ONION DEHYDRATION

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GENERAL DESCRIPTION

All onions for processing are grown from specific varieties best suited for dehydration. Specific strains of the Creole Onion, Southport Globe Onion, and the Hybrid Southport Globe were developed by the dehydration industry. They are white in color and process a higher solid content which yields a more flavorful and pungent onion.

Onion dehydration involves the use of a continuous operation, belt conveyor using fairly low-temperature hot air from 38 - 104°C. The heat originally was generated from steam coils, but now natural gas is more popular. Typical processing plants will handle 4500 kg of raw product per hour (single line), reducing the moisture from around 83 percent to 4 percent (680 - 820 kg finished product). These plants produce 2.25 million kg of dry product per year using from 35 - 46 MJ/dry kg produced (+14 MJ/kg of electrical energy), or 9.3 MJ/kg of water evaporated.

An example of one type of processing equipment, the Proctor dehydrator, is a single-line unit 64.5 x 3.8 m wide, requiring 2450 m^3 of air per minute and up to 42 million kJ per hour. Due to the moisture removal, the air can, in some cases, only be used once, and thus, is exhausted. Special silica gel–Bryair, desiccations units are required in the final stage. Approximately $200,000 in fuel are, thus, used in a single-line dryer in a year's operation (180 days).

PROCESSING STEPS

Onion dehydration using a continuous conveyor dryer involves the following basic steps: a) harvesting, b) transporting to the plant, c) curing, d) washing, e) slicing, f) dehydration in three to four stages, g) milling, and h) packaging. Each of these steps is discussed in detail for a Proctor (Proctor and Schwartz, Inc. of Horsham, PA) dehydrator. A diagram of a typical dryer is shown in Fig. 1.

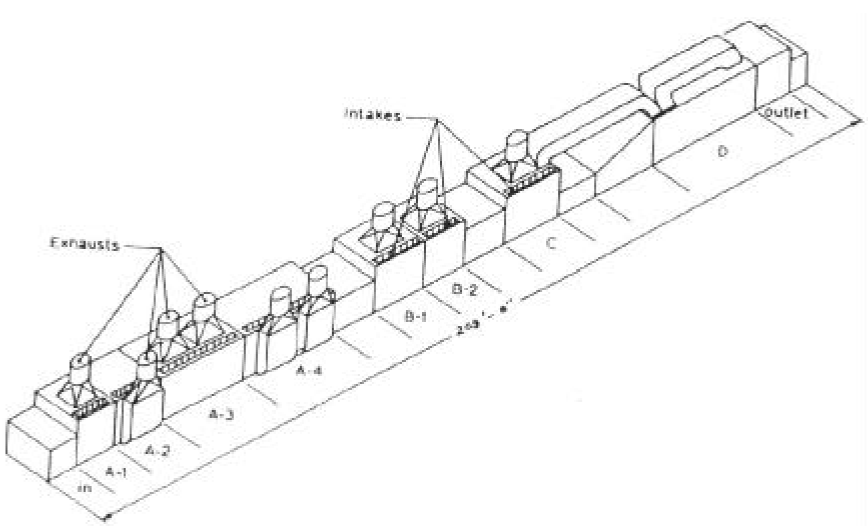

Figure 1. Single-line onion dehydrator.

Harvesting is accomplished mechanically by specialized equipment that is designed and fabricated by the processing industry. Harvesting is accomplished by a small crew of 20 to 30 people used to inspect the onions and to operate the equipment. The onions are topped, dug, inspected, and loaded into bulk trucks holding about 22,700 kg each.

The trucks loaded with onions are taken directly to the plant. They are loaded into large curing bins, where excess moisture is removed by passing large volumes of heated air (38^{o}C) through the onions. Curing conditions the onions so that peeling and processing can be accomplished successfully.

After curing for 48 to 72 hours, the onions are passed into the processing line. The earlier method of scooping up the onions with a tractor has been replaced with an automatic conveyor system that gently carries them to the preparation line. Machines automatically remove any tops that may remain attached to the onions. They are then inspected, washed in a high-pressure washer, soaked in a stainless steel tank to remove sediment, washed again in a high-pressure washer, and re-soaked in a bath of highly chlorinated water in order to reduce bacteria to the lowest possible level. The onions are then re-inspected and placed in stainless steel surge tanks. Two large stainless steel tanks are used so that one can be washed as the other is being used. The onions are fed out of the surge tanks into the slicers. Razor-sharp rotating knives cut the onions into uniform slices, which are then passed to the dryer.

From the slicers, a continuous and uniform flow of onions is conveyed to the wiper feed that carries the sliced product laterally across the open-feed end extension. Here, the onions are carefully transferred to the dryer conveyor for the first stage of drying. This is the most critical stage; where, under high-volume air flow conditions and with moderately high temperatures, the bulk of the water is rapidly removed from the onion. The moisture content of the onion is reduced from an initial 83 percent to 25 percent. This is called the “A” stage; where, onion loading depth is approximately 10 cm.

Absolute uniformity and controlled depth of loading on the dryers is necessary to prevent “pinking,” an enzymatic discoloration that can take place in the onion slice if proper drying conditions are not maintained. The pure white color of the discharged product from this drying stage is a test of the high quality of the product. Normal drying temperature for stage “A” is around 104^{o}C; however, temperatures as low as 82^{o}C can be used. The lower the temperature will increase the processing time; however, the quality will be improved.

High-powered blowers and exhaust fans move the air over natural gas burners (or geothermal heat exchangers), and through the beds of onions on the dryer conveyor, to evaporate the necessary tons of water removed from the product each hour. Close air volume and pressure control must be maintained in all parts of this drying stage as the air moves up and down through the bed to obtain product drying uniformity. Automatic temperature controllers and a long list of safety devices control the continuous operation.

At the proper point in the drying process, the onions are automatically transferred to the second stage (“B” stage) of drying; where, under reduced temperature conditions and deeper bed loadings (approximately 30 cm), the difficult to remove diffused water is slowly withdrawn. Here, moisture content is reduced 10 percent. At the special transfer zone, the onions are gently handled by rotary devices that assure full removal from the first-stage dryer and separation removal of clumps for uniform second-stage loading.

The second stage of drying transfers to the third stage (“C” stage) with even deeper loading (approximately 75 to 100 cm deep), as the deeply diffused water becomes even more difficult to remove. Moderating temperatures and air flows are used to maintain close product temperature control as a steady evaporation of water is reduced from each onion slice and the evaporative cooling effect can no longer be counted on to maintain the low product temperature required for maximum product quality. After leaving the “C” stage, moisture content is down to 6 percent.

A special unloader takes the now nearly dry onions off the third-stage conveyor, transferring them to the elevating conveyer for the fourth and final stage of dehydration (if necessary). Here, conveyor loading depths up to 1.8 m are used for final moisture reduction and equilibration. Dehumidified air from a two-stage desiccation unit is counter-flowed through this deep layer to bring the finished onions to the point (about 4 percent moisture) where milling can best be accomplished and shelf life maintained.

After drying, the onions are passed over a long stainless steel vibrating conveyor that gently carries them to the milling area. In the mill, skin is removed by aspirators from the onion pieces. The onions are then milled into sliced, large chopped, chopped, ground, granulated and powdered onions.

POWER PRODUCTION AND ENERGY REQUIREMENTS

The energy requirements for the operation of a dryer will vary due to differences in outside temperature, dryer loading, and requirement for the final moisture content of the product. A single-line Proctor dryer handling 4500 kg of raw product per hour (680 - 820 kg finished) will require about 530 GJ/day, or for an average season of 150 to 180 days, 80 to 95 TJ using approximately 35 MJ/kg of dry products. This is estimated to cost 11 cents per kg of finished product.

The energy is provided by natural gas or geothermal fluid; air is passed directly through the gas flame or geothermal heat exchanger in stages A and B, and over steam coils in stages C and D. The steam coils are necessary to prevent turning of the onions in the last two stages.

In addition to the heating requirements, electrical energy is need for the draft and re-circulation fans, and small amounts for controls and driving the bed motors. Total electric power required for motor is from 500 to 600 horsepower (370-450 kW), or about 1×10^4 kWh/day, or 2×10^6 kWh/season. This amounts to 2.30 MJ/kg of finished product and increases to about 14 MJ/kg when all electrical requirements are considered.

The details of each stage of a typical process are listed in Table 1.

Table 1.

Stage	Size (length)	Motor Output (kW)	Air Temp.(^oC)	Air Volume (m^3/s)*	Depth of Onions (cm)	Moisture Content
Curling Bin Transfer	30 x 30 m	–	38	variable	variable	80 - 85
A (4 compartments)						
Transfer	22 m	300	88 - 104	108	10	20 - 25
B (2 compartments)						
Transfer	7.6 m	67	68 - 77	28	25	12 - 16
C (2 compartments)						
Transfer	7.6 m	52	57	33	75 - 100	6 - 8
D (2 compartments)						
Transfer	7.6 m	30	49	9.5	150 - 180	4 - 5

* Some air may be re-circulated depending upon moisture content.

In general, four stages (A through D) are preferred; however, if the ambient air humidity is below about 10 percent, stage D can be eliminated. Also temperature and number of compartments in each stage may vary.

Stage D, supplying desiccated air with a Bryair unit, reduces the moisture content of the product to a point below that of the ambient air. The unit is divided into two sides: the process side, which supplies desiccated air to the dryer after it has been passed through silica gel beds; and the reactor side in which heated air is passed over the silica gel beds in order to remove the moisture which had been absorbed in the process side.

The process air is drawn in from the outside under ambient conditions of temperature and humidity, passed through a filter and a cooling coil, and then is circulated through a dry silica gel bed where some of the moisture is absorbed. The process air then is drawn out by a fan and directed to the D2 stage of the dryer. This process air leaves the Bryair unit at a temperature of about 49ºC with a moisture content of about 4 g per kg.

On the reactor side, ambient air is drawn into the intake and passed over a gas burner which heats the air to about 121ºC, after which the air is circulated through the silica gel beds so that the moisture which had been absorbed in the process side is removed.

A suction fan on the discharge side then exhausts the moisture-laden reactor air to the atmosphere at temperatures of from 66 - 107ºC. A slight pressure differential is maintained between the process and reactor sides so that air is prevented from leaking to the process side from the reactor side.

A specific example of a Proctor dehydration is detailed in Table 1 and Figure 2. The total energy requirements, using natural gas as a fuel, varies from 22 - 27 x GJ/hr depending upon the ambient air varying from 18 - 4ºC. Air flows depend upon temperature and amount or recirculated air–which could only be estimated.

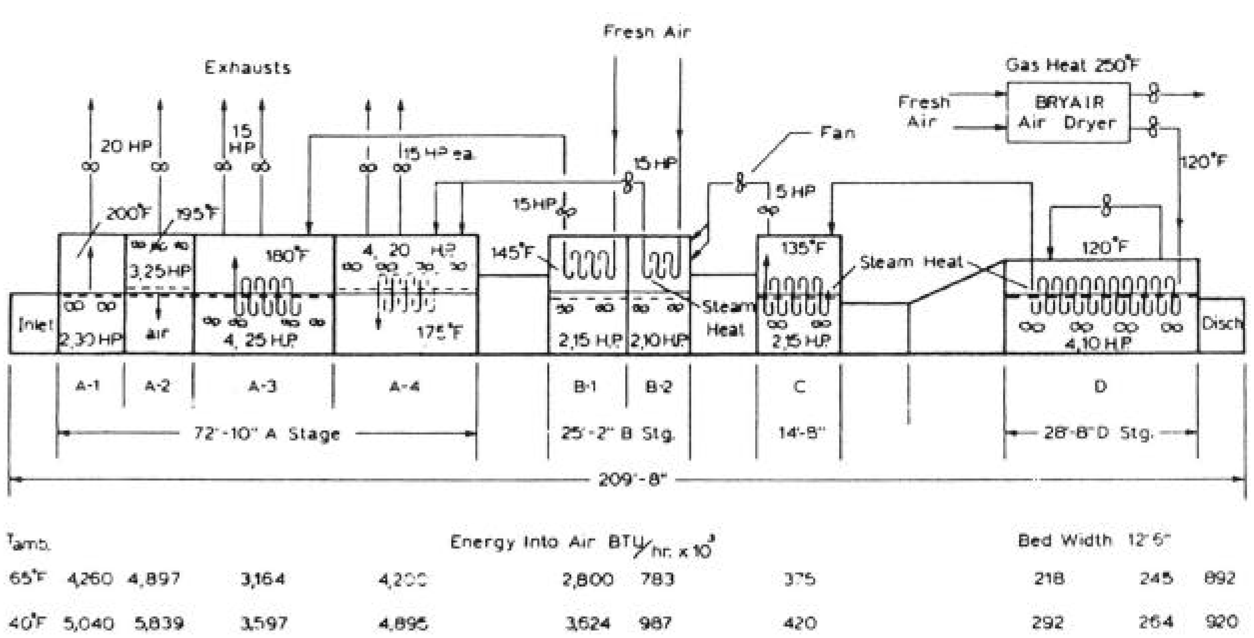

Figure 2. **Temperature and energy requirements for each compartment of a single-line onion dehydrator.**

GEOTHERMAL APPLICATIONS

Using the specific example detailed in Table 2 and Figures 1 and 2, a design was made to convert the Proctor dehydrator to geothermal energy. Using a 11°C minimum approach temperature between the geothermal water and process air, a well with 110°C water is required.

Table 2. Onion Dehydration

Stage	Air Temperature (°C)	Heat Supply	Approximate HE Opening Size (m)	Estimated Air Flow (m^3/s)	Estimated* KJ/hr x 10^6
A1	100	Gas burners	3.3 x 1	13.6	5.3
A2	100	Gas burners	4.3 x 1	13.6	6.2
A3	88	Gas burners	4.0 x 1	19.3	3.8
A4	82	Gas burners	4.6 x 1	19.3	5.2
B1	71	Gas burners	4.3 x 1	8.0	3.8
B2	63	Steam coils	3.3 x 1	9.0	1.0
C	54	Steam coils	4.6 x 1	9.4	0.4
D	49	Steam coils	8.8 x 1	4.9	0.6
Bryair	150	Gas burners	2.3 m^2	3.0	1.0
				Total	27.3 x 10^6

* Assuming ambient at 4°C; total = 22.1 x 10^6 kJ/hr at 18°C.

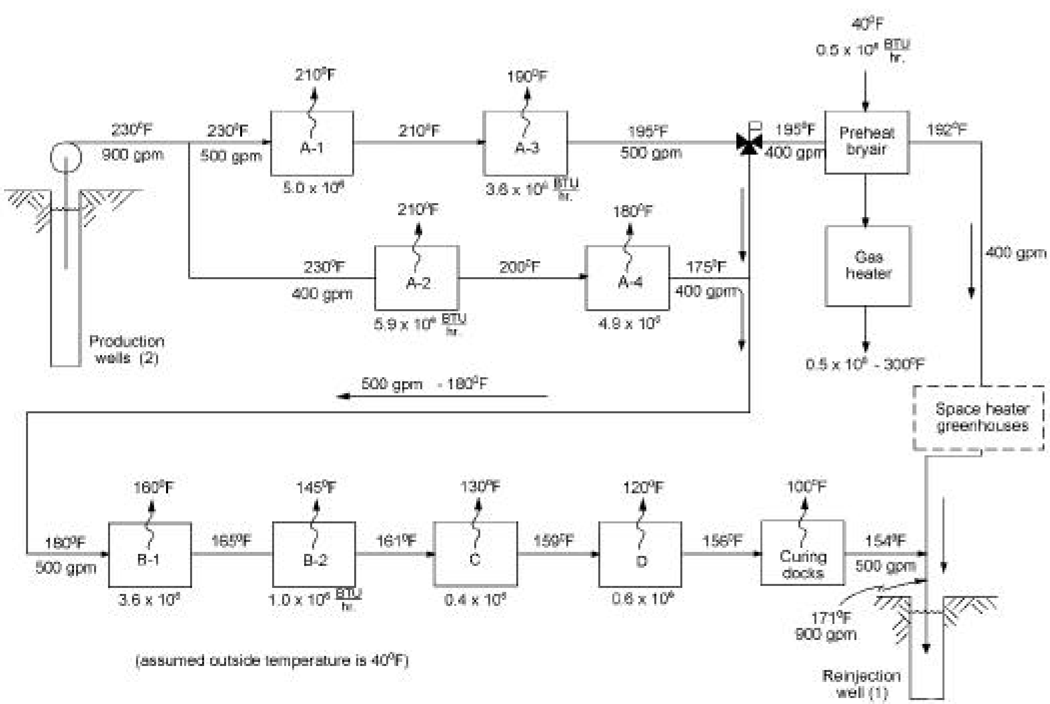

Figure 3. Design 1 - single-line onion dehydrator using 110°C geothermal water and 4°C ambient air.

The first-stage air temperature can be as low as 88°C; however, temperatures above 93°C are desirable, as indicated by the industry.

Figure 3 indicates Design 1 using 110°C water and considers the ambient air to be 4°C. The line has to be split between compartments A-1 and A-2, since both require 100°C air temperature. A total of 57 L/s is required. Two wells can probably supply this volume. The Bryair desiccator requires 150°C on the reactor side; thus, only half of the 1.0 x 10^6 kJ/hr energy requirements can be met geothermally. Geothermal heat will be used for preheating to 80°C with natural gas or propane used to boost the air to 150°C. The waste water from the Bryair preheater has a temperature of 90°C; thus, this could be used for space heating, greenhouses or other low-temperature energy needs. The waste water would be returned to an injection well.

In compartments A-1, A-2, A-3 and A-4, four finned air-water heat exchangers in parallel would be required to satisfy the energy requirement and water velocity flows. The remaining stages would require from one to two heat exchangers in each compartment, depending upon the energy requirements.

Due to the competitiveness of the industry, specific details and energy requirements are difficult to obtain. Most of the details have been obtained from "Economic Study on Low Temperature of Geothermal Energy in Lassen and Modoc Counties, California," by VTN-CSL for the state of California, 1996, and "Application of Solar Energy to Continuous Belt Dehydration," final report by Trident Engineering Associates, Inc., for ERDA, 1977.