DEVELOPMENT OF DRYING TECHNOLOGY IN THE USSR

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The development of drying technology during the last 50 years can be illustrated with reference to certain branches of the national economy.

Grain drying had long been used in Tsarist Russia as a means of preserving grain. However, the techniques employed were very primitive. Modern machinery was gradually introduced, but until the Revolution it was very thinly distributed.

During the years of Soviet rule grain drying technology has been transformed beyond all recognition. Many thousands of mechanized grain dryers have been built and new designs have been developed, notably by the All-Union Heat Engineering Institute (VTI), the All-Union Institute of Agricultural Machine Building (VISKhOM), etc.

The VTI is developing shaft dryers with various capacities and has designed the "Kuzbass" mobile mechanized grain dryer. Small fixed VIZM grain dryers are being widely used in agriculture.

The Promzernoproekt has done a great deal to improve shaft dryers (the DSP dryer, etc.).

It should be stressed that the VTI shaft dryers were a considerable advance on previous models in both output and fuel economy. But the nonuniformity of drying in such dryers combined with loss of grain quality made it necessary to investigate other drying techniques.

An essentially new method was developed at the Institute of Heat and Mass Transfer of the Academy of Sciences of the Belorussian SSR. This method combines recirculation of the grain with an oscillating regime (alternate heating of the grain in the fluidized state and cooling in a fixed bed) and contact mass transfer between the fresh and circulating grain. Grain heated in the fluidized state is heated much more uniformly than in the fixed bed of a shaft dryer. Heat transfer in a fixed bed always involves a considerable degree of nonuniform heating due to the nonuniform motion in the shaft of both the packing itself and the gaseous heat transfer agent. The alternation of heating and cooling of the grain in a recirculating dryer prevents deepening of the evaporation zone inside the grain and lowers the temperature gradient over the grain section. This results in much improved quality: gluten is preserved, which gives better baking properties, while seed grain treated in this way gives a 15–20% better yield.

The Kazakh Branch of the VNIIZ has introduced a modification of the recirculating grain dryer in which the grain is raised by a bucket conveyor instead of pneumatically. In this case the grain is heated not in the fluidized state but in a falling bed.

At present, about 60 powerful recirculating grain dryers with a capacity of 50 ton/hour are operating in the eastern Soviet Union.

The development of the chemical industry led to the extensive introduction of batch vacuum drying cabinets. These are hermetically sealed cylindrical or rectangular chambers equipped with a series of hollow horizontal plates through which steam or hot water flows. Trays of material are supported on the plates and water vapor and air are evacuated with vacuum pumps.

In the thirties the chemical industry used a type of scraper rotary vacuum dryer consisting of a horizontal drum fitted with a steam jacket and a mixing system. These dryers had the disadvantages of batch operation, complexity, moving parts, and a high scraper breakdown rate.

At the same time atmospheric twin-drum dryers were introduced. Although the dryers themselves operated continuously, the material was filtered on periodically operating filter presses and the filtered material was fed manually into the receiving tank of the drying apparatus. Moreover, on the rolls the material was dried only to 36–42% residual moisture content, so that a supplementary drying process was required.

In the fifties a continuous filter-dryer with rotary vacuum filters and twin-drum atmospheric dryers fitted with auxiliary screw dryers was introduced.

The spray drying of solutions was proposed a long time ago. This involves atomizing the solution in a drying chamber. Flue gases or hot air serve as the heat transfer agent. However, for a long time spray drying was not used because of certain technical shortcomings: the moisture content of the product was nonuniform and a large amount of heat was consumed.

This method has since been much improved. Preheating to a temperature close to the boiling point at pressures of 60–150 atm is used to improve the characteristics of the drying chamber in drying thermally stable solutions. As a result of the reduced pressure the solutions evaporate spontaneously and become finely dispersed in the chamber. M. V. Lykov and others have proposed such a dryer for drying and dehydrating salts of phosphoric acid. The atomized and partially dehydrated products are dried by a counterflow of gas with subsequent cooling.

P. D. Lebedev, M. I. Verba, and B. I. Leonchik have suggested that thermostable solutions of inorganic salts not containing crystals or other mechanical impurities should be preheated to a temperature above their boiling point at atmospheric pressure. In this case the internal heat of the solution also contributes to the dehydration of the droplets and the efficiency of the chamber is almost doubled.

It has also recently become common practice to dry solutions in fluidized beds.

There are various methods of drying granular (including crystalline and finely dispersed) materials; these include conveyor, chamber, shaft, rotary, and pneumatic gas dryers, as well as fluidized-bed apparatus. Crystalline materials are generally dried in rotary dryers. As a result of tumbling the particles become abraded and reduced in size. Air-fountain, penumatic gas and fluidized-bed dryers are the most promising for crystalline materials.

To achieve uniform drying two- and multistage fluidized-bed dryers are employed. Such a dryer is used at the Zaporozhe Byproduct Coke Plant for drying ammonium sulfate. At the Moscow Coke and Gas Plant high-speed drying of ammonium sulfate in a vortex chamber has been introduced. The material moves along a curved trajectory in a stream of heated air or flue gas injected tangentially through nozzles inside the chamber.

Combined dryers (e.g., pneumatic gas dryers with an air-fountain chamber) have been designed to intensify the drying processes in a fluidized bed.

Coarsely granular materials are dried in cylindroconical dryers with a spouting bed.

Pneumatic drying gives good results for materials with surface moisture, especially potassium salts.

The external-heating method may be very promising for drying certain materials, chiefly those that cannot be allowed to come into direct contact with the heat transfer agent.

Food products have one important characteristic in common, namely a relatively low permissible heating temperature. This and other severe requirements impose very difficult additional conditions on the design of food dryers.

The last decade has seen considerable progress in the modernization of drying technology in the food industry. The principal advances include:

a) use and development of freeze-drying;

b) use of fluidized-bed techniques;

c) introduction of radiant heating;

d) use of oscillating drying regimes for heat-sensitive products.

The sublimation or freeze-drying principle was disclosed in a 1921 invention by the engineer G. I. Lappa-Starzhenetskii. It is one of the most advanced methods of drying many, especially perishable, products. The structure of the material is preserved almost unchanged and the dried material is characterized by a high degree of dispersity and porosity. Volume, color, taste, smell, and vitamins are preserved to a much greater degree than in other methods of drying. Materials that can be dried in this way include: meat and fish, yeast, endocrine preparations, antibiotics and biologicals.

The introduction of this method was long delayed because of deficiencies in vacuum technology. In 1954–1955 the "Smychka" freeze-drying plant, the first such plant in the Soviet Union with Russian equipment, was built at Rostov-on-Don.

The economy of a method largely depends on the duration of the drying process, i.e., on the means of supplying heat. It has been found that radiant heat drying is twice as fast as conduction drying. A freeze-drying plant installed at the Leningrad Meat Combine uses high-temperature radiators to reduce the drying time by a factor of 2 or more.

In the production of sugar drying is the last stage of the process. Simple rotary dryers have long been used for drying granulated sugar. Further research led to the development of the twin-drum dryer for drying and cooling the sugar and the single-drum dryer that combines both functions. Rotary dryers have a number of disadvantages. Therefore work proceeds on the development of new plant operating on the principle of the vibrated of fluidized bed with external heating of the tube dryer.

The drying of refined sugar is now also at a fairly high level. Automated production lines with continuously operating dryers have been developed.

Fruit and vegetable drying is an ancient art. In pre-Revolutionary Russia fruit was dried in the sun and in simple ovens and tunnel dryers, vegetables in tunnel dryers and drying drums. Later, fruit and vegetables were dried in batch convection dryers.

However, the use of purely convective drying is limited by the special properties of the products, especially fruits.

In drying fruits it is necessary to preserve their valuable properties (acids, sugar, vitamins, etc.), the external appearance and color, and the cell structure. Favorable results have recently been achieved with infrared radiation adapted to convection-type dryers and freeze-dryers.

The fluidized-bed process appears to be particularly promising for drying diced vegetables (potatoes, beets, carrots, etc.). It has been demonstrated that oscillating drying regimes in a fluidized bed give high-quality dried vegetable products. The chief advantages of the method include the compactness and efficiency of the plant, and the low final moisture content and high quality of the product.

In yeast production the early chamber and cabinet dryers are being rapidly replaced with continuous tip-shelf shaft dryers. Continuous air-blast and pneumatic dryers are also in commercial use.

Considerable progress has also been made in the drying of other food products. This has involved primarily the use of the fluidized bed (granulated sugar, sunflower seed, pearl barley, tomato seed), and oscillating drying regimes, which is especially important in connection with thermolabile materials.

After the Revolution the rapid development of industry and its power engineering base gave a great impetus to the development of fuel drying technology.

In the late twenties the power stations began using pulverized fuel, which required the installation of a large number of dryers. Plants for drying pulverized fuel (esp. brown coal) in the suspended state were widely introduced.

Improvements in plant efficiency and the increasing use of low-grade fuels with high moisture contents led to parallel developments in fuel-drying techniques.

The direct use of the flue gases from boilers and other thermal plant opened up new possibilities for drying high-moisture fuels.

Rotary gas dryers are widely used in Soviet power stations, chiefly for predrying fuel. These dryers have a reputation for reliability.

Steam-heated tube dryers are widely used for drying various kinds of coal. One of their greatest advantages is economy, especially when steam bled from turbines is used for heating the dryer.

Research at the Dzerzhinskii All-Union Scientific Research Thermal Engineering Institute has shown that when tube dryers are heated with steam bled from turbines a fuel economy of 9–20% can be obtained, better than that obtained by converting the power station to operation with steam at super-critical parameters. The consumption of steam for predrying fuel remains almost constant over the year, which further increases the economic effectiveness of using heating turbines.

In recent years the design of steam tube fuel dryers has been much improved. Thus, special tube inserts are now used to make mixing more uniform and enlarge the heat-transfer surface, and the dryers are equipped with novel feeding devices to ensure that the tubes are uniformly filled with material. To reduce entrainment of fuel with the spent air, the dryers are fitted with specially designed electric filters.

The consumption of heat per 1 kg evaporated moisture in these dryers is relatively low, for Moscow coal it is 730–780 kcal/kg.

"Peko" dryers are being used for drying milled peat. Drying takes place in pneumatic tubes with external heating, spent turbine steam usually being used as the heat transfer agent. The fuel passes successively through five drying stages, three of which are steam-heated; in the other two the heat of the spent drying agent of the final predrying stage is used.

The advantages of the "Peko" dryer include low heat consumption per kg evaporated moisture (700–750 kg/kg). However, the device is complicated in operation. The tube system of the drying chambers is soon clogged and the power consumption is more than twice as great as that of a tube dryer owing to the greater resistance of the system and the greater specific air consumption per kg of evaporated moisture.

Before the Revolution lumber was mainly dried in the open air, a process governed by climatic conditions. In certain yards small Grum-Grzhimailo convection dryers were employed.

After the Revolution the work of these yards was scientifically reorganized. Artificial drying was introduced and large drying kilns were built. Most of these operated on the convection principle employing warm air, superheated steam, and flue gases as drying agents.

The early Grum-Grzhimailo natural-circulation dryers were converted to forced circulation, which made drying more uniform and increased the output. Further kiln improvements included optimal siting of the blowers and more efficient circulation of the drying agent.

Gas kilns, using the combustion products of various kinds of fuel (solid, liquid, and gaseous) rather than heated moist air, were also introduced. One of the first kilns to operate on combustion gases was the "Optimum" continuous dryer. Numbers of Soyuzteplostroi continuous gas dryers were later installed. These were so designed that the gas supply to each chamber could be individually regulated.

The direct use of combustion gases considerably reduces the cost of the dryer, since it is possible to dispense with steam boilers, heaters, and other equipment.

In the recently introduced Giprodrev and Latgipprom batch drying kilns the drying agent is superheated steam at a temperature of above 100° C. In such kilns the drying time is much reduced. Superheated-steam kilns are used mainly for softwoods and some hardwoods with good capillary permeability (birch, aspen).

A certain amount of lumber is being dried in hydrophobic liquids, particularly hot petrolatum. These plants take the form of steam-heated baths. The drying time is less than for convection drying. A disadvantage is the contamination of the surface of the material which is detrimental to subsequent working and gluing. Petrolatum dryers are used where the material does not have to satisfy any special requirements.

Variable magnetic fields created with commercial-frequency current are now beginning to be used for drying lumber. The drying process is based on the transfer of heat to the material from ferromagnetic elements installed between the rows of lumber.

Veneers, used by the furniture-making and plywood industries, are dried in high-capacity roller dryers using steam heat and longitudinal and transverse air circulation; gas dryers operating on the combustion gases obtained by burning solid, liquid, and gaseous fuels are also in use.

The first devices for artificially drying ceramic articles were stages that either formed a continuation of the firing kiln or were built over it. The heat transfer agent was usually warm air obtained from the cooling of the articles. Since the "above-kiln" dryers did not allow for regulation of the air flow, they were replaced with Grum-Grzhimailo batch chamber dryers. These dryers, however, gave nonuniform drying and consumed a large amount of heat.

The Rosstromproekt chamber dryers with multiple natural circulation are widely used in the structural ceramics industry. The mixing of the ascending and descending air flows creates multiple circulation of the heat transfer agent.

The Leningrad Institute of Refractories has designed and built a number of ejection drying chambers which give very uniform drying.

Counterflow tunnel dryers with various modifications (in particular, zonal regulation of the parameters) for accelerating the drying process are widely used, as are dryers with a variable vertical air flow designed at the Institute of Structural Materials.

Many structural porcelain plants are using State Ceramics Institute ejection tunnel dryers. The ejection devices create internal circulation of the heat transfer agent.

Ceramic pipe is dried in throughflow-counterflow tunnel dryers developed by the Scientific Research Institute of Structural Ceramics. The tunnels are equipped with monorail tracks along which the pipe supports move.

Conveyor dryers are often used for ceramic articles that can be dried quickly (e.g., in the porcelain and faience industry). These dryers consist of two parallel moving chains from which drying cradles are suspended.

Rotary drums are generally used for drying the ceramic raw material itself. In most cases these drums operate on the once-through principle. Various devices are installed inside the drum to break up the clay into small pieces and ensure that it dries uniformly. Drum dryers have the disadvantage of being clumsy and using a large amount of heat.

Apart from these drums, clay is also dried in air-fountain dryers, while spray dryers have been introduced for drying slips. The latter method makes it possible to dispense with a subsequent grinding operation.

In drying paint and varnish coatings it is necessary, above all, to give the film sufficient strength, preserve its color, and avoid cracking.

The early paint dryers were based on the convection principle. In the thirties infrared drying was introduced. This method gave much more intense heating than could be achieved in convection dryers. In recent years much improved paint dryers of both types have been developed, especially for the automobile and aircraft industries.

After the war conveyor infrared, combined, and convection dryers were introduced for baking paint and varnish coatings.

Tests on a series of radiant-heat dryers in automobile plants (Gor'kii) have shown that in some cases the drying time for lacquers and enamels can be reduced by a factor of 12 (as compared with convection drying).

The Institute of Tractors and Agricultural Machinery has developed a new and efficient dryer with gas radiant panels, while the Novocherkassk Electric Locomotive Building Plant has successfully tested large through chambers for the convection drying of locomotive finishes. The chambers are equipped with recirculating and exhaust systems.

In the early fifties a new method of drying coatings with commercial-frequency current was introduced in the Soviet Union. It depends upon the eddy currents created in metal parts by passing alternating current through inductor coils. These generate heat that is transmitted from the substrate to the coating.

There have been sharp changes in the dryers and drying processes used in textile plants during the last 30 or 40 years. Many of these changes can be traced to the work of the All-Union Thermal Engineering Institute.

During the thirties the best cloth dryers were heated cylinders on which the cloth was dried in direct contact with the cylinder. The equipment was designed to operate at a maximum temperature of 120° C.

Cylinder dryers were eventually replaced by roller and loop dryers. These were cheaper and more suitable in cases where it was necessary to regulate the drying temperature during the process, dry stretched fabrics, economize on space, etc.

Woolens, silks, cottons, etc., that have to be dried in the stretched state are dried on tenters. These function in various ways and have a number of special zonal air regulating and bypass features.

The drying process has a very important influence on the quality and cost of the cloth. In the postwar period a great deal of research was done on high-temperature heat transfer agents, which tend not only to cheapen the process but also to improve the quality of the product. One of the most effective means of intensifying the drying process is to use the combustion products of gaseous fuels as the drying agent.

In 1953 an automatic gas dryer with a drying agent temperature $t_1 = 400°$ C was introduced into the Soviet textile industry. This machine was later modernized and t_1 increased to 550° C.

Apart from designing new high-performance drying machinery, Soviet engineers are improving existing dryers with a view towards intensifying the drying process and obtaining higher-quality products.

A process of blowing warm air through the cloth has been successfully substituted for surface blowing. A combined radiant-heat and convection process is being used to predry the cloth before it is passed on to the drying cylinders.

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