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COMPARISON OF
ETHYL CELLULOSE AND NITROCELLULOSE
IN LACQUERS

THE UNIVERSITY OF LOUISVILLE

A DISSERATION
SUBMITTED TO THE FACULTY
OF THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENTS OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF
CHEMICAL ENGINEERING

By
WILLIAM WILSON PEDERSEN

1938

COMPARISON OF
ETHYL CELLULOSE AND NITROCELLULOSE
IN LACQUERS

Director: Dr. R. C. Ernst.

Approved by Reading Committee:

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May 25, 1938

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INTRODUCTION

Ethyl cellulose is one of the most recent cellulose derivatives of commercial importance. It has already found use in the plastic, wrapping, and protective coating industries, and has shown a great deal of promise in many other fields. One of its uses in the protective coating industry has been in lacquers. Until the present time practically all lacquers have been made from nitrocellulose.

The purpose of this investigation was to show the effect of the substitution of ethyl cellulose for nitrocellulose and also the influence that changes in lacquer composition would have upon such properties as flexibility, hardness, tensile strength, and cold check resistance. This was accomplished by making numerous lacquers containing both nitrocellulose and ethyl cellulose, the compositions of which varied so that all feasible proportions of cellulose derivative, resin and plasticizer were included. The properties of each of these lacquers were then determined and the results represented by a series of trilinear charts. These properties were investigated by means of mandrel tests, elongation and tensile strength of

the free film, print tests, and cold checking tests.

The results of all the lacquers containing a given resin and plasticizer have been plotted in one case with ethyl cellulose and in the second case with nitrocellulose. On both charts various areas were determined that had similar properties, but shifted in their relative position. Thus the effect of substituting ethyl cellulose for nitrocellulose in a given lacquer was determined. This enabled a possible quick and easy formulation of an ethyl cellulose lacquer, if the composition of a suitable nitrocellulose lacquer were known.

HISTORICAL

Although cellulose has been known to exist for centuries, the first attempt to convert this important raw material to nitrocellulose was not until 1838 by Pelouze (1). However, he did not realize the utility of his discovery. A few years later Schonbein (2) became interested in this derivative and prepared many nitrates of cotton cellulose by a secret process during 1845-46. The foundation of our present nitrocellulose industry might be said to have started in 1846 when Knop (3) carried on his nitration with sulphuric and nitric acids.

The first practical uses for the derivative came in 1848 by Maynard (4) and Bigelow (5) who independently used a solution of the cellulose nitrate in ether and alcohol as a protective dressing for small wounds. Another practical use appeared in 1851 when Archer (6) successfully used collodion in photography.

Alexander Parkes (7), the greatest of the pioneers in this field, recognized the advantages of nitrocellulose as a film forming material, but found himself too handicapped by the inadequacy of

the available solvents. All known solvents at this time evaporated too fast and only deposited whitish, opaque films of low tensile strength. Parkes, however, did work on plastics and discovered in 1864 the improvements that could be obtained by the addition of camphor to the nitrocellulose.

Nitrocellulose lacquers can be said to have originated in 1882 when Stevens (8) patented the use of amyl acetate as a solvent for nitrocellulose. This solvent for the first time permitted the deposition of hard, lustrous, transparent films of cellulose with good durability. The new finish gave solutions of very high viscosity and was suited only for specialities such as brass and silver lacquering, and in the production of artificial leather.

The rise of this new industry created a vast demand for solvents with the result that new and vastly improved methods of fermenting grain were developed for their production. These developments proved it possible to produce enough amyl and butyl alcohol to satisfy the needs of the industry until the advent of synthesized butanol.

The next advancement of significance was the patenting of a process for reducing the viscosity of the nitrocellulose so that a practical amount of solids could be sprayed.

Lacquers first replaced varnishes in appreciable quantities when the automobile finishers realized the advantages of nitrocellulose compositions. Here production schedules were speeded up from two weeks for the old slow drying varnishes to a few days. The lacquer finishes also had the added advantages of greater durability, ease of application, and resistance to gasoline and acids. Lacquers have continued this replacement of other types of finishes in many industries requiring protective coatings.

The use of nitrocellulose has been further developed by the discovery of many new plasticizers and synthetic resins until it has become one of our major industries. It has established a permanent place for itself in the finishing and plastic industries. However, as countless new uses are found for nitrocellulose, other cellulosic derivatives are being developed simultaneously some of which

are replacing this early derivative in various industries because of their more desirable properties.

One of these new derivatives is ethyl cellulose. This material was first suggested as a commercial possibility by Dr. Otto Leuchs and Dr. Leon Billienfeld in 1912 and since that time it has proved to be one of the most promising cellulose derivatives.

THEORETICAL

A lacquer can best be defined by considering the nature and purpose of its various components. Lacquers have volatile and non-volatile constituents: the non-volatile consisting of cellulose derivative, plasticizers, and resin; the volatile consists of cellulose derivative solvents, resin solvents, and diluents.

Of the permanent, film-forming materials in the lacquer, the cellulose derivative actually gives the resultant film the properties most truly characteristic of a lacquer finish. By the addition of nitrocellulose the film is greatly improved with respect to rapid setting, permanence, light color, and toughness, as well as resistance to heat, water, and chemical attack. Ethyl cellulose will provide all these advantages especially in regard to toughness and chemical resistance, as well as heat stability, flexibility, light stability, and low flammability.

Resins are added to cellulose derivatives in an attempt to introduce some of the desirable properties of varnishes. These properties are essentially adhesion, body, and lustre. The more

desirable resins not only produce these results, but also are light in color and compatible with the cellulose derivative and its solvents. The resins are of three kinds, i.e. natural, semi-synthetic, and synthetic. The natural gums probably find the widest use because of their lower cost. Typical of this class are damar gum and shellac. Of the semi-synthetic class, ester gum is probably the most widely used. This is a glycerol ester of rosin acids. The synthetic resins are recently developed materials capable of producing lacquers that are far superior to those made from the natural gums. These new resins are chemical combinations of such compounds as glycerol, phthalic anhydride, and fatty acids; phenol and formaldehyde; and urea and formaldehyde.

The third component of the non-volatile portion of a lacquer is termed the plasticizer. This constituent has to be added for many reasons, some of which have been discussed by Sanderson (9) as follows:

The function of a lacquer plasticizer is first of all to impart distensibility to the film so that it can flow to some extent, under stress, without rupture. The film can then elongate and contract with temperature changes, it will stand bending, and yield

under impact without fracturing. These improvements in toughness and elasticity are accompanied by a lowering of hardness and tensile strength and may finally result in stickiness as excess plasticizer is added.

A solution of nitrocellulose dries as a gel structure, shrinking in all directions, and therefore tending to pull away from the surface to which it is applied. The addition of a solvent type plasticizer keeps down the viscosity of the solution while it becomes concentrated as the volatile solvent evaporates, and permits the film to flow, so that it tends to contract down to the surface to which it is applied rather than to pull away from it. Hence, proper plasticizing permits good adhesion, altho it may not contribute as directly to it as do resins and other ingredients. By keeping the film from shrinking the plasticizer also eliminates the tendency to bridge over porous spots and corners.

Plasticizers may be classified into three types, i.e. oils, true cellulose solvents, and resins of liquid consistency. Castor oil is representative of the first class and is by far the most widely used. The second class consists of such materials as di-butyl phthalate, tricresyl phosphate, and tri-phenyl phosphate. The third class has recently developed and consists of such compounds as methyl, ethyl, and benzyl abietate, some of the chlorinated diphenyls, toluol-sulphonamid-aldehyde resins, and many of the softer varieties of alkyd resins.

Besides being practically non-volatile, plasticizers should be water white in color, free from residual odor, and non-toxic, and at the same time possessing high solvent strength, low flammability, and chemical and light stability.

The volatile portion of the lacquer actually does not add anything to the permanent film, but serves only as an instrument to assemble the non-volatile constituents and then deposit them uniformly on the desired surface. However, a great deal of emphasis must be placed on the formulation of any lacquer solvent.

In this problem the cellulose derivative solvents that have to be considered are only those for ethyl and nitro cellulose. Nitrocellulose is best dissolved by esters and ketones when single solvents are being considered. Ethers and alcohols alone are not solvents for the common grades of nitrocotton. However, in combination with each other or with esters or ketones, they act as latent solvents. The most frequently used nitrocellulose solvents are ethyl, butyl, and amyl acetates in combination with the alcohols from which these

esters are obtained.

Compared to nitrocotton, ethyl cellulose is extremely soluble. It is soluble in all nitro-cellulose solvents, and also the alcohols, ethers, aromatics, and chlorinated solvents even when these compounds are used as single solvents.

The best resin solvents and also those that can be used for practically any resin are the aromatics, namely benzol, toluol, and xylol. Most resins are rather widely soluble materials. However, several of the highly polymerized resins are alcohol insoluble.

The last division of the volatile section, the diluents, is composed of petroleum naphthas, either in their natural state or after they have been hydrogenated. These diluents are added only for economic reasons because of the relatively high cost of the esters. The extent to which they can be used depends upon the tolerance of the cellulose derivative and resin solvents, as well as the cellulose derivative and resin itself.

The combination of these three types of solvents must be carefully formulated. First the solvent must be "slow" enough so that rapid evaporation does not cause water to condense on the film and precipitate the resin or cellulose, yet it must allow enough time for the lacquer to flow out smooth. The relative evaporation rates of the resin and cellulose solvents must be so close that there is never a deficiency of either one. Many other factors also influence the selection such as resultant viscosity, odor, physiological effects, stability, and cost.

RAW MATERIALS

The raw materials used in this investigation were ethyl cellulose and nitrocellulose with suitable resins, plasticizers, and solvents.

The resins selected because of their compatibility and commercial importance were damar gum, ester gum, and Beckacite 1110. These three resins are representative of the types used in industry.

Castor oil, Dow P-6, and Paraplex S-B were the plasticizers selected. These three are representative of the types of plasticizers.

Two different solvent combinations were used in this work, as the expensive solvent needed for the nitrocellulose was not needed for the ethyl cellulose. Throughout this work the nitrocellulose solvent is referred to as Solvent "A" and is composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol. The solvent that will dissolve only ethyl cellulose is referred to as Solvent "B" and is composed of 70% xylene, 15% butanol, and 15% ethanol.

The properties of these raw materials are listed below:

Damar Gum - This gum was imported by Stroock & Whittenberg Corp. (10) and was classified as A/E Standard Batavia Damar. It had a melting point of 102 - 107 C, direct acid number of 25-31, and a specific gravity of 1.04-1.05.

Before being used in the lacquers, the gum was dewaxed by dissolving it in toluol and precipitating the wax with alcohol.

Ester Gum - This semi-synthetic was a product of Robert Rauh, Inc. (11) and is termed "Rauzene Lacquer Ester AS-1". This material has an acid number of from two to four, specific gravity of 1.10, melting point of 85 -90 C, and a N-WW color. It is soluble in all solvents except alcohol.

Beckacite 1110 - This synthetic resin was manufactured by the Beck, Koller Co. Inc. (12), It is a hard non-phenolic alkyd with a melting point of 92.5 -101.5 C. It has an acid number of from 17 to 22, with a specific gravity of 1.14-1.18.

Castor Oil - This plasticizing oil was a product of the Baker Castor Oil Co. (13), by whom it was sold under the name Bakers' #15 Castor Oil. It is a blown oil with a specific gravity of 0.960-0.967 at 15°/15° C.

Dow P-6 - This is a phosphate plasticizer manufactured by the Dow Chemical Co. It is water white in color.

Paraplex 5-B - This plasticizing resin is a product of the Resinous Products & Chem. Co. (14). It is an alkyd resin with a specific gravity of 0.98 and an acid number of from 35 to 48.

Ethyl Cellulose - This cellulosic derivative was supplied by the Dow Chemical Co. (15), under the name of Ethocel. It is of standard ethoxy content and has a viscosity of 20 centipoises. It has a specific gravity of 1.14 and is colorless.

Nitrocellulose - RS Nitrocellulose 1/2 Second Viscosity manufactured by the Hercules Powder Co. (16) was the other cellulosic derivative used in this investigation. It was supplied 'wet' with

30% of its weight alcohol. It is colorless and has a specific gravity of 1.65.

Toluol - This lacquer diluent was manufactured by the Anderson, Prichard Co. (17). It is water white and has a specific gravity of 0.738. Its initial boiling point is 93°C and 98% will distill before 121°C .

Toluol - This solvent was a product of the Neville Company (18) and is sold by them under the name Industrial Pure Toluol. It is water white in color, and has no acidity, and a specific gravity of 0.864 to 0.874 at $15.6^{\circ}/15.6^{\circ}\text{C}$. It has a distillation range entirely within 2°C including 110.5°C .

Butyl Acetate - Normal butyl acetate was used, which was supplied by the Franco American Chemical Works (19). It is clear white in color, being 87-92% butyl acetate with not over 0.02 acid as free acetic. It has a specific gravity of 0.875-0.885 at 15.5°C . The boiling range is from 115° to 135°C with not more than 15% below 120°C and contains no residue on evaporation.

Butanol - The butanol used was normal butyl alcohol manufactured by the Franco-American Chemical Works (19). It is clear white in color and contains no saponifiable esters and less than 0.02% acid as free acetic. It has a specific gravity of 0.812-0.816 at 15.5°C. The boiling range is from 113°C to 120°C with over 90% between 115°C-118°C. and contains no residue on evaporation.

Ethyl acetate - The ethyl acetate used was a product of the Carbide & Carbon Chemical Corp. (20). It is water white in color, being 85-90% by weight ethyl acetate and containing an acidity of not more than 0.01% as free acetic. It has a specific gravity of 0.885. The boiling range is between 70°- 80°C with not more than 10% below 72°C.

Ethanol - The ethyl alcohol used was manufactured by the Pennsylvania Alcohol Corporation (19) and denatured by Formula SD No 1. It weighs 6.62 pounds per gallon at 15.5°C and has a boiling range between 76°-79°C.

Xylene - This solvent was a product of the Neville Company (18) and is termed by them as "Ten Degree Xylene". It is water white in color and has no

acidity. Its specific gravity is 0.860 at 15.6°/15.6°C. The distillation range is entirely between 135°C and 145°C.

GENERAL PROCEDURE

After the resins, plasticizers, and solvents had been selected, trilinear charts were made for both ethyl cellulose and nitrocellulose with each resin and plasticizer combination. In addition three charts were made for blends of ethyl cellulose and nitrocellulose with castor oil and damar gum. Solvent "A" was used in the lacquers on these charts. Three other charts were made for lacquers containing Solvent "B" with ethyl cellulose, castor oil, and the three resins.

With the aid of these charts the formulas for the lacquers that would be most helpful for this study were selected. The selected compositions varied in cellulosic content from 10% to 70%, in resin content from 10% to 70%, and from 10% to 40% in plasticizer content.

The composition and number of lacquers made for every chart is summarized in Table I.

All the lacquers were then made by blending solutions of known solids content of ethyl cellulose and nitrocellulose with the proper resins and plasticizers, and then diluting these mixtures

TABLE I
SUMMARY OF LACQUERS
STUDIED IN THIS INVESTIGATION

Ingredients	Solvents	Number
Ethyl cellulose, castor oil, damar gum	A	18
Nitrocellulose, castor oil, damar gum	A	18
Ethyl cellulose, castor oil, damar gum	B	5
Ethyl cellulose, castor oil, ester gum	A	7
Nitrocellulose, castor oil, ester gum	A	5
Ethyl cellulose, castor oil, ester gum	B	5
Ethyl cellulose, castor oil, Beckacite 1110	A	6
Nitrocellulose, castor oil, Beckacite 1110	A	5
Ethyl cellulose, castor oil, Beckacite 1110	B	5
Ethyl cellulose, Dow P-6, damar gum	A	8
Nitrocellulose, Dow P-6, damar gum	A	6
Ethyl cellulose, Dow P-6, ester gum	A	5
Nitrocellulose, Dow P-6, ester gum	A	5
Ethyl cellulose, Dow P-6, Beckacite 1110	A	5
Nitrocellulose, Dow P-6, Beckacite 1110	A	5
Ethyl cellulose, Paraplex 5-B, damar gum	A	6
Nitrocellulose, Paraplex 5-B, damar gum	A	5
Ethyl cellulose, Paraplex 5-B, ester gum	A	5
Nitrocellulose, Paraplex 5-B, ester gum	A	5
Ethyl cellulose, Paraplex 5-B, Beckacite 1110	A	5

TABLE I (CON'T)
SUMMARY OF LACQUERS
STUDIED IN THIS INVESTIGATION

Ingredients	Solvent	Number
Nitrocellulose, Paraplex 5-B, Beckacite 1110	A	5
80% Ethyl cellulose - 20% nitrocellulose, castor oil, damar gum	A	6
50% ethyl cellulose - 50% nitrocellulose, castor oil, damar gum	A	6
20% ethyl cellulose - 80% nitrocellulose, castor oil, damar gum	A	6

with solvent until the viscosity had become suitable for casting films. The lacquers were then dissolved by agitation for a two hour period.

All the lacquers were cast on glass with a Dow Filmograph and dried for eight hours at 50 C. The films were soaked from the glass by placing a wet towel over them for at least an hour. All lacquers that were not too brittle were peeled off the glass, and these resultant free films were stored at constant temperatures and humidity for 48 hours for elongation and tensile strength tests.

After satisfactory films had been obtained from as many lacquers as possible, all the lacquers were then thinned to spraying viscosity. In the meantime the following panels were being prepared for each lacquer:

- (1) primed 1" x 10" steel panel for mandrol tests
- (2) primed 3" x 10" steel panel for print tests
- (3) primed 4" x 10" steel panel for cold checking tests
- (4) 4" x 6" maple panel for cold checking tests
- (5) 3" x 6" Dow Metal panel for cold checking test.

The primed steel panels were made from #31 gage sheet steel primed with one sprayed coat of duPont white Prepara-kote. The maple panels were $\frac{1}{8}$ " x 4" x 6" sanded, kiln-dried, close grained hard maple. The Dow Metal panels were wire brushed and stored under toluol until ready for spraying.

All the panels for each lacquer were then sprayed together with successive coats until a uniform film of fifteen ten-thousands had been built up. After the panels had air-dried for 24 hours, they were placed in an oven and dried for eight hours at 50 C. The panels for the print and mandrel tests were stored in the constant temperature room, while the cold checking panels were stored at room temperature until the individual test on each panel was run.

In this investigation the only lacquers that have been made and studied were those that are fairly close in formulation to lacquers in commercial practice. Consequently in applying these results to the trilinear charts, the only part of the lines dividing the charts into areas of good and bad flexibility, hardness and cold check resistance

that are absolutely accurate is that part in the area of most practical importance. However, in all cases these dividing lines have been extended to the sides of the charts. The author believes that the entire length of all dividing lines is approximately correct. However, the results obtained from the charts must be used with discretion when the area in question is not near the area containing the lacquers in wide industrial usage.

PART I

MANDREL TESTS

THEORETICAL

The mandrel test is one of the simplest methods of testing the flexibility and-to a certain extent-the adhesion of various organic finishes when applied to metal panels. Because of its simplicity this test has found wide usage and consequently exists in many varied forms. All mandrel tests consist in clamping one end of a thin metal panel coated with the material in question and then bending the free end of the panel around a cylinder of definite radius until the film ruptures or the panel is bent 180 degrees. A great deal of care must be taken to make sure that the panel closely follows the contour of the mandrel. Schuh (21) reports that the rate of bending of the film has very little if any effect upon the results.

As the panel is bent around the mandrel the coating undergoes a definite amount of stretching depending upon the panel thickness and the mandrel diameter. The amount of stretch increases with increasing panel thickness and decreases with increasing size of mandrel. The results of the tests can either be reported as the degrees bend over

a certain size mandrel on a definite thickness and treated panel, or by calculating the actual elongation and expressing it in terms of per cent stretch on a definitely treated panel.

For comparative results the same base coat must always be used, for the test depends upon the adhesion at the film base interface as well as on the flexibility. In cases of extremely poor adhesion, the elongation resulting from this test will be almost the same as that of the free film; and after the test, the ruptured film will fall completely from the base coat.

EXPERIMENTAL WORK

The instrument used for the mandrel tests conducted in this investigation was quite similar in design to the majority of apparatus employed for this purpose. It consisted of a vise to clamp the panels being tested, and supports to hold either the 1/8", 1/4", or 1/2" diameter mandrels. The vise was so placed that the front side of the 1/8" mandrel was directly over the back side of the vise. When the larger mandrels were being used, shims were placed on the back face of the vise to keep this vertical relationship constant.

In operating the instrument a coated panel was first tightened into the vise in a vertical position. A mandrel was then inserted in the vertical supports at the side of the vise so that it was perpendicular to the test panel. A stiff piece of metal was placed on the test panel about a half inch above the point of contact between the mandrel and panel, and the two bent backwards over the mandrel until a crack appeared in the stressed area. The angle of bend was then measured in degrees by noting the inclination of the stiff metal and panel on a protractor so fastened that its center corres-

ponded with the center of the mandrel. In order to make the test more nearly accurate, a light was focused on the stressed area, and the panel was observed with the aid of a magnifying glass.

Test strips were prepared for all lacquers studied in this investigation in the manner outlined in the general procedure.

The results of the tests were reported as degrees bend over a definite size mandrel. These results have been plotted on trilinear paper for all compositions by dividing the chart into two areas. The one area containing all lacquers that have sufficient flexibility to pass the mandrel test, while the other area contains all lacquers that failed the test.

RESULTS

TABLE II
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
70	15	15	150	150	150
60	30	10	150	150	150
60	20	20	150	150	150
60	10	30	150	150	150
50	30	20	150	150	150
50	20	30	150	150	150
50	10	40	150	150	150
40	30	30	150	150	150
40	20	40	150	150	150

* Solvent composed of 25% toluol, 25% Trowoil, 20% butyl acetate, 10% butanol, 10 ethyl acetate, and 10% ethanol.

TABLE II (CON'T)

MANDREL TESTS OF LACQUERS CONTAINING

ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM

IN SOLVENT "A"

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
40	10	50	20	20	20
30	40	30	150	150	150
30	30	40	150	150	150
30	20	50	150	150	150
30	10	60	40	40	40
20	30	50	150	150	150
20	20	60	150	150	150
15	15	70	20	20	20
10	30	60	150	150	150

MANDELL TEST
OF
ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

or

Solvent "B"

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Ethyl Cellulose

Dewaxed

Damar

Gum

Castor
Oil

CHART I

TABLE III
 MANDREL TESTS OF LACQUERS CONTAINING
 NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
70	15	15	20	20	20
60	30	10	20	30	20
60	20	20	20	20	20
60	10	30	20	30	30
50	30	20	150	150	150
50	20	30	150	150	150
50	10	40	20	20	20
40	30	30	150	150	150
40	20	40	20	20	20

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE III (CON'T)

MANDREL TESTS OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Dammar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
40	10	50	20	20	20
30	40	30	150	150	150
30	30	40	150	150	150
30	20	50	20	20	20
30	10	60	20	20	20
20	30	50	150	150	150
20	20	60	30	30	30
15	15	70	10	10	10
10	30	60	150	150	150

WANDER TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - BS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Demar Gum

Solvent "A"

Nitro Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Dewaxed

Demar

Gum

Castor

Oil

CHART II

TABLE IV
MANDREL TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel "Without Failure"		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	10	40	150	150	150
40	20	40	150	150	150
30	30	40	150	150	150
15	15	70	20	20	20

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE V
 MANDREL TESTS OF LACQUEIS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	20	20	150	150	150
50	10	40	150	150	150
40	20	40	150	150	150
40	10	50	20	20	20
30	30	40	150	150	150
30	10	60	20	20	20
15	15	70	20	20	20

* Solvent composed of 25% toluol, 25% Toluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

or

Solvent "B"

Area

of

Good

Flexibility

Area

of

Good

Flexibility

Ester

Gum

Castor

Oil

CHART III

TABLE VI
MANDREL TESTS OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	20	20	20	20	20
50	10	40	20	20	20
40	20	40	50	50	50
30	30	40	150	150	150
15	15	70	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

Nitro Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Ester
Gum

Castor
Oil

CHART IV

TABLE VII
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
 IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	10	40	50	50	50
40	20	40	150	150	150
30	30	40	150	150	150
20	20	60	90	150	150

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE VIII

MANDREL TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	20	20	150	150	150
50	10	40	20	20	20
40	20	40	60	30	20
30	30	40	150	150	150
30	10	60	20	20	20
15	15	70	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Beckacite-1110

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

Area
of
Poor

Flexibility

Area
of
Good

Flexibility

TABLE IX
 MANDREL TESTS OF LACQUES CONTAINING
 NITROCELLULOSE, CASTOR OIL, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	20	20	20	20	20
50	10	40	30	20	20
40	20	40	30	20	20
30	30	40	60	50	50
15	15	70	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Beckacite 1110

Solvent "A"

Beckacite
1110

Nitro Cellulose

Castor
Oil

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

CHART VI

TABLE X
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110
 IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	10	40	20	20	20
40	20	40	20	20	20
30	30	40	150	150	150
20	20	60	20	20	20

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE XI
MANDREL TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE, DOW P-6, AND DAMAR GUM
IN SOLVENT "A"

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	20	30	150	150	150
50	10	40	20	20	20
40	20	40	90	100	120
40	10	50	20	20	20
30	40	30	150	150	150
30	20	50	60	70	90
20	20	60	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, and 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow F-6

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

Area
of
Poor

Flexibility

Area
of
Good

Flexibility

Dewaxed

Damar

Gum

Dow

CHART VII

TABLE XII

MANDREL TESTS OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	40	70	90
50	20	30	30	30	30
50	10	40	20	20	30
40	20	40	30	30	40
40	10	50	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TESTS

OF

NITROCELLULOSE LACQUEES

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Dow P-6

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

TABLE XIII
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, DOW P-6, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
50	20	30	50	70	80
50	10	40	30	30	30
40	20	40	150	150	150
40	10	50	30	30	30
30 -	20	50	30	30	30

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Ester
Gum

Dow

P-6

TABLE XIV
 MANDREL TESTS OF LACQUERS CONTAINING
 NITROCELLULOSE, DOW P-6, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
50	20	30	40	60	80
50	10	40	20	20	30
40	20	40	20	20	20
40	10	50	30	30	30
30	20	50	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITROCELLULOSE LACQUEPS

Nitrocellulose - RS - $\frac{1}{8}$ Second

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Nitrocellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Ester Gum

CHART X

TABLE XV
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, DOW P-6, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Degrees Bend over Mandrel Without Failure		
			1/8"	1/4"	1/2"
50	20	30	20	20	20
50	10	40	20	20	20
40	20	40	30	30	30
40	10	50	20	20	20
30	20	50	20	20	30

* Solvent composed of 25% toluol, 25% Trelucil, 25% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Beckacite
1110

Dow

P-6

TABLE XVI
 MANDREL TESTS OF LACQUERS CONTAINING
 NITROCELLULOSE, DOW P-6, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
50	20	30	20	20	20
50	10	40	20	20	20
40	20	40	20	20	20
40	10	50	20	20	20
30	20	50	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDEEL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Dow P-6

Resin - Beckacite 1110

Solvent "A"

Beckacite

1110

Dow

P-6

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

TABLE XVII

MANDREL TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	10	40	20	20	20
40	20	40	150	150	150
40	10	50	30	30	30
30	40	30	150	150	150
20	20	60	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TESTS

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-P

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

TABLE XVIII
 MANDREL TESTS OF LACQUERS CONTAINING
 NITROCELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	30	30	30
50	10	40	20	20	20
40	20	40	20	20	20
30	40	30	150	150	150
20	20	60	10	10	10

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Dewaxed Damar Gum

Solvent "A"

Nitro Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Dewaxed
Damar
Gum

Paraplex
5-B

TABLE XIX
 MANDREL TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE, PARAPLEX 5-B, AND ESTER GUM
 IN SOLVENT "A"

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	20	20	20
50	10	40	20	20	20
40	20	40	20	20	20
30	40	30	150	150	150
20	20	60	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

Area

of

Poor

Flexibility

Area

of

Good

Flexibility

Ester

Gum

Paraplex

5-B

TABLE XX

MANDREL TESTS OF LACQUERS CONTAINING
NITROCELLULOSE, PARAPLEX 5-B, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	20	20	20
50	10	40	20	20	20
40	20	40	20	20	20
30	40	30	150	150	150
20	20	60	20	20	20

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Ester Gum

Solvent "A"

Nitro Cellulose

Ester
Gum

Paraplex
5-B

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

TABLE XXI

MANDREL TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
50	10	40	10	10	10
40	20	40	20	20	20
30	40	30	150	150	150
20	20	60	10	10	10

* Solvent composed of 25% toluol, 25% troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

Beckacite
1110

Paraplex
5-B

TABLE XXII
 MANDREL TESTS OF LACQUERS CONTAINING
 NITROCELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	20	20	20
50	10	40	20	20	20
40	20	40	20	20	20
30	40	30	90	110	120
20	20	60	20	20	20

* Solvent composed of 25% Troluol, 25% toluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

MANDREL TEST

OF

NITRO CELLULOSE LACQUERS

Nitro Cellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Beckacite 1110

Solvent "A"

Nitro Cellulose

Beckacite
1110

Paraplex
5-B

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

TABLE XXIII
MANDREL TESTS OF LACQUERS CONTAINING
CELLULOSE DERIVATIVE X**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"

Per Cent Cellulose Blend X	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
60	10	30	20	20	20
50	20	30	150	150	150
50	10	40	20	20	20
40	20	40	70	110	120
40	10	50	20	20	20

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

** 80% ethyl cellulose - 20% nitrocellulose

MANDREL TEST
OF
80% ETHYL CELLULOSE -
20% NITRO CELLULOSE
LACQUERS

Solvent "A"

20% Nitro Cellulose

80% Ethyl Cellulose

Ethyl Cellulose-20 Centipoise
Standard Ethoxy

Nitro Cellulose -
RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin -
Dewaxed Damar Gum

Area
of
Good
Flexibility

Area
of
Poor
Flexibility

Dewaxed
Damar
Gum

Castor
Oil

CHART XIX

TABLE XXIII

MANDREL TESTS OF LACQUERS CONTAINING
CELLULOSE DERIVATIVE, Y**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend Y	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	150	150	150
60	10	30	30	30	30
50	20	30	40	40	50
50	10	40	30	30	30
40	20	40	30	30	30
40	10	50	30	30	30

* Solvent composed of 25% Toluol, 25% Troluoil, 20% butyl acetate,
10% butanol, 10% ethyl acetate, and 10% ethanol.

** 50% ethyl cellulose - 50% nitrocellulose

MANDREL TEST

OF

50% ETHYL CELLULOSE -

50% NITRO CELLULOSE

LACQUERS

Solvent "A"

50% Nitro Cellulose

50% Ethyl Cellulose

Ethyl Cellulose-20 Centipoise
Standard Ethoxy

Nitro Cellulose -
RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin -
Dewaxed Damar Gum

Area
of
Good
Flexibility

Area
of
Poor
Flexibility

Dewaxed
Damar
Gum

Castor
Oil

CHART XX

TABLE XXV
 MANDREL TESTS OF LACQUERS CONTAINING
 CELLULOSE DERIVATIVE Z**, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Cellulose Blend Z	Per Cent Castor Oil	Per Cent Damar Gum	Degrees Bend Over Mandrel Without Failure		
			1/8"	1/4"	1/2"
60	30	10	40	40	40
60	10	30	20	20	20
50	20	30	30	30	30
50	10	40	20	20	20
40	20	40	30	30	30
40	10	50	30	30	30

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

** 80% ethyl cellulose - 80% nitrocellulose

MANDREL TEST
OF
20% ETHYL CELLULOSE -
80% NITROCELLULOSE
LACQUERS
Solvent "A"

20% Ethyl cellulose
80% Nitrocellulose

Ethyl Cellulose - Std. Ethoxy
20 Centipoise

Nitrocellulose -
RS 1/2 Second

Plasticizer - Castor
Oil

Resin - Dewaxed
Damar Gum

Area
of
Poor
Flexibility

Area
of
Good
Flexibility

CONCLUSIONS

All lacquers in this investigation were subjected to mandrel tests over three different size mandrels, 1/8", 1/4", and 1/2" diameter. However, the expected variation in the degrees bend with the same lacquer over the different mandrels was not obtained. Instead the lacquer would fail at approximately the same angle for each mandrel. The only effect mandrel size had was to make the area of failure wider for the larger size mandrels.

As was expected from the reports of other investigators (22), the evaluation of a lacquer by means of mandrels is effected by the adhesion of both primer and lacquer. This fact becomes more noticeable in lacquers of high cellulosic content because of their relatively high tensile strength and poor adhesion. In many instances with lacquers of high cellulose content the film would suddenly rupture and fly from the panel in the adjacent area leaving either an exposed metal surface or the primed surface.

With a given resin-plasticizer combination ethyl cellulose lacquers have a much greater flexi-

bility than do the corresponding nitrocellulose lacquers. This fact is shown by a comparison of the Charts, such as I & II, III & IV, or V & VI, containing the same resin and plasticizer with both derivatives. On these charts the increase in area with ethyl cellulose lacquers that will pass the 180 degree mandrel test is remarkable when compared to the same area for the nitrocellulose lacquers. This increase can be readily understood when it is realized that the substitution of ethyl cellulose for nitrocellulose increases the number of components that will pass the 180 degree mandrel test when used by themselves from one component to two components. In other works with nitrocellulose lacquers, the plasticizer is the only component that, when applied to a panel by itself, possesses enough flexibility to pass a mandrel test. While in the case of ethyl cellulose lacquers, two components - the cellulosic derivative and the plasticizer - will pass this mandrel test.

Of the three tested plasticizers castor oil imparts a slightly higher degree of flexibility as shown by the mandrel tests than does Dow P-6, while these two plasticizers are better than

Paraplex 5-B. This is indicated by a comparison of Charts I, VII, & XIII containing each of the three plasticizers with ethyl cellulose and damar gum.

Damar gum is a slightly more flexible resin than is ester gum, while Beckacite 1110 is not nearly so flexible as either of these resins. This fact is shown by a comparison of Charts I, III, & V containing each of the three resins with ethyl cellulose and castor oil.

PART II

COLD CHECK TESTS

THEORETICAL

Cold checking is a recently developed method of testing protective coatings to determine their resistance to thermal changes. The need for this test became evident in the early months of 1934 and since that time numerous methods varying greatly in their procedure have been suggested and tried. Although very little has been reported in the literature to date, the most general method for lacquer films is to alternate the test panels between a hot box of at least 150°F and a cold box of at least 0°F in cycles of at least one hour duration. The resistance of the coating to cold-check is determined by the number of cycles it can stand before checking.

A coating with a lower coefficient of expansion than its substrate will readily crack on the first few cycles when subjected to high and low temperatures. However, most lacquers have a higher coefficient of expansion than their substrate and do not show any evidence of checking before at least ten cycles.

An article written by Wayne C. Norris (23) discusses some of the possible causes of cold checking of lacquers on wood. A section of this article is quoted as follows:

The thermal coefficient of linear expansion for wood is considerably greater across grain than it is with the grain. It ranges from five times as much for chestnut to twenty-three times for beech, with the value for maple and walnut at approximately seven and one-half times. As the co-efficient of expansion for lacquer is high and more nearly like that of wood across the grain, films could be expected to tend to follow the wood in its movement across grain and thus show relatively little tendency to crack with the grain. Conversely, the lacquer film would tend to expand or contract to a greater degree than the wood in the direction with the grain, and thus set up relieving cracks perpendicular to this movement, which amounts to cross-grain checking. In practice, however, the failure is not so definitely and predominantly of this type as one would like to expect. This is due to such interfering factors as lack of perfect film continuity, which probably favors cracking with the grain, and to the fact that when the panel is subjected to the cold the film is chilled - and probably thoroughly chilled - before the wood undergoes appreciable cooling accompanied with its unequal contraction. Under these conditions insufficiently plasticized lacquer would, therefore, tend to immediately rupture equally in all directions, or in view of the above mentioned film continuity effect mostly in a direction with the grain. On the other hand, if the film remains intact until the wood reaches the same temperature, the differentials again become operative and cross-grain failure is favored. Experience has shown that cross-grain cracking or checking can properly be taken as the end point. It may be associated with a greater or less amount of cracking with the grain and is often transverse or partially of each type.

The general observations indicate that the cracking of a film on metal can be in any or all directions. This diversity may be explained by the fact that the coefficient of expansion is the same in all directions. However, metal panels are always subjected to stress of some nature and since the cracks from cold checking will follow the line of least resistance, the tendency is for the cold checking to appear first in the direction in which the metal is stressed.

A possible reason for the checking of lacquers on different cycles is that a cold checking test becomes a fatigue test after the first few cycles. Thus, if a lacquer fails in the first few cycles, it is probably because of a large difference between its thermal coefficient of linear expansion and that of its substrate. However, if the lacquer fails on later cycles, the failure is probably because the lacquer has passed its fatigue point for this type of continued deformation.

In order to obtain comparable results, as well as keeping such factors as time and temper-

ature difference constant, the lacquer must have the same thickness on all panels and all panels must be treated in the same manner while being stored before treatment. Fluevog, Godshalk, and Parker (24) have shown that satisfactory finishes at normal or twice normal thickness can be made to fail if the film is built up to four times its normal thickness. They have also shown that the moisture content of the film has a great deal to do with the number of cycles before failure. Those panels that are stored in a dry place have much better cold check resistance than those that are stored in places with high humidity.

Norris (23) also reports that lacquers continuing 18 cycles before failure are excessively safe, while those that fail at nine cycles are of the intermediate safe type. It is generally recognized that lacquers that will stand 15 cycles are sufficiently safe for commercial use.

EXPERIMENTAL WORK

The equipment for this test consisted of a hot box and a cold box. The hot box was an insulated metal chest divided into two horizontal sections by a reinforced layer of asbestos. The heating medium was in the bottom of the box and consisted of ten electric light bulbs. The top section of the box contained shelves to hold the panels that were being tested. The box was heated by using all the electric bulbs, and maintained at constant temperature of 150°F by turning off part of the bulbs. Approximately eight minutes were required to heat a batch of cold panels.

The cold box consisted of an ordinary household Frigidaire unit mounted in an insulated ice chest. The cold box operated at 0°F , and took about one half hour to reach this temperature whenever a batch of warm panels was placed in it.

In running a test, the two groups, each of about 25 panels, were started in the hot box and brought up to temperature, while the cold box was allowed to run by itself about an hour and a half

to reach 0°F. When the cold box had reached its operating temperature one group of panels was switched from the hot to the cold box. This group was inspected after one hour and then placed back in the cold box for another hour. After the second hour the cold group was again switched to the hot box, while the warm panels were placed in the cold box. By operating in this method both groups of panels passed through two complete cycles every day. After the end of the second cycle for both groups, all panels were placed in the hot box and brought to the operating temperature before being shut off for the night. 9

Wood and steel panels were prepared by the method indicated in the general procedure for all lacquers tested in this investigation. Dow Metal panels were prepared only for those lacquers containing either damar gum or castor oil.

Panels were inspected on at least every other cycle depending upon the number of the cycle. Any failure no matter how slight was always recorded, but the panels were not removed until there was at least one complete crack entirely across

the panel. All panels were discontinued if they had not failed after having passed thirty cycles.

The panels were inspected on the cold cycle only as the hot cycle frequently caused the cracks to disappear in lacquers of high plasticizer or gum content.

The results of the cold checking resistance of the lacquers on primed steel have been plotted on trilinear paper for all compositions. Every chart has been divided into two areas. The one area represents all lacquers with a resistance of at least 15 cycles, while the other area represents those lacquers with poorer resistance.

RESULTS

TABLE XXVI
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
70	15	15	-	-	-	30	30	30
60	30	10	-	-	-	30	30	30
60	20	20	-	-	-	30	30	30
60	10	30	-	-	-	30	30	30
50	30	20	-	-	-	30	30	30
50	20	30	-	-	-	30	30	30
50	10	40	-	-	-	30	30	30
40	30	30	-	-	-	30	30	30
40	20	40	-	-	-	30	30	30

TABLE XXVI (CON'T)

COLD CHECK RESISTANCE OF LACQUERS CONTAINING

ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM

IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
40	10	50	11	15	-	-	-	30
30	40	30	-	-	-	30	30	30
30	30	40	-	-	-	30	30	30
30	20	50	12	16	-	-	-	30
30	10	60	4	6	-	-	-	30
20	30	50	-	-	-	30	30	30
20	20	60	11	11	18	-	-	-
15	15	70	2	2	5	-	-	-
10	30	60	-	-	-	30	30	30

* Solvent composed of 25% Toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Dewaxed Damar Gum

HART XVII

Castor Oil

TABLE XXVII
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
70	15	15	-	-	-	30	30	30
60	30	10	-	-	-	30	30	30
60	20	20	-	-	-	30	30	30
60	10	30	-	-	-	30	30	30
50	30	20	-	-	-	30	30	30
50	20	30	15	19	-	-	-	30
50	10	40	12	12	22	-	-	-
40	30	30	-	-	-	30	30	30
40	20	40	10	12	28	-	-	-

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol

TABLE XXVII (CON'T)

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM

Per Cent Nitro- Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
40	10	50	8	10	24		-	-	-	
30	40	30	-	-	-		30	30	30	
30	30	40	13	20	-		-	-	30	
30	20	50	-	9	24		-	-	-	
30	10	60	3	3	9		-	-	-	
20	30	50	15	15	21		-	-	-	
20	20	60	4	5	-		-	-	-	
15	15	70	3	3	4		-	-	-	
10	30	60	-	18	-		-	-	-	

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Dewaxed Damar Gum

CHART XVIII

Castor Oil

TABLE XXVIII
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	-	30	30	30	-
50	10	40	21	25	-	-	-	-	21	-
40	20	40	34	-	-	-	-	30	30	-
30	30	40	-	-	-	-	30	30	30	-
15	15	70	6	2	11	-	-	-	-	-

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE XXIX
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Cycles for Panel Failure			Test Discontinued No Failure			
			Wood	Steel	Dow Metal	Wood	Steel	Dow	Metal
60	20	20	-	-	-	30	30	30	
50	10	40	13	14	-	-	-	30	
40	20	40	8	13	10	-	-	-	
40	10	50	5	3	4	-	-	-	
30	30	40	-	-	-	30	30	30	
30	10	60	3	2	3	-	-	-	
15	15	70	2	2	2	-	-	-	

* Solvent composed of 25% teluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Athoxy

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

of

Solvent "B"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Ester Gum

CHART XXIV

Castor Oil

TABLE XXX
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	20	20	28	21	-	-	-	-	-	30
50	10	40	11	13	-	-	-	-	-	30
40	20	40	10	13	39	-	-	-	-	-
30	30	40	-	31	-	-	30	-	-	30
20	20	60	3	3	5	-	-	-	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Ester Gum

CHART VVV

Castor Oil

TABLE XXXI
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	-	30	30	30	-
50	10	40	10	12	56	-	-	-	-	-
40	20	40	7	12	-	-	-	-	30	-
30	30	40	-	34	-	-	21	-	30	-
20	20	60	2	2	6	-	-	-	-	-

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

CHART XXXII

GOLD CHECK RESISTANCE OF LACQUERS CONTAINING ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
60	20	20	-	-	-	30	30	30
50	10	40	8	11	-	-	-	30
40	20	40	8	11	21	-	-	-
30	30	40	10	13	-	-	-	30
30	10	60	3	2	12	-	-	-
15	15	70	2	2	2	-	-	-

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Anoxy

Plasticizer - Castor Oil

Resin - Peckacite 1110

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

Area of

Poor

Cold Check

Resistance

Area of

Good

Cold Check

Resistance

Peckacite 1110

CHART VIII

TABLE XXXIII

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
60	20	20	14	18	-	-	-	30
50	10	40	4	6	24	-	-	-
40	20	40	2	4	24	-	-	-
30	30	40	15	13	-	-	-	30
15	15	70	1	2	2	-	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Beckacite 1110

Solvent "A"

Nitrocellulose

Area of
Poor

Cold Check
Resistance

Area of
Good

Cold Check
Resistance

TABLE XXXIV

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110
 IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Cycles for Panel Failure			Test Discontinued No Failure			
			Wood	Steel	Dow Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	30	30	30	
50	10	40	6	8	16	-	-	-	
40	20	40	4	6	-	-	-	30	
30	30	40	15	13	-	-	-	30	
20	20	60	1	2	2	-	-	-	

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE XXXV
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, DOW P-6, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure			
			Wood	Steel	Dow Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	30	30	30	
50	20	30	-	-	-	30	30	30	
50	10	40	9	-	-	-	30	30	
40	20	40	30	25	-	-	-	30	
40	10	50	8	16	-	-	-	30	
30	40	30	-	-	-	30	30	30	
30	20	50	14	21	-	-	-	30	
20	20	60	5	8	23	-	-	-	

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Dewaxed Damar Gum

CHART XXVIII

Dow P-6

TABLE XXXVI
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	-	30	30	30	-
50	20	30	23	-	-	-	-	30	30	-
50	10	40	16	12	30	-	-	-	-	-
40	20	40	15	13	-	-	-	-	20	-
40	10	50	5	6	-	-	-	-	25	-
30	20	50	6	7	28	-	-	-	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE XXXVII
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, DOW P-6, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Cycles for Panel Failure		No Failure Test Discontinued	
			Wood	Steel	Wood	Steel
50	20	30	-	28	19	-
50	10	40	9	15	-	-
40	20	40	10	19	-	-
40	10	50	4	8	-	-
30	20	50	4	7	-	-

* Solvent composed of 25% teluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XXXVIII
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND ESTER GUM
IN SOLVENT "A".

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
50	20	30	-	18	19	-
50	10	40	13	10	-	-
40	20	40	8	11	-	-
40	10	50	5	8	-	-
30	20	50	4	8	-	-

* Solvent composed of 25% toluol, 25% Trelucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUES

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Low P-6

Resin - Ester Gum

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XXXIX

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, DOW P-6, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
50	20	30	16	19	-	-
50	10	40	4	6	-	-
40	20	40	11	13	-	-
40	10	50	2	2	-	-
30	20	50	3	4	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise

Plasticizer - Dow P-6

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XL
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
50	20	30	11	15	-	-
50	10	40	4	7	-	-
40	20	40	2	8	-	-
40	10	50	1	2	-	-
30	20	50	5	3	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE
OF
NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second
Plasticizer - Dow P-6
Resin - Beckacite 1110

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Beckacite 1110

CHART XXXIII

Dow P-6

TABLE XLI
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	-	30	30	30	-
50	10	40	-	25	24	-	-	-	-	-
40	20	40	16	27	-	-	-	-	30	-
40	10	50	11	14	11	-	-	-	-	-
30	40	30	-	-	-	-	30	30	30	-
20	20	60	3	4	28	-	-	-	-	-

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Athoxy

Plasticizer - Paraplex 5-B

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLII

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
60	30	10	-	-	-	30	30	30
50	10	40	16	10	-	-	-	30
40	20	40	9	17	-	-	-	30
30	40	30	-	-	-	30	30	30
20	20	60	5	4	11	-	-	-

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLIII

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, PARAPLEX 5-B, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Cycles For Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
60	30	10	-	-	30	30
50	10	40	12	14	-	-
40	20	40	5	10	-	-
30	40	30	-	-	30	30
20	20	60	3	3	-	-

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate,
10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

Ester Gum

CHART XXXVI

Paraplex 5-B

TABLE XLIV
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, PARAPLEX 5-B, AND ESTER GUM
IN SOLVENT "A".

Per Cent Nitro- Cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
60	30	10	-	-	30	30
50	10	40	5	9	-	-
40	20	40	8	10	-	-
30	40	30	-	-	30	30
20	20	60	3	2	-	-

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-R

Resin - Ester Gum

Solvent "A"

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLV

GOLD CHECK RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
60	30	10	-	-	30	30
50	10	40	5	9	-	-
40	20	40	5	5	-	-
30	40	30	-	-	20	25
20	20	60	3	3	-	-

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLVI

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Nitro- Cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Cycles for Panel Failure		Test Discontinued No Failure	
			Wood	Steel	Wood	Steel
60	30	10	-	-	20	19
50	10	40	2	2	-	-
40	20	40	3	2	-	-
30	40	30	-	-	20	26
20	20	60	2	2	-	-

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

COLD CHECK RESISTANCE

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Beckacite 1110

Nitrocellulose

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLVII

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND X**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend X	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
60	30	10	-	-	-	30	30	30
60	10	30	-	-	-	30	30	30
50	20	30	-	-	-	30	30	30
50	10	40	-	35	-	30	-	-
40	20	40	14	21	-	-	-	-
40	10	50	11	14	-	-	-	25

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

** 80% ethyl cellulose - 20% nitrocellulose

COLD CHECK RESISTANCE

OF

80% ETHYL CELLULOSE -

20% NITROCELLULOSE

LACQUERS

Solvent "A"

80% Ethyl Cellulose

20% Nitrocellulose

Ethyl Cellulose -
20 Centipoise
Standard Ethoxy

Plasticizer - Castor
Oil

Resin - Dewaxed
Damar Gum

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLVIII

COLD CHECK RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND Y**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend Y	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure				Test Discontinued No Failure			
			Wood	Steel	Dow	Metal	Wood	Steel	Dow	Metal
60	30	10	-	-	-	-	30	30	30	-
60	10	30	-	-	-	-	30	30	30	-
50	20	30	24	-	-	-	-	30	30	-
50	10	40	11	24	-	-	-	-	20	-
40	20	40	10	25	-	-	-	-	30	-
40	10	50	4	11	25	-	-	-	-	-

* Solvent composed of 25% toluol, 25% Toluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

** 50% ethyl acetate - 50% nitrocellulose

COLD CHECK RESISTANCE
OF
50% ETHYL CELLULOSE -
50% NITROCELLULOSE
LACQUERS
Solvent "A"

50% Ethyl Cellulose
50% Nitrocellulose
Ethyl Cellulose -
20 Centipoise
Standard Ethoxy
Nitrocellulose -
PS - $\frac{1}{2}$ Second
Plasticizer - Castor
Oil
Resin - Dewaxed
Damar Gum

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

TABLE XLIX
COLD CHECK RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND 2**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend 2	Per Cent Castor Oil	Per Cent Damar Gum	Cycles for Panel Failure			Test Discontinued No Failure		
			Wood	Steel	Dow Metal	Wood	Steel	Dow Metal
60	30	10	-	-	-	30	30	30
60	10	30	-	-	-	30	30	30
50	20	30	13	18	-	-	-	-
50	10	40	8	14	-	-	-	30
40	20	40	10	12	-	-	-	-
40	10	50	7	11	21	-	-	-

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

** 20% ethyl cellulose - 80% nitrocellulose

COLD CHECK RESISTANCE
OF
20% ETHYL CELLULOSE -
80% NITROCELLULOSE
LACQUERS
Solvent "A"

20% Ethyl Cellulose
80% Nitrocellulose
Ethyl Cellulose -
20 Centipoise
Standard Ethoxy
Nitrocellulose -
RS - $\frac{1}{2}$ Second
Plasticizer - Castor
Oil
Resin - Dewaxed
Damar Gum

Area of
Poor
Cold Check
Resistance

Area of
Good
Cold Check
Resistance

CONCLUSIONS

As stated in the theoretical part of this section, there are a great many factors affecting the determination of cold check resistance. In this investigation every effort was made to keep these various factors constant; however, the results obtained were not consistent in every case. With many of the lacquer samples, duplicate and triplicate checks were obtained; but with some, the results would vary as much as 50%. The results that were obviously inconsistent were rechecked if possible or completely discarded.

Errors in the results of the lacquered wooden panels can be traced, at least partially, to the difficulty of obtaining the same thickness of coat on each panel because of the porosity of the surface. With Dow Metal panels errors may have been introduced before the panels were lacquered because of the high reactivity of the brushed Dow Metal surface when exposed to the atmosphere.

The checking on the wood was always across

the grain. In many instances the wooden panels would check on the ends before there was any sign of failure in the central area of the panel. The steel panels always failed in long continuous cracks in practically every direction. In some cases the Dow Metal panels would fail similarly to the steel panels, although usually the lacquers would fail by developing small circular cracks over the entire surface of the panel.

With lacquers of high and medium cellulose derivative content, the hard maple panels usually cold checked about 25% sooner than the steel panels. With lacquers of low cellulose content, the maple and steel panels failed on approximately the same cycle. Lacquers sprayed on Dow Metal had much more resistance to cold checking than they did on either wood or steel.

As was expected, the lacquers made with ethyl cellulose had higher resistance to cold checking than did those made with nitrocellulose. The extent of this increase is demonstrated in the following table which shows the per cent of cellulose derivative needed in combinations composed

only of resin and cellulose in order that the lacquer will not cold check in less than fifteen cycles.

TABLE L
PERCENTAGE OF CELLULOSE NEEDED WITH RESINS
TO PASS COLD CHECKING TEST

	Ethyl Cellulose	Nitrocellulose
Damar Gum	45%	60%
Ester Gum	54%	63%
Beckacite 1110	67%	71%

This is also shown by a comparison of Charts XXII & XXIII containing the derivatives with castor oil, and damar gum.

Dow P-6 is slightly better than castor oil in preventing cold check, while these two plasticizers are much better than Paraplex 5-B. This is shown in Charts XXII, XXVIII, & XXXIV. These contain each of the three plasticizers with ethyl cellulose and damar gum.

As the resins are the only ingredient of lacquers that will cold check when used alone,

this component plays the most important part in the resistance of lacquer combinations to cold checking. Of the three resins studied in this investigation damar gum is the most resistant to cold checking, while Beckacite 1110 is the most easily cold checked. Ester gum is intermediate between these two resins in its resistance. The effect of the resins on cold checking resistance is shown by comparing Charts XXII, XXIV, & XXVI. These contain each of the three resins with ethyl cellulose and castor oil.

PART III
PRINT TESTS

THEORETICAL

The print test is another very simple test adopted in lacquer work to examine the hardness and, to a certain extent, the plasticity of coatings. This test exists in many varied forms, but the method adopted by the A.S.T.M. (25) is probably the most widely used. This method consists in covering the test panel with two pieces of ordinary cheese cloth and then a layer of felt about $3/32$ inches in thickness. A known uniform pressure is then applied to the felt over a circular area for a given length of time at room temperature. The piece of felt is used in order to distribute the weight more evenly over uneven surfaces. Print resistance may be evaluated by the load required with a given time, or the time required with a given load, or by comparing the imprint under identical loads and duration of test.

It can readily be seen that the harder a film, the more print resistance it will have; while the softer it is, the less print resistance the film will have.

For comparable results the tests must be run at the same temperature, and the thickness of the lacquer coating must be the same in all cases.

A lacquer is considered to have satisfactory print resistance for commercial purposes when there is no print after 24 hours at room temperature with a weight of 2# per square inch.

EXPERIMENTAL WORK

In this investigation the print tests were run quite similarly to the method described in the A.S.T.M. Standards (25). The cheesecloth that was used was of the coarsest variety, so that the test could be made more severe and a sharper imprint could be obtained. Instead of the felt, a piece of glass two inches square was placed over the cheese cloth. This gave a sharply defined area of four square inches for the print test. A small piece of wood almost the size of the glass was placed over the glass to support the known weight. These weights were of four, eight, and twenty pounds and consisted of sand in bottles. These weights gave print tests of one, two, and five pounds per square inch.

In running the test on the panels after they had been in the constant temperature room (25°C) for two days, each panel was placed on a hard horizontal surface and the weight applied in the manner described above for 24 hours at 25°C . The weight was then removed and the panel examined two hours later. The delay was because the result wanted was

the permanent print, and not the temporary print that quickly disappears because of plastic flow.

Panels were prepared for all lacquers studied in this investigation by the method described in the general procedure.

In grading the printed panels, six standard panels were first made, and all tested lacquers were compared to these. The standard panels were designated by six letters -A- being the highest and only panel with satisfactory print resistance, while -F- was the lowest and had such poor resistance that the cheese cloth usually stuck to the panel.

The results of the print test were plotted for all compositions on trilinear paper by drawing a line dividing the chart into two areas. The one area consisting of all lacquers that received the grade -A- with a given pressure, while the other area consisted of those lacquers that had grades lower than -A-. On each chart, lines were drawn for one, two, and five pounds per square inch print test.

RESULTS

TABLE LI
PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
70	15	15	A	A	A
60	30	10	A	A	A
60	20	20	A	A	A
60	10	30	A	A	A
50	30	20	A	A	B
50	20	30	A	A	B
50	10	40	A	A	A
40	30	30	A	B	D
40	20	40	B	C	D

* Solvent composed of 25% toluol, 25% Toluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LI (CON'T)

PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A".

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer resistance to Print Test		
			One Pound	Two Pound	Five Pound
40	10	50	A	B	D
30	40	30	E	E	F
30	30	40	C	D	E
30	20	50	C	D	D
30	10	60	B	D	D
20	30	50	D	E	F
20	20	60	D	E	E
15	15	70	D	F	F
10	30	60	F	F	F

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Dewaxed Damar Gum

CHART XLIII

Castor Oil

TABLE LII
 PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
70	15	15	A	A	A
60	30	10	A	A	A
60	20	20	A	A	A
60	10	30	A	A	A
50	30	20	A	A	A
50	20	30	A	A	A
50	10	40	A	A	A
40	30	30	A	A	B
40	20	40	A	A	B

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LII (CON'T)

PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
40	10	50	A	A	B
30	40	30	C	E	F
30	30	40	C	D	-
30	20	50	B	D	-
30	10	60	B	C	C
20	30	50	D	E	F
20	20	60	D	D	E
15	15	70	E	F	F
10	30	60	F	F	F

PRINT TEST

OF

NITROCELLULOSE LACQUEES

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

--- 5# Test Dividing Line

— 2# Test Dividing Line

--- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LIII
 PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, CASTOR OIL, AND DAMAR GUM
 IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	B	C	D
30	30	40	C	D	D
15	15	70	D	E	F

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE LIV
PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "A"

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	20	20	A	A	A
50	10	40	A	A	A
40	20	40	A	C	D
40	10	50	A	B	C
30	30	40	C	D	E
30	10	60	B	C	D
15	15	70	D	F	F

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

----- 5" Test Dividing Line

———— 2" Test Dividing Line

----- 1" Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LV

PRINT RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	20	20	A	A	A
50	10	40	A	A	A
40	20	40	A	A	B
30	30	40	B	C	D
20	20	60	C	D	F

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF
NITROCELLULOSE LACQUERS

Nitrocellulose - RS = $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

Nitrocellulose

----- 5" Test Dividing Line

———— 2" Test Dividing Line

----- 1" Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Ester Gum

CHART XVI

Castor Oil

TABLE LVI

PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND ESTER GUM
IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Ester Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	C	D
30	30	40	C	D	E
20	20	60	D	E	E

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol

TABLE LVII

PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	20	20	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	30	40	A	B	D
30	10	60	A	A	A
15	15	70	B	C	-

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST
OF
ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Peckacite 1110

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

--- 5# Test Dividing Line
— 2# Test Dividing Line
---- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LVIII
 PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, CASTOR OIL, BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Lacquer Resistance to Print test		
			One Pound	Two Pound	Five Pound
60	20	20	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	30	40	A	A	B
15	15	70	A	B	D

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Peckacite 1110

Solvent "A"

Nitrocellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LIX

PRINT RESISTANCE OF LACQUERS CONTAINING
ETHYL CELLULOSE, CASTOR OIL, AND BECKACITE 1110
IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Beckacite 1110	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	30	40	A	B	C
20	20	60	B	C	D

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol

TABLE LX
 PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, DOW P-6, AND DAMAR GUM
 IN SOLVENT "A".

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	B
50	20	30	A	A	B
50	10	40	A	A	A
40	20	40	C	E	E
40	10	50	B	D	E
30	40	30	E	F	F
30	20	50	D	E	F
20	20	60	F	F	F

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

----- 5# Test Dividing Line
———— 2# Test Dividing Line
---- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Dewaxed Damar Gum

CHART XLIX

Dow P-6

TABLE LXI
PRINT RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	C
40	10	50	A	A	B
30	20	50	B	D	F

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST
OF
NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second
Plasticizer - Dow P-6
Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

----- 5# Test Dividing Line
————— 2# Test Dividing Line
----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Dewaxed Damar Gum

CHART L

Dow P-6

TABLE LXII
 PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, DOW P-6, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
50	20	30	A	A	C
50	10	40	A	A	B
40	20	40	B	D	E
40	10	50	B	B	C
30	20	50	C	E	E

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

----- 5% Test Dividing Line

————— 2% Test Dividing Line

----- 1% Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LXIII

PRINT RESISTANCE OF LACQUERS CONTAINING
NITROCELLULOSE, DOW P-6, AND ESTER GUM
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Ester Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	B
40	10	50	A	A	A
30	20	50	A	B	C

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST
OF
NITROCELLULOSE LACQUERS

Nitrocellulose - PS - $\frac{1}{2}$ Second
Plasticizer - Dow P-6
Resin - Ester Gum

Solvent "A"

Nitrocellulose

----- 5# Test Dividing Line
————— 2# Test Dividing Line
----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Ester Gum

CHART LII

Dow P-6

TABLE LXIV
 PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, DOW P-6, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
40	10	50	A	A	A
30	20	50	A	A	B

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

----- 5# Test Dividing Line
————— 2# Test Dividing Line
----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LXV

PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, DOW P-6, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Beckacite 1110	Lacquer resistance to Print Test		
			One Pound	Two Pound	Five Pound
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
40	10	50	A	A	A
30	20	50	A	A	A

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate,
 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST
OF
NITROCELLULOSE LACQUEES

Nitrocellulose - RS - $\frac{1}{2}$ Second
Plasticizer - Dow P-6
Resin - Beckacite 1110
Solvent "A"

Nitrocellulose

- 5# Test Dividing Line
- 2# Test Dividing Line
- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LXVI
 PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	B	B
40	10	50	A	B	B
30	40	30	B	D	E
20	20	60	D	E	F

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

----- 5% Test Dividing Line

————— 2% Test Dividing Line

----- 1% Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LXVII
 PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, PARAPLEX 5-B, AND DAMAR GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	40	30	A	B	B
20	20	60	D	D	E

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% ethyl acetate, 10% butanol, and 10% ethanol.

PRINT TEST
OF
NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second
Plasticizer - Paraplex 5-B
Resin - Dewaxed Damar Gum
Solvent "A"

Nitrocellulose

----- 5# Test Dividing Line
———— 2# Test Dividing Line
----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Dewaxed Damar Gum

CHART LVI

Paraplex 5-B

TABLE LXVIII

PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, PARAPLEX 5-B, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Lacquer resistance to Print ¹ test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	B	C
30	40	30	B	C	E
20	20	60	B	E	E

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-R

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

- 5% Test Dividing Line
- 2% Test Dividing Line
- 1% Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Ester Gum

CHART LVII

Paraplex 5-R

TABLE LXIX
 PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, PARAPILEX 5-B, AND ESTER GUM
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Ester Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	40	30	A	B	B
20	20	60	B	B	B

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Ester Gum

Solvent "A"

Nitrocellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Ester Gum

CHART VIII

Print 1-2-3

TABLE LXX

PRINT RESISTANCE OF LACQUERS CONTAINING
 ETHYL CELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	40	30	A	B	C
20	20	60	A	B	B

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate,
 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

ETHYL CELLULOSE LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Peckacite 1110

Solvent "A"

Ethyl Cellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

TABLE LXXI
 PRINT RESISTANCE OF LACQUERS CONTAINING
 NITROCELLULOSE, PARAPLEX 5-B, AND BECKACITE 1110
 IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Beckacite 1110	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
50	10	40	A	A	A
40	20	40	A	A	A
30	40	30	A	A	A
20	20	60	A	A	B

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

PRINT TEST

OF

NITROCELLULOSE LACQUERS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Peckacite 1110

Solvent "A"

Nitrocellulose

----- 5% Test Dividing Line

————— 2% Test Dividing Line

----- 1% Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Peckacite 1110

CHART IX

Paraplex 5-B

TABLE LXXII

PRINT RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND X**, CASTOR OIL, DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend X	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
60	10	30	A	A	A
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	B	C
40	10	50	A	B	B

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate,
10% butanol, 10% ethyl acetate, and 10% ethanol

** 80% ethyl cellulose - 20% nitrocellulose

PRINT TEST
OF
80% ETHYL CELLULOSE -
20% NITROCELLULOSE
LACQUERS

80% Ethyl Cellulose

20% Nitrocellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

Area of
Poor Print
Resistance

Dewaxed Damar Gum

CHART IXT

Castor Oil

TABLE LXXIII

PRINT RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND Y**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend Y	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
60	10	30	A	A	A
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	B
40	10	50	A	A	B

* Solvent composed of 25% teluol, 25% Troluoil, 20% butyl acetate,
10% butanol, 10% ethyl acetate, and 10% ethanol.

** 50% ethyl acetate - 50% nitrocellulose

PRINT TEST

OF

50% ETHYL CELLULOSE -

50% NITROCELLULOSE

LACQUEPS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Tamar Gum

Solvent "A"

80% Ethyl Cellulose ? 50%

20% Nitrocellulose ? 50%

----- 5# Test Dividing Line

————— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

Dewaxed Tamar Gum

CHART VIII

Castor Oil

TABLE LXXIV

PRINT RESISTANCE OF LACQUERS CONTAINING
CELLULOSE BLEND 2**, CASTOR OIL, AND DAMAR GUM
IN SOLVENT "A"*

Per Cent Cellulose Blend 2	Per Cent Castor Oil	Per Cent Damar Gum	Lacquer Resistance to Print Test		
			One Pound	Two Pound	Five Pound
60	30	10	A	A	A
60	10	30	A	A	A
50	20	30	A	A	A
50	10	40	A	A	A
40	20	40	A	A	B
40	10	50	A	A	B

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

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PRINT TEST

OF

20% ETHYL CELLULOSE -

80% NITROCELLULOSE

LACQUERS

Ethyl Cellulose - 20 Centipoise
Standard Athoxy

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

20% Ethyl Cellulose

80% Nitrocellulose

----- 5# Test Dividing Line

———— 2# Test Dividing Line

----- 1# Test Dividing Line

Area of
Good Print
Resistance

Area of
Poor Print
Resistance

A B

Dewaxed Damar Gum

CHART IXIII

Castor Oil

CONCLUSIONS

All lacquers tested in this investigation were subjected to the one, two, and five pound print test. The charts were plotted as described in the general procedure for all combinations and contain the dividing lines for lacquers passing each of the three print tests. Ethyl cellulose and nitrocellulose were the only components employed that were hard enough to pass the print test. The dividing lines always formed an arc across the chart including the 100% cellulose corner and limiting the maximum amount of gum and plasticizer that could be used in satisfactory lacquers.

As was expected the per cent cellulose content had to be increased when ethyl cellulose was substituted for nitrocellulose. The extent of this increase depended upon the hardness of the resin and plasticizer employed in the particular combination. In the case of both derivatives with damar gum and castor oil, as shown by Charts XLIII and XLIV, the cellulose content had to be increased about 8%, based on total cellulose, resin, and plasticizer content equaling 100%, when ethyl

cellulose was substituted for nitrocellulose. This eight percent increase was allowed for by a corresponding decrease in the total per cent of castor oil and damar gum employed. Similar examples can be seen by comparing the ethyl cellulose and nitrocellulose charts for other resin-plasticizer combinations. The following table shows this increase by comparing the relative amounts of cellulose derivative needed for satisfactory print resistance in two component systems.

TABLE LXXV

Per Cent Cellulose Derivative Needed for Two Component Combination to Pass Two Pound Print Test

	Ethyl Cellulose	Nitrocellulose
Castor Oil	56%	48%
Dow P-6	64%	56%
Paraplex 5-B	47%	37%
Damar Gum	43%	36%
Ester Gum	44%	35%
Beckacite 1110	19%	17%

Over the entire range of the dividing lines the difference in ethyl cellulose content between those lacquers that will pass the five pound test

and those that will pass the two pound test is about 5%, based on cellulose, resin, and plasticizer equaling 100%. This same difference exists between the lacquers that will pass the two pound test and those that will pass the one pound test. In the case of nitrocellulose the difference in cellulosic content between the dividing lines amounts to about 4%. This decrease between the difference of the compositions on the nitrocellulose chart and those on the ethyl cellulose chart is because nitrocellulose is a harder material and its rate of change of hardness down the chart will be greater.

Of the three plasticizers used Paraplex 5-B produces the hardest films, with castor oil next, and Dow P-6 making the softest films. This is shown by a comparison of Charts XLIII, XLIX, & LV. These charts relate the three plasticizers with ethyl cellulose and damar gum.

Beckacite 1110 makes much harder lacquer films than either damar gum or ester gum. Of the last two resins, damar gum makes slightly harder lacquers than ester gum. This fact is

shown by a comparison of Charts XLIII, XLV, & XLVII. These show the three resins with ethyl cellulose and damar gum.

PART IV

FREE FILM TESTS

THEORETICAL

The free film method of testing protective coatings consists in stressing the film and observing its characteristics before rupture. This method tests the free coating separate from any adhering body, although actually it is always used as an integral part of some base material. Authorities (26) believe, however, that this test permits the evaluation of almost all the mechanical properties excepting the adhesion.

The action of a sample of coating that is being stressed is quite similar to the action of any plastic material, such as a steel rod, under the same conditions. As the stress is applied the sample will elongate until it reaches its yield point in such a manner that the stress is always proportional to the elongation. During this period the sample will always return to its original dimensions if the load is released. After passing this stage the film goes through a region in which the molecules of the film are aligning themselves and there is a great deal of deformation with the addition of practically no

load. This new internal arrangement results in a new region in which more load is needed for greater deformation. The extent of this period before rupture depends upon the length of the molecules. For short molecules rupture appears before the completion of the rearrangement. The total elongation of the film is a measure of the film flexibility, while the product of the load and the elongation represents the toughness of the film. The yield point is a measure of the film hardness.

For comparable results it is necessary that the load is always applied at the same rate. This requires that the testing machine should always be run at the same rate, and that the films to be tested should always be of the same cross section area.

EXPERIMENTAL WORK

The production of the films for this work was described under the general procedure. After being cast, all the films were sent to the Cellulose and Plastics Laboratory of the Dow Chemical Co., in Midland, Michigan, to be tested. Here the films were stored in a conditioned room at 50% relative humidity and 70 F for 48 hours. They were then cut into five strips one-half inch wide and fifteen centimeters long, and measured in order to determine the cross section area at the thinnest point. These strips were then placed between the jaws of a tensile strength machine* and the load gradually applied until rupture. At this point readings were taken of the maximum load applied and the total elongation. From these readings the percent elongation and the tensile strength in kilograms per square centimeter can be determined.

An attempt was made to evaluate the properties of all the lacquers studied in this thesis by the above method, but this proved to be impossible for

* Model X-5, Henry L. Scott Co., Providence, R. I.

several reasons. In the first place, many of the ethyl cellulose and most of the nitrocellulose films were too brittle to cut into the necessary strips for the film tests. Some of the films were so sticky that they could not be handled, and other films that were flexible enough to be tested were damaged in transit to Michigan.

The actual list of lacquers that were tested can be seen in this section under Results.

RESULTS

TABLE LXXVI
FREE FILM TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE AND CASTOR OIL
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Per Cent Beckacite 1110	Per Cent Ester Gum	Tensile Strength Kg/Cm Sq	Per Cent Elongation
60	30	10			136	12
40	30	30			65.6	13
30	30	40			44.5	22
50	30	20			111	8
70	15	15			412	4
60	20	20			222	5
60	20		20		194	4
60	20			20	188	5

* Solvent composed of 25% toluol, 25% Troluol, 20% butyl acetate, 10% butanol
10% ethyl acetate, and 10% ethanol.

TABLE LXXVII

FREE FILM TESTS OF LACQUERS CONTAINING

NITROCELLULOSE AND CASTOR OIL

IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Per Cent Ester Gum	Tensile Strength Kg/Sq Cm	Per Cent Elongation
30	40	30		66.4	33
30	30	40		100.0	5

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LXXVIII
 FREE FILM TESTS OF LACQUERS CONTAINING
 ETHYL CELLULOSE AND CASTOR OIL
 IN SOLVENT "B"*

Per Cent Ethyl Cellulose	Per Cent Castor Oil	Per Cent Damar Gum	Per Cent Beckacite 1110	Per Cent Ester Gum	Tensile Strength Kg/Sq Cm	Per Cent Elongation
60	30	10			135	14
60	30		10		200	6
60	30			10	140	13
40	20			40	84	6

* Solvent composed of 70% xylene, 15% butanol, and 15% ethanol.

TABLE LXXIX
FREE FILM TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE AND DOW P-6
IN SOLVENT "A"*

Per Cent Ethyl Cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Per Cent Beckacite 1110	Per Cent Ester Gum	Tensile Strength Kg/Sq Cm	Per Cent Elongation
60	30	10			140	14
50	20	30			280	4
60	30		10		205	10
60	30			10	140	10
50	20			30	240	3

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LXXX
FREE FILM TESTS OF LACQUERS CONTAINING
NITROCELLULOSE AND DOW P-6
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Dow P-6	Per Cent Damar Gum	Per Cent Ester Gum	Tensile Strength Kg/Sq cm	Per Cent Elongation
60	30	10		538	2
60	30		10	337	2

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LXXXI
FREE FILM TESTS OF LACQUERS CONTAINING
ETHYL CELLULOSE AND PARAPLEX 5-B
IN SOLVENT "A".

Per Cent Ethyl Cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Per Cent Beckacite 1110	Per Cent Ester Gum	Tensile Strength Kg/Sq Cm	Per Cent Elongation
60	30	10			190	5
30	40	30			30	35
60	30		10		265	5
30	40		30		100	6
60	30			10	212	6
30	40			30	23.2	42

* Solvent composed of 25% toluol, 25% Troluoil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

TABLE LXXXII
FREE FILM TESTS OF LACQUERS CONTAINING
NITROCELLULOSE AND PARAPLEX 5-B
IN SOLVENT "A"*

Per Cent Nitro- cellulose	Per Cent Paraplex 5-B	Per Cent Damar Gum	Per Cent Ester Gum	Tensile Strength Kg/Sq Cm	Per Cent Elongation
60	30	10		515	4
60	30		10	580	5
30	40		30	121	15

* Solvent composed of 25% toluol, 25% Trolucil, 20% butyl acetate, 10% butanol, 10% ethyl acetate, and 10% ethanol.

CONCLUSIONS

As mentioned previously in this section the results on the free film tests are not complete because of the many difficulties and limitations involved in this work. For this reason very few quantitative results can be drawn on the behavior of the lacquers with changes in composition.

However, from the results obtained the following facts may definitely be asserted:

(1) Ethyl cellulose is definitely more flexible than nitrocellulose, while nitrocellulose is higher in tensile strength. Evidence of this is shown on several occasions, but one case in particular will be considered. This case is shown in Table XXXIII and Table XXXIV in a lacquer consisting of 60% derivative, 30% castor oil, and 10% damar gum. When the derivative is ethyl cellulose the composition has a tensile strength of 140 Kg/Sq Cm and a 14% elongation. The same nitrocellulose lacquer has a tensile strength of 538 Kg/Sq Cm and only a 2% elongation.

(2) In considering the three plasticizers, castor oil and Dow P-6 produce films of approx-

imately the same properties, while Paraplex 5-B lacquers are higher in tensile strength and lower in flexibility. An example of this is shown in Tables XXX, XXXIII, and XXXV in the case of a lacquer containing 60% ethyl cellulose, 30% plasticizer, and 10% damar gum. When castor oil is used as the plasticizer, this lacquer has a tensile strength of 136 kg/sq cm and a 12% elongation, while with Dow P-6 this lacquer has a tensile strength of 140 kg/sq cm and a 14% elongation. However, when Paraplex 5-B is used as the plasticizer this same lacquer has a tensile strength of 190 kg/sq cm and only a 5% elongation.

(3) Ester gum and damar have very nearly the same effect on the tensile strength and elongation, while Beckacite 1110 produces films of higher tensile strength and lower flexibility. Two examples of this phenomenon are shown in Table XXXV. The lacquer to be considered consists of 30% ethyl cellulose, 40% Paraplex 5-B, and 30% resin. In this lacquer the damar gum and ester gum produce films with a tensile strength of 30 and 23.3 kg/sq cm respectively. However, the Beckacite 1110 lacquer of this same composition has a tensile strength of 100 kg/sq cm and an elongation of only 6%.

SUMMARY

SUMMARY

The object of this investigation was to determine areas on trilinear charts that had similar properties with ethyl cellulose in one case and nitrocellulose in the other while using a given resin - plasticizer combination. The properties that were to be tested were mandrel tests, cold checking tests, and print tests.

These areas were determined by plotting the dividing lines between the passing and failing lacquers of the three tests on the same charts. For the print test the two pound dividing line was used, which bounds the desired area by showing the minimum amount of resin and plasticizer that can be used. The dividing line for the mandrel tests in the case of ethyl cellulose lacquers bounds the area by showing the minimum amount of plasticizer and the maximum amount of resin, while placing no limit on the ethyl cellulose. In the case of nitrocellulose lacquers, the mandrel test dividing line also limits the maximum amount of nitrocellulose to be used. In most cases the divid-

ing line for the cold check does not further restrict the passing area. However, in a few cases the cold check dividing line does cut the corner of the passing area and sets a lower maximum amount of resin that can be used.

For the ethyl cellulose lacquers the areas on the trilinear charts always included the 100% cellulosic corner and was bounded on the other side by a line joining the side of the trilinear chart representing 0% plasticizer and the side representing 0% resin. The boundary line joining the two sides of the chart always passed through a point showing the minimum amount of cellulose that could be used.

For the nitrocellulose lacquers the passing areas did not include the 100% nitrocellulose corner and was always in the form of a triangle point out into the diagram from the side of the chart representing 0% resin. The apex of the triangle always showed the point that would still pass all the tests and contained the minimum amount of nitrocellulose.

These passing areas have been determined for nitrocellulose and ethyl cellulose with all the resin - plasticizer combinations studied, and for blends of ethyl cellulose with nitrocellulose with one resin-plasticizer combination. These results are contained in trilinear Charts LXIV through LXXXIV.

Another object of this program was to determine a correlation between flexibility as studied by the free film elongation, mandrel test, and the cold check test.

As previously stated the results of the free film tests are rather limited, so that a complete attempt to correlate the data from this test with those from the other two flexibility test is impossible. However, every lacquer that was flexible enough to be tested by the free film method passed both the mandrel and the cold checking test.

A comparison of similar charts from the mandrel and cold check tests shows that it is impossible to make a general correlation between these two tests. Any correlation that could be made would

always have to be used with materials of similar properties, since the relative position of the dividing lines varies with materials of widely varying properties, such as ester gum and Beckacite 1110. This fact is shown by a comparison of Charts VII and XXVIII with Charts XI and XXXIII.

In the case of nitrocellulose lacquers of high cellulosic content the correlation is absolutely impossible since these lacquers pass the cold checking test and fail the mandrel test. The only correlation is with similar lacquers having between 15% and 35% cellulose content. Under these conditions the two dividing lines could be used interchangeably as the general variation is not over 5%.

The various blends of ethyl cellulose and nitrocellulose in castor oil, damar gum lacquers have been studied and the results plotted on triangular charts for the mandrel test, print test, cold check test, and also for the area that passes all three tests. In every case the dividing lines have appeared in the right order and position as

shown by the corresponding charts for straight ethyl cellulose and straight nitrocellulose.

Because of the inaccuracies of the physical tests by means of which the lacquers were tested, it is impossible to say whether or not the physical properties are additive in the same ratios as the two celluloses are blended.

The results of the mandrel and print tests show that the substitution of Solvent "B" for Solvent "A" in the lacquer had no effect upon the physical properties influencing the tests. Insufficient results were obtained from the cold checking test to determine whether this substitution affected the results of this test.

COMPOSITE CHARTS

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

———— Cold Check Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

Dewaxed Damar Gum

CHART LXV

Castor Oil

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Ester Gum

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

----- Mandrel Test Line

———— Cold Check Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second
Plasticizer - Castor Oil
Resin - Ester Gum

Solvent "A"
or
Solvent "B"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

Ester Gum

CHART LXXVII

Castor Oil

ETHYL CELLULOSE LACQUEES

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Castor Oil

Resin - Beckacite 1110

Solvent "A"

or

Solvent "B"

Ethyl Cellulose

———— Cold Check Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Beckacite 1110

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

———— Cold Check Test Line

--- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Dow P-6

Resin - Dewaxed Damar Gum

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

———— Cold Check Test Line

---- Print Test Line

Area of Satisfac-
tory Lacquers

Area of
Unsatisfactory
Lacquers

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND GOLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Dow P-6

Resin - Ester Gum

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of Satisfac-
tory Lacquers

Area of
Unsatisfactory
Lacquers

ETHYL CELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Dow P-6

Resin - Beckscite 1110

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line

----- Cold Check Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Dow P-6

Resin - Beckacite 1110

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of Satisfac-
tory Lacquers

Area of
Unsatisfactory
Lacquers

Beckacite 1110

CHART LXXV

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizers - Paraplex 5-B

Resin - Dewaxed Damar Gum

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND GOLD CHECK
TESTS

Nitrocellulose - PS - $\frac{1}{2}$ Second
Plasticizers - Paraplex 5-B
Resin - Dewaxed Damar Gum
Solvent "A"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Unsatisfactory
Lacquers

Area of
Satisfactory
Lacquers

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY

MANDREL, PRINT, AND COLD CHECK

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Ester Gum

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line

———— Cold Check Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND GILD CHECK
TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second
Plasticizer - Paraplex 5-B
Resin - Ester Gum

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Unsatisfactory
Lacquers

Area of
Satisfactory
Lacquers

ETHYL CELLULOSE LACQUERS

HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Plasticizer - Paraplex 5-B

Resin - Beckacite 1110

Solvent "A"

Ethyl Cellulose

----- Mandrel Test Line
———— Cold Check Test Line
---- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

Beckacite 1110

CHART LXVY

Paraplex 5-B

NITROCELLULOSE LACQUERS

HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

Nitrocellulose - RS - $\frac{1}{2}$ Second

Plasticizer - Paraplex 5-B

Resin - Peckacite 1110

Solvent "A"

Nitrocellulose

----- Mandrel Test Line

----- Print Test Line

Area of
Unsatisfactory
Lacquers

Area of
Satisfactory
Lacquers

80% ETHYL CELLULOSE -
20 % NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK

80% Ethyl Cellulose -
20% Nitrocellulose

TESTS

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy

Nitrocellulose - PS - $\frac{1}{2}$ Second

Plasticizer - Castor Oil

Resin - Dewaxed Damar Gum

Solvent "A"

----- Mandrel Test Line

----- Print Test Line

Area of
Satisfactory
Lacquers

Area of
Unsatisfactory
Lacquers

50% ETHYL CELLULOSE -
50% NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

50% Ethyl Cellulose -
50% Nitrocellulose
----- Mandrel Test Line
----- Print Test Line

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy
Nitrocellulose - FS - $\frac{1}{2}$ Second
Plasticizer - Castor Oil
Resin - Dewaxed Damar Gum
Solvent "A"

Area of
Satisfactory
Lacquers
Area of
Unsatisfactory
Lacquers

20% ETHYL CELLULOSE -
80% NITROCELLULOSE LACQUERS
HAVING SATISFACTORY
MANDREL, PRINT, AND COLD CHECK
TESTS

20% Ethyl Cellulose -
80% Nitrocellulose
----- Mandrel Test Line
----- Print Test Line

Ethyl Cellulose - 20 Centipoise
Standard Ethoxy
Nitrocellulose - RS - $\frac{1}{2}$ Second
Plasticizer - Castor Oil
Resin - Dewaxed Damar Gum
Solvent "A"

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