily determined by the available cooling water temperature; constant sugar temperatures downstream of the cooler can thus be produced irrespective of the ingoing air temperature that is influenced by the ambient conditions.
- Product flow (from top to bottom) not forced by air flow but by gravity
- Openings in air distribution bottom maintain product flow also in the absence of air flow (emergency operation)

4 Energy requirements

The plant versions that have been presented above differ in the costs involved and evidently also in their energy efficiency. The table in Fig. 6 provides an overview and allows for an easier comparison of the energy requirements of the different versions.

	Cold ambient conditions			Warm ambient conditions		
	Fig. 1	**Fig.2**	**Fig. 3**	**Fig. 1**	**Fig.2**	**Fig. 3**
DDC Drum dryer/cooler HFC Horizontal fluidised-bed cooler AC Air condition VFC Vertical fluidised-bed conditioner	DDC	DDC + HFC	DDC + HFC +AC	DDC + AC	DDC +HFC + AC	DDC + VFC + AC
Steam [kW]	**224**	**212**	**196**	**116**	**148**	**131**
Condensate [kW]	**-**	**-**	**-**	**184**	**74**	**-**
Surface water [kW]	**-**	**518**	**412**	**281**	**663**	**277**
Electric consumption w/o chiller [kW]	**195**	**228**	**211**	**235**	**257**	**233**
Cold water from chiller [kW]	**-**	**-**	**12**	**1033**	**824**	**299**
Electric consumption chiller [kW]	**-**	**-**	**4**	**344**	**120**	**100**

Fig. 6: Overview of energy consumption figures

In terms of the energy requirements, version 1 with drum dryer / cooler is the best solution when the plant has to be operated under cold ambient conditions. In a warm environment, this version is however by far the least effective solution.

5 How to choose the right system for your application?

There are also other important aspects, in addition to energy requirements, which have to be considered when it comes to selecting an appropriate plant. Fig. 7 below lists additional criteria and how these should be weighed under special conditions.

Decision Criteria	**Cold ambient conditions**			**Warm and / or humid ambient conditions**		
	DDC Fig.1	DDC + HFC Fig. 2	DDC + VFC +AC Fig. 3	DDC + AC Fig. 1	DDC + HFC +AC Fig. 2	DDC + VFC +AC Fig.3
Capacity						
<40 t/h	**++**	**0**	**-**	**++**	**-**	**-**
40 - 80 t/h	**+**	**++**	**-**	**++**	**+**	**+**
>80 t/h	**+**	**++**	**++**	**-**	**++**	**++**
Ambient conditions						
operation in winter only	**++**	**++**	**0**	**0**	**0**	**0**
operation all year long	**0**	**+**	**++**	**++**	**++**	**++**
operation in tropical areas				**++**	**++**	**++**
Sugar temperature after cooler						
> 35 °C	**++**	**0**	**-**	**++**	**-**	**-**
30 - 35 °C	**+**	**+**	**+**	**+**	**+**	**+**
< 30 °C	**0**	**+**	**++**	**+**	**++**	**++**

Required space for installation (m³ building volume)	approx. 100 %	approx. 170 %	approx. 160 %	approx. 120 %	approx. 190 %	approx. 160 %
Sugar properties						
big variations in crystal size MA and sugar quality	++	0	+	++	0	+
crystal size MA < 0.5 mm	++	++	++	++	++	++
crystal size MA mid-size	++	++	++	++	++	++
crystal size MA > 0.8 mm	0	+	+	0	+	+
gloss of cooled crystals	0	+	+	0	+	+
raw sugar	++	--	--	++	--	--
white or refined sugar	++	++	++	++	++	++
low remaining dust in cooled sugar	+	++	+	+	++	+
Complexity						
Number of machines	++	+	+	+	0	0
complexity process	++	+	+	+	0	0
complexity measuring and controls	++	+	+	+	0	0

Fig. 7: Decision criteria

There is obviously no single "most favourable" option for all applications. The situation has to be closely examined from case to case and adequately considered in designing a plant.

6 Conclusions

During several years BMA has continually improved the sugar drying and cooling process as well as the equipment. The development has always focused on the optimisation of the sugar quality in terms of residual moisture considering the most different climate conditions and specific needs.
With its drying and cooling range comprised of drum dryer, horizontal fluidised-bed cooler and the new vertical fluidised-bed conditioner BMA answers your most stringent drying and cooling demands.

References

Meadows, D.M. (1997), Sugar drying, conditioning & storage – an overview; Pak. Sugar Journal Oct.-Dec. 1997