Finishing and Packaging Soaps and Detergents

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IN THE 1952 SHORT COURSE several of the talks (1, 2, 7) covered quite a bit of the assigned topic so I shall attempt to avoid unnecessary repetition even though this attempt may not be completely successful. However there is a fair amount of background material available that may make some repetition worthwhile.

Any discussion of this subject might well begin with a look at the magnitude of the business and the relative importance in the market of the various physical forms of the detergents (both soap and synthetic), and Table I gives the latest available information. While the figures are divided into soap and synthetic, the finishing and packaging problems normally are common to the two when produced in the same physical form so the two will be considered together.

TABLE I

Total Soap and Detergent Sales (from AASGP) 1955 in lbs.—000 omitted

Synthetic detergents	Retail package	Bulk	Total
Granules	2,070,141	75,949	2,146,090
Liquids (except shampoos)	122,480	43,093	165,573
Shampoos	?	?	28,767
			2,340,430
Soaps			
Bars	721,508	—	721,508
Granules	249,648	93,112	342,760
Soap chips and flakes	66,741	99,173	165,914
Liquids	?	?	41,958
Miscellaneous	65,805	19,512	85,317
			1,357,457
Grand total			3,697,887

Granules obviously are the form of choice of the housewife for the majority of her tasks. Once the granules have been formed in the spray-drying operation, the major problems remaining are to get the right amount into the package and to build into the package sufficient protection so that the granules may be poured out readily when needed.

Getting the proper amount of the product into the package means that the contents must average at least the weight marked on the package at the time of possible checking by a state or local inspecetor, but at the same time a problem of product density is involved as the outage or void area above the package contents must not be great enough to raise questions of false economy in the housewife's mind or even questions from the Federal Trade Commission. Every effort is made to fill the package to the point that trouble with sealing is just avoided, and agitation either of the filled package before sealing or of the product before entering the package is used to minimize settling as a result of the handling the package receives before it reaches the consumer. However some settling is unavoidable, and outages generally are considered satisfactory if they do not exceed 10% of the package volume at time of opening.

The problem of maintaining satisfactory weight and outage control on their production is always a troublesome item in the minds of the packing-room supervision. As speeds of filling packages vary greatly, even for a given size, the magnitude of the problem of producing every package with correct weight and outage will be quite a different thing for the man running a packing line at 40 cartons per minute from that of the man running a line with the same-sized cartons at a speed 5 or more times higher than 40 c.p.m. The soap industry is no exception to the move to higher and higher speeds to reduce unit costs so the problem will persist.

Consequently the first processing step on granules after they leave the spray-drying system is a density determination, which may be made simply by weighing a known volume of the stream of dried product. Usually at this point in the process the granules are run into portable bins of 1,000 lbs. or more capacity, and the disposition of the individual bins is determined by the density of the contents as long as the product is packable from other quality aspects, such as specks and lumps. Direct feeding to the packing equipment, blending to a standard density with other product, or even reworking follow.

The packing line normally consists of a means of forming the carton, which is received flat from the maker, into its finished form, a filler, a means of inspecting cartons to reject any not filled adequately, a means of closing the filled carton, and a packing area where closed cartons are placed in the shipping containers. These may be separate machines or the latest equipment attachments on a single machine.

Fillers are weight- (Figure 1) or volumetric-actuated (Figure 2). If weight-actuated, then a properly adjusted machine will produce cartons uniformly at the correct weight, but varying density of the product will cause outage problems. Similarly volumetric fillers normally give little difficulty with outage in filled cartons but present a continual problem with control of package weights.

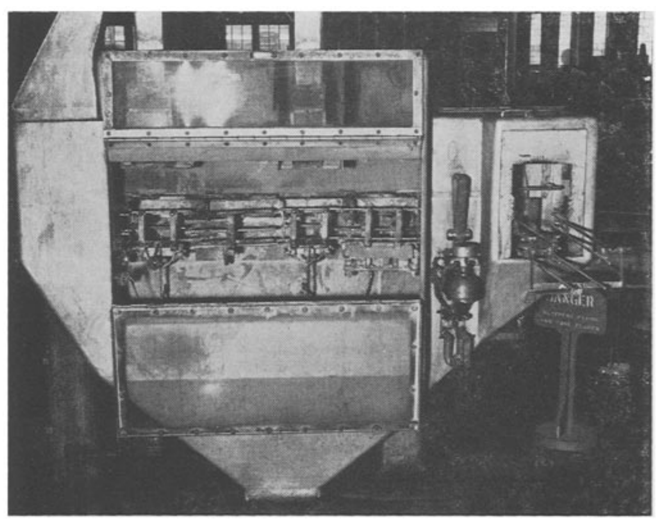

FIG. 1. A weight actuated filler.

Packing may be manual or mechanical, and the filled shipping container is sent either to storage or shipment. With storage properly regulated, the

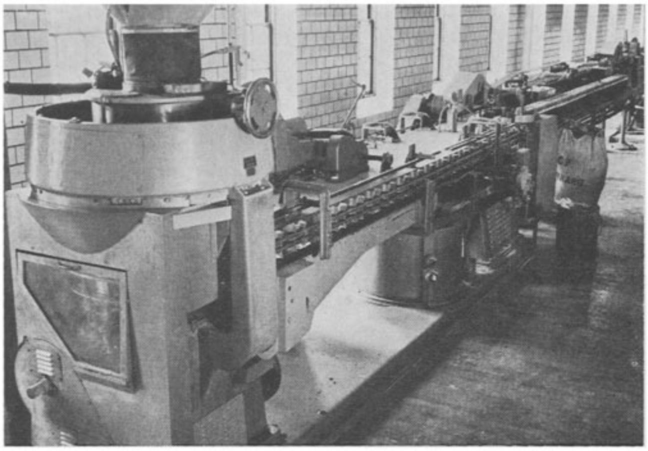

FIG. 2. A volumetric filler.

product is protected against deterioration prior to sale, and a careful inspection program will ensure that only good quality product is released.

RETAIL PACKAGES of granules proliferate in number as time passes. In a single factory we may put a single product in as many as seven different retail package sizes today, and there is no reason to believe that this trend will soon reverse. In as diverse a group of packages as these it might seem that there are no common principles to ensure uniformly satisfactory packaging, but there are, and this is a convenient point to list such points.

First, there is the underlying knowledge that customers in their minds associate the quality of a product offered for sale with the appearance of its package. For instance, when you are in a self-service store, do you reach for the package that looks fresh or the shopworn one beside it? Impression-buying accounts for a large percentage of present-day purchases, and that is the first principle we must remember, the customer buys a product because it looks good. Manufacturers are eager to promote such a trend because, by proper packaging, they are able to deliver fresher products, reduce return merchandise, and maintain customer satisfaction at a lower cost. Because new materials and machines become available almost daily, you must work hard to utilize the new possibilities or you will find yourself with an obsolete package on your product with the accompanying effect on the brand turnover.

Within this constant effort to be up-to-date there are a multitude of specific qualities that must be checked on each new package. Without going into almost infinite detail, we might take a glimpse at a few of the items that are more obvious to a purchaser, hence the more important. Among the physical properties of a package we determine the caliper of the board, the resistance to breaking on folding, the resistance to abrasion, the color and the uniformity of that color in production runs. Beyond these and many other physical properties there are others that might be termed functional properties, the permeability to water, oils, perfume, or insects, the sealing strength, the possibility of reaction with the product, and the effect of exposure over the market life on the qualities that are satisfactory in a new package. Once all of these details have been worked out other questions arise: is the new material that looks so good available in the quantity we would like to have? if not, what does the manufacturer have to do to expand? can the increased cost of the new package be justified on some basis? or do railroad package specifications permit such a package to be shipped? finally, will the package be one that the factory can handle easily in its operations, will the stores be able to stack it for display, and will the consumer find it an easy one to store with the myriad of other packages she has in her closet or under her sink? Those are a few of the principles that apply to every package.

Since it is necessary to tailor-make every package to fit the product it is to carry and the end-use it must serve, some specific questions must be examined in designing a package for a granules product. A granules brand is not likely to enjoy popularity if a housewife has to beat the package against the wall five or six times to loosen up enough product from the solid cake therein to do her washing job. Since many granule products are subject to humidity caking, how to design a package to protect such a product? Storage tests under specific extreme humidity conditions soon will tell whether moisture barriers like asphalt containers are enough, whether the individual carton must be fabricated from wax-laminated board, or whether both must be used. Since the protection afforded by the special container is equal to that provided by the special cartons until the container is opened, the expected shelf life of the product has to be considered in determining whether the extra cost of providing protective cartons can be justified. Also one cannot protect against every contingency and keep package costs reasonable. Therefore we pack so that we keep out of trouble on all but the minute percentage of product that faces very unusual conditions. Regular examinations of product in the trade will soon determine if the proper balance of all of the factors has been obtained. Return of damaged merchandise is an expensive way to learn that the package is not good enough. Therefore extensive pre-testing of a change is necessary.

Once you have drawn up your specifications for any package, the normal problem of acceptance sampling and testing must be faced to be sure that all of your development work has not gone for naught through the failure of a supplier to meet the specifications. So much for retail granules products and their packages.

GRANULES ARE ALSO PACKAGED for bulk sale for many purposes. Paper bags, fiber drums, and more rarely barrels are filled with products processed in the same way as the retail products, or specialty products such as low titer soaps for cold-water solubility, highly alkaline-built soaps for commercial-laundry heavy-duty work, etc. Since bulk filling normally is to a designated package net weight, a scale is an integral part of the equipment and individual adjustment of package weights is made.

The next largest share of the total detergent market is held by the bar products, practically all of which to date are soaps though synthetic detergent bars are being marketed on a relatively small scale. About 60% of the bar products available today are so-called milled soaps, which have been transformed by milling or other working into firm bars that lather well. Details of the processing used may be found in the discussion on this same subject in the 1952 Short Course. However it will be profitable perhaps to spend some time on the physical changes that occur in the soap during milling and their contribution to the consequent improvement in performance.

A series of papers by Ferguson *et al.* (3, 4, 5, 6) has described the phases and phase changes which occur in solid commercial soaps. A knowledge of these phases will enable one to understand more clearly the empirical processes used to produce soap in a solid form.

Briefly there are three important phases in which solid soap may exist, beta, delta, and omega. The fourth, alpha, is of little practical importance. Identification of the phases so far has been possible only by x-ray diffraction, using the short spacing rings as the crystals involved are too small for photomicroscopy. These three phases contribute markedly to the usage characteristics of the finished bar as Table II shows. The beta phase obviously is desired

TABLE II

Properties of Three Phases of a Typical Commercial Soap

	Beta	Omega	Delta
Firmness, arbitrary units	8.0	7.2	3.0
% soap rubbed off bar in use in water[a]	2.4	0.5	1.7
Reaction to water when soaked	Swells and disintegrates	No swelling or disintegration	Cracks, with little swelling

[a] This figure is a measure of the ease of lathering of the bar of soap; the pronounced difference between beta and omega is readily observed in ease of lather tests.

for its combination of firmness and good lathering although it also has the drawback of some loss in resistance to smear when left in contact with water. The omega phase with its firmness, low lathering ability, but high resistance to smear, is the phase usually obtained by chilling neat soap rapidly without working. Its formation is favored by higher temperatures, lower moistures, and lower molecular weights. The beta phase can be formed from the omega phase by working the soap at temperatures and moisture levels where the beta phase is stable. It is this transformation that the milling process performs when carried out under the conditions which have been determined as proper empirically. The transformation of omega to beta phase is illustrated in Figure 3, in which four x-ray diffraction patterns of the same soap are shown side by side with additional working being done between each resampling. The characteristic rings for the omega phase are seen strongly in the left pattern and decrease in intensity as the succeeding patterns are examined after additional working. At the same time the rings indicating beta phase increase in intensity from left to right. The figures below the individual patterns indicate the relative wear rates on the particular samples shown.

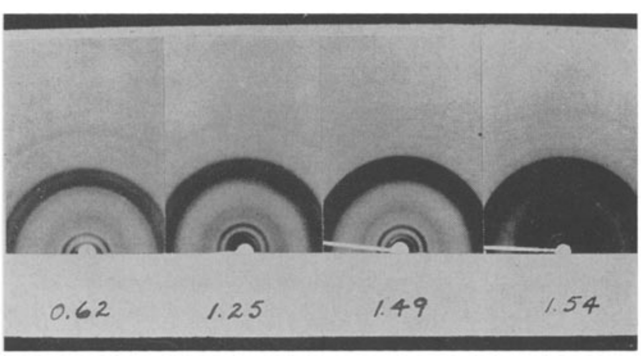

FIG. 3. X-ray diffraction patterns illustrating change in phase from omega to beta obtained by working soap (the figures below the patterns indicate relative washing wear rates of the samples).

A glance at the complexity of the phase diagram in Figure 4 of a commercial soap reinforces the need

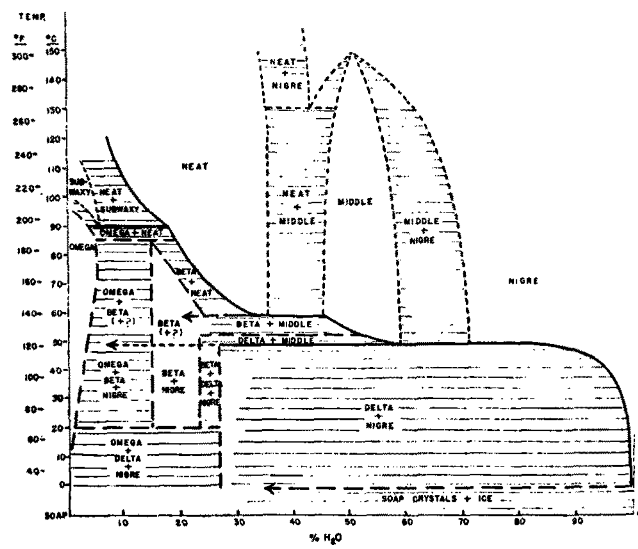

FIG. 4. Soap phases in a commercial soap.

which has been learned to control carefully the conditions of milling if the firm, easily lathering product desired is to be obtained. Control must be close of moisture in the dried soap sent to the amalgamator and milling temperatures developed in the soap if the end is to be in the small region in the diagram that gives a stable beta phase.

The third important phase, the delta, which you will remember is characterized by softness and an intermediate lathering ability and is favored by lower temperatures, lower soap content, and higher molecular weights, is formed if the soap is higher than desired in moisture or too low in temperature.

Another objective which is obtained during the milling operation is the removal of so-called hard specks that are overdried soap particles. Hard specks make a bar used at normal washing temperatures feel as though sand were embedded in its surface. The milling surfaces, when set closely enough together, reduce these hard specks to individual particles too small to be felt. If hard specks are encountered on usage of a bar, particles of soap which stand in the equipment overnight and therefore dry out and then are reintroduced into the soap or overdried soap chips are usually found to be the cause. Thorough cleaning of the equipment, plus resetting of the rolls, should eliminate the problem.

PACKAGE DESIGN for bar soaps has its own host of special problems, to mention just a few. The paper in the wrapper must not stain the soap by dye or ink bleeding or, in turn, must not be stained by the soap. The sheet must be free of mold foods like proteins or starches otherwise the high moisture level of the soap may encourage mold growth. If mold inhibitors are used, they must be free from reaction with perfume constituents. Every new additive like cold cream or deodorant causes a re-examination of all the previous decisions. Then a desire for an improved appearance may force a change to a thermoplastically sealed paper or foil wrap. Again with a change in the wrapper, how about the wrapping machines? what rebuilding is necessary there? It can be seen that a packaging engineer is a necessary part of your technical group.

Of the remaining bar soap production, some 10% is in the yellow laundry framed soap although its share of the market is decreasing.

The remainder of bar soap production is in the white floating and laundry classification. While some years ago all of this group likewise was produced by the framing process, the conversion to continuous processing has appeared on a broad basis in recent years. Complete equipment for such a process, which turns out a plodded continuous bar ready for stamping, is available from several manufacturers, among them Mazzoni and Mecchaniche Moderne. A leading American bar soap, Ivory, is produced by a semi-continuous process described by Mills in U. S. patents 2,295,594–6 (8), and a short description perhaps will be of interest although, in passing, it should be mentioned that the process is not limited in usefulness only to a floating product of high real soap content.

Neat soap is heated sufficiently in heat exchangers with high-pressure steam so that flashing at atmospheric pressure will reduce the moisture to about 20%. The soap then is passed through a continuous crutcher seen in Figure 5, where perfume, antioxidants, and air may be intimately admixed. The soap then is forced through a continuous freezer, based on the type used widely in the edible shortening and margarine industries (Figure 6). Working of the soap as it is being cooled effects a substantial change in phase from omega to beta to obtain the desired lathering characteristics. By control of the rate of cooling the soap issues from the mouth of the freezer onto a carry-off belt in a cohesive smooth continuous strip shaped to the desired bar cross-section. The strip is cut into lengths equivalent to three or four bars, which are then placed automatically onto trays. The cut lengths are cooled to about room temperature to provide a skin resistant to excessive marring, then cutting into individual bar blanks, stamping, wrapping and packing follow. With a bar expected to float, stamping pressure must be controlled so that too dense a bar is not produced.

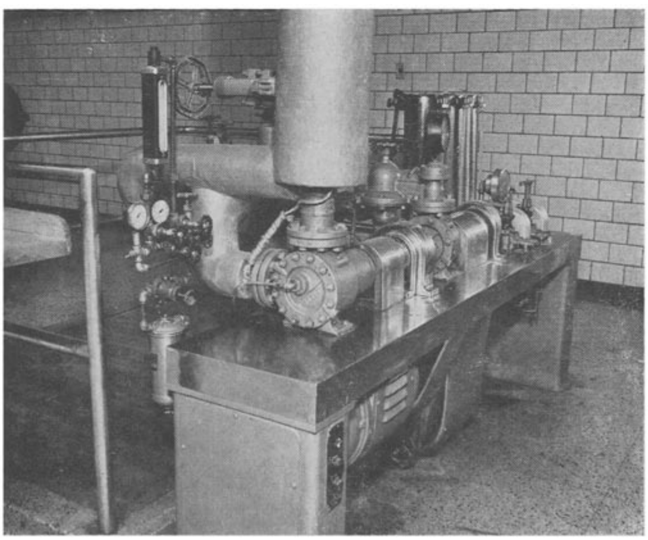

FIG. 5. Continuous crutcher.

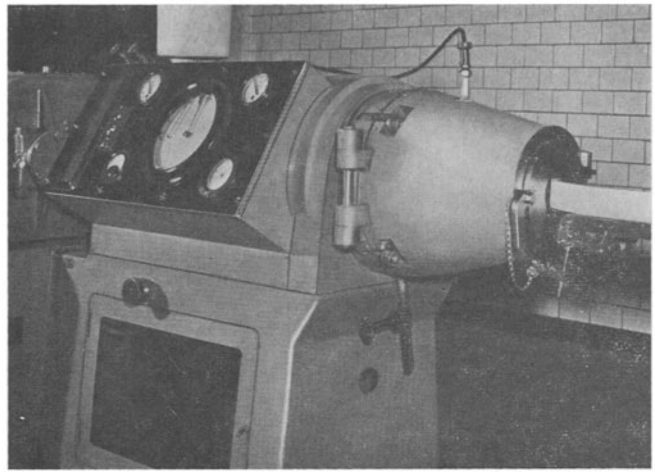

FIG. 6. Continuous freezer for Ivory.

FLAKES REPRESENT a physical form of soap that has been popular for light duty tasks but does not seem to be finding new customers at present. For retail purposes, the thin flake is the more popular form as granules have replaced the slowly soluble chips almost completely. The flakes of about .0020-in. thickness are produced on hollow steel rolls assembled in multiple vertical stands known as mills and equipped for internal heating or cooling. Soap chips which have been dried to a carefully controlled low moisture level and which contain about 1½% of glycerine as a plasticizing agent are fed with or without additional working to the lowest pair of rolls in a stand. The sheet of soap formed on the upper roll of the pair is picked up by the next higher roll, which is cooler and travelling at a higher speed than the lower roll, and a thinner sheet results. At the junction point of two rolls a bead of soap appears on properly adjusted mills, and the shearing action therein provides the work necessary to promote the desired phase change. Phase change and flake thinness make possible the desired quick solubility in usage. Either one mill or multiple mills may be used. By the time the soap sheet has reached the top roll of the final mill, it has been adjusted to the final thickness and, while on that roll surface, is cut into the desired flake shape and size by rotary cutters riding on the roll surface. Mechanical condition of the cutters and rolls must be watched carefully and repairs made promptly if individually cut flakes are to be sent to the packing unit at all times. Otherwise strips and ribbons will be common. Since packing speeds usually exceed milling production speeds, intermediate storage in the form of a bin normally is provided. Packing is by weight fillers similar to those used on granules. Although every effort may be taken at the time of packing to fill the package completely, flakes have a habit of aligning themselves with the large dimensions parallel as the filled carton is subjected to handling in warehousing and shipping, and this so-called "stacking" action brings about a real problem of excessive outage when the package of flakes reaches the consumer.

Bulk flakes and chips are packaged directly from the chip drier, or after mixing in of builders with the dry-mixer. A large amount of such bulk production is represented by an unbuilt chip used as a catalyst in the polymerization step in synthetic-rubber making.

ONE OF THE MORE ACTIVE commercial areas at the moment is that of liquid synthetic detergents both for light- and heavy-duty washing. The original light-duty products appeared in glass but, since some consumers seem to prefer a can, are now also being packaged in that fashion. Though as mild as soaps, their long exposure-time caused a corrosion problem with the cans, which has been overcome by the use of treated can plate and polyethylene nozzles among other innovations. The heavy-duty liquids now appearing on the market are also in cans, and many packaging problems of the same type have had to be solved. In general, these products are mixtures of alkyl benzene sulfonates or other actives, phosphates, and various additives such as brighteners and suds builders, all solubilized into a single phase mixture. The elimination of the dissolving period is an advantage of this type of retail product heavily stressed in the advertising.

Liquid soaps usually are potash coconut soaps sold in bulk for washroom dispensers and similar uses. If not chilled and filtered during making, they frequently develop an unsightly precipitate.

In the miscellaneous field there are many specialty products, such as cleaners, cleansers, dishwashing compounds, cold-water washing products for woolens, shaving cream, and many more. While they all have some soap or synthetic detergent present to provide cleansing action, they are not usually considered soaps. Likewise the shampoos form a field of their own.

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Heat Transfer

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HEAT TRANSFER continues to be one of the most important operations in a majority of industrial companies. It is not surprising then that research in this field is and has been conducted by a large number of investigators. As a result, new developments and equipment designs are common.

In the last few years much heat transfer research has been done in nuclear and aeronautical fields (10, 11, 12). Numerous studies have been reported of heat transfer through molten metals and through gases flowing at high Mach numbers. Development and research work has continued, in addition, in chemical and oil processing industries. The results of these studies have thrown considerable light on the basic fundamentals of heat transfer.

The general basic theory of heat transfer and some of the common correlations will be outlined here. In addition, recent developments, especially those that might apply in the oil processing industry, will be reviewed.

Modes of Heat Transfer

Heat transfer can occur by three modes (4, 22, 30, 34). Briefly these are as follows: conduction, or transfer of kinetic energy from one molecule to an adjacent one; convection, or transfer of heat caused by the mixing of molecules or portions of a fluid with other molecules (Convection may be either natural or forced. Mechanical agitation is provided for forced convection.); and radiation, or transfer of energy through space by means of electromagnetic waves. (These waves can be transmitted, reflected, or absorbed by matter. Only that portion which is absorbed will appear as heat.)

In most industrial operations, heat transfer occurs by more than one of the above modes. Frequently the operation can be divided into steps though, in which only one or possibly two modes are significant.

The basic equation for steady-state unidirectional heat flow by conduction is Fourier's equation (4, 22, 30, 34):

$$(1)\quad Q = -kA\frac{dT}{dX}$$

In the case of constant k and A (as frequently occurs),

$$(2)\quad Q = -\frac{kA}{\Delta X}\Delta T$$

where ΔX is the thickness of the material across which heat is being transferred, ΔT is the temperature difference, or the driving force. The resistance to heat transfer is $(\Delta X/kA)$. If heat were being transferred by conduction through a series of substances, the sum of the resistances would have to be obtained. The ΔT to be used then would be the total. In industrial processes heat transfer through solids is generally by conduction although in some cases radiation may be significant too.

The basic equation for the radiation of a "black" body is as follows (4, 22, 30, 34):

$$(3)\quad Q = \sigma AT^4$$

Since radiation is proportional to the absolute temperature raised to the fourth power, it is obvious that radiation is much more significant at high temperatures. Radiation is industrially of importance in furnaces, flames, etc. Correction terms must generally be applied to the above equation to account