Radio frequency heating applications in the European food industry

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During the years following the end of the second world war there was considerable interest in capacitive dielectric heating for a number of food applications in Europe as well as in the United States, and favourable results were frequently reported in small scale laboratory testing. The results were, however, difficult to translate into production scale operation; the reliability, efficiency and costs were not acceptable, and the food industry was hardly ready for any immediate large scale application of such an unfamiliar heating method. A few applications were gradually found suitable for limited industrial use, but for long remained unimportant compared to the use of RF-heating for wood-glueing, plastic welding etc. Applications in the European food industry are still predominantly based on capacitive heating in the frequency range 10-40 MHz, whereas microwave heating was, until a few years ago, used only for institutional reheating of frozen or refrigerated precooked meals and not for industrial heating applications. By comparison, use of dielectric heating in the US food industry became a reality first with the advent of sufficiently high-power microwave applicators about 5 years ago.

The industrial dielectric heating of foods in Europe is probably predominantly used for bread baked products for which possibly as many as 100 installations have been put into operation, for the thawing of fish and meat and for finish-drying of sugar, all in the frequency range 27 to 40 MHz. However, since 1967 installation of nearly a dozen lines for microwave finish-drying of chips has been reported in Britain, and possibly as many small units are in use in Europe for trials with bread pasteurization. In the following, the various known industrial applications for dielectric heating of foods in Europe are described in some more detail.

Baking

The two main competitors in capacitive RF baking equipment, Brown Boveri (Reforma) and Radyne Ltd, represent two different schools of thought. While the Brown Boveri ovens are made for
simultaneous baking with dielectric heating and crust formation by IR-radiation, the Radyne ovens are designed for post baking at the final stage of the baking line. Another difference is that the Brown Boveri ovens use a vertical RF-field between flat horizontal electrodes, where the bottom electrode is in direct contact with the stainless steel conveyor, while the Radyne ovens have a horizontal field arrangement claimed to be less sensitive to dimensional differences in the load. Increase in capacity of 50% or more for a given length of line is claimed by both companies, with improvements in volume and moisture control. Brown Boveri have developed also a leavening tunnel and claim reduction of leavening time to 1/3 by using RF heating for quickly raising dough temperature to 35-40°C.

Together, the two companies claim to have installed well over a hundred baking or post baking lines for products such as biscuits, rusks and crisp bread but also for white bread. In Italy, Radyne has recently installed a post-baking unit with eleven 25 kW generators. So far, no microwave tunnel has been promoted for baking purposes in Europe.

_Bread pasteurization_

The Radyne post baking units are promoted also for bread pasteurization (and for thawing of bread), particularly for loaves of larger thickness than a few inches. It is claimed that dielectric heating permits larger freedom of recipe, such as considerably higher fruit content in fruit pies. Otherwise the main interest appears to lie in microwave heating, and applicator tunnels for frequencies of 900 or 2450 MHz and about 10 kW power output have been announced by at least four different companies, claiming a processing time of 1-2 minutes and capacities around 250 kg/hr.

Brown Boveri have developed a 10 kW conveyorized tunnel with four waveguides radiators two of which are vertically and two horizontally polarized. The four magnetrons can be operated independently, and the cooling air from the magnetrons is used for heating the tunnel walls. They have also developed a 20 kW 915 MHz tunnel, which has been tested with apparently good results in terms of temperature distribution and improved penetration, but this system is at present being redesigned.

The Herfurth company in Germany and the Thomson C.S.F. in France have advertised cavity tunnels operating at 2450 MHz for bread pasteurization and for thawing, but it appears uncertain
whether marketing of these tunnels will be continued. The Herfurth company have advised they plan to concentrate on applications at 27 MHz, since microwave equipment appears to be too expensive for the time being.

The GEC/AEI in Britain, in cooperation with the Cadbury company, recently announced the successful use of a cavity tunnel operating at 896 MHz for pasteurization of packaged cakes. The experience at Cadbury's has, reportedly, been that the application as such is sound, but that it was difficult to combine with the batchwise baking process used, which resulted in end temperature variation in pasteurization due to variations in holding time after baking. However, the GEC/AEI have disclosed they are working on a large continuous plant for cake pasteurization in Italy.

Apart from cost and the difficulties owing to variation in feeding temperature, it seems that reabsorption of condensed moisture and moisture permeability characteristics of available wrapping materials represent major problems in microwave bread pasteurization.

Defrosting

Equipment for industrial dielectric thawing of foods has been developed in Britain, mainly as a result of experimental work done at the Torry research Station with thawing of sea-frozen fish, and in Switzerland. There are probably well over a dozen thawing plants installed, most of them operating with fish, meat or meat offal, all using capacitive dielectric heating at 35 or 27 MHz. The application for thawing blockfrozen round cod is the one most publicized, although probably not the most ideal one. Because of the nonhomogeneity of the material, water immersion in plastic trays is necessary, and thawing times as long as 1 hour to avoid preferential heating. In comparison, blockfrozen herring or meat can be thawed in half the time and without recourse to the use of water immersion. A plant in Scotland thaws meat offal for pet food manufacture at a capacity of 4 to 5 tons/hr using 250 kW of high frequency power. In Switzerland a few smaller plants with capacities of below 1 ton/hr are used for thawing meat in meat processing factories and for veterinary inspection of imported frozen meat. Considerable savings in drip
loss are claimed, compared with conventional meat thawing practices. Costs are reported to be about 1/2 cent/lb at high capacity and degree of utilization. The development is slow, partly because there has been no important overall cost saving compared with other methods, partly because of varying experience from factory trials and because of a conservative attitude, especially within the fish industry. Reportedly, one of the Radyne post baking units is used also for the thawing of frozen bakery products. Owing to the low water content of bread, times for thawing and heating above the temperature necessary for avoiding staling is only 5 minutes in 35 MHz equipment, and this may be an interesting application for cutting production peaks at the end of the week.

Satisfactory results have been reported also in thawing experiments with various products in microwave tunnels, but no commercial installation of microwave equipment for this purpose is known to the author.

Drying

The post baking of biscuits is really a finish drying operation with the objective of shortening the time necessary to reach the desired final moisture level and to achieve as little variation as possible in moisture level over the width of the conveyor.

Other notable finish drying operations using dielectric heating concern sugar cubes, table salt and potato chips. About 5 years ago the Swedish Sugar Corporation introduced its method of continuous finish drying of sugar cubes by high frequency heating at 27 MHz, which is now in use in several European countries and also in the US. The plant in Arlöv in Sweden is of particular interest since it is probably still the largest known for dielectric heating of foods producing nearly 1000 kW of radio frequency power. Sugar cubes formed by vibrating moist sugar crystals inside teflon molds are dried from 2% to 0.6% moisture in 30 seconds by a combination of dielectric heating and hot air drying. The whole operation from forming to packaging is fully automated, can be supervised by unskilled personnel and claims an overall operating reliability of over 95% over a two year period. Total processing costs are said to amount to about 0.1 cent/lb of sugar.
The most promising development for industrial microwave heating so far in the European food industry has been in the finish drying of potato chips. A joint development project between GEC/AEI and the Smith’s Food Group was started five years ago, probably inspired by the development work earlier started in the US. As well known, the US work led to the first breakthrough there in industrial microwave food processing and also resulted in at least two or three installations of American-made equipment in Europe.

The first processing line based on the British development work was installed in 1967 and has since been followed by the installation of an additional ten or so lines of 75 kW microwave power. The processing line consists of applicators of Meander folded waveguide type, the equipment operates at 2450 MHz and has an overall efficiency, from the mains, of over 75%. Evidently the operating experience has been very satisfactory with this "second generation" type of chips plant, which is rather similar in design to a plant recently announced by the Raytheon company in the US.

**Sterilization, Pasteurization, Desinfestation**

A large pilot plant for the sterilization of canned fruits was operated in the USSR for several years, apparently with good qualitative results, but was discontinued, possibly because of economic reasons and because of difficulties met in designing suitable containers. A sterilizing plant for animal feed operating at 27 MHz is in use in Switzerland at the biological research centre of the Ciba and Sandoz companies.

In cooperation with research workers in Belgium Brown Boveri have developed plant and procedures for the destruction of parasites, both at 15 and 2450 MHz. A temperature rise of 20-40°C in 20-60 seconds has been found to destroy parasites in all stages of their development, including the eggs. With a 10 kW plant operating at 15 MHz a capacity of 300-500 kg product/hr is claimed.

Brown Boveri also report good experience with dielectric pasteurization of beer in glass bottles (for export) with heating times of only 2 min compared to 40-60 minutes in water pasteurization and with considerable reduction of glass breakage.
Other developments

Until a few years ago developments in microwave heating of foods have been limited almost entirely to the institutional field which is not the subject of this article. However, some of the equipment developed for the heating of frozen or refrigerated precooked meals may be of interest also for industrial heating applications. The Husqvarna Co in Sweden sell a conveyorized microwave tunnel for mass feeding in schools, military establishments etc. which is based on a 5 kW module system. A module is roughly 1.5 m long and is built as a narrow rectangular tunnel, into which three wave guides are coupled according to the magic T principle. Lines with up to seven such modules have been installed. The company claims that satisfactory results are obtained in heating many frozen, precooked meal components in one step from the frozen state to eating temperature in this equipment. A limiting factor in industrial heating applications would be the narrow tunnel section.

Several years ago the Philips company in Holland developed a tunnel with a wide conveyor, using parabolic radiators as microwave applicators. The design gave excellent field distribution across the conveyor and permitted the use of very high field densities in the narrow radiating zones, alternating with temperature equilibration zones. However, like the Litton Co in the US, Philips decided to concentrate their microwave effort on the small oven business and to discontinue work on tunnels. A further development of the radiator design was worked out at the Atlaswerke in Germany, the so called "broadside array". This device consists, in principle, of a trough of multisected waveguide, giving linear polarisation, and is claimed to give very even field distribution also near the edges of the tunnel section. Conveyorized equipment at a power rating of 20 kW at 2450 MHz was built, but the work was suspended due to change of ownership and direction of interests of the company. Fortunately, it appears that the work on this promising type of applicator will be resumed elsewhere.

In Sweden a new company, the Skandinaviska Processinstrument AB, was recently formed for the exploitation of a novel type of "microwave cushion" applicator for industrial heating purposes, developed at the Department of Microwave Technology of the Royal Institute of Technology, Stockholm. Prototype tunnels of 5 to 15 kW
power rating built on their principle were primarily used for experiments with finish drying of paper, but it appears that the special features of design may be very attractive also for applications in the food field, giving promise of good control of field distribution, large width and height of tunnel opening, good accessibility and very compact construction. A number of food applications are presently being investigated, such as pasteurization, finish drying, precooking etc.

General outlook

At the present time the total installed microwave hardware in the European food industry probably does not represent more than about 1 kW of power, while installations in the frequency range 15-40 MHz probably amount to about four times this level. Combined, it is still a very modest figure, and although there is growing recognition of dielectric heating as a promising processing tool, its use is increasing only slowly, disappointingly slowly to many electronics companies who have ventured into food applications of radio frequency heating. However, judging from discussions with manufacturers of equipment, it seems that, at present, the outlook is more optimistic in Europe than in the US, where manufacturers appear downhearted from the slow development lately, after the earlier success with finish drying of chips.

Being latecomers as far as industrial microwave heating is concerned, the European companies will have the advantage of being able to go directly into second generation type of plant with improved field distribution and efficiency and more compact design. On the other hand, development in Europe is hampered by the fact that only the 2450 MHz frequency is generally permitted, and that in several countries the legal aspects of stray radiation are not clearly defined. Only in Britain is the frequency around 900 MHz allocated for heating purposes. As in the States, there is a lack of really versatile pilot plant equipment for industrial experimentation.

Considerable research and development activity is in progress, particularly in Britain and in Sweden, and there seems to be less reluctance against joint ventures by different companies and by experts in different fields than in the US. A very important factor is the cost, and there is increasing interest in combining dielectric heating with other heating sources to lower overall costs.
The activities so far in the field of dielectric heating applications have proved valuable to the food industry not only in themselves but by stimulating the development of competing conventional processing methods, as illustrated by the development of industrial thawing by water, circulating air, resistance heating etc., and the recent Dutch development in vacuum drying of potato chips.

As for the future of dielectric heating in the European food industry, a personal opinion is that the growth will probably continue to be slow in the immediate future, but that it will eventually become an important unit operation in the food field for special heating applications, where advantages such as very rapid and even heating throughout a food material can best be utilized. As for the relative merits of microwave heating and capacitive dielectric heating at lower frequencies, microwave heating often represents about a factor of ten reduction in heat processing time, because microwaves are more readily absorbed and because higher power input can be used without increase in field strength. However, in cases where the desired power input can be achieved with capacitive dielectric heating with satisfactory temperature distribution, this heating method may often be preferable to microwave heating, such as in the finish drying of sugar cubes, because of lower equipment costs and greater reliability of the electronic components.

Literature

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