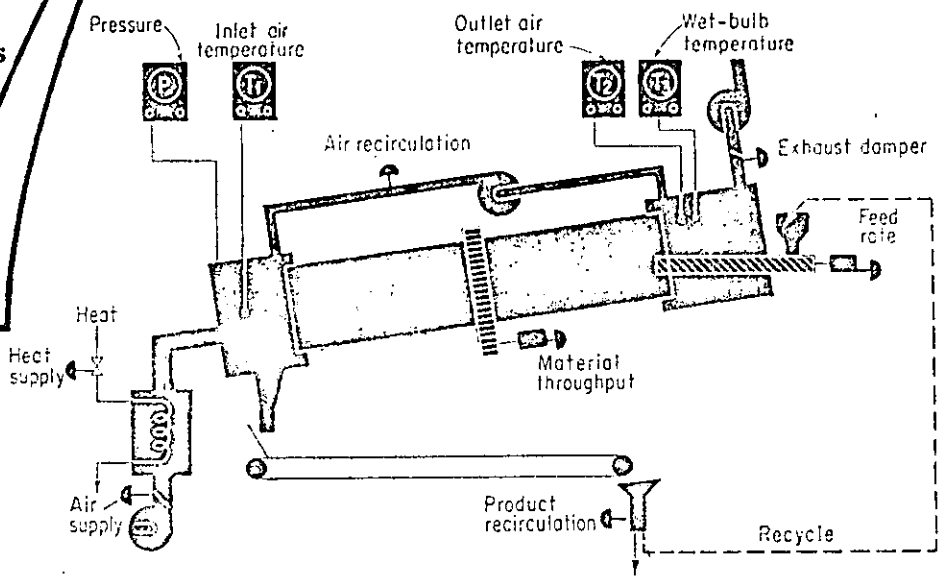
7 Possibilities for process control in drying systems



Control Solids-Drying Equipment

Awareness of the many variables in dryer operation is essential to the design of dryer control systems.

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Drying operations have a number of significant variables that are not easy to measure directly. Therefore, general practice is to hold measurable conditions constant so that a uniform product will be made. This works well if there are no load changes. The basic control problem is essentially the same for rotary, traveling screen, moving sheet, tray and screw-conveyor dryers. This discussion, in terms of the typical rotary dryer, also applies to the other types. Spray dryers present additional problems and are discussed separately.

Both temperatures and pressures are usually easy to measure in drying systems. These or any other readily available measurement can be used for control since system dynamics are favorable in drying systems where there is a reasonably rapid response to change. A generalized drying system in the form of a rotary dryer is shown in the illustration.

Process control for dryers can be supplied at seven points:

- Heat Supply—Can be steam, fuel or electrical energy.
- Air Supply—Controlled by damper in the discharge of a fan.
- Material Throughput—Movement of the material in a rotary kiln or dryer depends on speed, diameter and slope of the dryer. Belt dryer throughput rate is easily controlled by belt speed.
- Air Recirculation Rate—In some screen dryers, recirculated air is introduced at one or more points with a separate blower. It is controllable by a damper. Generally, air recirculation is not deliberately introduced or controlled in other types of dryers, but it is present to some extent due to convection currents.
- Feed Rate—Feed rate of material to be dried is commonly held constant or it is determined by production needs. Theoretically, it could be varied in response to a measurement.
- Exhaust Damper—Air can be pushed (forced-draft fan) or pulled (induced-draft fan) through a dryer. If both types of fans are used, either but not both can control air flow. The other fan can control pressure at a single point between the two dampers.
- Product Recirculation—This is an infrequent practice, used mostly when the material handling problem becomes troublesome. It is useful in rotary kilns to prevent ring formation of reacting products. Product recirculation takes place in designs with countercurrent air at sufficient velocity to move some of the product to the feed end.

Probably no single dryer has been built with all seven conditions automatically controlled. However, all of these conditions affect dryer performance to some extent. Any of the seven conditions can be held

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Possible control arrangements for dryers—Table I

	Heat Supply	Air Supply	Belt or Shell Speed	Air Recirculation Rate	Feed Rate	Exhaust Damper	Product Recirculation
Common measurements							
Inlet air temperature, T_1	**A**	A				A	
Exhaust air temperature, T_2	A	A		B	A	A	B
Pressure, P		A				**A**	
Exhaust air/ wet bulb temperature, T_3	A	A		**A**	A	A	B
Product Qualities							
Temperature	A	A	A	A	B		B
Moisture	A	A	A	A	B		B
Degradation	A	A	A	A	B		B
Operating conditions							
Solids depth			A		A*		
Retention time			A		A		A
Air velocity		A		A		A	
Evaporation rate	A	A			A	A	
Solids/gas ratio		A		B	A	A	

A and B represent good and fair control, respectively, of loop determined by intersection of row and column. Colored **A** represents variables commonly controlled by each measurement. A* for rotary unit and blank for screen dryer.

constant either because it is not convenient to control them, or because there is no suitable measurement within the system to regulate these conditions.

Control of all system variables does not require each controllable condition to be manipulated automatically from a measurement. For example, an operator can adjust a valve in response to an appropriate measurement. Each control element can be operated manually or automatically.

Table Lists Control Arrangements

Possible control arrangements for dryers are shown in Table I. The vertical columns are the seven elements that can be used to control the system. Horizontal rows depict:

- Measurements that are commonly used.
- Product qualities that are desirable to control where suitable direct measurements are possible.
- Conditions within the dryer that can serve as guides for proper operating conditions.

An A at the intersection of a row and column means that the measurement in that row can be used to control the condition shown in the given column. B means that closing this control loop is not as satisfactory, but is possible in most installations. Blank spaces in the table indicate that control would be unsatisfactory. Good control of a single loop, indicated by A, assumes that the equipment is operating with all control elements in a fixed position and that the one element under question is varied.

For example, in column 1, A appears opposite the measurements for inlet air temperature, exhaust air temperature, exhaust air wet-bulb temperature, product temperature, product moisture, product degradation and evaporation rate. This means that all of these measurements, actual or potential, would be influenced by a change in the position of the valve in the heat supply. Thus, almost any one of these measurements, if available, can be used to control the heat supply. However, the moisture content of the final product would be ideal in principle.

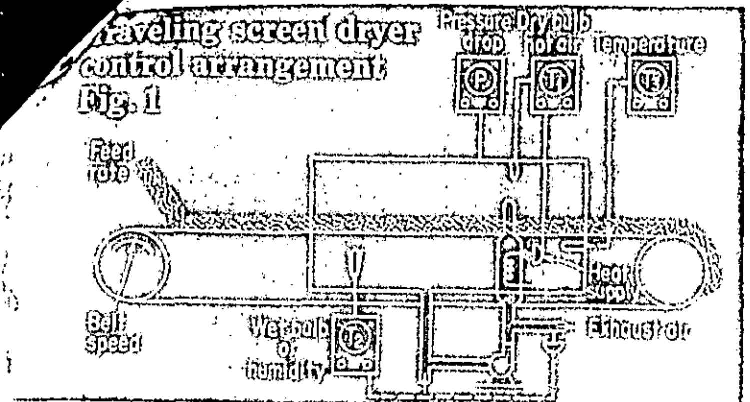
In Table I, the A values printed in color indicate variables commonly controlled by each measurement. The three in color are: (1) inlet air temperature, T_1 that controls heat supply; (2) pressure, P that controls the exhaust damper and (3) exhaust air wet-bulb temperature, T_3 that controls air recirculation rate. Only the measurements T_1, T_3 and P will be controlled. The others vary within certain limits.

Examine Variables That Affect Control

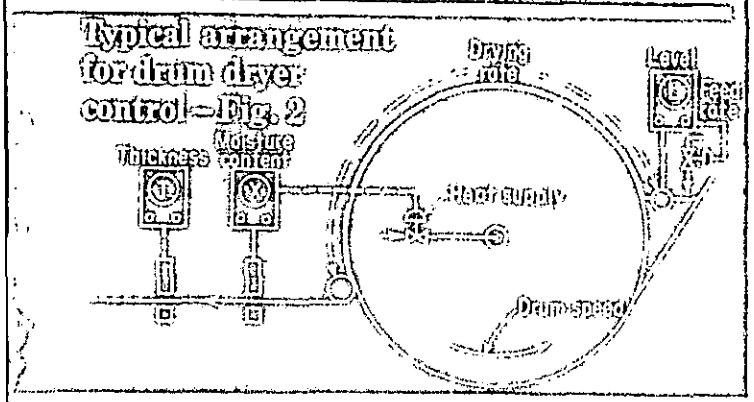
In most dryer systems, the following variables influence the performance of the control system and, hence, are of interest to us:

Dry Bulb Temperatures—Thermocouples, resistance thermometers or filled-system thermometers are used according to the range of temperatures encountered. It is important to locate the measuring element at a representative point and to protect it from corrosive and abrasive conditions.

Signal response time is not usually critical so that heavy-duty protective wells are common. In high-temperature gas streams, the temperature-sensing element must be properly shielded from cold surfaces, which would cause radiation errors. Suction pyrometers or very small, shielded, bare thermocouples are necessary to obtain measurements approaching the true gas temperature.



Traveling screen dryer control arrangement: Fig. 1



Typical arrangement for drum dryer control—Fig. 2

Pressure—Dryer pressure measurements vary from fractions of inches of water to much higher values. For dusty conditions, it is good practice to purge the line between the point of measurement and the instrument. This prevents the accumulation of dust in the stagnant pipe run. Pressure can be controlled equally well from either of the dampers in the suction fan duct or the forced-draft fan duct. The damper not used to control pressure must be operated by some other measurement within the system. In combination, the two dampers will control the air flow and also the system pressure at the point of measurement. The pressure measurement can be located at any place between the two dampers.

Controlled pressure may be either positive or negative within the range of the two fans. If pressure is to be controlled close to atmospheric at a single point in the system, the pressure will differ from atmospheric at every other point in the system. A chimney effect will occur between different heights if the gas density inside the dryer differs from atmospheric density. There will also be a pressure drop due to air motion inside the dryer.

Humidity—Exhaust air humidity is usually measured with a wet-bulb psychrometer. Several electrical humidity-sensing elements are also available.

Product Temperature—Commonly used to guide operators in controlling dryers, this is a very useful measurement when it can be obtained.

Product Moisture Content—This measurement is used extensively for drying continuous sheets. However, moisture content of granular solids and powders is difficult to measure continuously. Dielectric constant has been used as a moisture content measurement of powders where the final desired moisture content is above 2-3% and the handling characteristics are favorable.

Thermal Degradation—This degradation of the product is a serious problem in many drying operations. It has rarely been successfully measured continuously and with sufficient rapidity for good control. Maximum temperature and minimum flow conditions are usually the basis for safe operating limits.

Operating Conditions in Dryers

The screen dryer in Fig. 1 shows a single drying section only. The controls on each zone of a multisection dryer would be the same except that pressure drop through the material, measured in only one section, is used to control the belt speed. A belt-speed change may be required to hold constant pressure drop through the material being dried if its consistency or throughput rate changes. The uncontrolled variable is feed rate.

With the drum dryer shown in Fig. 2, the product moisture content is measured and used to control steam input to the drum. The evaporation from the drum depends upon the external air condition and velocity as well as the drum temperature. The feed rate is controlled to hold the level in the feed hopper. The feed stream will vary with the capacity of the drum at various speeds, web thickness, and temperature conditions.

Table II shows the control loops possible between the various controllable conditions and the measurements that might be made in spray dryer operation.

A commonly used system for control of spray dryers is shown in Fig. 3. Air inlet temperature controls the heat input. Exhaust air temperature controls the feed rate. Pressure drop through the atomizing nozzle will also alter the average size and size distribution of the drops of liquid as well as the feed rate. Size distribution may be the most important factor in spray drying operation because the smaller drops dehydrate more rapidly. Also, the smaller the drops, the more variable is the distribution.

If the air flow is interrupted, an interlock is desirable to shut off the feed quickly. This arrangement avoids accumulation of wet material in the bottom of the dryer. Alarms are sometimes provided for high exit gas temperatures or pluggage of the product collecting system.

Dead-times for some spray dryers are shorter (response is rapid) than for other types and control may be easier. Faster measuring and control elements may be required. The system is usually sealed and there is no need to balance pressures. The system pressure is usually not controlled. An interlock is usually provided in the spray dryer to shut off the feed if temperature falls below operating limits.

Provide Adequate Safe Operations

Two types of specific safety problems may arise in the use of dryers. The first is flame failure detection in direct-fired units. The equipment generally provided to guard against flame failure is substan-

Control chart for spray dryers—Table II

	Heat Supply	Inlet Air Damper	Atomizer Speed	Air Recirculation	Feed Rate	Exhaust Damper	Product Recirculation
Common measurements							
Inlet air temperature	A	A				A	
Exhaust air temperature	A	A		B	A		B
Product qualities							
Temperature	A			B	A	A	B
Moisture	A	A	A	A	A	A	B
Thermal degradation	A	A	B	B	A	A	A
Size			A				
Size distribution			A				
Operating conditions							
Pressure		A				A	
Exhaust air humidity	A	A		B		A	
Retention time		A				A	
Air velocity		A		A		A	
Evaporation rate	A	A			A	A	
Solids/gas ratio		A		B		A	

A and B represent good and fair control, respectively, of loop determined by intersection of row and column. Colored A represents variables commonly controlled by each measurement.

tially more elaborate than the remaining instrumentation.

Failure of combustion safeguards because of manual cutout arrangements, etc., is often so serious that dual control systems should be used. The first system detects the existence of a flame in the conventional manner. The second system continuously analyzes the combustion products in the dryer for explosibility. Either system can shut down the equipment.

The second hazard exists where dusts or solvent vapors can form combustible mixtures with the air used to dry the materials. This condition has caused serious accidents even though no source of ignition presumably existed within the system.

Inert atmospheres are used to dry hazardous materials in some cases. Where this is impractical, the solvent concentrations have been controlled by continuous analyzers that sample the atmosphere in the dryer and control the drying rate to keep the mixture below the lower explosive limit.

The sample line leading to the gas analyzer must be kept above the dew point of the solvent (or combustible material) throughout its length to prevent erroneous readings. Both automatic blanketing with inert gases and shut down of the operation are triggered if the analyzer detects mixtures approaching the explosive limit. Alarm signals and interlock arrangements should be provided. They are actuated whenever unsafe conditions exist or are developing.

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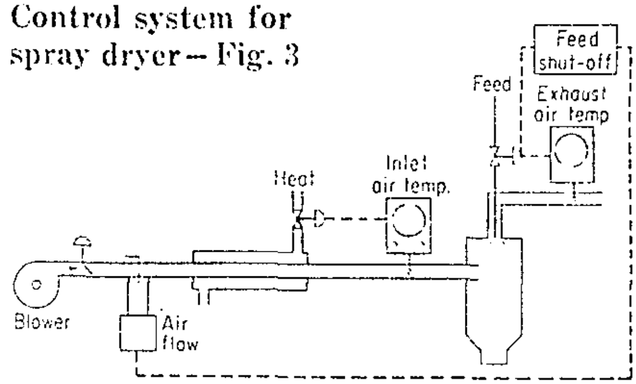
Control system for spray dryer—Fig. 3



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