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The Influence of Stock Surface Properties on Grease Resistant Films

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THE INFLUENCE OF STOCK SURFACE PROPERTIES ON GREASE RESISTANT FILMS

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INTRODUCTION

One of the main problems in applying a continuous film to a fibrous surface such as paper is that coating must cover fibers that lie in every direction. This produces a relatively rough mat, with some fibers protruding. The surface of paper varies, but all papers and board have a surface configuration resembling a range of mountains. In paper, the interstices can be loaded with fillers, but with boards, fillers are not practical due to the amount necessary. Thus, in coating board with a continuous film, the surface configuration of the board is the main determining factor of the amount of coating necessary. Calender treatment of board will tend to flatten the tops of the sharp peaks, but the stray fibers sticking up will not be decreased materially. To correctly balance the continuity and adhesion of a film with the surface configuration of the sheet to which it is applied is the problem of the grease resistant paper manufacturer.

One of the fastest growing fields in the Paper Industry today is the manufacture of coated papers. Few, if any, other fields can show the startling increases in tonnage that coated paper sales have shown. In 1935, less than a thousand tons of coated paper were sold. In 1942, the amount sold was 300,000 tons for an average annual increase of 7,000 tons. But, after the war, the total rose even faster, and by 1958, the tonnage was one million, six hundred thousand. Estimates for 1959 production place the total around one million, 752 thousand tons.

Even higher increases in tonnage are predicted for coated paperboard, although figures on production are not available. The Department of Commerce does not specify whether board is coated or uncoated, but estimates for 1958 are three million, 400 thousand tons. This, of course, is due in part to the high basis weight of paperboard, but also to new packaging uses for the board, especially in regards to food packaging. In a recent test by the Food and Drug Administration on the purity of milk carton stock, it was found that there are actually more bacteria in the milk itself than in the stock used to package it.

Of all the types of coated papers made, one of the most interesting, and challenging to the manufacturer, is the greaseproof coated paper. The film applied to a sheet must be absolutely continuous, or the film is not grease resistant. Very few fibers need to protrude thru

the coating in order to ruin it as a grease barrier. The protruding fibers act as capillary tubes or wicks, conducting the grease thru the film and into the sheet. This is especially bad in papers that are coated on both sides since the grease acts as a sheet plasticizer, and unnoticed, may cause a point of failure later in the finished product.

Requirements for a grease resistant film are high. The film must resist the solvent action of the grease. It must be applied heavily enough to cover minor surface irregularities, but not so heavily that it is too expensive. Films must adhere strongly to the sheet so that they will not split or pull loose from the sheet. They should be flexible enough to be scored and bent, without cracking, during conversion operations. Sheets should not "block" during prolonged storage.

In food packaging, several more requirements are necessary. The film should be tasteless, odorless, nontoxic, and be printable with existing equipment.

In spite of these exacting requirements, there are many films on the market today that satisfy them, and many different processes of application. However, there are only 4 basic types of coating: <u>lacquer</u> or <u>solvent</u>, <u>emulsion</u>, <u>dispersion</u>, and <u>hot melt</u> or <u>extrusion</u>. Regardless of the equipment used, each will form a greaseproof film.

Not all coating processes are applicable to all coatings, and some films form better by one process than by another. Lacquer type coatings have come to mean all

coating materials that form a film by evaporation of a solvent vehicle. This type of system will apply a very thin continuous film, but has several disadvantages. Unless a recovery system is included, solvent costs make this an expensive process. There is the ever present danger of fire and toxicity, and the relatively low per cent solids possible, although a large amount of solvent will evaporate quickly at room temperature or moderate heat. If forced drying is needed, driers using steam are essential for safety.

Dispersion coating utilizes droplets of polymer in a water suspension, carrying 35-50% solids by weight. The coating is applied and the water vehicle is driven off by low heat, around 110-120 degrees C. There are several advantages to this system: equipment is easily cleaned with H_2O; there is no danger of fire or health hazard. The heat utilized may be steam or gas driers. Comparable adhesion and strength for dispersion coatings to solvent coatings is claimed for most commercial products. Gloss of water base coatings is lower than that of solvent coatings. There are also several disadvantages to dispersion coating: the film deposited is not continuous, but must be fused during the drying since cold flow of the droplets would be too slow. Since most films that form at low temperature also have tack problems, the choice of materials is further restricted. Fusion with solvents or plasticizers is also possible, but this increases production costs. Curl problems are more

pronounced in thinner sheets when coated on one side and using plasticizers.

Emulsion coating is also applied from a water vehicle but the polymer is in the form of a latex emulsion. An emulsifying agent is necessary which may augment curl problems and sometimes contaminates the film which is formed. The same advantages as dispersion coating apply to emulsion coating. However, film formation is generally at a lower temperature, and somewhat higher per cent solids can be applied, minimizing the amount of heat needed for evaporation.

Hot melt or extrusion coating came about from early attempts to harden paraffin wax coatings. Until the development of the hot knife coater, only low molecular weight coatings could be applied. The hot knife coater can coat polymers up to 10,000 poises viscosity. The standard method now, however, is the extruder. It forms a very thin continuous film of hot polymer which may be applied to any sheet product and forms an effective barrier against grease. It gives thinner continuous films than any other process, but requires special equipment and a large amount of heat. Thermoplastic resins are needed, and sometimes cause "blocking" problems.

In the determination of the degree of grease resistance, the base stock is equally as important as the film being formed and, in fact, plays a deciding role. It must have definite properties and characteristics to be coated by any of the processes. The stock must have

enough strength to hold together during the coating operation. It must have little caliper variation for this varies with the thickness of the coating applied. Density in relation to the process to be used must be considered. The type of finish and sizing used is important, as is dimensional stability. But the biggest variations and most important properties of the base stock, from the point of view of film forming, are the surface properties.

Surface configuration is defined as the profile of the sheet, that is, the height, depth, width, frequency and distribution of the surface variations. It cannot be done exactly with an instrument since the film is affected by individual variations, and an instrument cannot be expected to cover a sheet completely. The value that an instrument gives is useful only if it can be correlated to the observed performances in production.

Smoothness of a sheet affects the adherence which a film has for that sheet. A rough, highly porous sheet will give maximum adhesion to an applied film due to the coating being driven into the interstices between fibers. However, this same rough, highly porous sheet will in all probability give a very low film continuity. Fibers and high spots in the sheet will protrude, and the coverage will be poor unless a very heavy coating is applied. Excluding the process of extrusion or hot melt, the problem of the greaseproof paper manufacturer becomes one of maintaining a high enough basis weight for strength of the

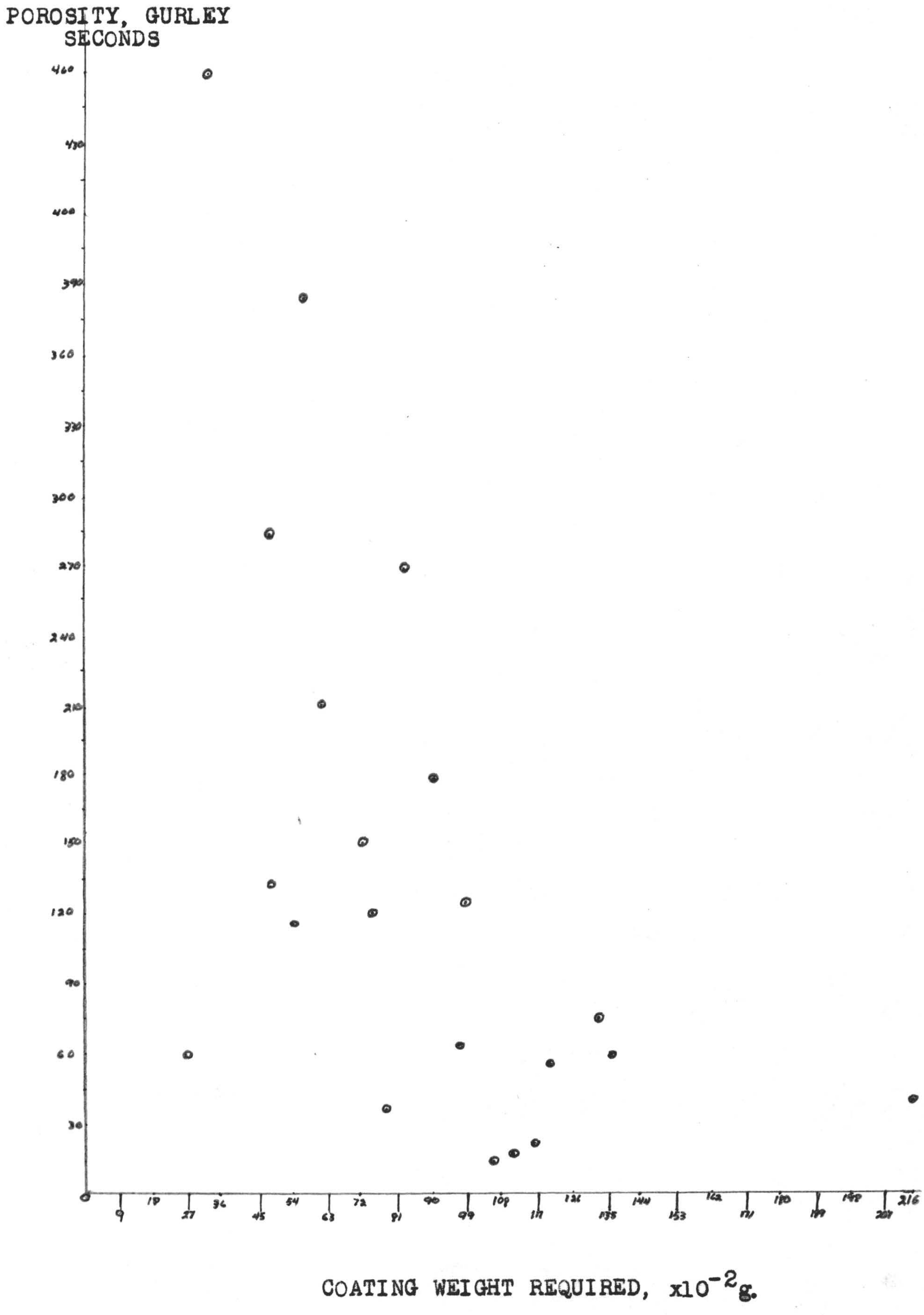
finished product, and balancing the amount of coating and degree of adhesion against the smoothness and porosity of the sheet. A thin film is very desirable from a cost stand point, but is seldom continuous. Very smooth supercalendered sheets are easy to coat with a thin film, but adhesion is poor and drying is slow, due to the hardening of the sheet. Loading of sheets produces a smooth surface, but the strength of the sheet is adversly affected by excessive loading. By balancing the adhesion and film thickness against smoothness and porosity, a middle ground is sought.

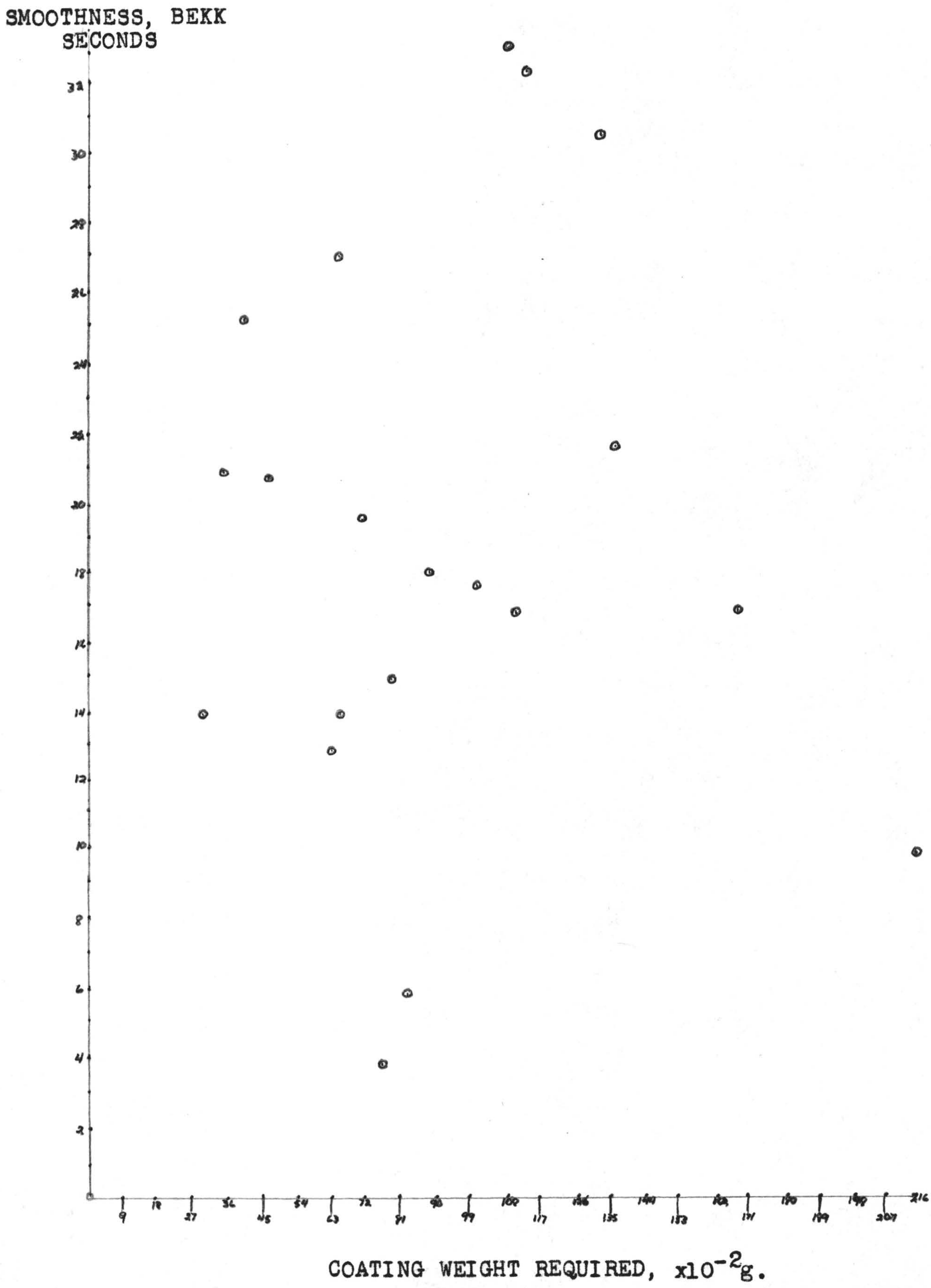
EXPERIMENTAL

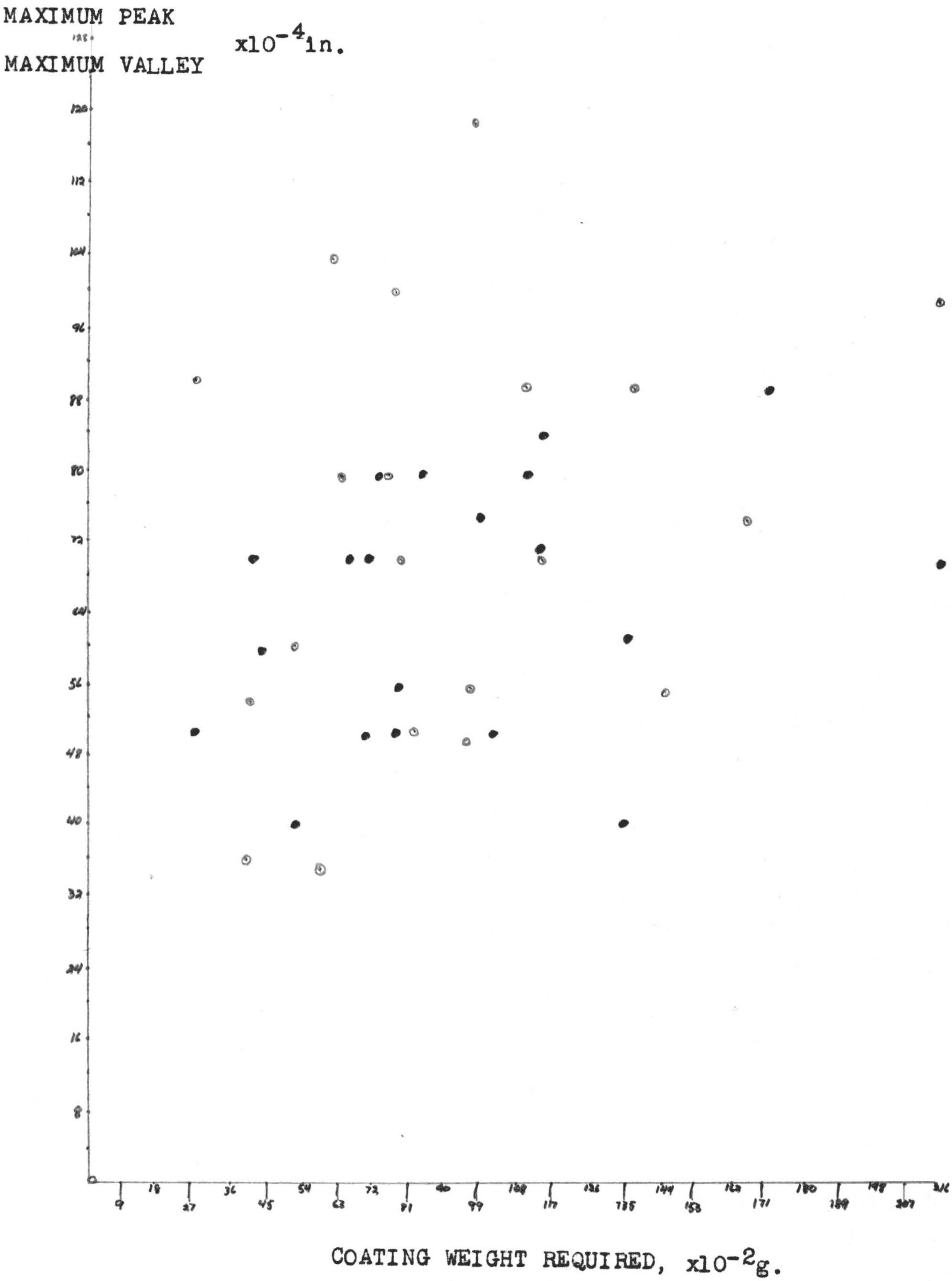
Tests were conducted to determine the porosity of 21 samples of various boards. Smoothness was determined both by an air leakage instrument (Bekk) and also by recording the exact size and shape of the surface variations of the samples. This was done by using the Brush Surface Analyzer. The Surface Analyzer is a combination of a piezo-electric crystal and an electron tube amplifier to form a generator of alternating current, whose frequency, amplitude and polarity are determined by the vertical flexing of the crystal. A diamond pointed stylus oscillates back and forth across the surface of the sheet, and the voltage produced is transferred to an oscillograph which records the value of the voltage. By suitable calibration, the graph obtained is read directly in microinches. The response of the piezo-electric crystal is accurate to ± 1%, if the surface has an average roughness of not more than 500 microinches. Above this value, a larger stylus is necessary. The area covered by the stylus is either .0625 inches or .625 inches, depending on the adjustment of the stylus drive mechanism.

By using these instruments to record the characteristics of the surface of the sheets, an attempt was made to relate the amount of coating required by the sheets to make a continuous film to the surface properties of the sheets.

The film that was applied and evaluated was a solution of ethyl cellulose in 20% alcohol-80% benzene, applied by a series of drawdowns with Mayer rods of different sizes. The solution was 20% ethyl cellulose by weight, with a viscosity of 340 centipoises. Continuity of the films was determined by application of the Tappi greaseproof test. This test uses pure red-dyed turpentine, applied to a cone of sand one inch in diameter at its base, and lasting for 30 minutes. If the film fails within 30 minutes, the film is considered to be non-resistant to greases. Only those films which sucessfully resisted the turpentine tests were evaluated as to smoothness and surface configuration.


POROSITY, GURLEY SECONDS
COATING WEIGHT REQUIRED, x10^{-2}g.


SMOOTHNESS, BEKK SECONDS
COATING WEIGHT REQUIRED, x10^{-2}g.


MAXIMUM PEAK
MAXIMUM VALLEY x10^{-4}in.
COATING WEIGHT REQUIRED, x10^{-2}g.

From interpretation of graphs of surface configuration of the same twenty-one samples, several points are readily apparent. One of the most surprising is that the actual height of the irregularities has little effect on the continuity of an applied film. The postulated mechanism is as follows: at the instant the Mayer rod passes over an irregularity, it is completely covered with coating. At any time thereafter, the coating, being quite fluid, will be flowing down from the high to the lower areas. The slope of the sides of the high area will determine the rate at which the coating will flow downward. Thus, a sharper irregularity will require more coating than a broad irregularity of identical height since the faster flow downward of the coating will uncover the peaks before the coating has time to gel. It is quite evident that in this case, the viscosity of the coating will be equally as important as the surface to which it is applied. In a solvent coating system, such as was used in this investigation, the solvent is being continuously driven off, even at room temperature. Gelation of the coating may take place before the peaks of the irregularity are uncovered, if the slope is relatively gentle, or if the coating is relatively viscous. The ultimate in viscosity may be regarded as a hot melt polymer, which can range in viscosity up to 10,000 centipoises. A polymer such as this can be applied to a piece of window screen and still form a continuous film.

Naturally, a surface with many large but gently sloping irregularities will, when coated in accordance with the above statements, contain innumerable small air pockets where the coating does not touch the sheet. This may help to explain why a grease resistant coating fails upon scoring. The unsupported areas will tend to fracture before the areas where the stock and coating are in contact, since the shear of such areas is lower.

When this line of reasoning is applied to dispersion coating, a few modifications are needed. Dispersion coatings may be pictured as a series of small globules spread over a rough surface. Heat is needed to fuse these discrete particles. Between the globules there are spaces which are quite small, filled either with water, or air. If moderate heat is applied, the globules flow, forming a screen-like film. However, there are still spaces between particles, filled with either air or water. The more heat is applied, the more the fusion of the globules progresses until a continuous film is formed. But, in order to fill the tiny air and water spaces, the visible surface of the coating surface will be lowered. In this case, the determining factor seems to be not the size of the peaks but the distance apart in relation to the size of the polymer globules. This method of coating undoubtably requires more coating polymer than solvent coating, since the air spaces left are much smaller. However, many polymers can be used in dispersion coating that are impractical

or impossible to use in solvent coating and the properties of such polymers or their cost may offset the added amount needed, plus the required extra heat for fusion.

A mathematical relationship between the Brush Analyzer graphs and the amount of coating needed for a continuous film was not found. It was found, belatedly, that Mayer rods do not deposit a thin enough film or one which may be built up in precise increments. The film deposited by any Mayer rod varies with the smoothness of the sheet, when using coatings of fairly low viscosity. As viscosity increases, the surface configuration ceases to be the determing factor.

Combined with this effect is that of the coating trapping air between it and the sheet, which would present the coating from flowing downward at all until the air had leaked through the sheet. This is a means used to measure porosity. Graphs of porosity of the samples versus coating weight showed that there was a definite influence on the amount of coating required for a continuous film by the porosity of the sample. However, other variables lowered the correlation, so results were somewhat inconclusive.

It is felt that, if porosity, variables in application of the film, and a method of progressively building up a film in small increments, could all be kept constant, there would be found a direct relationship between porosity and coating weight needed for a greaseproof film, when using fairly fluid polymers for coating paper.

BIBLIOGRAPHY

Pulp and Paper Magazine, "Spectacular Increases in Coating" June, 1950, p. 90-92

Pulp and Paper Magazine, "1958 Coating Conference Report", by Maurice R. Castagne, July, 1959, p. 52-55

Modern Packaging, "Progress in Resin Coatings", by F. M. Burgess and L. B. Swec, Sept., 1956, p. 151-155

TAPPI 40, No. I, "Acrylic Emulsions in Greaseproff Coatings" by A. D. Jorden, Jr., Jan., 1957, p. 33-36

Modern Plastics Encyclopedia, 1951, p. 320-321, 1953, p. 214

Modern Plastics Encyclopedia, 1954, p. 578, 1956, p. 364

TAPPI 40, No. 5, "Emulsion Polymers in the Paper Industry" by Leonard Shapiro, May, 1957, p. 387-96

TAPPI 39, No. 10, "Latex Emulsion Paint Technology as Applied to Paper Coating", by J. P. Talley, J. P. Davies, and R. E. Benton, p. 160-163

Paper Industry, "Organic Coatings for Paper, part 12: Polyamide Resins", No. 39, p. 28-29

Fiber Containers and Paperboard Mill, "Plastic Coating of Food Containers", by C. G. Moore, March, 1958, Vol. 43

TAPPI 39, No. 8, "Glassine and Greaseproof: a Winning Combination", by R. I. Nazzaro, p. 22a-32a

TAPPI 35, No. I, "Polyamides Resins for Paper Coating", by Harold Wittcoff, M. M. Renfrew, and Fred B Speyer, p. 21-29

General Mills Bulletin, No. 11-D-2, 1957

General Mills Bulletin of Versamid Seminar Synopsis of 1958, p. 1-4

General Mills Bulletin, No. 11-A-1, 1958

Textbook of Polymer Chemistry by Fred W. Billmeyer, Jr. p. 250-251, 283-284

TAPPI 42, No. 6, "Surface Configuration of Paper and Paperboard and Its Measurement", by Raymond L. Janes, p. 172a-176a