Pure & Appl. Chem., Vol. 49, pp.1687 - 1702. Pergamon Press, 1977. Printed in Great Britain.

NOVEL CONCEPTS IN TECHNOLOGY AND DESIGN OF MACHINERY FOR PRODUCTION AND APPLICATION OF SMOKE IN THE FOOD INDUSTRY

C.M. Hollenbeck

Red Arrow Products Company, Manitowoc, Wisconsin, USA

Abstract - Several novel concepts in the technology and design of machinery for the production and application of smoke in the food industry have developed during the past few years. These concepts have resulted largely from the concern in the following four general areas: (1) better control of the flavor and color of smoked foods, (2) the possible carcinogensis by components in wood smoke, (3) the need to decrease smoke effluent from smokehouses, and (4) the need to increase rates of production. The production and use of smoke solutions as a replacement for direct vaporous smoking have aided greatly in all four of the above problem areas. New designs in smokehouses including using of electrostatically filtered smoke, closed system smokehouses, and carefully engineered smoking tunnels have contributed to less smoke effluent, as well as to lower hydrocarbon deposition on foods and smoking with better efficiency and through-put.

INTRODUCTION

Although the smoking or smoke flavouring of foods is an age-old process, many changes have occurred in recent years in the technology and design of machinery for the production and application of smoke to foods. Four general factors have influenced these changes, and/or have supplied the need for change, in the smoke flavoring process, namely, (1) the desire for better control of the flavor and color of smoked foods, (2) the concern for possible carcinogenesis by components in wood smoke, (3) the need to decrease the smoke effluent from smokehouses, and (4) the constant need for better design and faster through-put.

The desire for better control of the flavor and color level in smoked foods has stimulated considerable improvements in smoke generators, in better engineered smokehouses in terms of air changes, heat and humidity control, as well as to wide use of smoke solutions. The concern for possible carcinogenesis by components of wood smoke, and the means of identifying some of the known carcinogens, with the resulting development of processes for decreasing, or eliminating, these compounds from the smoking agent. Careful temperature control in the smoke generating system, various means of removing particulate matter from the smoke cloud, and the use of refined smoke solutions have all contributed to lower risk of possible carcinogenesis by wood smoke in foods. The environmental factor of decreasing the level of smoke effluent has brought developments in afterburner systems, in closed or recycle smoking systems, and also has greatly contributed to the use of wood smoke solutions. The economic factor of more production with less space and cost, has been the obvious force behind the development of the continuous processing tunnels. Inherent in the operation of these continous systems is the difficulty of applying sufficient uniform smoke to a moving mass of product. This problem of obtaining adequate smoke flavor and color on a moving product has been attacked by increasing the density of the smoke cloud from improved generators, and by drenching the moving product with liquid smoke.

More details are given in the following on some of the concepts and developments in smoking technology which have resulted from the efforts to solve the forementioned problems.

BETTER CONTROL OF SMOKE FLAVOR AND COLOR

Probably one of the major factors in contributing to the better control of smoke flavor and color of foods is the great amount of work and the many findings on determining the constituents of smoke and their relationship to the smoke flavoring and coloring process. As it has been aptly illustrated in earlier papers in this symposium, there have been many scientific papers written on the composition of smoke. Smoke, being as complex as it is, contains many compounds and the reaction of these compounds with each other, and with the protein of foods, results in the complex phenomena that we call smoking or smoke flavoring. In general, however, the compounds of smoke can be classified into three rough classes - namely, acidic substances, phenolic substances, and carbonyl compounds. These classes, of course, exclude the hydrocarbons which represent some of the trace materials unwanted in the smoking reactions.

Rougly speaking, these three major components of smoke contribute to the smoking process in the following ways: (1) The acidic substances accelerate the curing reaction which, of course, contributes to the pink coloration of cured meats. The acids also contribute to the denaturation of the meat surface proteins and form the skin on the surface of wieners and other meats. This skin formation is essential in the peeling of skinless wieners. (2) The phenolic substances contribute mainly to the flavor of smoke and smoked foods. They vary a good deal in the flavor potencies and astringencies and sometimes contribute adversely to the point of being medicinal. However, as a group, the phenolic substances are the stronger flavor contributors. (3) The carbonyls contribute to the sharpness in the flavor of smoke, but probably their main contribution is to the smoky brown color and sheen of smoked products. The most important color contribution of smoke is due to the browing reaction between the active carbonyls of the smoke and the amino groups of the protein in meat. During the course of our investigations using liquid smoke, we have studied the browing reaction of various carbonyls.

In a series of experiments using glycine solutions as the source of amino groups, we have studied the reaction of the various carbonyls, some of which would be present in wood smoke, others that are not. Aqueous solutions of the various carbonyls were prepared at a constant molarity and reacted with glycine solution by heating a mixture of the two in a hot water bath, and measuring the intensity of the developed brown color at 490 millimicrons. The data in Table 1 show the relative difference between various carbonyl compounds in the tendency for browing with an amino group. The results show, for example, glyoxal and crotonaldehyde to be very active color formers while dihydroxyacetone and acetaldehyde are only moderately active. Formaldehyde, on the other hand, does not give color under the conditions of these reactions.

Continuation of these and subsequent studies on the effect of various carbonyls on the brown coloration of meats exposed to liquid smoke, has demonstrated the importance of having active carbonyls present in order for the significant brown coloration associated with smoking to develop. By active carbonyls, we mean carbonyls with an unsaturated bond or keto-enol grouping adjacent to the carbonyls.

TABLE 1. The effect of heating glycine with various carbonyls on the formation of a brown color

Carbonyl	O.D. at 490 mu x dilution factor	
	Heated for 45 min.	Heated for 90 min.
Glyoxal	>2.00	>3.77
Crotonaldehyde	2.44	3.60
Dihydroxyacetone	0.75	1.23
Acetaldehyde	0.62	1.13
Furfural	0.60	0.92
5-(hydroxymethyl)-2-Furaldehyde	0.22	0.46
Diacetyl	0.13	0.30
Furfural Alcohol	0.03	0.07
Xylose	0.03	0.12
Propionaldehyde	0.03	0.02
Cyclopentanone	0.00	0.01
2-Butanone	0.00	0.01
Ascorbic Acid	0.00	0.01
Acetone	0.00	0.00
Dextrose	0.00	0.00
Formaldehyde	0.00	0.00

Obviously, to indicate that the simple browning reaction is the total explanation of the brown coloration in, and on, the surface of meat during smoking is an over simplification. The basic color forming reaction may well be between a carbonyl and an amino group, but the conditions must be present to allow this reaction to occur and to go to completion, that is go to the formation of the dark color. Since the browning reaction is essentially a condensation followed by a rearrangement and dehydration, it would seem to be very important to have conditions that allow first the condensation, then the rearrangement and dehydration. For example, the pH would have a very definite effect with the darker colors probably being produced at higher pH. This we have found, since we have learned that the strong acidification of smoke solution with vinegar, for example,decreases the brown coloration formed.

Furthermore, after the absorption of smoke, it would seem to be quite likely that to form a darker color it would be necessary to have a hot, dry surface to accelerate the dehydration aspect of the reaction. We have found this to be true, since it is necessary to have a period of relatively low humidity during the period right after the absorption of smoke, in order to develop the darker brown color. Meats treated with liquid smoke, for example, and heated in a water solution developed very little, if any, brown color. On the other hand, if the meat is treated with liquid smoke and held under relatively low humidity with high temperature conditions for a period after the application, a very dark brown color associated with heavily smoked products developed. With these basic premises, it is quite easy to assume that smokehouse conditions are very critical in the formation of the brown coloration, during and after the smoking of meats. More will be said later, on the newer concepts of smokehouse conditions.

Before proceeding into physical conditions of the smoking process, using liquid smoke or vaporous smoke, I would like to discuss one other aspect of the smoke coloring and flavoring reaction. We have often observed that better smoke flavoring, and especially better smoke coloring, was attained in wieners by applying two short periods of smoking versus one long period without interruption. For example, in showering skinless wieners with liquid smoke solution, we obtain better coloring in the end product by showering for two one minute periods, with a one minute rest between the application, compared to a continuous shower of two minutes. We assume that this same effect of interrupted application is true with vaporous smoking, but it is much more difficult to prove this with vaporous smoking than with liquid application.

The reason for this need for a rest period, we believe, is the saturation of the smoke components on the surface awaiting penetration for reaction. Conceivably the surface moisture can be saturated with the smoke components and the reaction has to wait until these components penetrate into the surface. This is easily demonstrated with water filled casing, where the penetration of the casing is enhanced if periodic rest periods are allowed during the smoke application. These observations indicate that better efficiency can be attained in a smokehouse operation, if the smoke application is broken up into at least two periods rather than one prolonged period.

With one of the objectives as better control of the smoke flavor and color of foods, and knowing more about some of the reactions that contribute to the smoke flavor and color of foods, probably the major change of the past five or ten years is the advent and growth of the use of liquid smoke preparations. In the areas in which I am the most familiar, U.S.A. and Canada, it is estimated that at least 65% of the "smoked" meats are now smoke flavored and colored by the use of liquid smoke (smoke flavor solutions). The reasons for this wider use of smoke solutions are the very reasons we have earlier outlined, that is, better control of the reaction, less chance of carcinogenesis, less smoke effluent, and the relative ease of adapting liquid to continuous systems with faster through-put.

There are three general methods of preparing aqueous solutions of smoke, namely: the smoldering of sawdust under controlled oxidation conditions and the absorption of smoke in water; the smoldering of sawdust under controlled conditions and the regular condensation of the smoke solution in a condenser; and contacting sawdust, or finely divided wood chips with superheated steam and the condensation of the steam distillate (U.S. Patent No. 3, 634, 108 Fessmann). The most prevalent method of producing liquid smoke in U.S.A. is the first named, that is, the pyrolysis of hardwood sawdust and the capturing the wood smoke in water by drawing the smoke countercurrent to water through an absorption tower (U.S. Patent No. 3, 106, 473 Hollenbeck). The drawing in Figure 1 illustrates this process.

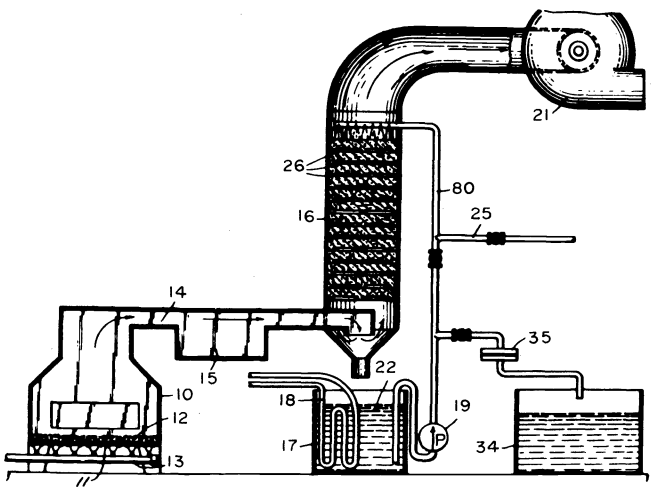

Fig. 1. (U.S. Patent No. 3, 106, 473 Hollenbeck)
Process for the production of smoke flavoring.

In this process the smoke solution is recycled until a given concentration is developed. The solution then is aged for a given period of time to allow for polymerization and tar precipitation, then is filtered through an absorption filter of cellulose pulp. This cellulose pulp filtration besides clarifying the solution, contributes to the removal of any trace amounts of hydrocarbons that remained dissolved in the liquid smoke. In general, these liquid solutions are used, as is, or with dilution with more water, in USA and Canada, without further concentration or refinement.

Smoke solutions can be further concentrated and refined, however, by the known chemical procedures and this concentration may definitely lead to some advantages in shipping and use. An illustration of a more concentrated product is described in the submitted paper.

"Novel Technology of the Preparation of Smoking Agent"
by Janusz Kulesza, Jerzy Podlejski, Josef Gora, Jadwiga Kolska, Jolanta Stolowska
of the Institute of Food Chemistry, Technical University of Łódź, Poland

These investigators describe a smoking material prepared by extracting a smoke polymeric concentrate with mineral acid to remove any organic nitrogen bases, or binding the organic nitrogen bases with ortho-phosphoric acid, removing the acid extract, and distilling the tarry concentrate at reduced pressure under an inert gas, or in the presence of powdered zinc, aluminum or iron powder. The application of the metal powders yields a distillate which has a light amber color. The fraction distilling below 80 - 90 °C at 30 - 20 millimeters of mercury pressure is discarded, since it contains low molecular weight organic acids, phenols, water, hydrocarbons and other ballast substances. The next fraction boiling at a 100 - 180 °C at 10 millimeters of mercury is collected and this fraction is the final smoking agent. A variation of this distillation is to add glycerol to the smoke preparation and distill the combination of the aqueous and glycerol solution.

The authors found that syringol as well as alkyl and alkenyl syringols are the predominant components of the desired fraction from this fractional distillation, although the authors also state that by gas chromatographic methods the distillate contains a mixture of more than 10 main components and many trace components. The yield of this distillate is about 15 - 40% by weight of the original smoke condensate.

The flavor analysis performed at the Institute of Meat Industry in Warsaw showed the flavor value of this distillate preparation is very high. In actual use, the preparation is diluted with such solvents as ethanol, ethylene glycol, glycerol or animal fats.

In USA and Canada, the major modes of application of liquid smoke to a food product comprise adding the liquid smoke directly to the product, such as a cheese spread, a meat emulstion, barbecue sauce, etc.; dipping the food product in smoke, as is often used in the Italian-type cheese industry, where the cheese product is dipped, or soaked, in a salt-smoke solution; showering of the smoke solution over the product, which is the major way of using liquid smoke in the continuous meat processes. In the continuous line process the meat product moves underneath the drenching, or showering head, and is showered with the liquid smoke. Other means of adding liquid smoke are atomizing the liquid smoke inside an enclosure, such as a smokehouse, to form a smoke fog, and using this fog in a manner very similar to the basic method of vaporous smoking; and vaporizing of the liquid from a hot surface, and converting the liquid back into a vaporous smoke and using it in the normal manner thereafter.

Each of these modes of application have definite advantages and each has some disadvantages, but all methods are used. The method of choice depends mainly on the food being smoked, the equipment and space available, the desired end product in terms of quantity of color and flavor, and last, but not least, the cost involved.

An example of adding smoke solution directly to a food product is discussed in the contributed paper:

"Use of the Smoking Liquid Preparation P.D.W. in Cheese Production"
by Stanisław Wasilewski, Janusz Kozłowski
of Warsaw Agricultural University, Warsaw, Poland

These authors describe a process for the addition of a liquid smoke preparation PDW directly to milk, and converting the flavored milk to cheese.

The PDW is added to milk at a temperature of 40 °C and homogenized to make a premix. The premix is then added to the rest of the milk, the flavored milk treated with chymosin, and the cheese process continued. The flavored cheese was ripened for four weeks, and evaluated both chemically and organoleptically. The taste tests showed that when the PDW concentration was in the 20 - 100 ppm range the smoke flavor could be detected, but was not distinctive. At levels above 100 ppm the flavor was quite distinctive.

Chemical analyses of the cheese indicated a decrease in nitrogen containing compounds with increased smoke flavoring levels. This indicated that the ripening process should probably be extended when higher levels of smoke are used.

The various modes of application by showering, atomization, and vaporization are illustrated in Figures 2, 3, 4, 5 and 6.

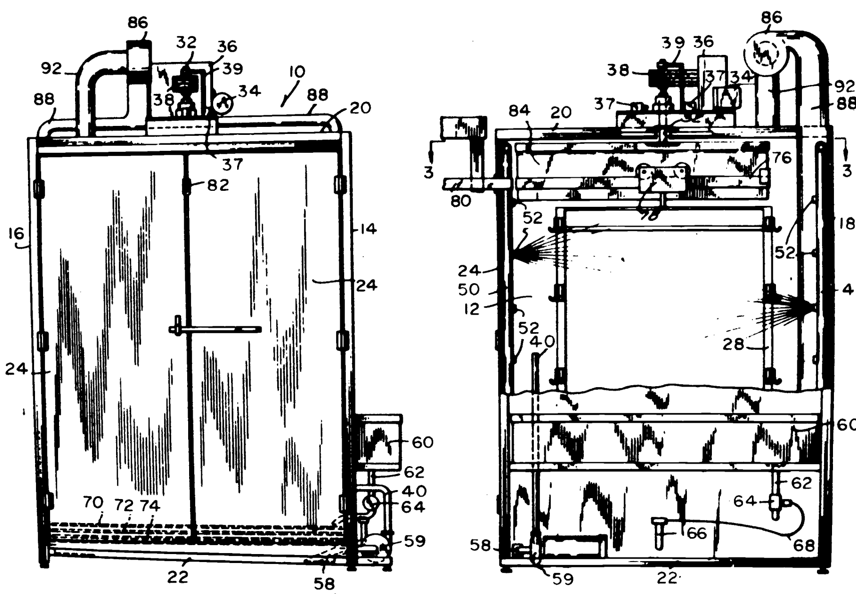

Fig. 2. (U.S. Patent No. 3, 877, 361 Trainor and Haug) shows a spray cabinet for liquid smoke designed to contain a food product on a rack. The rack is rotated while liquid smoke is sprayed through a plurality of nozzles onto the food product. The liquid smoke is filtered and recycled under controlled temperature conditions.

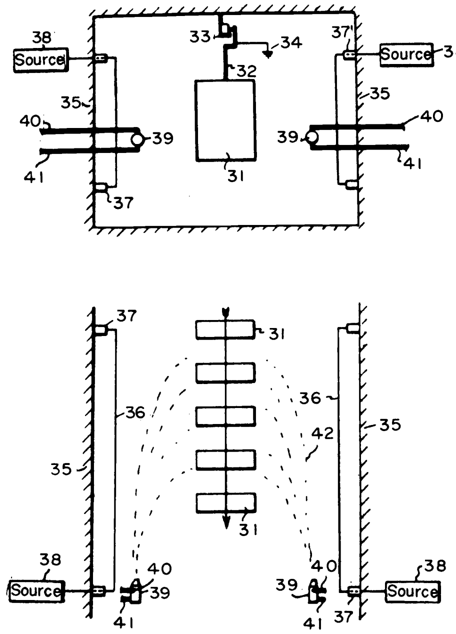

Fig. 3 . (U.S. Patent No. 3, 503, 760 Allen) The atomizing of liquid smoke by air pressure into a confined space (like a smokehouse) containing food products on racks.

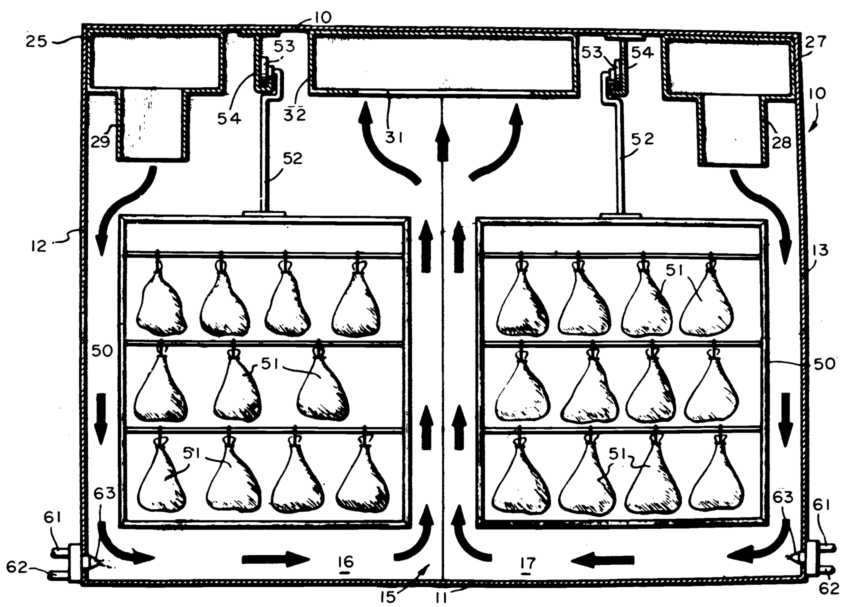

Fig. 4. (U.S. Patent No. 3, 896, 242 Moore) The atomizing of liquid smoke into a confined space containing food products with increased turbulence and recycling the smoke fog through a blower system.

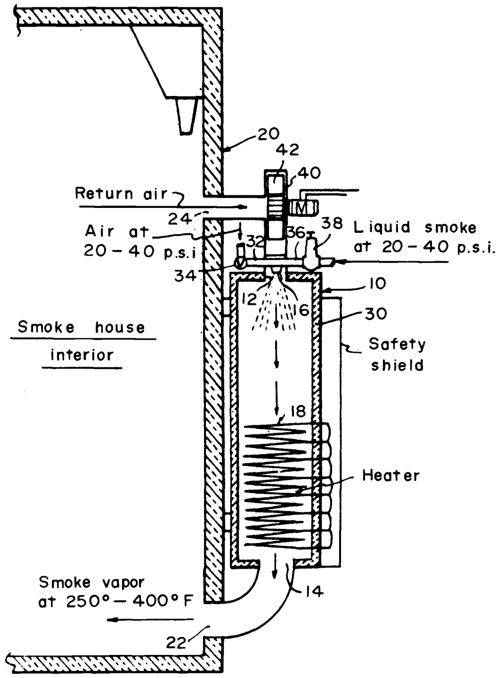

Fig. 5. (U.S. Patent No. 3, 861, 292 Gilliland and Wistreich) Regenerating smoke vapors from liquid smoke by spraying the liquid onto a hot surface and blowing the vapors into a confined space containing food products.

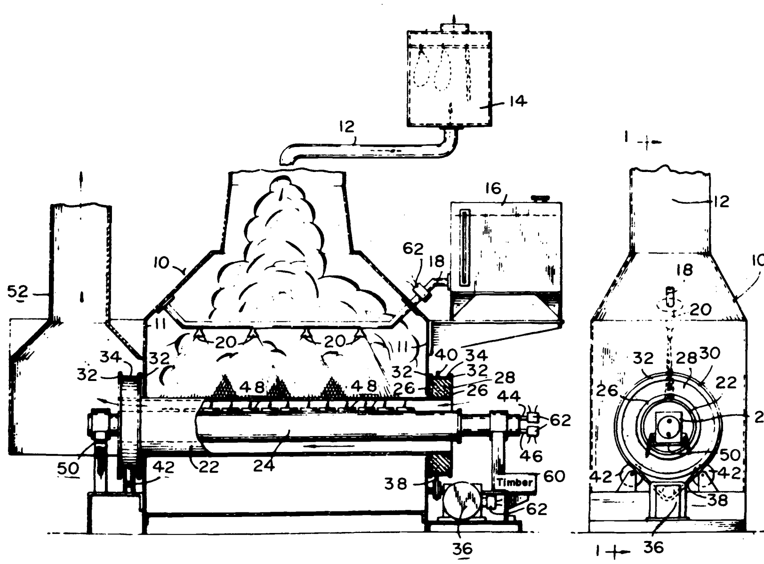

Fig. 6. (U.S. Patent No. 3, 871, 353 Haug) Regenerating the smoke vapor by spraying liquid smoke on the hot surface of a revolving drum.

THE CONCERN FOR POSSIBLE CARCINOGENESIS FROM COMPONENTS IN WOOD SMOKE

When the presence of polycyclic hydrocarbons in wood smoke, or wood smoke tar, was first discovered, we do not know. Rusz in his paper sumbitted to this symposium stated that the Czechoslovakian scientists, Sula and Dobes, established 25 years ago that the tar from smoking kilns contained the polycyclic hydrocarbon, benzpyrene. Probably the studies of Dungal in Iceland on the correlation of high incidence of stomach cancer with the high intake of home smoked meat products brought the problem of the presence of carcinogenic compounds in smoked foods into focus. The studies of Dungal and of Thorsteinsson, et al., are described in the submitted paper,

"The Development of Smoking of Food in Iceland"
by Th. Thorsteinsson, G. Thordarson, and G. Hallgrimsdottir
of the Institute of Experimental Pathology,
University of Iceland, Reykjavic, Iceland

These authors describe the earlier crude method of home smoking of meat, primarily sheep and lamb, in open fireplaces using the smoke from dried sheep manure and scrap wood. The meat was hung in the open fireplace where the smoke was most dense and kept there for 2 - 3 weeks, then the meat was placed in the kitchen where the smoke was not as heavy or stored in storage huts prior to eating.

The home smoking has since been replaced by commercial smoking. Commercial smoking is done in somewhat the same manner but with more control and with a shorter smoking period. Sheep and lamb are generally slaughtered in the months of September and October and then deep frozen. Carcasses are then cut up into the usual cuts. salted with a mixture of fine salt and sodium nitrate and then pickled in the salt brine. Following the salting process, it is washed in running water and hung in the smoking chambers where it is smoked for about 72 hours. In some cases, the lamb is injected with salt brine containing sodium nitrite and put into a cover brine prior to smoking. The shelf life of the commercial cold smoked meat is approximately 23 weeks in cold storage. After 3 weeks, however, the meat starts to dry and it molds, and its quality is reduced.

The incidence of stomach cancer has been very high in Iceland compared to other countries. Dungal showed that the high incidence of stomach cancer correlated with the high consumption of smoked foods. Dungal, and later Thorsteinsson et al., made many comparisons of the amounts of polycyclic hydrocarbons in the various Icelandic foods. The level of 3:4 benzpyrene, for example, in the home smoked mutton was found to be as high as 107 mg/kilo, while commercially smoked meats contained only a trace of benzpyrene. The great difference in the amount of benzpyrene between commercially and home smoked mutton was assumed due to the difference in smoking time and the cleaner smoking methods used in the commercial smokehouses. In addition to the home-smoked mutton contributing to the high incidence of stomach cancer, it is also believed that seabirds singed in the traditional manner of Iceland also contained high levels of benzpyrene, and contribute to the incidence of the polycyclic hydrocarbons in the diet.

Based on these findings, the farmers in Iceland are now urged to terminate the home smoke curing and leave the process to the industrial smokehouses. There is also an attempt to reduce the pollution of polycyclic hydrocarbons in the singing of sheep's heads by using propane gas rather than the long hot traditional process.

Since the work of Foster and Simpson in Scotland, it is generally concluded that wood smoke comprises two phases, namely, a particulate phase and a vapor phase. Foster and Simpson found that they could remove the particulate phase and that the vapor phase contributed the smoke flavor and color without the particulate phase being present. It has also been found that removal of the particulate phase also greatly decreased the level of benzpyrene in the smoke, due probably to the fact that the particulate phase contains.a large portion of the heavier smoke tars. Accordingly, it has been a practice to remove the particulate phase either by electrostatic precipitation, or by other means, to decrease the tarry components in the smoke, and thereby, reduce the levels of benzpyrene. The method of electrostatically filtering smoke is described in the submitted paper,

"Experiences with the Use of Electrostatically Filtered Smoke for Smoking of Meat Products"
by Josef Rusz
of the Research Institute of Meat Industry in Brno, Czechoslovakia

This author describes the process of obtaining the vapor phase of smoke essentially free from the particulate phase by using a laboratory electrostatic air filter containing an ionization section. This ionization section contains 8 negatively charged aluminium plates, with a surface area of about 0.72 square meter. Smoke was generated by the usual smoldering type generator and drawn through the electrostatic filter and used to smoke flavor and color various meat products. The composition of the smoke either electrostatically filtered, or not filtered, was determined by absorbing the smoke in water or ethanol and analyzing for acids, phenols and carbonyl compounds. The benzpyrene content of the smoke solutions was also determined, with and without the electrostatic filtration.

Generally, the difference between the normal and the filtered smoke in acid, phenol and carbonyl content was only quantitative. The filtered smoke being lower in all components, which might be expected. Sensory evaluation of the meat products smoked with the normal versus the filtered smoke showed that the filtered smoke produced products that were comparable in quality with the normal smoke. The outside color and the smoky aroma of the products smoked with the filtered smoke, howerev, were less intense due to the precipitation or the removal of the tarry substances by the electrostatic filter. The important findings, of course, were that the smoke from normal smoking without the filter averaged 38.5 micrograms/liter of benzpyrene while the filtered smoke was only 0.8 micrograms/liter. This study indicated that the use of an electrostatic precipitator does effectively remove the particulate phase and the resulting removal of benzpyrene, while at the same time produces the useful smoking agent.

Baker and Hoff (U.S. Patent No. 3, 615, 729) claims a method of reducing the carcinogen in smoke by passing the smoke through a cyclone which removes a substantial.portion of the particulate phase and, thereby, reduces the smoke in carcinogens. These authors also describe a process of regenerating the smoke by spraying the liquid smoke onto a hot surface and thereby regenerating the smoke vapors. They found that even when they added benzpyrene to the liquid smoke, and recondensed the regenerated vapor, that the content of the regenerated smoke was greatly reduced in benzpyrene by the hot surface regeneration process. Although the regeneration of liquid smoke is used extensively in the USA, as far as we know the addition of the cycloning effect to remove the particulate first is not being used. The process of Baker and Hoff is illustrated in Figure 7.

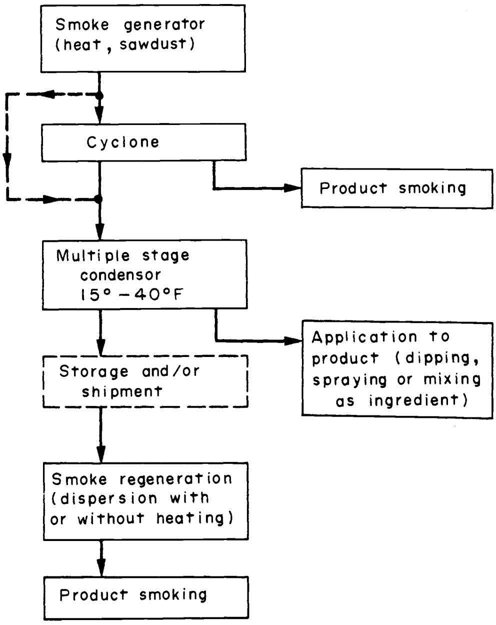

Fig. 7. (U.S. Patent No. 3, 615, 729 Baker and Hoff) Diagram showing passing vaporous smoke through a cyclone device.

As was mentioned previously, the wide usage of purified liquid products (smoke solutions) was stimulated by learning that the benzpyrene can be effectively removed from the liquid solutions by tar precipitation, or by filtering and absorbing out the tars on cellulose filters.

THE NEED TO DECREASE SMOKE EFFLUENT

The greatly intensified effort on the part of all peoples to clean the environmental air has placed restrictions on smoke effluent from any process. In USA there has been great progress on the part of meat processors to decrease the smoke effluent from the smoking process, in order to meat strict air standards set up by the environmental protection agencies. This trend has stimulated a scramble to use other processes, such as using liquid smoke, using afterburners on the smoke effluent, or using systems for smoking which are essentially closed and without smoke effluent.

The use of afterburners progressed for a few years but is now decreasing because of the large fuel usage by the afterburners. The afterburner, of course, burns the smoke effluent further to complete combustion leaving no particulate to go into the air. This is accomplished by the burning of natural gas or other fuels. These fuels are becoming scarce and restrictions are being placed on the use of afterburners because of the scarcity.

From a mechanical and engineering aspect, the trend is toward developing smoke house systems which are totally enclosed to eliminate having to contend with a smoke effluent. I shall describe two of these systems.

Freeland and Flannigan (U.S. Patent No. 3, 903, 788) developed the closed system smokehouse shown in Figure 8.

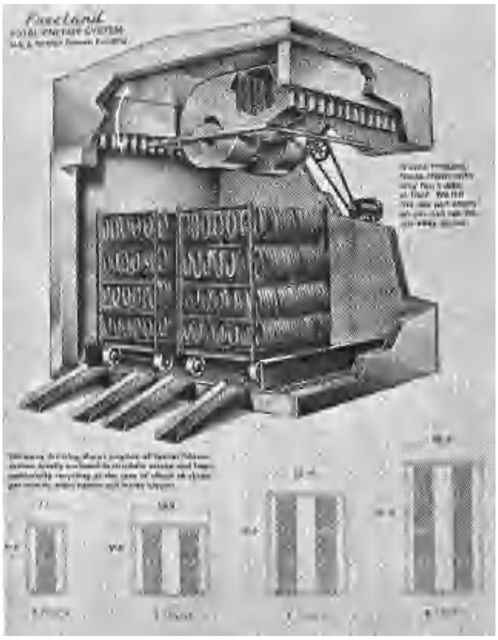

Fig. 8. (U.S. Patent No. 3, 903, 788 Freeland and Flannigan)
A closed system smoking chamber.

This smokehouse is designed in such a way as to incorporate the smoking, heating, and the circulation of the smoke and heat, all within the enclosure with little, or no smoke effluent. Based on the description in this patent the smoke is generated in the top of the house, is picked up by the blower system and along with electrically heated air is blown down along the sides of the house, and recycled again after being in contact with product being smoked. The whole operation being self-contained with only a small amount of air intake electrical heat , and no steam added, but using the moisture from product for humidity.

West (U.S. Patent No. 3, 805, 686) describes a process in which the effluent of the smokehouse is drawn through a condenser, then recycled back into the smokehouse. An illustration of the West process is shown in Figure 9.

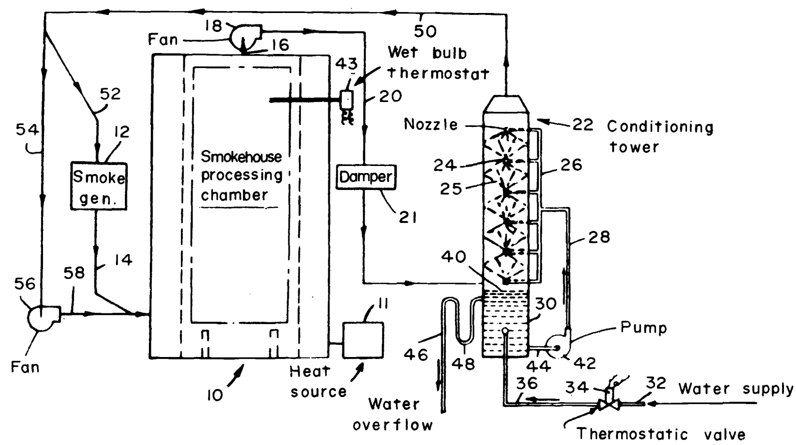

Fig. 9. (U.S. Patent No. 3,805,686 West) Closed system smoking with the effluent scrubbed and recycled.

Smoke is generated in the usual manner and blown into the smokehouse. After passing over the product, smoke is withdrawn and is recycled first through a condenser tower where it is in contact with water spray, then the washed smoke and air are recycled back into the smokehouse. By this means there is no smoke effluent to contaminate the outside air.

Closed smokehouse systems are gaining some popularity in USA, not only from the decrease of smoke effluent, but also from the conservation of heat inherent in the recycling. Some users of closed systems claim that they can save considerable amount of steam per thousand pounds of product, because the reheated air is recycled and does not leave the system as in the open-type smokehouse.

Of course, the need to decrease the smoke effluent has been a great stimulus to wider usage of liquid smoke products.

THE NEED FOR BETTER DESIGN AND FASTER THROUGH-PUT IN SMOKING SYSTEMS

In the smoking industry, like all industries, there is a definite drive toward more automation, more efficiency, and more through-put. The automated smoking-cooking tunnel for wieners has been in use for about 20 years, and during that time great strides have been taken in controlling processing conditions in these tunnels. The tunnels are now being used for bacon and hams.

Emphasis has been placed on producing a uniform, high quality product by means of sophisticated controls of the smoking-cooking-cooling steps in the process. Most of the continuous processes in U.S.A. use liquid smoke (by drenching or showering), since it is more adaptable to the continuous process than vaporous smoke.

Some of the parameters for design and use of a modern smokehouse are discussed in the following submitted papers:

"The Analysis of Conditions for Design of Smoking Chamber or Tunnel"
by Miloslav Adam and Petr Polach
of the Research Institute of Food Engineering, Prague, Czechoslovakia

These authors analyze the conditions for design and operation of smoking chambers based on four main factors, namely. properties and dimensions of products to be smoked, parameters of the smoking chamber atmosphere, conditions of operational technology, and design and construction of the equipment proper.

The thermophysical properties of products (meat, fish, cheese) which determine the heating rate are specific heat, thermal conductivity, and thermal diffusivity. The thermophysical properties of products varies with composition. Values for thermal conductivity of pork, for example, vary widely with fat, protein and moisture content. The dimensions of product influence the thermophysical properties. These can be analyzed by using a cylindrical body as a model. Small diameter products with small diameter casings are more ideal in heat transfer and diffusivity than larger products.

The conditions for temperature and humidity in the smoking chamber depend upon the intensity and rate of the production of the smoke aerosol, the convection and transfer of heat, and the moisture transfer between air and product. These factors are discussed with methematical models.

Some of the aspects for operational technology which must be considered for good integrated processes are types and rates of chilling of product, the inspection of product for quality (core temperature and shrinkage) and the uniformity of product.

The design and construction of the smoking chamber itself are very important due to the corrosive conditions of heat, humidity, and cleaning agents. Stainless steel construction, heavy duty sizing of all movable parts, and selflubricated bearings are mandatory. Control panels with all services to control heat and humidity conditions are desirable, as well as some means of controlling effluent such as an afterburner or scrubber.

The second submitted paper on this subject is:

"Application of Programmed Smoke Curing in Polish Fish and Meat Industries"
by M. Pietrzyk
of the Technological University of Gdańsk
Department of Food Preservation Technology and Technical Microbiology, Gdańsk, Poland

This author analyzed the basic parameters of the smoking process for fish, and the necessary requirements for smoking chamber which would provide all desired conditions. Some of the processing parameters discussed are the denaturation temperatures of the proteins, the hydrothermal changes in connective tissues, the diffusion and evaporation of moisture from product, and the intensity of the smoke.

Some of the necessary requirements of the smoking chamber studied were, the capacity of the unit in relation to the heat and air services, the air circulation and change, and the programming of heat and humidity with disc-type cams connected to dry and wet bulb thermometers.

The yield of product from the designed smoking unit was consistently better than from conventional smoking kilns. With a particle filter in the smoke duct from the friction type generator, the color of the food product was excellent as well as very uniform. Comparative data are given for engineering and cost factors between the designed smoking unit and regular commercial units.

In summary, there are many novel concepts in the technology and design of machinery for production and application of smoke in the food industry. Examples of some of these concepts are the wider use of liquid smoke applied by drenching, atomizing, or vapor re-generation; the refinement of vaporous smoke by electrostatic filters, and swirling devices; the development of closed system smoking chambers; and the construction of continuous smoking tunnels with improved efficiency and product through-put.