Meal Desolventizing and Finishing

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ABSTRACT

Soybean is the most widespread oilseed processed around the world, but the technology used in its processing is often extrapolated erroneously for the processing of other material. This paper will examine the traditional process, consisting of stacked desolventizer-toasters (D.T.), horizontal rotary steam dryers and air coolers, and make an analysis for its convenience in the processing of soft seeds such as rapeseed and sunflower. Factors affecting the sizing of the desolventizers are considered. An analysis also is made of alternate techniques such as combined desolventizer-toaster-dryer-cooler (D.T.D.C.), desolventizer-toaster-cooler (D.T.C.) and desolventizer-cooler (D.C.) systems, vertical rotary air dryers, vertical fixed and rotary air coolers or combined air dryers and coolers, vacuum dryers and coolers and fluidized bed coolers and penumatic cooling and conveying. Comparisons of energy, air flow and steam consumption are outlined.

In a solvent extraction plant, extracted meal desolventizing and conditioning account for the largest part of the steam, electricity and solvent consumption and play an important role in its investment cost, as well as in the quality of the meal. This is why we have found it useful to make a survey of these commonly used processes, indicating their conditions of application and underlining the advantages and disadvantages of each of them.

The most commonly used apparatus for desolventizing is the vertical desolventizer-toaster (D.T.) of the stacked trays type. This apparatus was designed initially for soybean meal. Many experimental studies have been made for optimizing the operating conditions of the D.T. in view of producing meal with good nutritional qualities, i.e., with low contents of urease and trypsin inhibitor and a high protein solubility.

A D.T. for soybean treatment basically has two sections, one for desolventizing and one for toasting and drying. Desolventizing is carried out by steam injection and by indirect heating. After desolventizing, the meal has a temperature of 100 C and a moisture which depends on the hold-up of solvent in the spent flakes, the initial moisture content and the heating surface in this section. Retention time of the meal in the desolventizing section is about 5 min. The moisture of the meal at the outlet of the desolventizing compartment is an essential factor because it determines the time during which the meal has to stay in the toasting-drying section for reducing urease activity.

The toasting-drying section comprises several heating trays to ensure the retention time of the meal at a minimum temperature of 100 C and to reduce the moisture of the meal to a value suitable for the subsequent drying equipment. Too low a moisture content (less than 17%) at the outlet of the desolventizing section has, as a consequence, a longer period of toasting-drying which is detrimental to solubility of the proteins and percentage of the available lysine. On the other hand, a high moisture (more than 22%) reduces considerably the retention time in the toasting-drying section. But, unless very large heating surfaces are provided, final moisture will be so high that the energy cost for subsequent drying becomes prohibitive.

Figure 1 shows a conventional desolventizer-toaster. Without going into all the details of the construction of the equipment, we would like to stress some particular points:

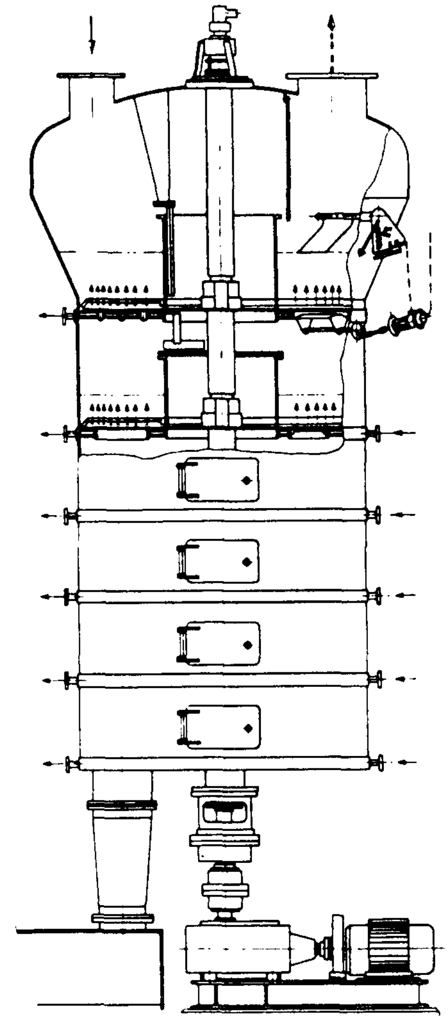


FIG. 1. De Smet desolventizer-toaster.

- the level of material in each compartment is regulated by an assembly comprising float, compressed air servo-valve and pneumatically controlled meal valve. This device presents the two following advantages: smooth operation and ease of adapting the level of material to the operating conditions.
- live steam injection through nozzles mounted on the sweep arms. This device ensures a perfectly even distribution of the steam in the meal for a homogeneous toasting of the meal, and the corresponding double bottom can be fed with high pressure steam and thus be used for heating.
- central chimneys, automatically cleaned, give an easy flow and avoid any build-up of pressure in the apparatus. To ensure useful recovery of the steam produced by the drying in the lower compartments, the chimney of the second compartment is closed, forcing the steam to pass through the grates of the second double bottom and to give off its heat to the material to be desolventized in the second compartment.

The mathematical study of a D.T. can be made using two equations; one for heat balance, the other for mass balance of water. The unknowns of the equations are: the quantity of injection steam and the moisture of the meal at the outlet. The parameters are: (a) moisture of the flakes fed to the extractor, (b) temperature of the material fed to the D.T., (c) retention of solvent at the outlet of the extractor, (d) temperature of the gases at the outlet of the D.T. and (e) heating surface and the heating pressure of the double bottoms.

The Heat Balance Equation says that the total heat given by the material entering into the D.T., the double bottoms and the steam injection is equal to the heat contained in the gases and the outgoing meal, leaving the D.T.

The mass balance equation for water says that the quantity of water entering into the D.T. is equal to the quantity of outgoing water. The two equations thus determine the quantity of steam injected and the moisture at the outlet.

We will examine successively the influence of each parameter taking the following fixed conditions as references: (a) moisture of the flakes: 11%, (b) temperature of the material fed to the D.T.: 55 C, (c) solvent retention at the inlet in the D.T.: 42 kg of solvent for 100 kg of meal + water, which corresponds to ca. 30% of solvent in the mixture, (d) temperature of the gases at the outlet of the D.T.: 75 C, (e) heating surface: 6 m^2 for 100 tons of soybeans per 24 hr and (f) steam pressure: 10 atm.

A. Influence of the Moisture of the Flakes

One percent variation of the moisture of the flakes corresponds to 1.2% variation of the meals moisture whereas the quantity of injected steam increases slightly with the moisture.

B. Influence of the Temperature of the Material fed to the D.T.

A drop of 5 C in temperature of the spent flakes results in an increase of 5 kg/t of the quantity of injected steam and of ca. 0.5% of the meal moisture.

C. Influence of Solvent Retention

For each additional 5 kg of solvent retained per 100 kg of meal, there is an increase of the injected steam of ca. 11 kg/t and an increase of the meal moisture of ca. 0.5%.

This shows the necessity, from the energy saving point of view, of having a sufficient draining time in the extractor and also of designing the D.T. with a predesolventizing section.

D. Influence of the Temperature of the Gases at the Outlet

Although the moisture of the meal is practically the same, the quantity of the injected steam is increased considerably. The temperature of the gases, in the case of soymeal, is an exact indicator of the D.T.'s efficiency. The lower the better.

E. Influence of the Heating Surfaces

An increase of the heating surface will increase the quantity of heating steam and reduce the injection steam and result in a slight increase of the total steam consumption and a significant reduction of meal moisture at the outlet and thus in a reduction of the total quantity of steam consumed in the whole process: D.T. plus drying.

Since this point is most important, we have shown it in the following curves where we include variation of another parameter: (a) temperature of the gases (Fig. 2) and (b) moisture of the flakes at the inlet (Fig. 3).

An alternative to the conventional D.T. is the apparatus designed by Heinz Schumacher: The desolventizer-toaster-dryer-cooler (D.T.D.C.) (Fig. 4). This particular apparatus consists of four stages: one predesolventizing stage, one stage of desolventizing-toasting by steam injection through a perforated double bottom, one stage of drying by hot air blown through another perforated bottom and one stage of cooling by cold air aspirated through the last perforated bottom.

Transfer of the meal from one stage to the next is ensured through special rotary valves extracting the meal along the whole radius, resulting in the same retention time for each meal particle in each stage. These rotary valves are driven by hydraulic motors, the speed of which is con-

TABLE I

Flakes moisture (%)	Injected steam in kg/t of soybeans	Meal moisture (%)
9	96	16.45
10	97.8	17.7
11	99	18.9
12	100	20.1

TABLE II

Temperature (°C)	Injected steam in kg/t of soybeans	Meal moisture (%)
55	99	18.9
50	104	19.4
45	109	19.85

TABLE III

Retention in kg of solvent for 100 kg of meal + water	Injected steam in kg/t of soybeans	Meal moisture (%)
37	87.7	18.3
42	99	18.9
47	110	19.4
52	121	19.9

TABLE IV

Temperature (°C)	Injected steam in kg/t of soybeans	Meal moisture (%)
70	86	18.9
75	99	18.9
80	117	18.8
85	158	18.7

TABLE V

S in m^2 for 100 t of soybeans/24 hr	Heating steam	Injection steam	Total steam	Moisture of the meal (%)
3	15.5	112	127.5	20.1
4.5	23.3	105	128.3	19.5
6	31	99	130	18.9
7.5	38.8	92.7	131.5	18.3
10	51.7	81.3	133	17.2

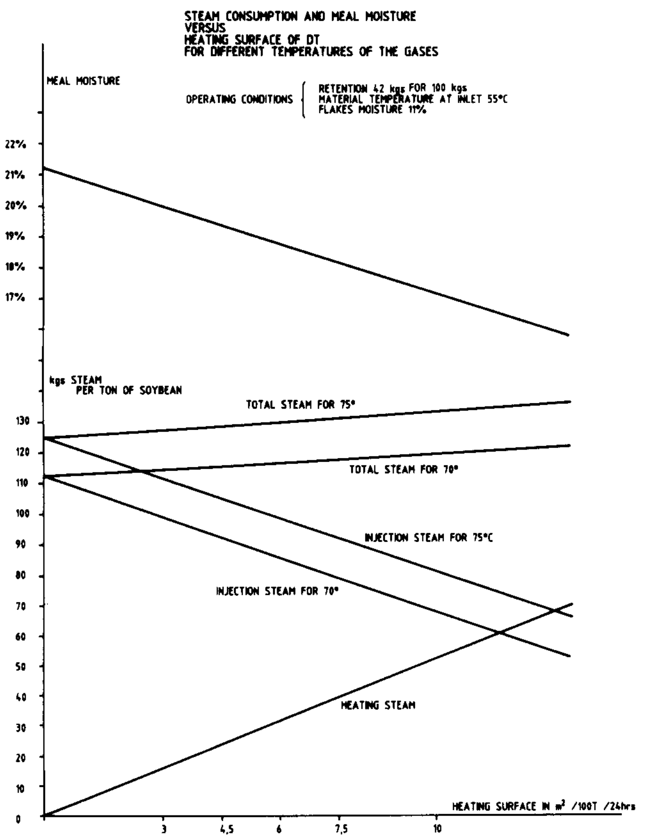


FIG. 2. Steam consumption and meal moisture vs heating surface of D.T. for different temperatures of the gases. Operating conditions: retention 42 kgs for 100 kgs, material temperature at inlet 55 C, flakes moisture 11%.

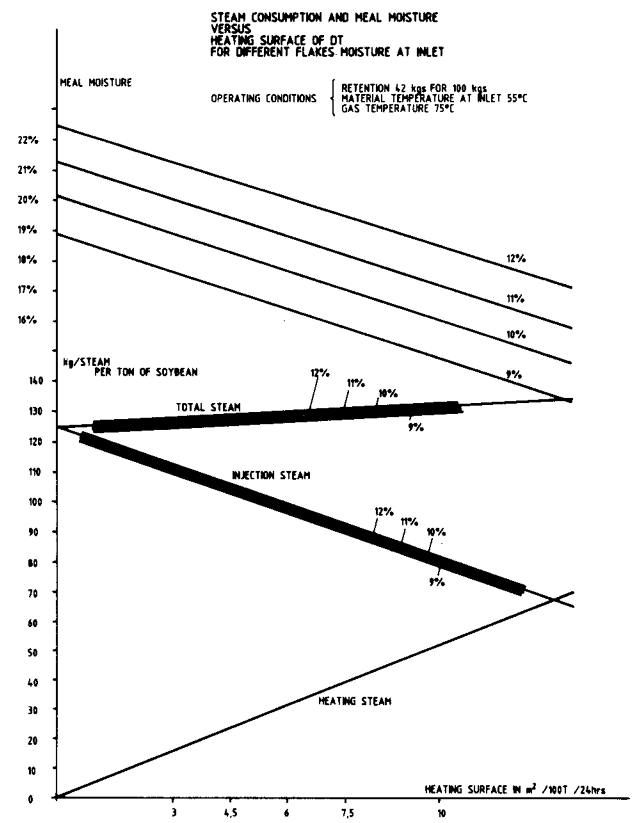


FIG. 3. Steam consumption and meal moisture vs heating surface of D.T. for different flakes moisture at inlet. Operating conditions: retention 42 kgs for 100 kgs, material temperature at inlet 55 C, gas temperature 75 C.

trolled pneumatically by a float in the upper part of the corresponding compartment.

Experimental curves show the efficiency of the toasting when only live steam is used (Figs. 5,6). For example, for a moisture of 17.5%, the urease activity can be reduced to 0.1 delta pH, in 15 min of steaming.

An important argument in favor of the D.T.D.C. is that it works with a high layer of material, making optimum use of the steam, heating and cooling air. As a consequence of efficient steam utilization, the temperature of the gases at the outlet are low corresponding to low steam consumptions.

In the initial apparatus, the desolventizing was only obtained by live steam injection. In these conditions, the moisture of the meal at the outlet of this stage was high: 22% for the reference conditions, flakes moisture 11%, temperature at the inlet 55 C and solvent retention 42 kg/100 kg, involving high steam consumption in the drying section.

The following improvement has been made to the original apparatus: In view of the reduction of the solvent content of the meal at the inlet of the desolventizing-toasting section, predesolventizing is carried out either by tubular driers or by steam-heated double bottoms. A noticeable reduction of the steam consumption of the whole process has been observed.

A further improvement has been brought to the Schumacher desolventizer. The toasting section has been divided in several compartments (Fig. 7). The direct steam is injected in the lowest compartment and passes from one compartment to the upper one, thanks to a great number of perforations in the steam heated tray. At each stage the section is uniformly redistributed in the meal, and the result is a very low temperature of the gases and a very low residual hexane content in the meal, even for the seeds which are the most difficult to desolventize, such as rapeseed.

Drying-Cooling of the Soybean Meal

- The most commonly used solution, at least in the U.S.A., is the conventional D.T., followed by a rotary dryer with steam-heated tube bundle and a rotary or stationary cooler with air aspiration.

  The vertical D.T. is generally supplied with a limited number of steam heated trays and will deliver meal with a rather high moisture content, ca. 21%. The flash evaporation which takes place when the material is discharged to the atmosphere will reduce this normally to 20%. The rotary dryer is sized for reducing the moisture down to 13.5% and the manufacturers indicate a steam consumption of 1.2 kg per kg of water evaporated, or 80 kg per ton of soybean for drying from 20% to 13.5%. To cool down to 10 C above the temperature of the ambient air and to reduce the final moisture to 12%, a rotary cooler with air aspiration is required.

  The water-cooled rotary coolers constitute an interesting alternative for the application. Air pollution is reduced but a supplementary steam consumption in the dryer is required because there is no drying effect by the cooling air as happens with air aspiration in the other type of cooler.
- Another solution for the drying-cooling consists of sizing

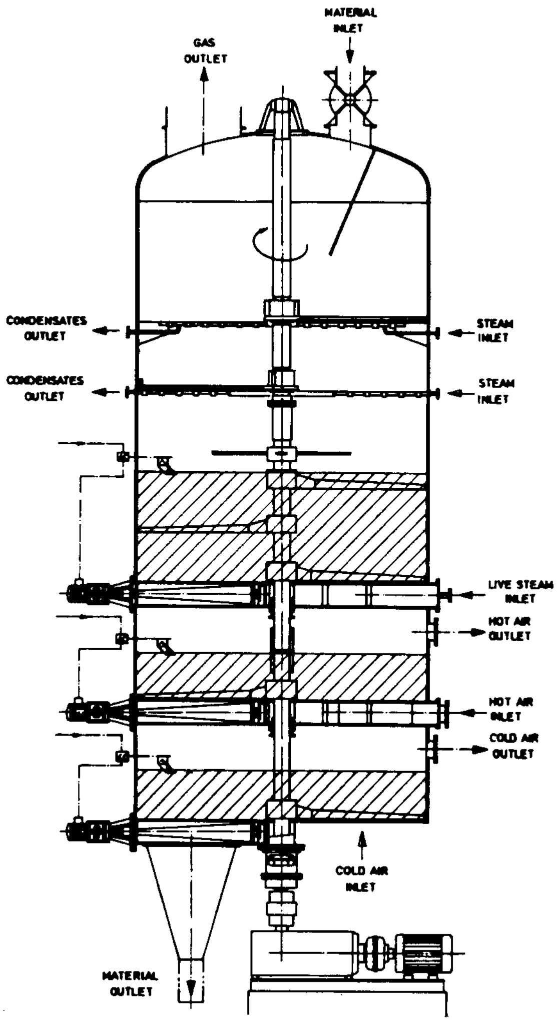


FIG. 4. De Smet desolventizer-toaster-dryer-cooler, Schumacher type.

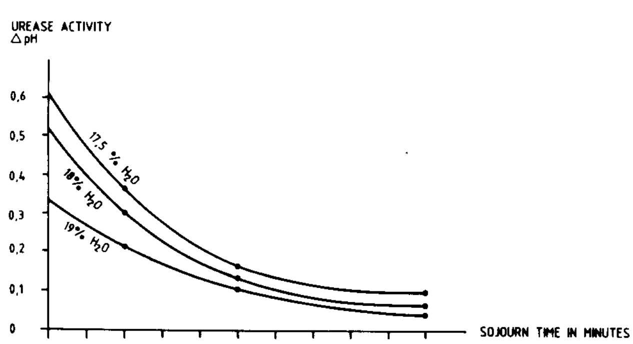


FIG. 5. Urease activity vs sojourn time for different moistures.

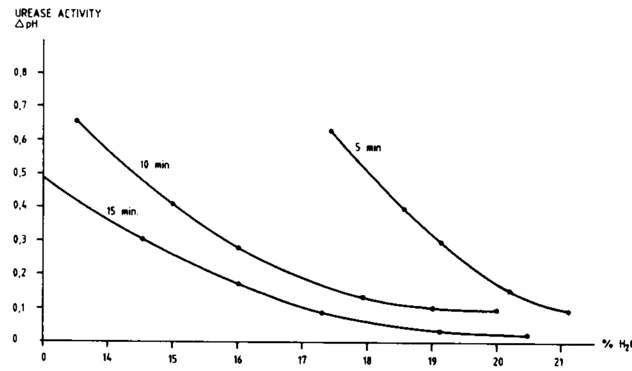
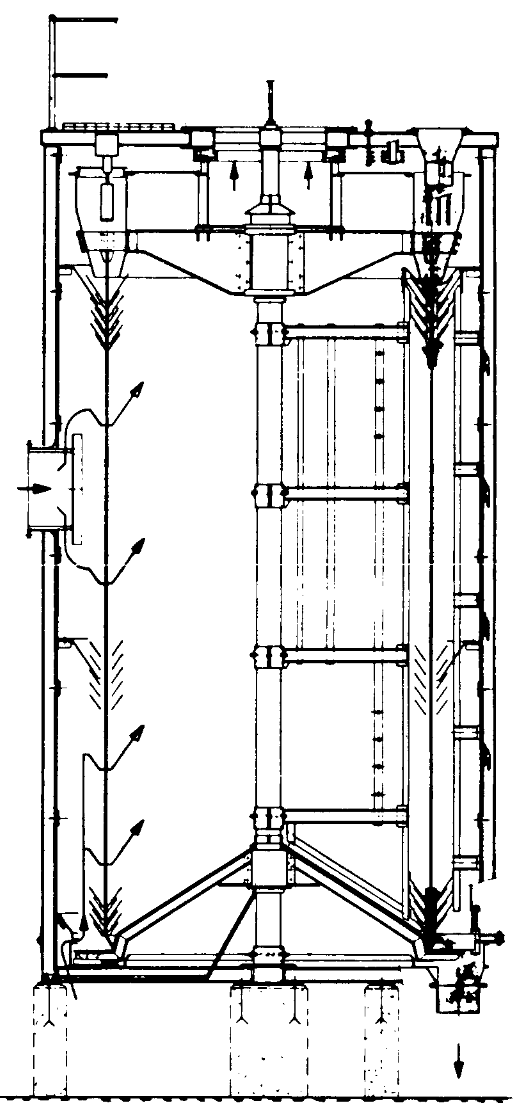


FIG. 6. Urease activity vs moisture for different sojourn times.



the D.T. to reach a moisture at the outlet of less than 19% before flash evaporation. In these conditions, the utilization of a rotary vertical cascade dryer-cooler with air aspiration is possible (Fig. 8).

In this type of apparatus, the meal flows by gravity through a succession of rotary cascades and is crossed by successive flows of hot and cold air. The discharge of the material is controlled automatically according to the meal level in the feeding hopper. Thus, the same apparatus performs the drying and the cooling, avoiding the necessity of intermediate conveyors.

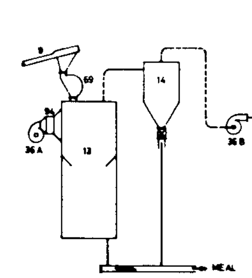


FIG. 8. Rotary cascade meal dryer cooler.

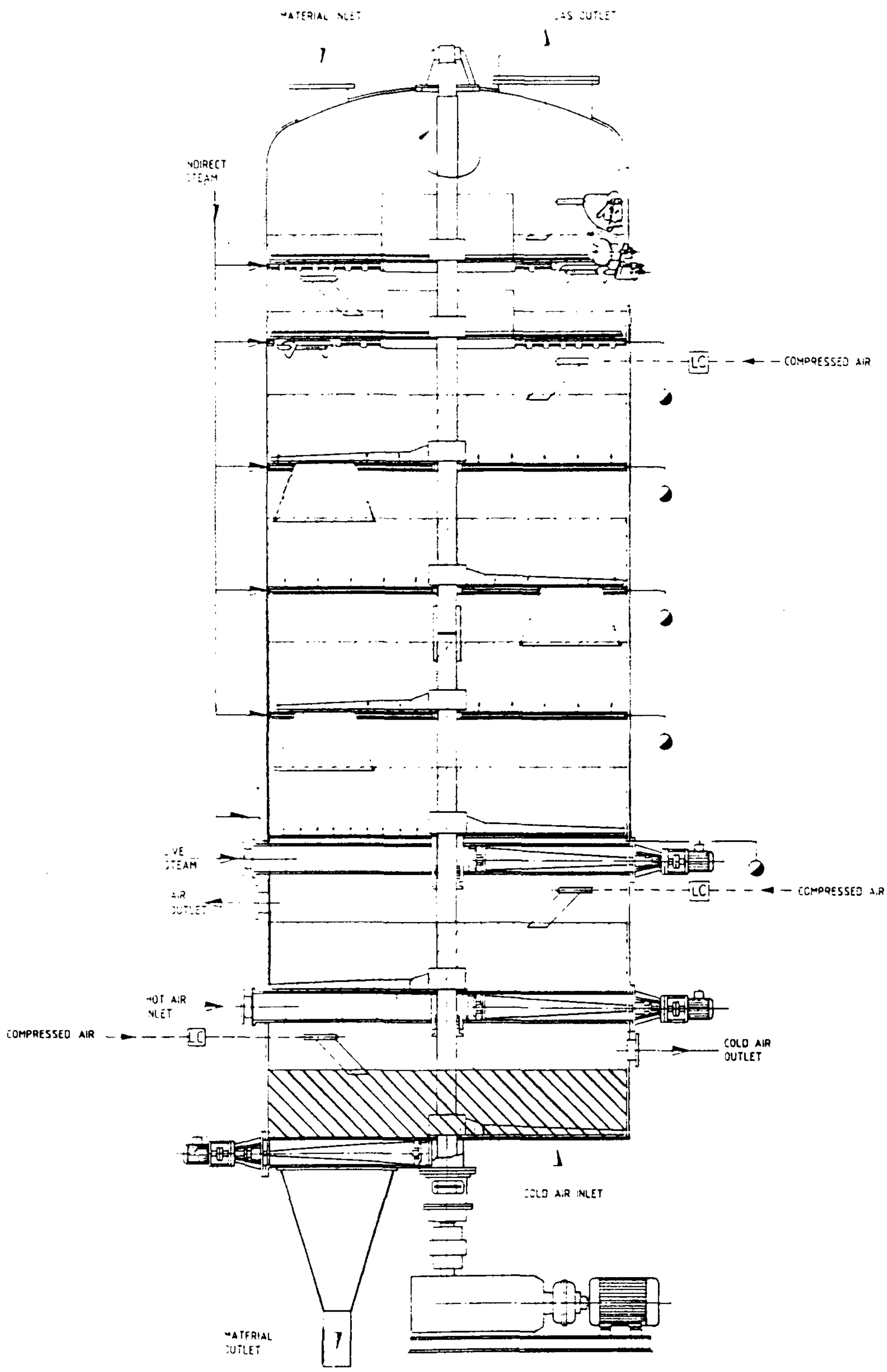


FIG. 7. New De Smet-Schumacher desolventizer-toaster-dryer-cooler.

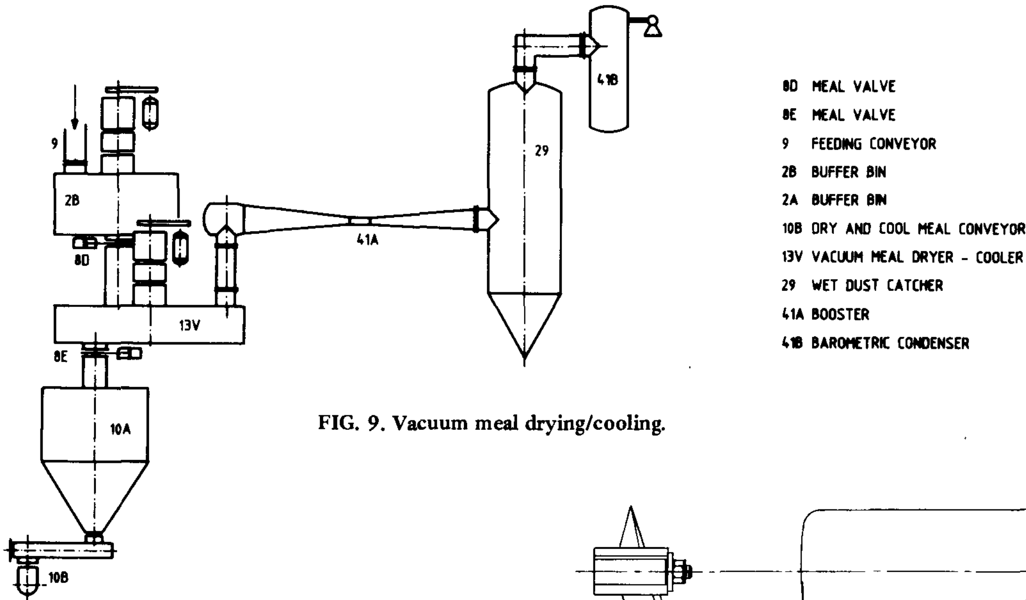


FIG. 9. Vacuum meal drying/cooling.

TABLE VI

	Moisture (%)	Steam (kg/t)	Electricity (kWh/t)
Solution I			
Conventional D.T. with reduced heating surface and rotary tube steam dryer and rotary air cooler.			
– D.T.	21	125	1.5
– Dryer	13.5	80	1
– Cooler	12	–	2
Solution II			
Conventional D.T. with oversized heating surface	18.9	130	2
Cascade air dryer-cooler	12	40	3
Solution III (Schumacher type)			
D.T. section	19	172	8
D.C. section	12		
Solution IV (new Schumacher type)			
D.T. section	18.7	165	7
D.C. section	12		

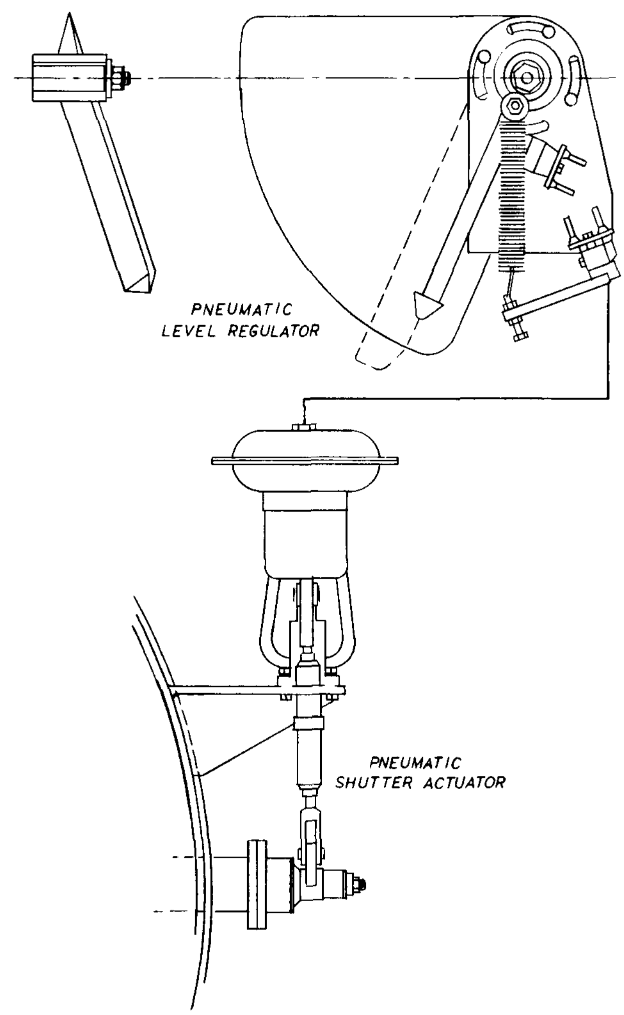


FIG. 10. Pneumatically controlled meal valve.

In this apparatus, as the meal is distributed in a thin layer on a large surface at the periphery of the rotor, the resistance to the passage of the air is negligible and the carryover of dusts considerably reduced. The steam consumption for a cascade dryer-cooler is 40 kg/t of soybeans for drying the meal from 18.5% to 12% and cooling it to ambient + 10 C. The electricity consumption is a negligible 3 kWh/ton.

– The third solution that we will consider is the D.T.D.C. (see Fig. 4 and 7). In the drying and cooling compartments, successively, the hot air and the cold air pass countercurrently through the layer of material, the height of which can be regulated between 300 and 500 mm. This high layer and the countercurrent flow ensure a great efficiency to the heat exchange but, on the other hand, the distribution of the air through the perforated bottoms and its passage through an important material layer results in an important power consumption (6 kWhT) of soybeans.

The simplicity of this apparatus, which combines in one vessel the three operations of desolventizing-toasting, drying and cooling, eliminates any intermediary conveyor and permits a lower investment and maintenance cost.

The principal figures of the three systems of drying-cooling are given in Table VI. These figures are based on the usual conditions: flake moisture 11%, temperature 55 C, solvent retention 42 kg and for a capacity of 1,000 tons of soybeans per 24 hr.

The solution IV is definitely the most interesting from the steam consumption point of view.

Electricity is high for solutions III and IV, but this disadvantage is compensated for by its simplicity, low investment cost and low maintenance cost.

Other Solutions

The fluidized bed dryer-cooler has steam consumption similar to the cascade dryer-cooler but requires more power consumption because of thickness of the material, distribution bed and high air speed (4.5 kWh/t).

The vacuum meal dryer-cooler is, at first sight, an interesting solution because all the heat necessary for evaporating the solvent is supplied by the material but for the same reason its use is limited to the cases where the desired reduction of moisture does not exceed 5%. Furthermore, like all the systems treating under vacuum solid particles, it has to be semicontinuous. The energy consumption necessary for establishing vacuum at each cycle, either by steam ejectors or vacuum pump, reduces a good part of its interest. Figure 9 shows the principle of the vacuum dryer with the two buffer bins ensuring the passage from the continuous process to the discontinuous and back to the continuous.

If, for the desolventization of the extracted meals of canola seed and sunflower, the theoretical study of the influence of the different parameters can be made by using the same equations of the heat and mass balances used for soya processing, the operating conditions are nevertheless essentially different. The toasting is not necessary while there is no urease to destroy in these seeds, but the critical factor is the desorption of the residual hexane. Experience has shown that, for these meals, the quantity of residual hexane can be reduced to admissible figures only by lengthening residence time at a temperature of 100 C and with an important stripping by sparge steam. Resistance to the diffusion of the hexane through the material is probably bound to the structure of the meal and especially to its fiber content.

Theoretical and laboratory studies are presently being conducted for determining the parameters influencing the form of the desorption curves of the hexane in these meals.

For the desolventization of canola and sunflower meals, with the vertical D.T. of Figure 1, the steam injection is distributed through the vertical shaft and the sweep arms, on all trays of the apparatus. The utilization of a double rotary union for steam adjusts separately the injection steam needed for the desolventizing and stripping sections. The central chimneys in the upper stages ensure the free flow of the vapors of water and solvent and prevent the buildup of excess pressure in the D.T. The bottoms of the lower stages are fitted with grids for the systematic utilization of the stripping steam coming from the lower trays. The system of pneumatically-controlled meal valves regulates independently the height of material in each stage and consequently the total residence time in the apparatus can be adjusted according to function of the product to be treated (Fig. 9).

These mechanisms contribute also to ensuring a narrow residence time spectrum of each particle in the D.T. Large heating surfaces are foreseen. In the lower stages, the accelerated evaporation of water speeds up the desorption phenomenon of the hexane, and makes useless any subsequent drying equipment.

The moisture of the meal at the outlet of the D.T. will be, depending on the initial moisture of the cakes, between 6 and 8% for the rapeseed and between 8 and 10% for the sunflower.

The new Schumacher type D.T. is specially suitable for the desolventization of canola, palm kernel and copra meal because the efficient sparge steam utilization and the extended residence time of the meal at a temperature of 100 C ensure very low residual hexane content in the meal.

[Received August 17, 1982]