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Predrying of Raw Materials — Purpose and Effect

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Das Vortrocknen von Rohstoffen — Zweck und Auswirkung
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Summary

The predrying of hygroscopic and non-hygroscopic plastic raw materials is a process which is often thought of as straight forward and rather simple. In recent years, equipment has emerged which can be fine tuned to the particular humidity and moisture content prevailing.

This paper details various operational parameters and process constraints relating to the predrying of raw materials and details a particular series of processing equipment.

1. Introduction

Today it is well-known that predrying of plastic raw materials in many cases offers many advantages in respect of capacity and quality.

Also it appears that the knowledge of the effect of the drying process is very limited among most processors, and they believe that drying is a very simple process which can be carried out by means of any equipment available as long as it is specified as a dryer.

However, drying of raw materials is influenced by many factors, making it not quite as simple as it sounds.

Apart from the cases where drying is carried out in order to obtain increased capacity, normally available by preheating of raw material, it will be necessary to adapt the drying process to the raw material itself. It will also be necessary to consider transport and storage conditions.

Generally, the raw materials can be separated into two main groups:

1. The non-hygroscopic materials as Polyethylene (PE), Polypropylene (PP), and corresponding materials where moisture occurs as a surface moisture only, mainly caused by condensation due to storage or a long transportation time.
2. Hygroscopic materials such as Acrylonitrile-Buladiene-Styrene (ABS), Polycarbonate (PC), Polyamide (PA), and Polyester (PET), etc. adsorb moisture from the ambient air in such a way that the moisture enters each single granule in the raw material.

The process in question also depends on how dry the material is, and it has been proved that the injection moulding process is not as sensitive to moisture content by processing as extrusion processes, i.e., blowing, sheet manufacturing, etc.

2. Purposes of Drying

The purpose of predrying of non-hygroscopic materials is mainly to reduce the problems which may occur by surface moisture being re-organised as steam in the screw or to increase capacity of the processing machine by pre-heating the raw material.

Granule shaped non-hygroscopic materials can normally be predried in any kind of dryer with satisfactory results as long as the dryer is of the right size, since a certain rest-time is necessary. Moreover, the demand to the degree of dryness should not be extremely high.

When hygroscopic materials are used, the question of drying will be quite different, as these materials are mostly dried in order to maintain original properties so that neither quality, surface finish, or strength of the final product are reduced. In other words, drying of hygroscopic materials is absolutely necessary if a quality product has to be processed.

In order to dry hygroscopic materials, very effective drying equipment is required as, usually, it is necessary to have a final moisture content below 0.1 % in the raw material before processing in order to obtain a satisfactory product. With hygroscopic materials the moisture enters into the material itself and a longer drying time is required in order to release the moisture.

3. Effect of Moisture

One of the best known and mostly processed hygroscopic materials is polycarbonate (PC) where a final moisture content below 0.02 % is required before processing in order to maintain the original properties, of which the most important is its excellent impact strength, i.e., resistance against stroke.

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The impact strength of PC is decreased gradually as the material adsorbs moisture, e.g., during transport or storage, and even during the stay in the machine hopper, as shown in Table 1.

Table 1: Drop in impact strength during storage of Lexan 101 PC

Storage/Hours air at 23 °C and 50 % R.H.	Average Impact strength according to Izod
2	13
4	7
6	7
21	1.8

It shows how the impact strength in Lexan 101 polycarbonate decreases due to adsorption of humidity during storage at 23 °C and 50 % relative humidity.

For Lexan 101 the maximum impact strength is 16 and from the table it appears that after only 3—4 hours of storage the impact strength is as low as 7 which means less than 50 % of the original strength, and after 21 hours as low as 1.8 or approximately 8 %.

Most storage facilities offer even worse conditions regarding temperature and relative humidity than specified in this example, causing faster and higher adsorption of moisture, resulting from a poor impact strength. This is also the case in material transport where changes in temperature can create condensing water which is adsorbed by the material.

4. Effect of Drying

The loss of impact strength during storage can be regained by predrying of the raw material.

Fig. 1 shows how Lexan PC regains the impact strength by drying until it reaches the original maximum strength 16 after 2 1/2 to 3 hours of drying at 120 °C, although the drying time will depend on the relative humidity in the drying air.

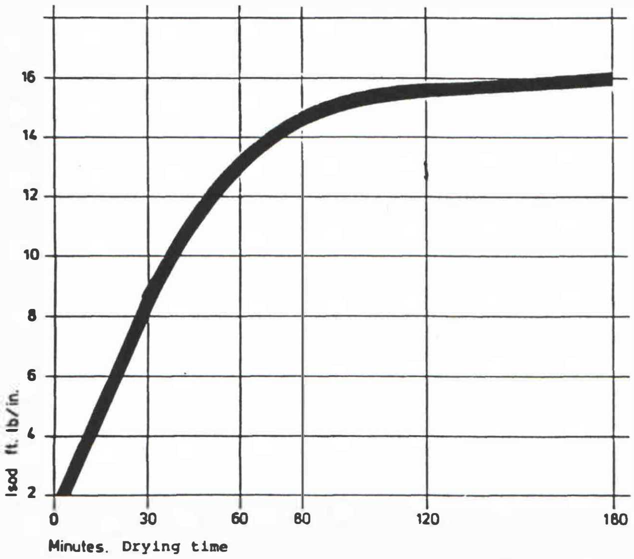

Fig. 1: Regaining of the impact strength in Lexan 101 PC during drying

Moisture in a raw material can also create other problems than loss of original properties, e.g., processing of parts with large wall thickness will require predrying of the raw material in order to avoid shrinkages.

The final moisture content before processing is also of great importance where moulded parts have to be plated, e.g., with chrome. As to ABS this will require a part, moulded from a material with a final moisture content less than 0.02 % in order to avoid the plating peeling off after a couple of months.

5. Processing Equipment

There are currently available many different techniques for drying plastic raw materials such as drying ovens, vacuum dryers or hopper dryers, the latter for mounting on the processing machine instead of the original hopper.

Table 1 shows how quickly the impact strength in polycarbonate decreases due to moisture adsorption. This proves that a hopper dryer will be advantageous as it prevents moisture adsorption during transport of the raw material to the machine hopper during its stay in the machine. Equipped with a hopper loader, the hopper dryer is the most effective solution.

All hopper dryers offered today generally work on the same principle (Fig. 2). The ambient air is taken in and heated whereafter it is blown into the raw material at the bottom of the dryer. While the air is passing the raw material, the air adsorbs moisture from the granules. Finally, this air is blown out in the factory. However, it is also possible to adjust a valve situated at the air inlet so that the air can be re-cycled or drying carried out with partly re-cycled air.

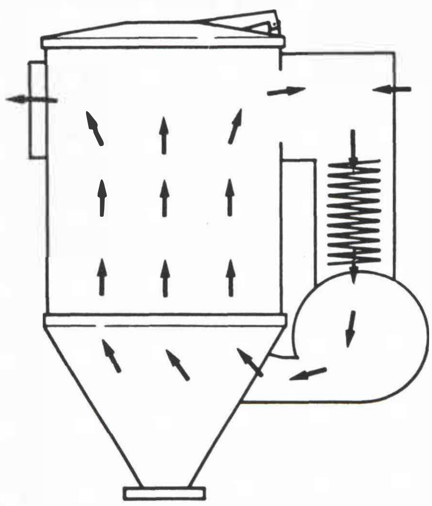

Fig. 2: Hot air dryer — principle

As mentioned before the hopper dryer will be suitable for most raw materials, but in the case where a very low final moisture content is necessary as required for hygroscopic materials, its performance will be limited by the relative humidity in the air as well as the drying temperature.

In order to dry down to a low final moisture content, the dryer may be equipped with a moist-off filter or dehumidifier which is connected to the dryer by means of a hose so that the ambient air passes this filter before entering the dryer. The moist-off filter (Fig. 3) is a container with drying pellets which adsorbs moisture from the ambient air passing through.

By connecting a moist-off filter to a dryer it is possible to reduce the moisture content of the drying air, but as the air has to pass through the moist-off filter it is not possible to re-cycle the air resulting in a greater power consumption.

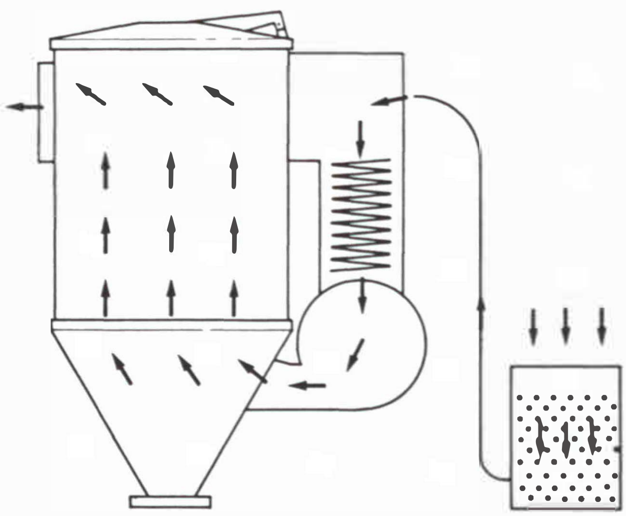

Fig. 3: Hot air dryer with manual Moist-off Filter — principle

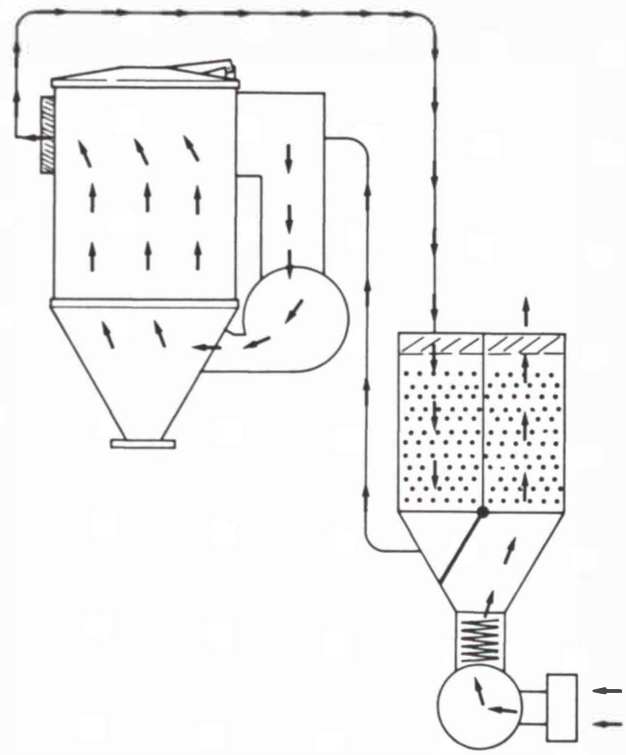

Fig. 4: Hot air dryer with automatic Moist-off Filter — principle

The disadvantage of using a moist-off filter in this form is that the drying pellets have to be regenerated in an oven. This means increased handling costs and further power consumption. The use of some kind of moist-off filter or de-humidifier is called desiccant drying.

In order to avoid the handling involved for regeneration of the drying pellets in a normal moist-off filter, the hopper dryer may be equipped with an automatic moist-off filter as shown in Fig. 4. The automatic moist-off filter offers the advantage that the drying air is re-cycled and in this way it is possible to create a desiccant drying system, securing maximum production independent of weather conditions.

The principle in the automatic moist-off filter is, in fact, the same as in the manual moist-off filter as the air passes the drying pellets adsorbing moisture before it enters the dryer.

An automatic regeneration of the drying pellets secures that the air used for drying is constantly dry.

6. Predrying the Drying Air

Now the question arises whether this extra drying of the air, the so-called desiccant drying, is necessary at all, or if it would be possible to heat up the air only, as has been done for many years with satisfactory results.

The drying process itself is very complex due to the many factors influencing it, especially the raw material itself and the relative humidity in the drying air.

During the last years a great number of new plastic raw materials have been introduced, and the number of hygroscopic materials used for technical mouldings and other special purposes has increased, creating a demand for more effective drying.

Table 2 shows the main parameters and related drying temperatures and the final (desired) moisture contents for a series of special materials which are typically utilised in the injection moulding and extrusion plastics processing operations. The following conclusions may be drawn:

1. All materials listed demand a very low final moisture content, all below 0.1 %.
2. The extrusion processes are more sensitive with regard to moisture content in the raw material than injection moulding. This appears very clearly from ABS at the upper line, requiring 0.08 % for injection moulding and 0.02 % for extrusion.
3. Desiccant dryers offer certain advantages in respect of time which again means that a smaller dryer can be used for the same capacity.
4. Also, it appears that materials such as PA6, PA66, PA10, and PET, all processed in increased amounts today, simply demand desiccant drying because hot air drying is not sufficient enough.

7. Influence of Relative Humidity

Besides the raw material, the other major important factor, greatly influencing the drying process, is the weather.

Fig. 5 shows the average humidity in the air over a one year period in Denmark and Norway, in grams of water per kg of air.

The relative humidity varies through the year with the highest moisture content in the period from June to October, depending on the temperature. In July-August, normally, the temperature and the moisture content are at the highest level.

At the bottom of the diagram there is a curve, showing the relative humidity in the air used for drying in a desiccant dryer and operating with re-cycled air.

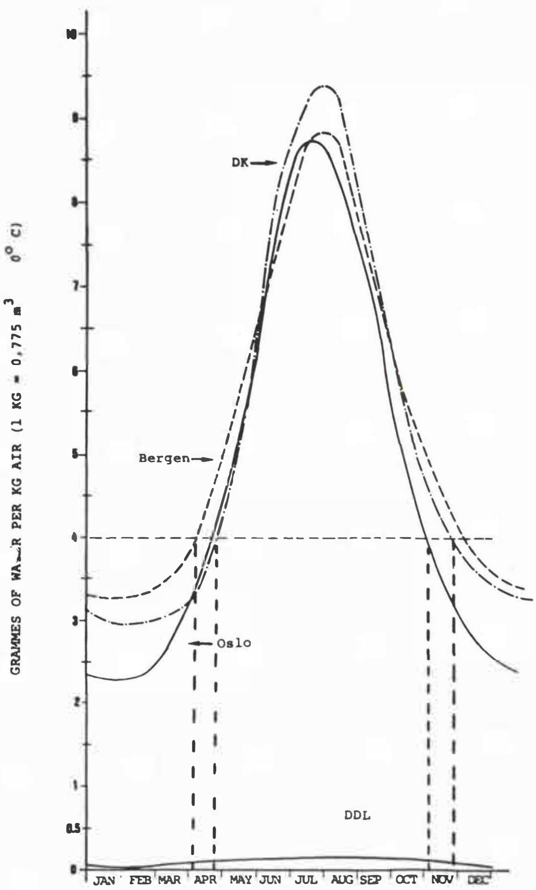

Fig. 5 Average RH in Denmark and Norway expressed in grammes of water per kg of air

Apparently, approximately 4 grams of water per kg of air is a limit and a higher amount may create problems, depending on the drying temperature. Fig. 5 shows values for Denmark and Norway exceeding 4 grams of water from the months of February throughout the year. It might be possible to change this condition just by heating up the drying air, however, there is also a limit as too high a drying temperature can lead to miscolouring or start of plastification in the dryer which causes the material to stick together.

It is logical that it will be impossible to get a raw material dryer than the air available for drying, as everybody knows that it is impossible to dry clothes when it rains. The upper curves in Fig. 5 prove that throughout the year it is not possible to dry certain materials with hot air only as the air will not be dry enough.

When looking at the lower curve which shows the water content in the drying air, used in a desiccant dryer, we can see that the drying air always has a much lower moisture content, and that this low moisture content is a constant one. The low moisture content allows the air to absorb much more water, independent of the drying temperature, and it will always be possible to achieve a sufficient effective drying even if it will be necessary to lower the drying temperature.

The effective predrying of the air guarantees complete uniform dried material and consequently a quality product, independent of the humidity of the ambient air. No corrections in the machine adjustment will be necessary.

8. Hot Air Drying versus Desiccant Drying

In order to show the differences between hot air drying and desiccant drying as clearly as possible, Fig. 6 shows a series of performance drying curves. There is an obvious difference between drying with undried heated ambient air and heated predried air as in a desiccant dryer.

The upper curve shows the drying performance achieved when drying raw material with the ambient air, heated to 80 °C. In cases where a final moisture content of 0.1 % is required this can only be achieved after 3 hours of drying.

However, in order to achieve the 0.1 % it is necessary that the relative humidity in the ambient air is low enough to make this final moisture content possible. In cases where a lower moisture content is required, e.g., 0.06 % it appears that this will hardly be possible under circumstances given by hot air drying.

Table 2: Recommended drying temperature and final moisture content for hygroscopic materials

	Drying Temperature		Drying Time/h		Required final moisture content	
Material	Ambient Air Dryer	Desiccant Dryer	Ambient Air Dryer	Desiccant Dryer	Injection Moulding	Extrusion
ABS	80	80	2—3	1—2	0.08	0.02
CA	70—80	75	1—1.5	1	0.1	0.02
CAB	70—80	75	1—1.5	1	0.1	0.02
PA6	not to be recommended	75—80	—	2	0.1—0.2	0.08
PA 66 610	not to be recommended	75—80	—	2	0.1—0.2	0.08
PBTP	120	120	3—4	2—3	0.005	0.005
PETP	not sufficient	170—180	—	3	0.004	0.004
PC	120	120	2—4	2	0.015	0.01
PMMA	80	80	1—2	1—1.5	0.08	0.02
PPO	120	120	1—2	1—1.5	0.04	0.01
SAN	80	80	1—2	1—1.5	0.08	0.02

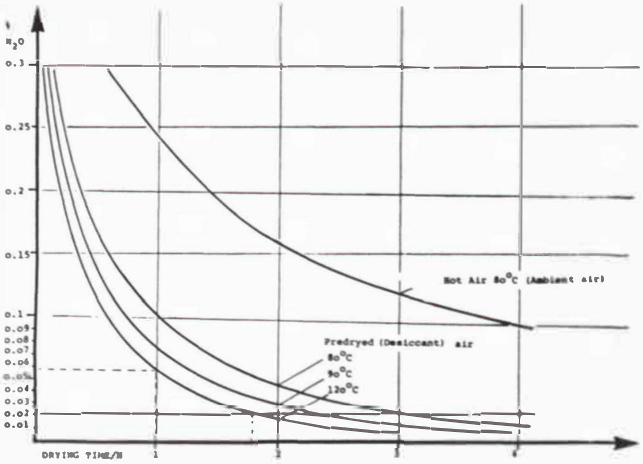

Fig. 6: Drying performance curves

When comparing this curve with the upper curve of the three lower ones, showing the drying efficiency with predried air which has been heated to 80 °C, it can be seen that after drying for 1 hour a final moisture content of 0.1 % has been reached. After drying for one more hour, a final moisture content of 0.06 % which hardly could be achieved with heated ambient air, will be available.

It should be noted, however, that the final moisture content which is shown in the figure is valid for the drying air only. How soon a similar moisture content in the raw material can be achieved will depend on the drying temperature and the raw material itself, as a certain rest-time will be required in order to release the moisture in any hygroscopic material. From experience we know that, e.g., with PA6 the final moisture content in the material will be equal to the final moisture content in the drying air after 1 to 3 hours depending on the original moisture content.

Speaking in general terms, there is no doubt that drying with predried air offers certain advantages in respect of capacity and also a guarantee that it will always be possibie to obtain the final moisture content which is required for a certain raw material.

So far, there is no doubt either that the desiccant dryer is advantageous, however, the disadvantage with the constructions known up to now is that it occupies much space on the machine as well as adjacent to it, as the desiccant bed is separated from the dryer. In addition to the dryer, a conveyor for the raw material will be necessary. Also, the operating costs for a desiccant dryer are high, since blowers must be available for drying the raw material, regeneration of the desiccant bed as well as conveyance.

In view of the disadvantages mentioned LABOTEK developped the Desiccant Dry Loader (DDL).

When designing the unit, emphasis was placed on building a unit having the advantages of the hopper dryer, but with a comparatively low net weight and a low power consumption.

The Desiccant Dry Loader as shown in Fig. 7 is produced in 6 different sizes. It was possible to combine the desiccant bed and the drying hopper achieving the advantage of hopper mounting. Only the smallest unit has a separate desiccant bed.

In order to reduce the weight, the cover is made of glass fibre which is resistant to dents, and an effective insulation reduces the loss of energy to a minimum.

By means of a special turn-table valve it is possible to have one blower only, taking care of all functions including conveying of raw material to the drying hopper, and reducing weight and height of the unit.

As standard equipment the socket is equipped with a very effective magnetic separator, pneumatic slide valve and sight glass which allows to see if the material is entering the processing machine or not. The slide valve is situated in such a way that the hopper magnet can be cleaned during operation and mounting of the slide valve also makes the DDL usable as a batch dryer. The socket is also equipped with a low situated discharge valve that makes it possible to empty the drying hopper completely as the discharge valve is equipped with a turnable outlet, offering the facility of mounting a piece of hose, whereby the material can be emptied into a bin next to the processing machine without any waste.

Fig. 7: Desiccant Dry Loader

A standard equipment to the Desiccant Dry Loader is a separate control, connected to the unit by means of multiple plugs which secure that all switches and buttons for operation are reachable, independent of the size of the processing machine. Also dismounting of the dryer for cleaning is simplified hereby (Fig. 8).

The three functions which have been built into the DDL, i.e.,

— Desiccant drying of the raw material,
— Conveying of raw material to the drying hopper,
— Regeneration of the desiccant bed,

have been made possible by utilizing the suction side as well as the pressure side of the blower, combined with change of blower rotation as well as the turn-table valve leading the air in different directions as required.

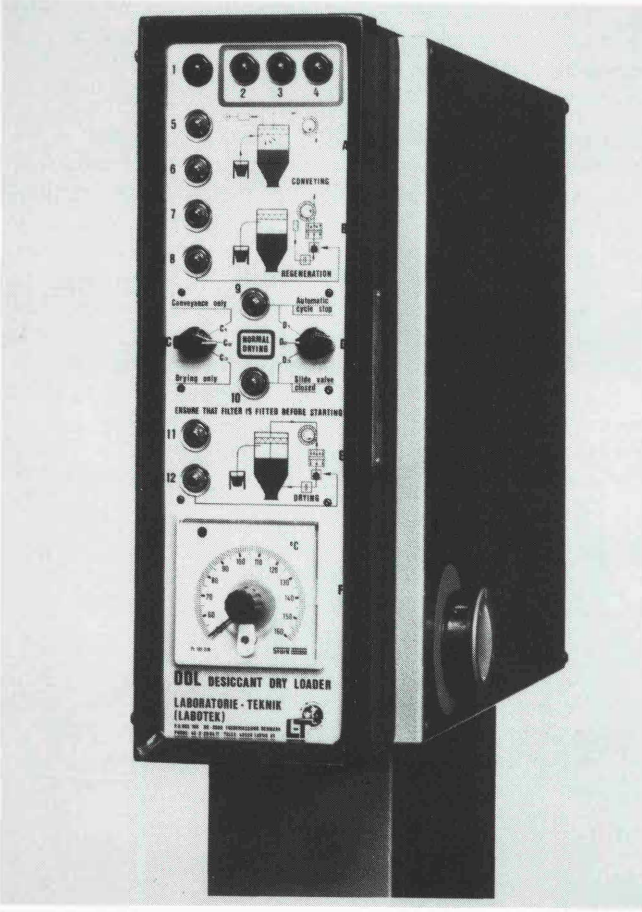

Fig. 8: Control for Desiccant Dry Loader

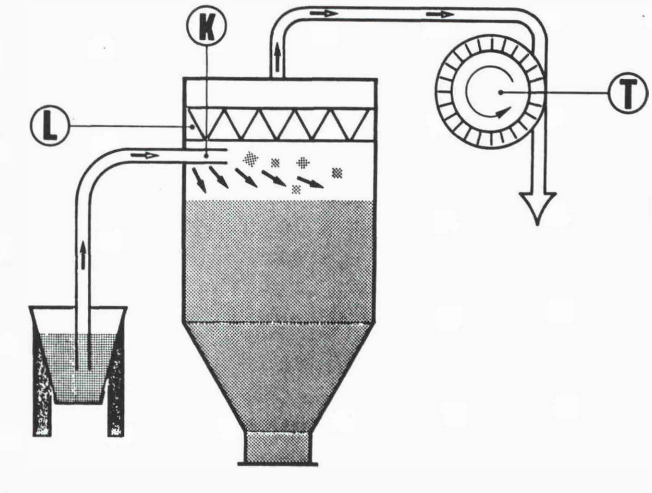

Fig. 9: Principle of conveying with DDL

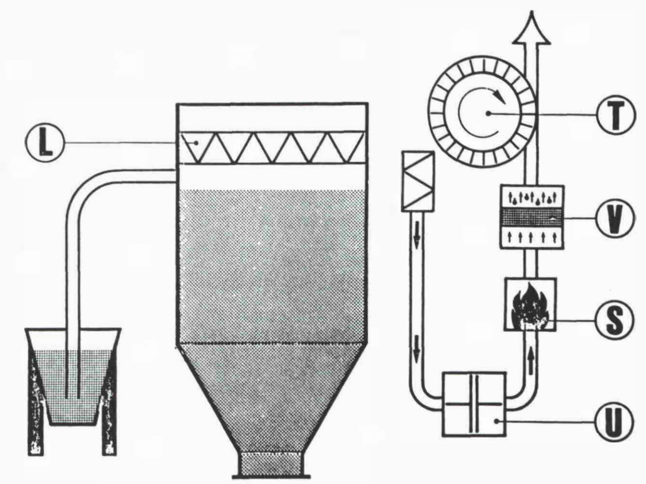

Fig. 10: Principle of drying with DDL

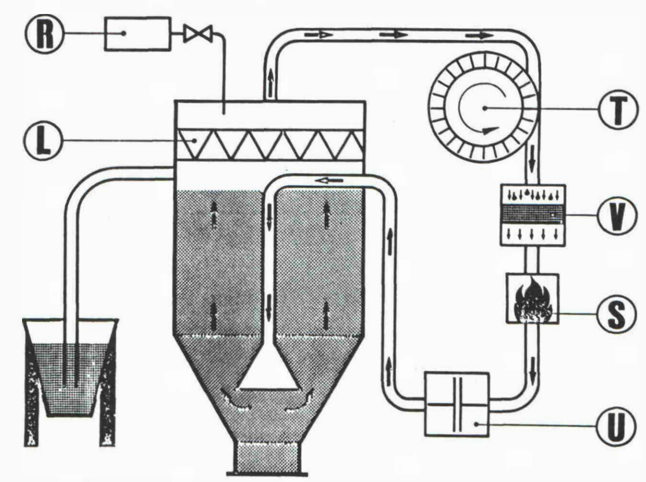

Fig. 11: Principle of desiccant bed regeneration on DDL

The Desiccant Dry Loader can be operated either manually or partly automatically. In automatic operation the DDL operates in the following pre-set time cycle:

When the rotating paddle on the level sensor, mounted in the drying hopper, is able to rotate freely, the turn-table valve is positioned for conveying, and the slide valve in the bottom of the unit closes. The blower T sucks air out of the hopper through the filter L, whereby a vacuum is created in the hopper, causing ambient air to enter the telescopic suction probe which is placed in a bin or bag with raw material. The air that enters the probe will carry raw material along to the hopper where it is spread equally over the surface by means of a cyclone. When the level in the hopper reaches the paddle level sensor, the blower T stops. The slide valve in the bottom opens and a cleaning of the filter is carried out by means of compressed air, stored in a compression chamber (Fig. 9).

Conveyance will take place as long as the level sensor is able to rotate, i.e., until the hopper is full.

When the hopper is full, drying will start (Fig. 10). The turntable valve is positioned for drying of raw material. The blower T sucks air from the material hopper. The air is blown through the desiccant bed V past the heater S through the heat accumulator Y, entering the hopper through a distributor pipe which is fitted by means of a quick release coupling for easy disconnection. The predried heated air is moving equally up through the raw material in the hopper, leaving through the filter L back to the blower T in a closed loop.

When the drying cycle, which is adjustable from 60 to 120 minutes, has been carried out, regeneration of the desiccant bed takes place (Fig. 11).

Table 3: Drying results achieved by predrying of PET with Desiccant Dry Loader

Material/ supplier	Drying temperature degrees C	Required final moisture content PPM/%	Original moisture content PPM/%	Moisture content after 2 hours drying PPM/%	Moisture content after 4 hours drying PPM/%
PET for bottle blowing/ICI B 90	180	20/0.002	2000/0.2	80/0.008	20 = 0.002
PET for injection moulding/ DUPONT					
Rynite 530 with 30 % glass fibres	120	234/0.02	1110/0.11	234/0.023	
Rynite 545	110	234/0.02	431/0.04	234/0.023	

Note that drying at higher temperature than 130 degrees centigrade requires cooler in order to obtain full capacity from the desiccant bed.

The turn-table valve is positioned for regeneration of the desiccant bed. The blower T has changed rotation and sucks ambient air through an air filter through the heat accumulator J and past the heater S, where it is heated to a very high temperature and further through the desiccant bed V, regenerating the content of the molecular sieve. The air which leaves the desiccant bed V passes through the blower T and is being blown out.

Regeneration is automatically carried out after each drying period and the regeneration time is pre-set from the factory to approximately 10 minutes at a high temperature to be followed by 5 minutes of cooling time.

On the front panel all functions are indicated by means of lamps and warning lamps for missing material, filter change, and faulty heater is standard equipment.

Depending on the time in which the material stays in the drying hopper, the DDL may reach a final moisture content of 40 ppm corresponding to 0.004 %.

The compact design of the new three-in-one Desiccant Dry Loader presents the fully automatic performance of:

1. Drying of raw material with predried air,
2. Conveyance of raw material to the processing machine,
3. Regeneration of the desiccant bed.

Hereby the DDL offers facilities such as:

— Homogeneous drying, independent of weather conditions,
— Improvement of the quality of the final products,
— Lower power consumption,
— Low construction compared to the usual constellation dryer/conveyor, and
— as the DDL is designed for hopper mounting, it does not occupy floor space.

Table 3 shows results from drying polyester with a Desiccant Dry Loader. It is interesting to note that after 4 hours drying at 180 °C the PET from I.C.I. was dried from an original moisture content of 2000 ppm to 20 ppm (0.2 % — 0.002 %).

PET has gained total acceptance in use of bottles for carbonated drinks and I.C.I. estimate West European PET bottles usage to be from 12,000 tons in 1980 to 30,000 tons in 1984.

PET is one of the most hygroscopic materials and can only be processed with a moisture content of between 0.02 % to 0.002 %, which can only be achieved with a desiccant dryer.