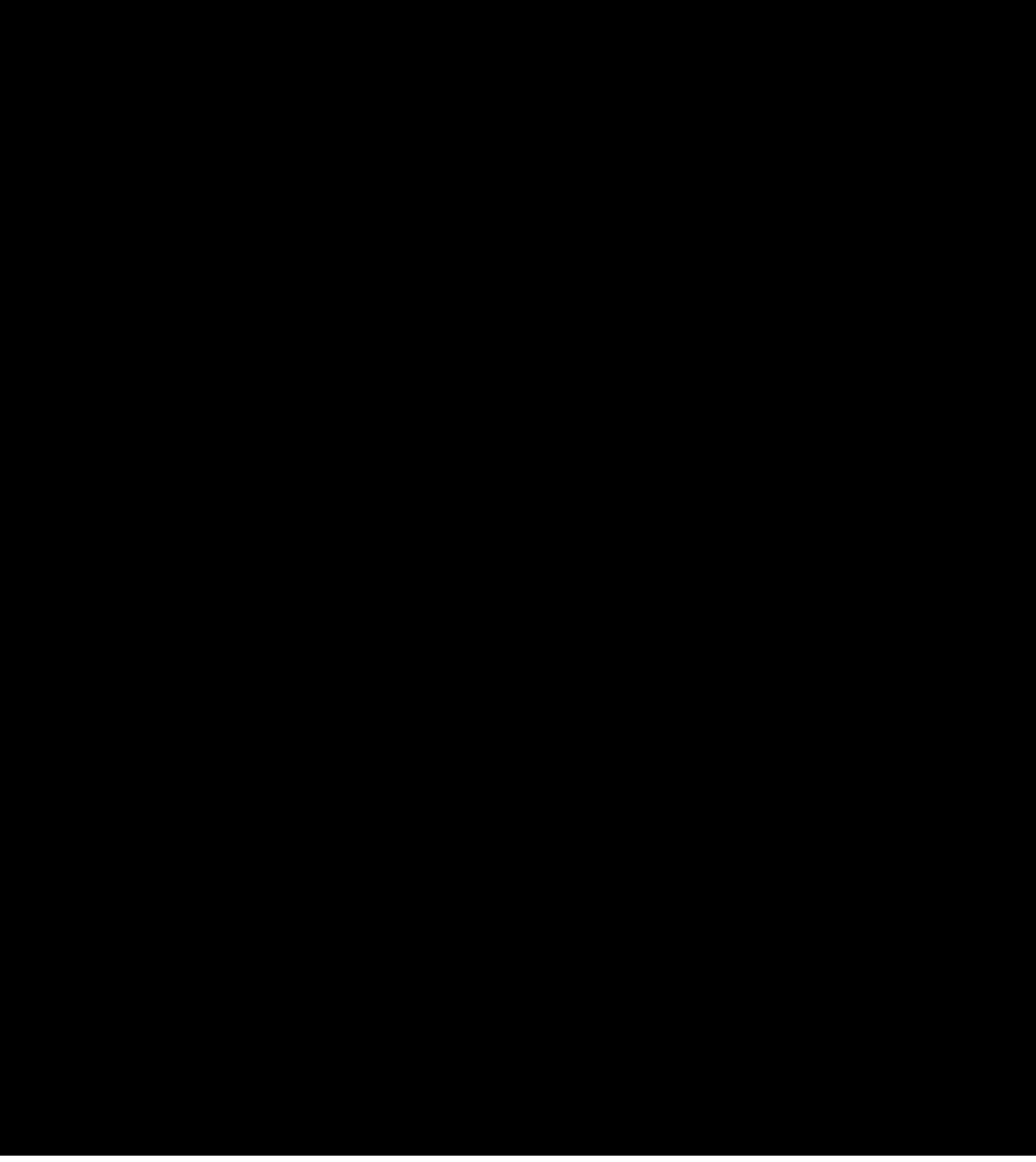




E. I. DU PONT DE NEMOURS & COMPANY, INC.
FABRICS AND FINISHES DEPARTMENT
PRODUCTION DIVISION
PROCESS ENGINEERING

Report PE 62-03

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PREPARATION OF "LUCITE"® METALLIC COLOR PANELS

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DATE ISSUED: 8/27/62

PROJECT: P-57 - COLORIMETER-CHART COLOR ADJUSTMENT SYSTEM

PE-6203

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ABSTRACT

A study of the factors that affect the reproducibility of "Lucite"® metallic color panels and the development of a technique to control their effect on panel reproducibility.

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I. CONTROLLED ENVIRONMENT SPRAY SYSTEM - "LUCITE" METALLICS

A. Introduction

The preparation of metallic color panels through the use of spray techniques has long been recognized as a prime source of difficulty in color control and shading due to the lack of reproducibility under moderately varying environments. In previous years, products had more latitude due to their formulation and were relatively darker, less sensitive colors. It was possible to reproduce metallic color panels for color, gloss and film properties over a wide range of environmental changes. The recent trend has been toward less spraying latitude due to the formulation changes required to improve film properties and the lighter metallic colors now in vogue. The 1963 colors now have very little latitude and require extremely narrow test method specifications to reproduce color panels.

As metallic colors become more sensitive to spray variations, color control could only be achieved on a practical basis through the expedient of respraying these colors with minor environmental changes until the panel looked "right." The present practice is to adjust conditions within the limits of the current test memorandum to obtain a panel with a smooth appearance and a high degree of glamour, resulting in panels being prepared on the "wet" side and decreasing the application latitude. The variance in color obtained, although following the present test memorandum, is greater than the variance that can be tolerated for automotive color control. This condition is the direct result of the inadequate characterization of the current spraying techniques by the applicable Test Methods.

The trend toward light metallic colors containing a high percentage of aluminum has served to grossly emphasize this lack of spray reproducibility. Fortunately, the application of instrumental color control in this area of pigmented finishes soon followed and it became apparent that immediate and positive corrective action was necessary to provide a technique for reproduction of metallic color panels and provide the necessary basis of instrumental control.

The objectives of this portion of the color study became:

1. To define those variables inherent in the preparation of metallic panels and to determine the significance of each on the overall panel variability.

2. To develop suitable techniques and application apparatus in order to provide positive control of each variable and thus establish overall control of metallic panel reproducibility. Success in this area of study was obviously essential, not only for the future development of instrumental shading techniques, but also for the maintenance of our current position as a supplier of visually shaded Automotive metallic finishes.

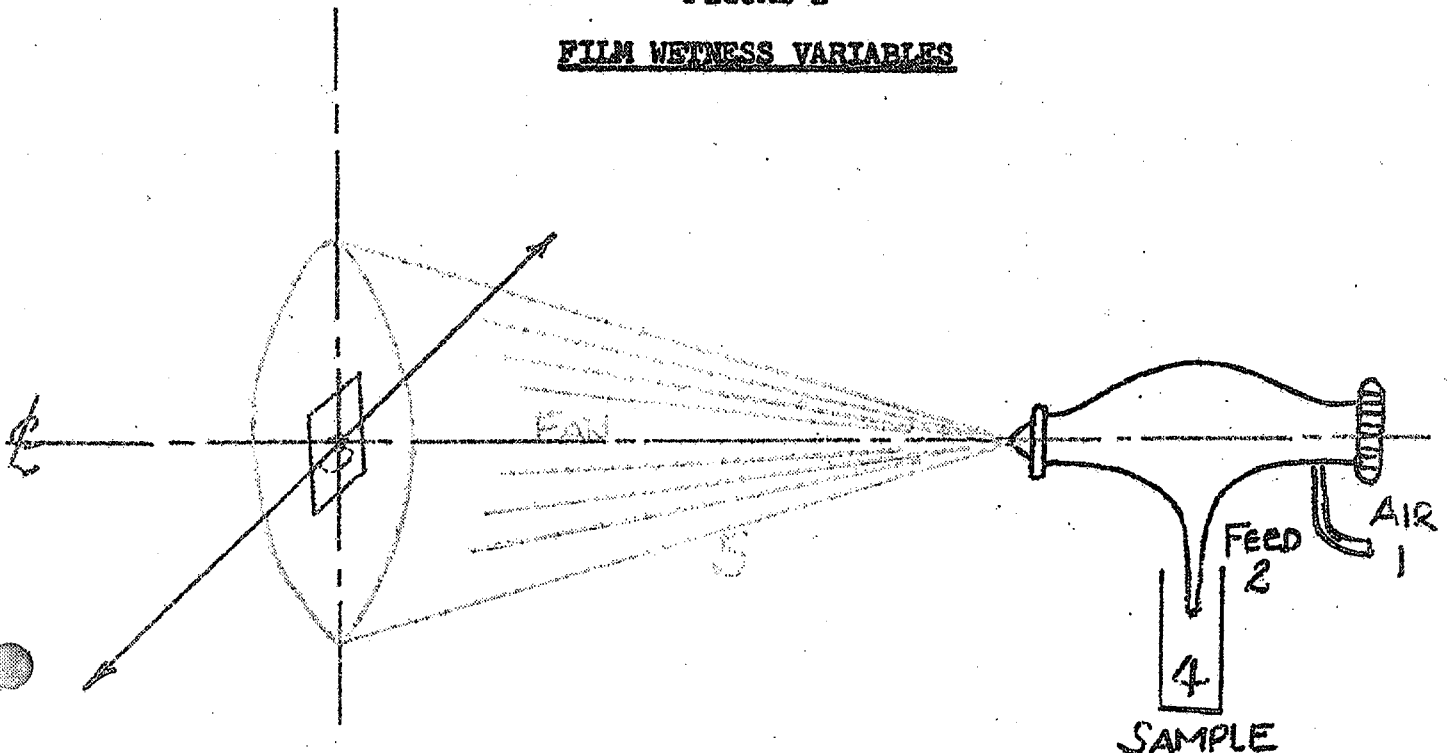
B. Results

An analysis was made, using colorimetric techniques, of all variables which might conceivably affect the color and two-tone reproducibility of metallic color panels. Many of the variables thought to have a major influence on panel color were found statistically to be minor in effect. The results of this investigation proved conclusively that the panel color variation was primarily a function of:

1. The wetness of the deposited film.
2. The rate of solvent evaporation from this film.

Further study was directed toward the isolation of each of the parameters contributing to these two factors and defining the extent to which they had to be controlled. As a result of this investigation, the 17 factors illustrated in Figure I were isolated for study.

FIGURE I
FILM WETNESS VARIABLES



Variables Studied

1. Compressed Air
Pressure
Temperature
2. Gun Settings
Fluid Flow Rate
Fan Pattern
Cap, Needle and Head
3. Panel
 - a. Distance from Gun
 - b. Position in Fan Pattern
 - c. Temperature of Panel Speed
4. Sample
 - a. Reduction
 - (1) Type of Solvent
 - (2) Amount of Solvent
 - b. Viscosity
 - c. Temperature
 - d. Product Characteristics
5. Environment Temperature
Humidity
Air Flow Rate

Of all of the parameters studied, the environment (spray room) temperature, humidity and the rate of flow past the panel were the most important contributors to panel variability and the least susceptible to positive control. It will be noted from Figure I that most of the remaining variables can be rigidly defined under normal operating conditions. Previous attempts have been made to control environmental conditions through the use of extensive air-conditioning apparatus. This approach was believed to be too costly for routine plant operation and accordingly, based on our test results, a new approach was made to the problem of environmental control of the air affecting the rate of dry.

This new approach utilized a concept known as the Controlled Environment System (C.E.S.). Basically, The C.E.S. derives all of the advantages of spray room temperature and humidity control at a fraction of the cost. It achieves its purpose through providing a local air environment controlled for temperature, humidity and velocity in the very area through which the panel must pass during the flash period. This air is essentially room air heated to a high temperature in order to drop the ambient humidity below the critical level established in this study.

Equipment and definitive procedures were developed to permit the utilization of the C.E.S. concept to the routine spraying of production metallic color panels. Extensive trials over a 9-month period at Process Engineering and the Flint Plant have proven the validity of both the concept and the techniques used for definition of the various spraying variables. Working drawings of the apparatus and a definitive proposed test method are appended to this report. Study of the test method will indicate that panels prepared by this technique can be directly baked without the "flash" period inherent in currently effective panel preparation procedures.

C. Conclusions

1. The reproducible preparation of "Lucite"* metallic color panels requires a reproducible orientation of the metallic aluminum flake in the film. This condition can only be achieved through positive control of those factors which affect the application rate and composition of the applied film and the viscosity characteristics during the drying stage. The Controlled Environment System achieves by rigorously defining the method of application to provide a reasonably reproducible applied film thickness and composition and then controls the film viscosity during drying by reproducing the rate of solvent evaporation from the film.
2. The inherent advantages gained from improved metallic panel reproduction achieved under the C.E.S. techniques will improve the capability of the Production Division to cope with the manufacture of the newer and more spray sensitive formulations currently comprising our offering to the Automotive industry. As a result, the practice of "gun-shading" (i.e., color manipulation resulting from spray variations within the context of current testing procedures) will be eliminated under the more definitive procedures developed under this study.
3. The adoption of the C.E.S. procedures and equipment are advocated not only for "Lucite"* Automotive products but also for "Dulux"* and "Duco"* products of this nature. Preliminary tests at Toledo and Ajax indicate the validity of the application of these concepts to the "Dulux"* product range.

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4. One area remaining to be resolved concerns the preparation of Automotive metallic color standards. The C.E.S. because of the necessity to obtain reproducible aluminum flake orientation and thus reproducible panels provides panels of lower "glamour" than the current Automotive standards. Automotive standard preparation is traditionally geared to provide standards of utmost gloss and glamour. This result can only be achieved through spraying wet films - a condition which sacrifices any possibility of panel reproduction with current spray sensitive formulations. Some idea of the panel reproduction problem can be obtained when it is realized that a percentage of the standards sprayed from the same can at the same time must be rejected for gross appearance differences. Additionally, spot measurements made on virgin accepted standards indicate that their variability exceeds the acceptable color tolerance for the color.

RANGE ΔL Δa Δb AND ΔTT OF A LIMITED SAMPLING

Std. 1961 (Random Sampling)	0.60	.20	.20	3
1962 Stds. " "	0.80	.50	.50	5
1963 Stds. " "	2.00	1.20	1.20	12
16 O.K. Color Panels 867-95183	2.20	1.50	1.50	12
10 O.K. Retains Resprayed 867-95183	2.00	1.10	0.75	6.0
Req'd Control Tolerance Limits (Panels evaluated by E.T.A. and E.A.M. for O.K. then read) 867-95183	1.00	1.00	0.50	6

It is obviously impractical to expect Production to consistently match panels prepared under these conditions; therefore, the system of standards loses much of its value by resulting in the "gun-shading" necessary to achieve a satisfactory match.

D. Recommendations

Install the C.E.S. equipment and program for the preparation of all metallic color panels. Although these panels do not match the material as applied at the Automotive plants, this is not a serious problem as the customer will be supplied material within closer color limits than under the present system.

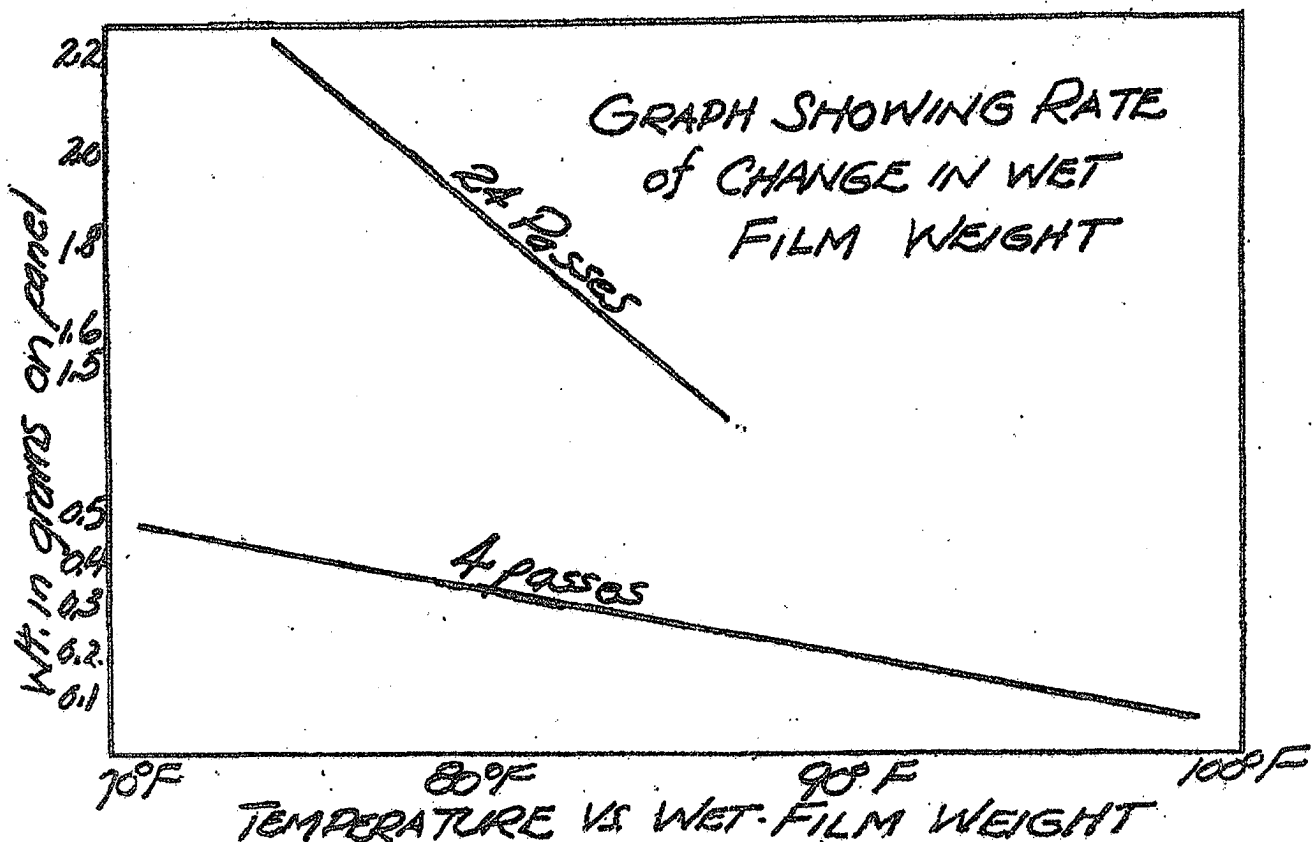
It will be necessary to establish the first standard on the C.E.S. equipment then match all standards to this one by adjusting solvents to produce panels of equal color and two-tone.

II. DISCUSSION OF METALLIC PANEL PREPARATION

A. Background of Problem

The wet film thickness and drying rate must be controlled within very narrow limits so the aluminum particles that arrive at the panel in a turbulent state can orient into a position closely parallel to the plane of the panel substrate. If the spray is too dry the particles will remain in the random positions as they hit the panel and if the spray is too wet, thermal currents within the film will cause flooding. Both these conditions have a marked effect upon the L, a, b and TT values. Changes in wet film are very difficult to characterize as the film viscosity does not remain constant long enough to be accurately measured so an effort was made to correlate wet film weight with film viscosity.

The high percentage of H-30, Acetone, in the 867 line formulas makes the wet film of spray application vulnerable to minor changes in air temperature, relative humidity and/or air velocity. The variance in the loss of H-30 between the gun and the panel causes various degrees of wetness which in turn result in different color and TT.



CONTROLLED TEMP & HUMIDITY
SPRAY ROOM.

RH 60%-70%

AIR VELOCITY 10'/MIN.

COLOR CHANGE VS. TEMP

887-94696

Δ VALUE

0

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

Red Reflectance

Green Reflectance

Blue Reflectance

WET FILM →

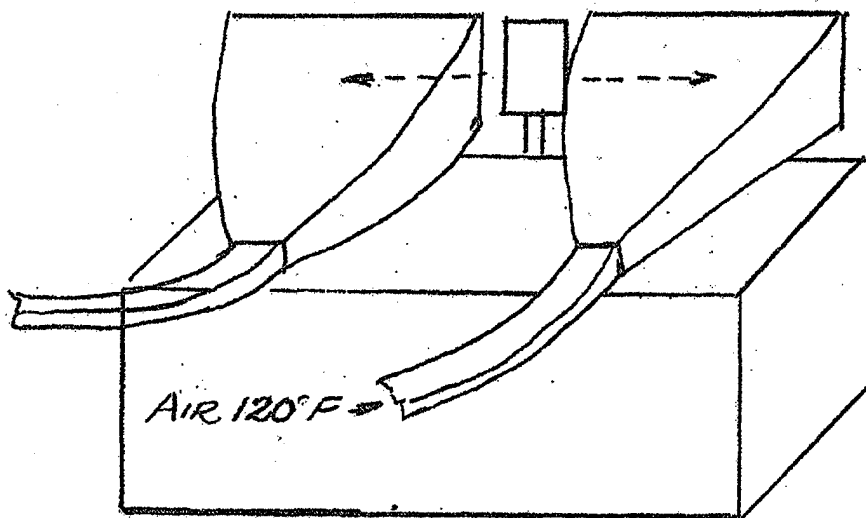
DRY

75°F 80° 85° 90° 95° 100°

This loss cannot be controlled but can be tolerated if the rate of dry is controlled by a controlled environment system. Such a system was developed which would achieve the reproducibility necessary for an I.C.A. program. The controlled environment system keeps the rate of evaporation from the deposited film constant so the orientation of the aluminum particles form a consistent pattern over a wider range of room temperatures and relative humidities.

No adequate spray facilities were available in the F. & F. Department for a quantitative study of spray variables. The high number of uncontrollable variables made it impossible to study one variable while the others were held constant and to determine if the variables were dependent or independent variables. Most of the studies were qualitative for an approximate set of conditions. They served as a guide to develop a program to yield the most reproducible panels and give an approximate range of the variable effect.

The proposed controlled environment system (C.E.S.) is based on results of work conducted over a year and a half at Philadelphia and Flint Plants.



C.E.S.

B. Study of Problem

The importance of metallic color panel reproducibility has been brought into sharper focus as the application latitude has narrowed due to increased demand for high initial gloss and glamour. This is in sharp contrast to the latitude that was experienced when producing "Duco"® metallic panels.

The customer's added demand for very close control under a system of narrow latitude has placed a demand upon production that has increased cost due to longer mixer cycles and shading man-hours. The customer's demand for very close color control may be real or imaginary as his limits of reproducibility are now only an opinion. It is suspected that he is unable to utilize to full advantage the narrow controls being exercised by the plants due to his lack of control of temperature-humidity on the production line and method of application. To minimize our production cost it is essential that practical color limits be established which can be expressed in terms of Adams Coordinate System ΔL , Δa , Δb and ΔTT . This would eliminate the excessive control now being practiced and establish a pattern of uniform color production tailored to fulfill the demands of the customer.

This will not be an easy task as the whole color control program is in a state of frustration as a result of decisions being based on opinion and not facts. There are no established limits except those in the minds of individuals which fluctuate broadly depending upon many physical and psychological factors. The eye is an extremely sensitive organ in discerning very small color differences so it requires good judgement to determine and maintain a consistent level of acceptance that is not adequately defined by numerical values.

A basic requirement for the evaluation of color panels is a degree of reliability in the preparation of the standards and control panels that is consistent with the color limits established. At the present time there is very little latitude in preparing "Lucite"® metallic color panels and small deviations in spray conditions change the color of a panel from an approval to a rejection. It is common practice to respray a color if it is close in the hope that a change in environment is such that an approved panel will be obtained.

It becomes obvious that a standard color panel can only be used for a standard at a given set of conditions. In the past, the test memorandum 349-F was adequate since the products controlled under it had a broader latitude for preparing color panels. It is also obvious that it is not adequate for the present 867 line.

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PANEL REPRODUCIBILITY
RANGE OF VARIANCE

5 Panels of Each Color 1961 Standards

	<u>ΔL</u>	<u>Δa</u>	<u>Δb</u>	<u>ΔTT</u>
887-95181	0.72	0.15	0.32	1.1
95183	0.49	0.33	0.09	4.7
95187	0.38	0.09	0.23	3.5
95185	0.58	0.22	0.17	2.7

5 Panels of 1962 Standard

867-95183	0.79	0.44	0.07	2.7
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1963 Standards

867-95999	1.04	0.50	0.24	4.8
867-				
867-				

16 Panels of O.K. 1962 Colors

867-95185	1.80	1.53	2.00	8.0
95191	1.32	1.65	0.83	9.0
95187	2.55	1.12	1.04	13.0
95183	2.11	1.27	0.90	7.2

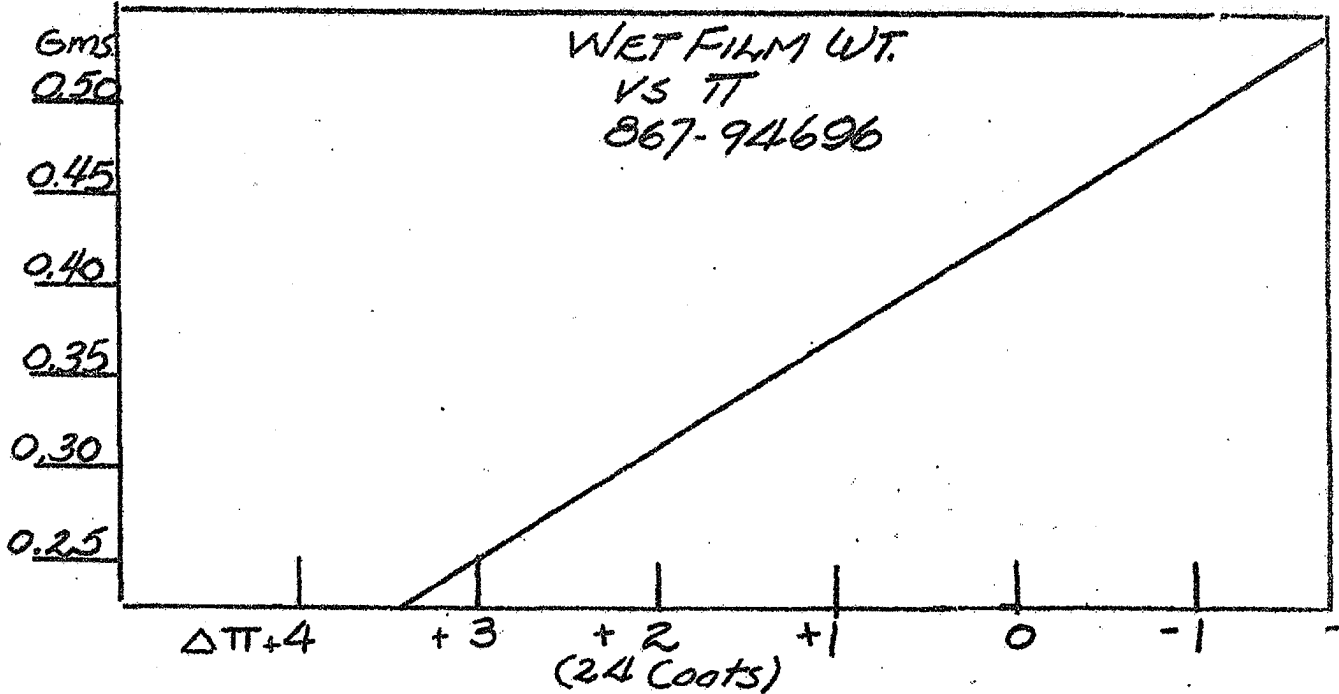
10 O.K. Retains - Sprayed Same Day

867-95183	1.95	1.13	0.75	6.0
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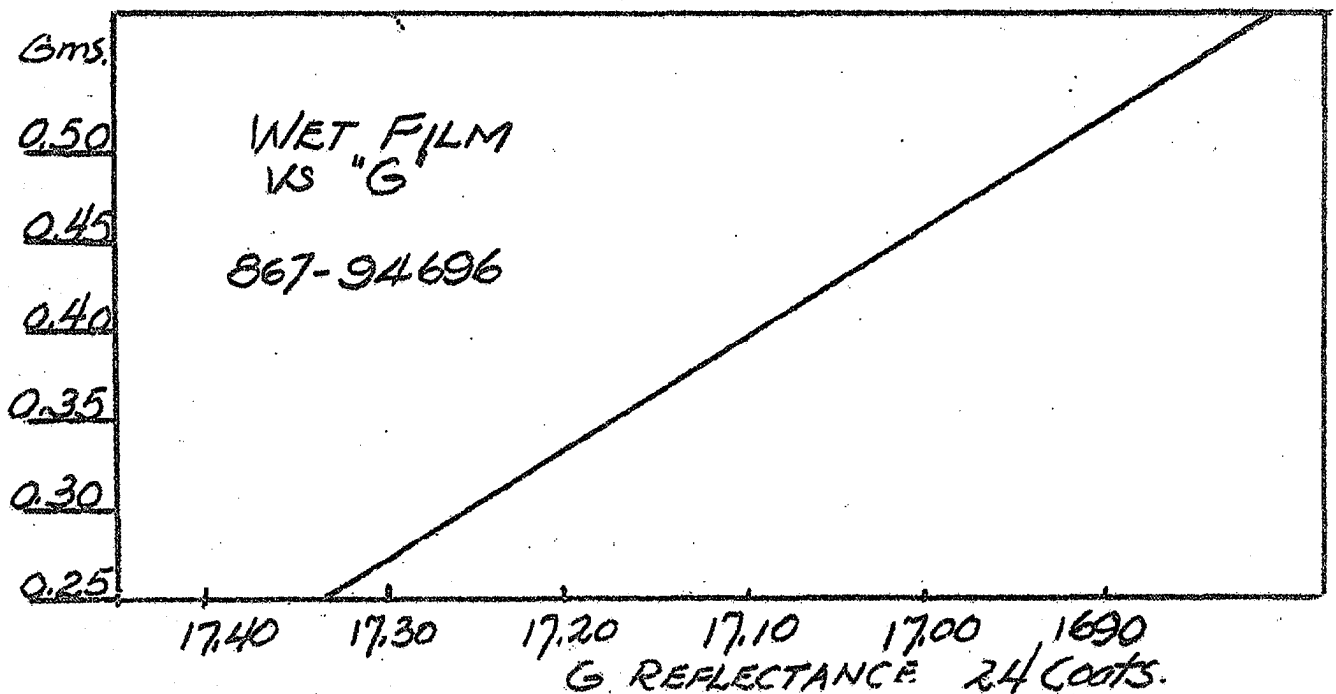
Following the present test memorandum 349-F very closely, it is possible to prepare two panels from the same container with a color difference that exceeds control limits when minor changes in temperature are encountered. See appendage for "Report on 'Lucite'® Metallic Color Panel Preparation."

This color difference is due to different orientation patterns of the aluminum particles in an applied film and is a function of the wetness of the film.

Wet Film wt. 1/4 passes



Wet Film wt. 1/4 passes



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Color and TT decrease in value as wetness increases; therefore, it becomes necessary to maintain a given wet film thickness for the degree of reproducibility required for the I.C.A. program. The wet film thickness changes with the following:

1. Spray Gun
 - a. Cap - Needle - Tip
 - b. Fan Pattern
 - c. Fluid Flow Rate
2. Panel
 - a. Gun to Panel Distance
 - b. Position in Fan Pattern
 - c. Panel Speed
 - d. Temperature
3. Flash Time
4. Temperature of Bake
5. Compressed Air
 - a. Pressure
 - b. Temperature
6. Sample
 - a. Reduction
 - b. Temperature
 - c. Agitation
 - d. Solvent
7. Environment
 - a. Temperature
 - b. Humidity
 - c. Air Flow Rate

The effect of each variable on film wetness was studied to determine its range and type of control that would be necessary to yield color panels with the reproducibility required for I.C.A. program and Automotive color control.

The wide range of temperature and humidity experienced throughout the year is shown in the appendage.

Variables Studied

1. Spray Gun

The spray gun adjustments are mechanical adjustments that do not vary with changes in environment but have a marked effect on the wetness of the film. The method used to control the fan pattern is currently

one of judgement that allows a wide deviation of film wetness. It is proposed that a wet film weight for a fixed set of conditions be the final check on spray gun adjustments to eliminate the judgement measurement.

The following spray gun factors affect film wetness:

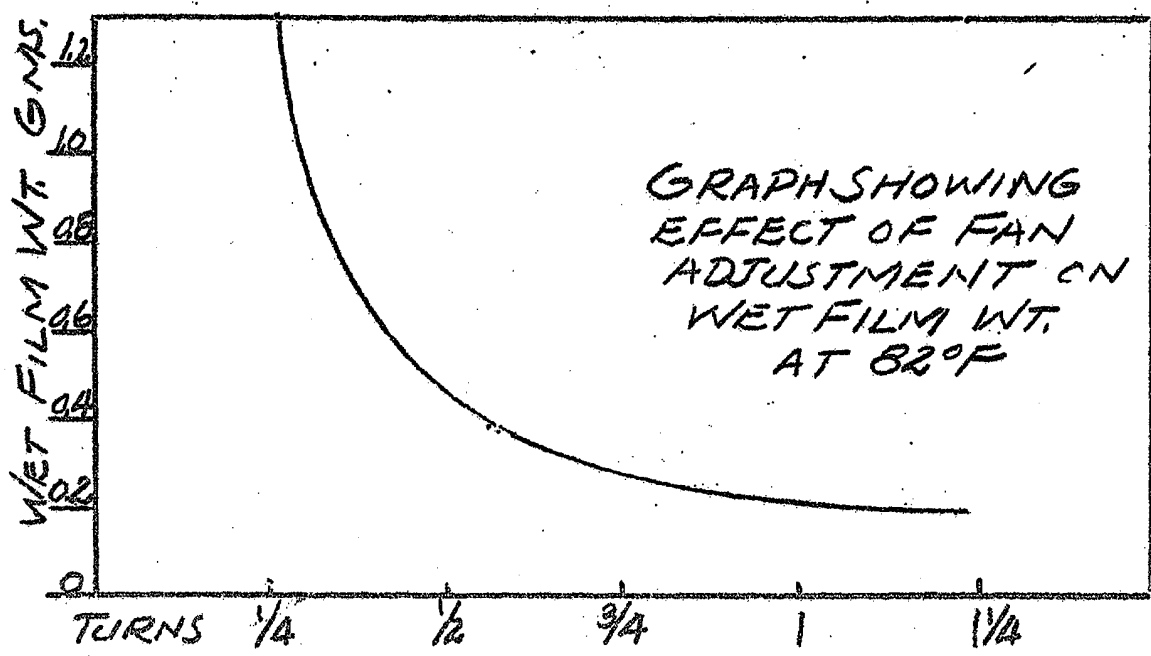
a. Cap - Needle - Tip

The parts numbers are specified and it is only necessary to guard against worn parts. They will cause a fan distortion such as hour glass figure and affect film wetness. If the fan pattern is not elliptical in shape the needle and tip should both be replaced.

b. Fan Pattern

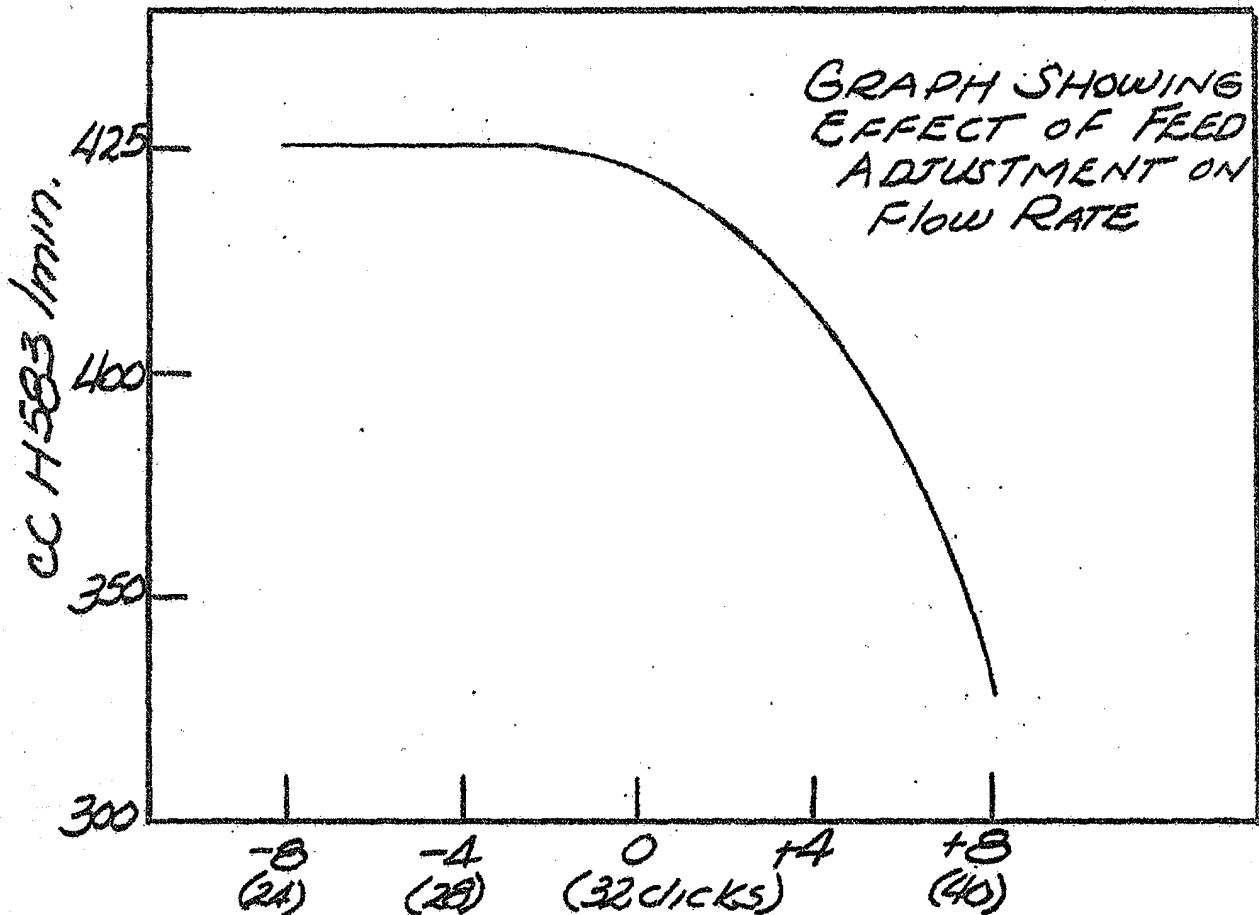
The fan should be adjusted to the recommended 10-1/2" and have a uniform elliptical pattern. The center of the panel should pass through the center of the fan. The fan pattern is not a precise measurement and the 10-1/2" distance on the major axis of ellipse is one of judgement that serves as a guide for the first round of adjustments. After all other spray gun adjustments are set, a final check should be made on the fan pattern by measuring a wet film of 100 cc of standardized 868-0124 reduced with 125 cc of solvent and sprayed for a fixed number of passes. This should be compared to an established standard. (See proposed Test Memorandum) The fan can be adjusted to obtain the established weight and still meet the 10-1/2" pattern.

To keep the fan pattern constant it is essential that the gun be kept thoroughly clean, free of worn parts and adjustments secured.



c. Fluid Flow Rate

The fluid flow rate of the reduced sample is very critical because any variance directly affects the applied film wetness. The fluid flow rate is easy to adjust and can be controlled closely by adjusting the feed to flow 100 cc of H-583 in 14 seconds. This should be checked each day. The effect of flow adjustments on flow rate is shown below.



2. Panel

a. Gun to Panel Distance

The distance from the gun to the panel is 11" and should be checked daily. A change in distance has a direct effect on the applied film wetness or weight due to the change in concentration per unit area in a cross-section of the fan. The applied film is wetter as the distance decreases and drier as it increases.

	10-1/2	11-1/2
ΔL	0	0.7
Δa	0	0.08
Δb	0	0.17
ΔTT	0	2.3

b. Position in Fan Pattern

The panel should be set on the panel holder so that it passes through the center of the fan. The gun position should be checked daily so that the center line of the gun is always in the same position. A measurement can be made from the gun cap to some fixed point as a means of control.

c. Panel Speed

The panel speed control is adequate as no change in color and TT was observed by changing the speed $\pm 100'$ per minute if length of travel is constant. The panel should pass equal distances on each side of the center line of the fan.

When two panels are being prepared, the right-hand panel will differ slightly from the left-hand panel. This is due to differences in flash time between passes. Therefore, it is good practice to always select the panel from the same side if two are prepared at the same time. For best reproducibility only one panel should be prepared.

	<u>Left</u>	<u>Right</u>
ΔL	0	+ 0.14
Δa	0	- 0.11
Δb	0	- 0.10
ΔTT	0	+ 0.5

d. Temperature

A small heat exchanger was used as a panel holder and temperature varied from 75° to 180°F. At high temperatures the panels were flooded due to reduced viscosity of the film. The film is thermoplastic and there is internal flow at high temperature.

Controlling the temperature at a constant 78°F increased the reproducibility. At 90° there was a slight orange peel.

The heat exchanger was not studied further although it affected the rate of dry of the applied film because at the desirable high temperature the film was adversely affected. The C.E.S. panels maintain a constant temperature of 120°F.

3. Flash Time

The flash time had no effect on the color after panels flashed 10 minutes. The proposed C.E.S. eliminates the flash.

4. Temperature of Bake

The temperature of the bake is not critical for color as the comparison of two bakes 40°F apart is not very large.

	<u>120°</u>	<u>160°</u>
ΔL	0	- 0.25
Δa	0	+ 0.32
Δb	0	- 0.10
ΔTT	0	1.0

The length of bake in excess of 20 minutes had no effect on the color or TT.

5. Compressed Air

a. Pressure

A difference of 2#/sq.in. has very little effect on color. A change from 55#/sq.in. to 50#/sq.in. has the following effect on color.

	<u>50#/sq.in.</u>	<u>55#/sq.in.</u>
ΔL	0	+ 0.44
Δa	0	- 0.15
Δb	0	- 0.01
ΔTT	0	+ 1.5

The air pressure is usually consistent but a simple alarm device could be put on the line ahead of the transformer if wide fluctuations are common.

b. Temperature

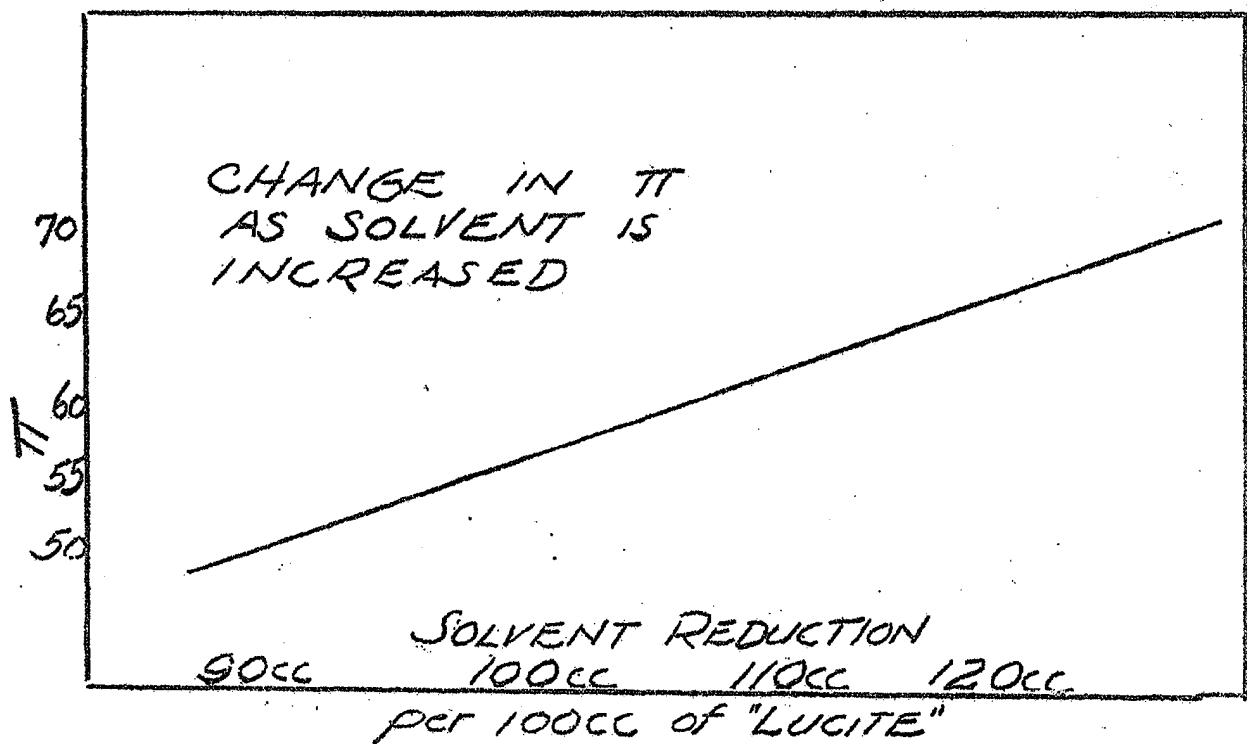
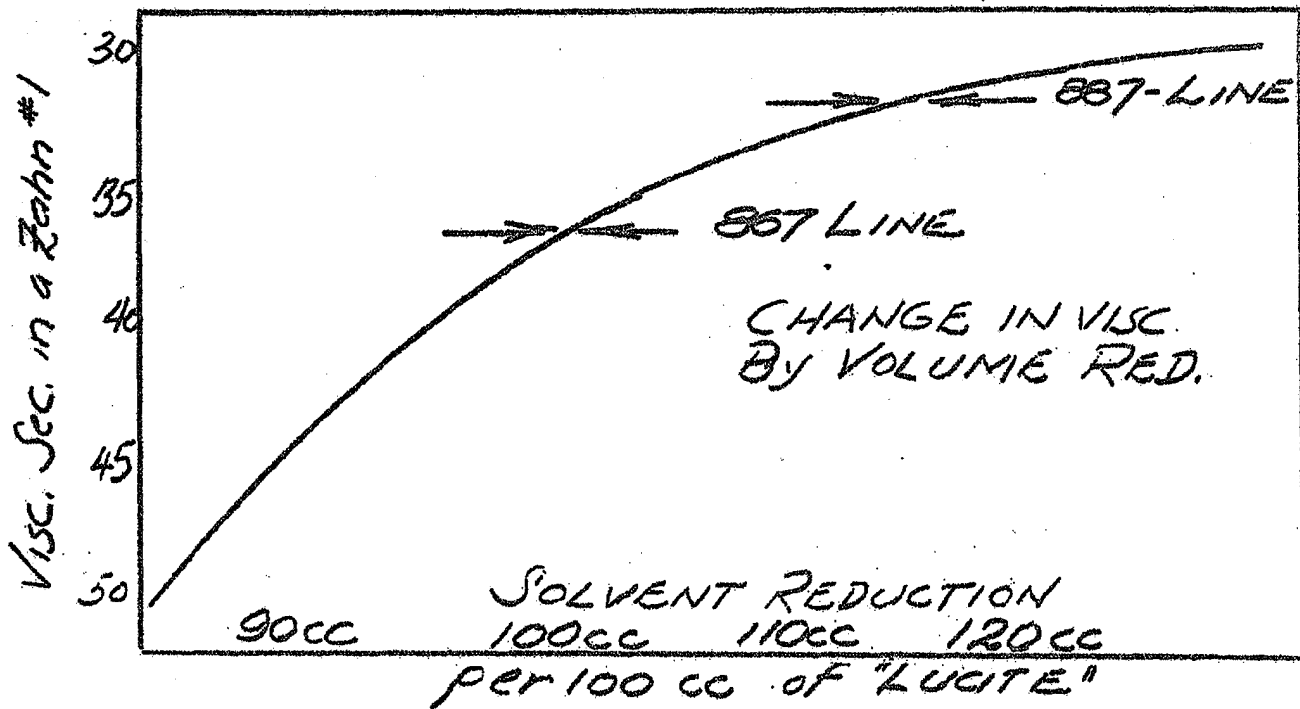
The temperature of the compressed air has a minor effect on the wetness but no change in color was noted when the compressed air temperature was held between 75°F and 95°F. Temperatures in excess of these values should be corrected by installing a large surge tank in the spray room.

6. Sample

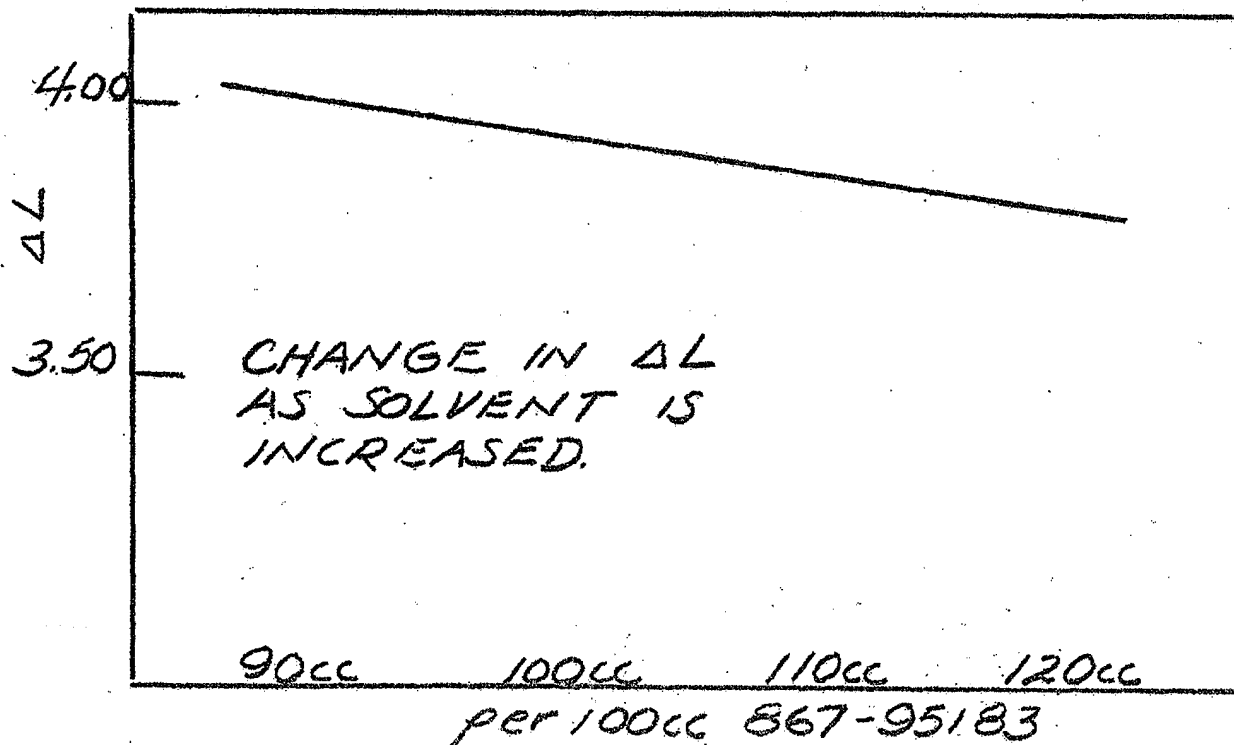
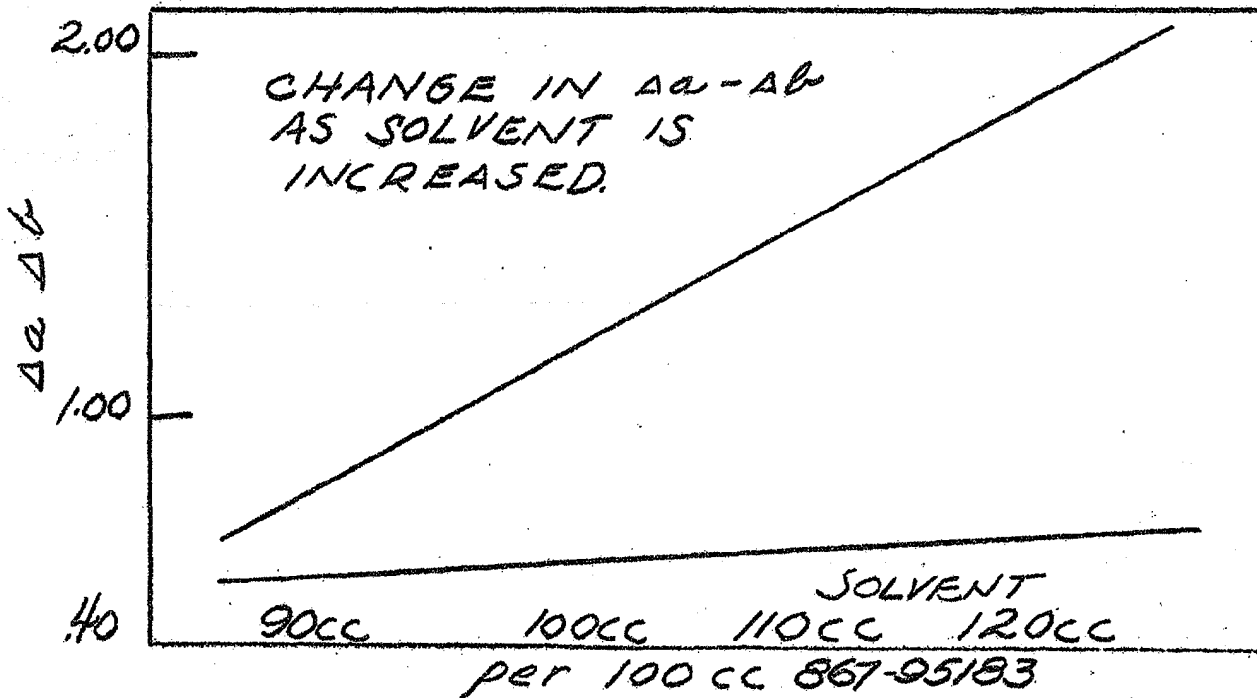
a. Reduction

The 867 line is reduced to a specific viscosity with a range of two seconds. The resolution of the test is 2 seconds at 25°C. The temperature is not measured when testing viscosity and ranges from 22°C to 28°C which results in a viscosity change of two seconds. The total range for the test is 4 seconds which would mean a 30% difference in the amount of solvent used for reduction. The effect of changes in the amount of reduction solvent is shown on the following pages.

15A



15 B



Reduction for 100 cc 867-95183

	<u>100 cc Solvent</u>	<u>130 cc Solvent</u>
ΔL	0	- 0.15
Δa	0	+ 0.85
Δb	0	+ 0.08
ΔTT	0	+ 13.0

It was found that a fixed amount of solvent for reduction gave significantly more reproducible results and the small difference in viscosity had no effect on the flow through the gun or on the panel viscosity.

The following table shows that the viscosity of the material before reduction has very little effect on the reduced viscosity.

867-95183
Viscosity

M-8 Equal Parts M-47/E-79

<u>Serial</u>	<u>Init. Visc. Parlin 10 cup</u>	<u>Visc. Before Reduction Parlin 10 cup</u>	<u>100 cc 867 110 cc Solvent M-8</u>
18157	5/15 43 sec.	5/24 60 sec.	41.5
18156	5/15 51 "	5/24 69 "	41.5
17783	5/16 41 "	5/24 46 "	41.2

b. Temperature

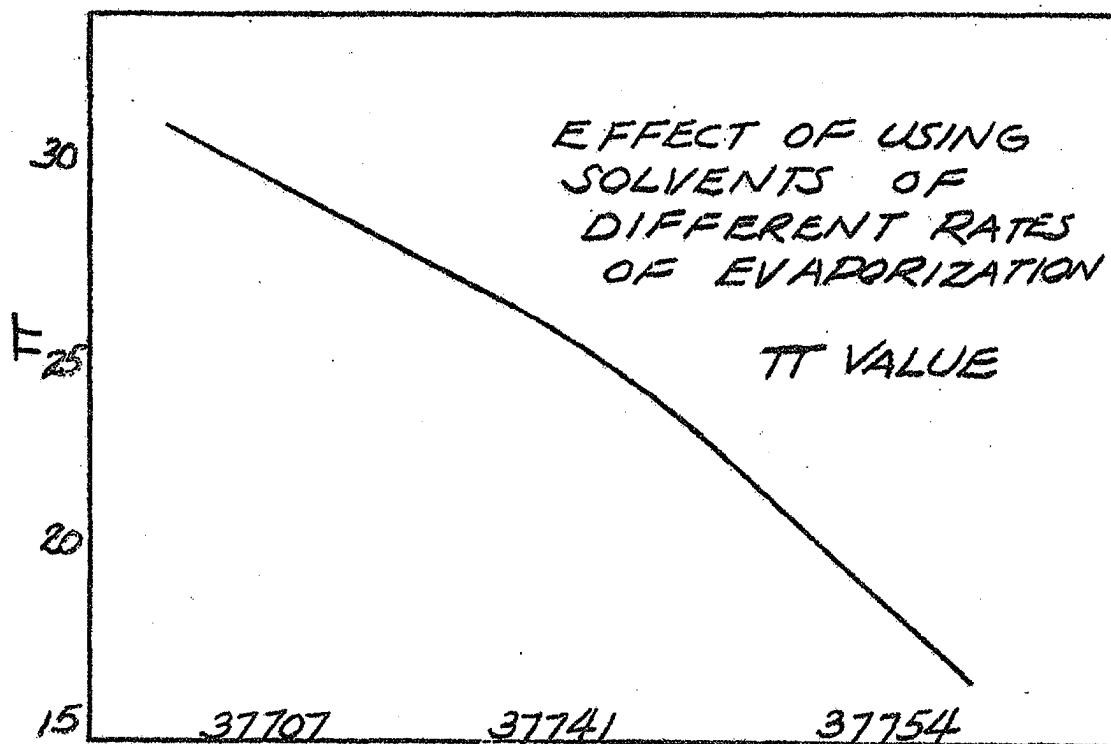
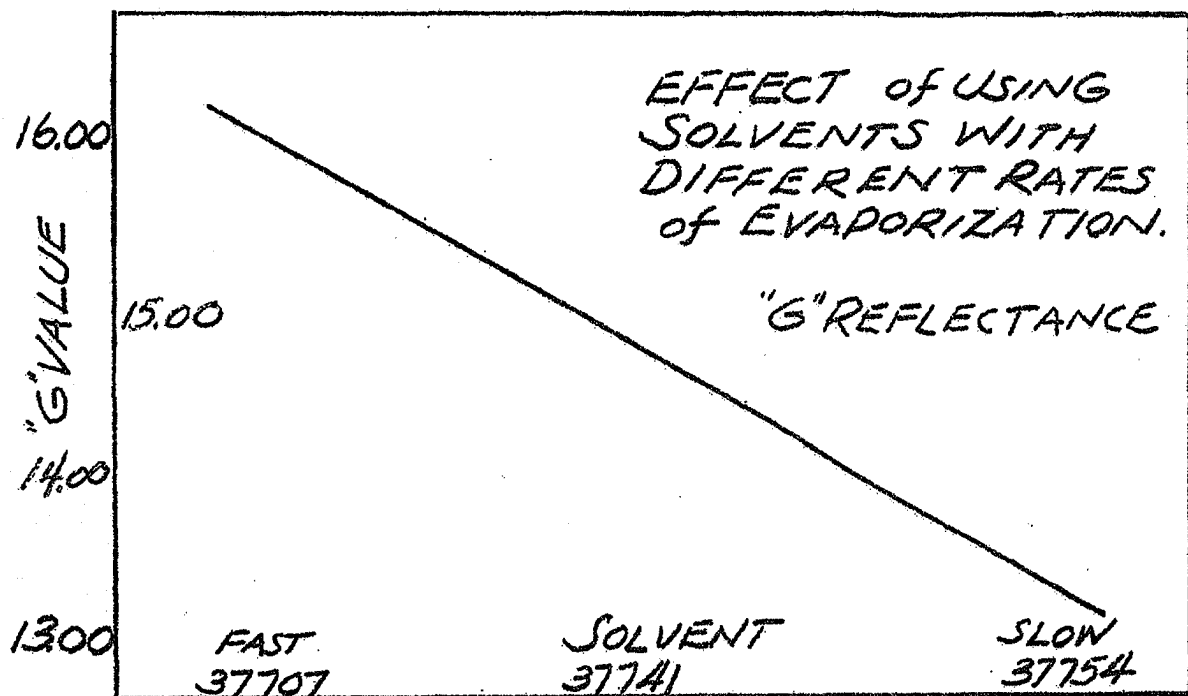
The temperature of the reduced material should be held between 75°F and 85°F as extreme temperatures will affect color.

c. Agitation

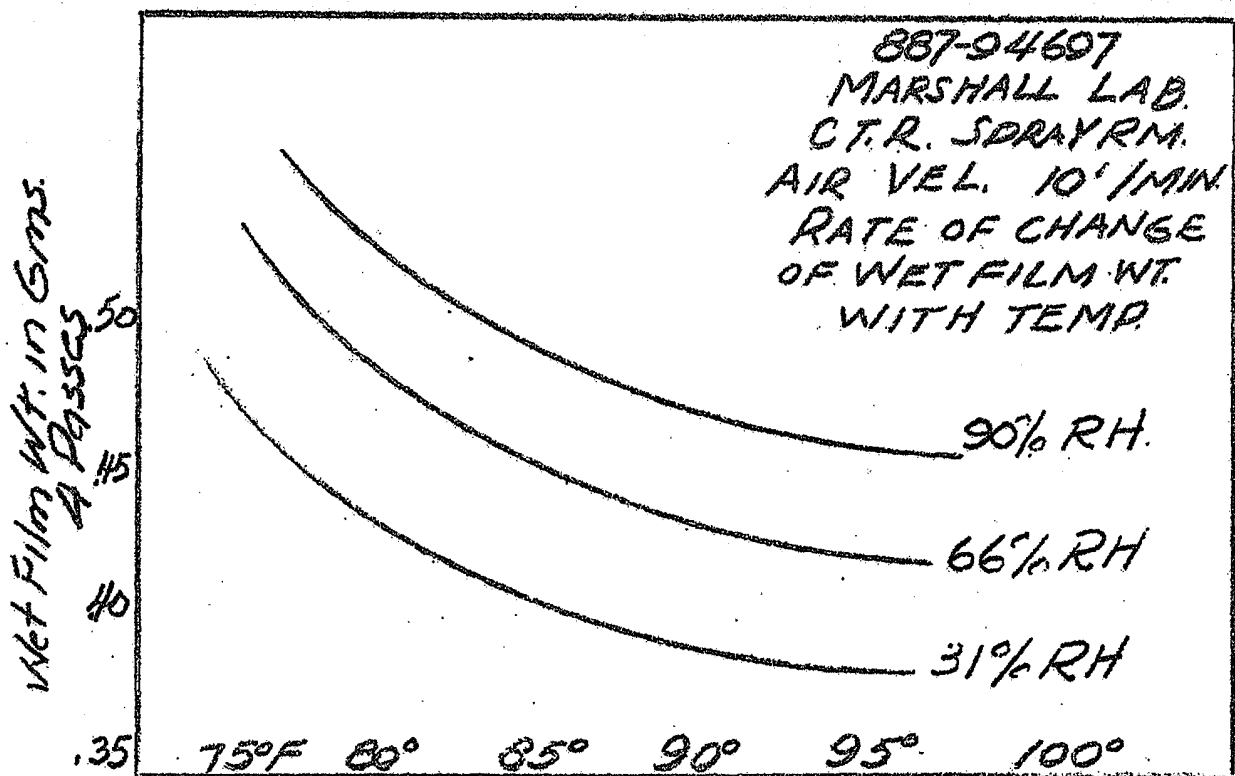
In the study, it was also found that the sample increased considerably in viscosity due to loss by evaporation when the agitator was used and the booth air velocity was 300 ft./min. If possible, a closed cap system should be used and no agitator. There has been no difference observed in agitated and non-agitated reduced samples in our studies ("Lucite"* only).

d. Solvent

The rate of evaporation of a solvent in combination with an 867 line is one of the most important factors in the film wetness.

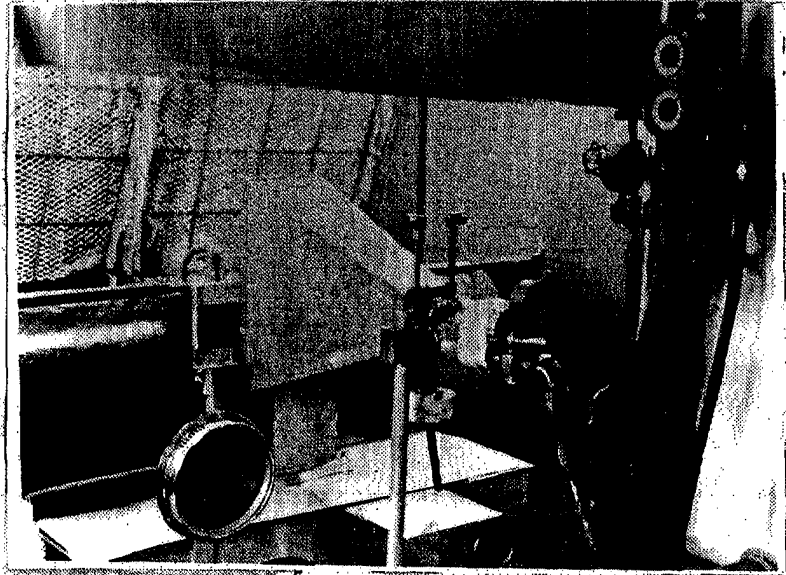


To maintain constant film wetness for consistent color the solvent loss between the gun and the panel must be constant. The loss of solvent from an 867 line product let down with 37767 is 25% from the gun to the panel at 80°F. The loss varies with temperature and humidity as shown on the chart below. Change in film weight or wetness causes changes in TT and color.



The fan approaches the temperature of the surrounding air at a distance of 3 to 4 inches from the gun. At the gun tip the temperature is 10 to 15°F lower. To overcome this problem an attempt was made to set up a method of controlling the temperature and humidity of the air surrounding and affecting the rate of solvent loss around the fan. The funnel or horn-shaped

device as shown was tried but failed as the booth air flowed back into the fan due to air currents created by the fan. An attempt was also made to supply controlled air to the funnel near the gun but this also failed to stop the air currents flowing back into the mouth of the funnel.

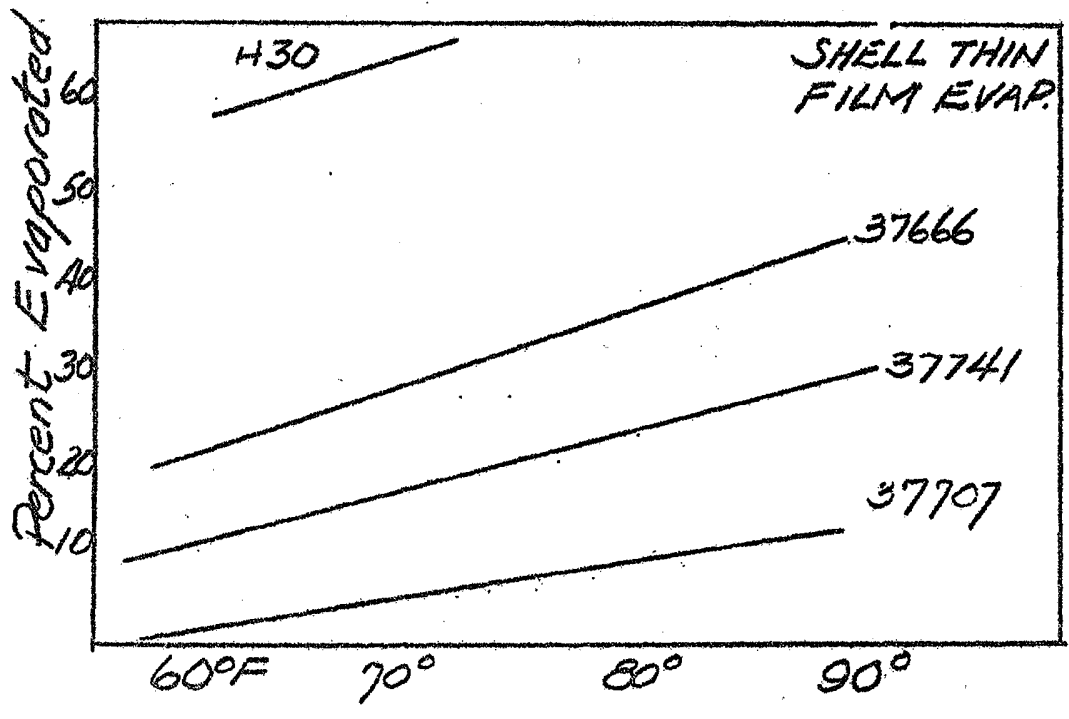
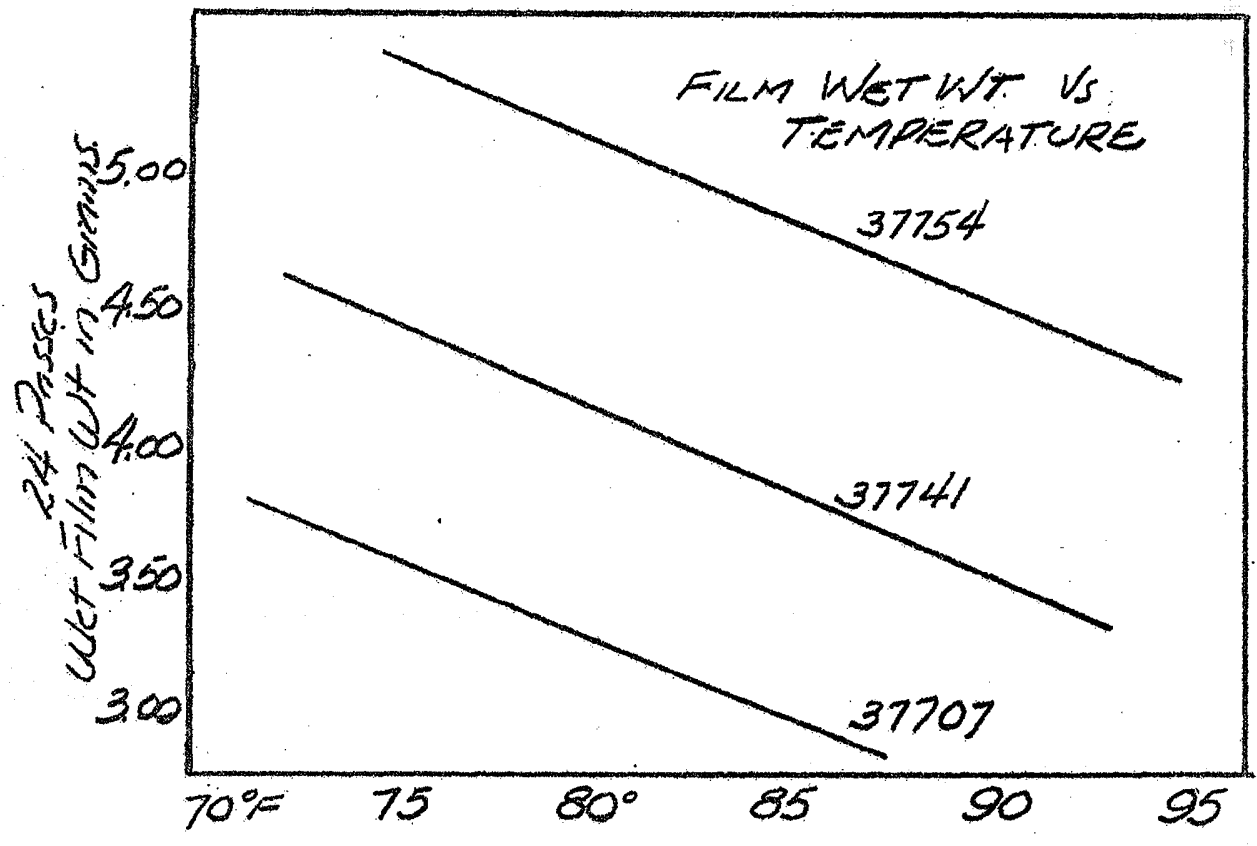


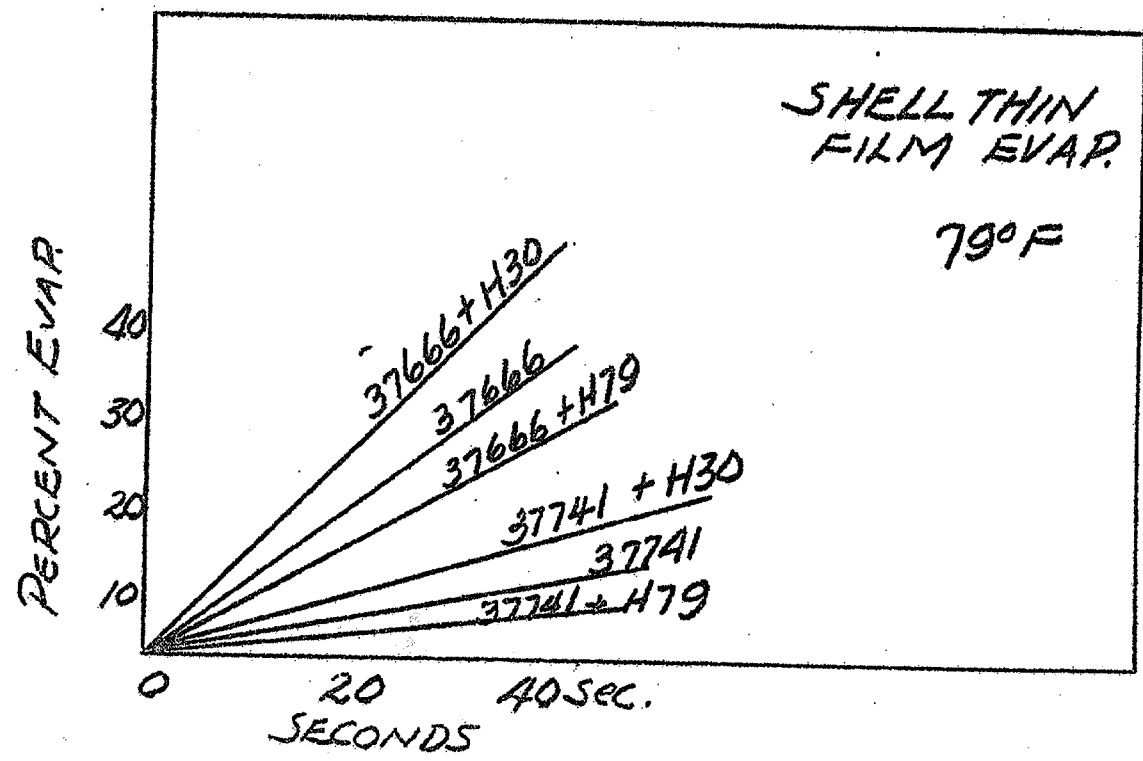
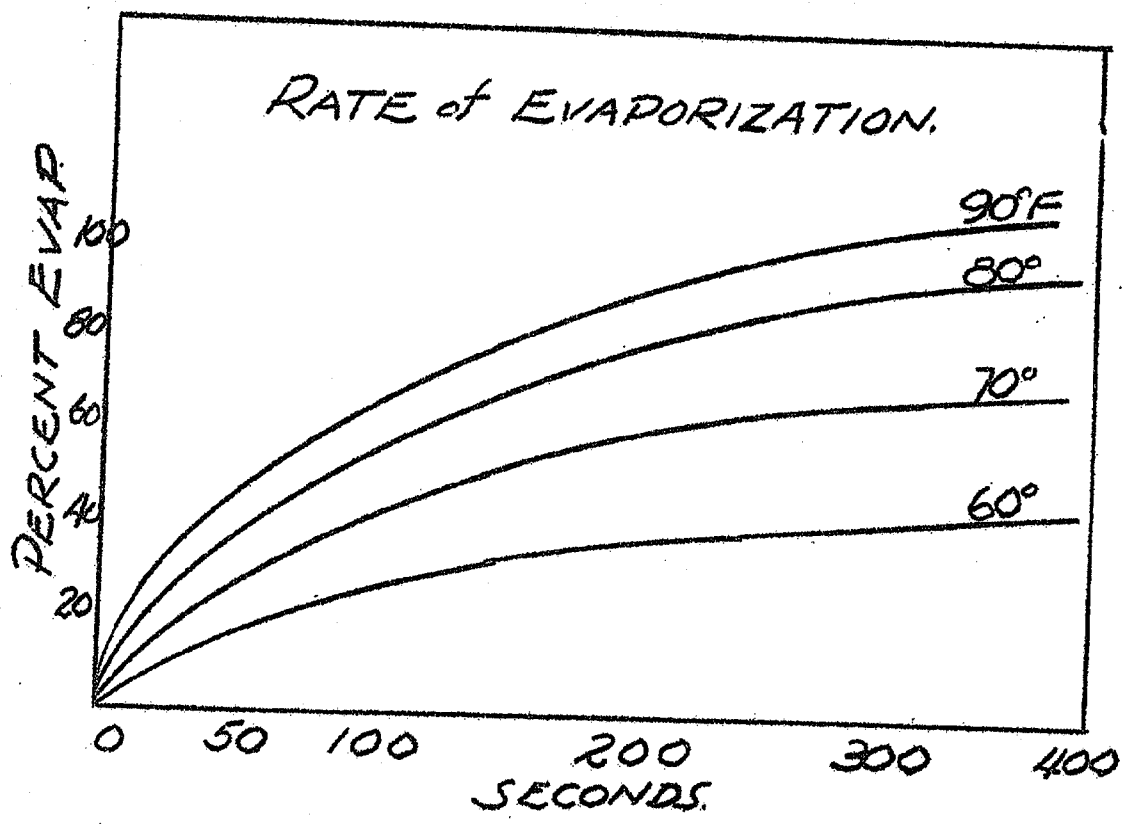
This should be further explored as it is the minimum investment to control the loss of solvent between the gun and the panel for maximum reproducibility. It may be possible to shield the fan from the surrounding air by a fin and coil arrangement that had a constant temperature. This would be based on the assumption that high humidity would not be a problem.

The loss between the gun and panel can be reduced to a minimum which no longer affects color by selecting suitable solvents for ranges of temperature and humidity. (See Chart - Page 20.)

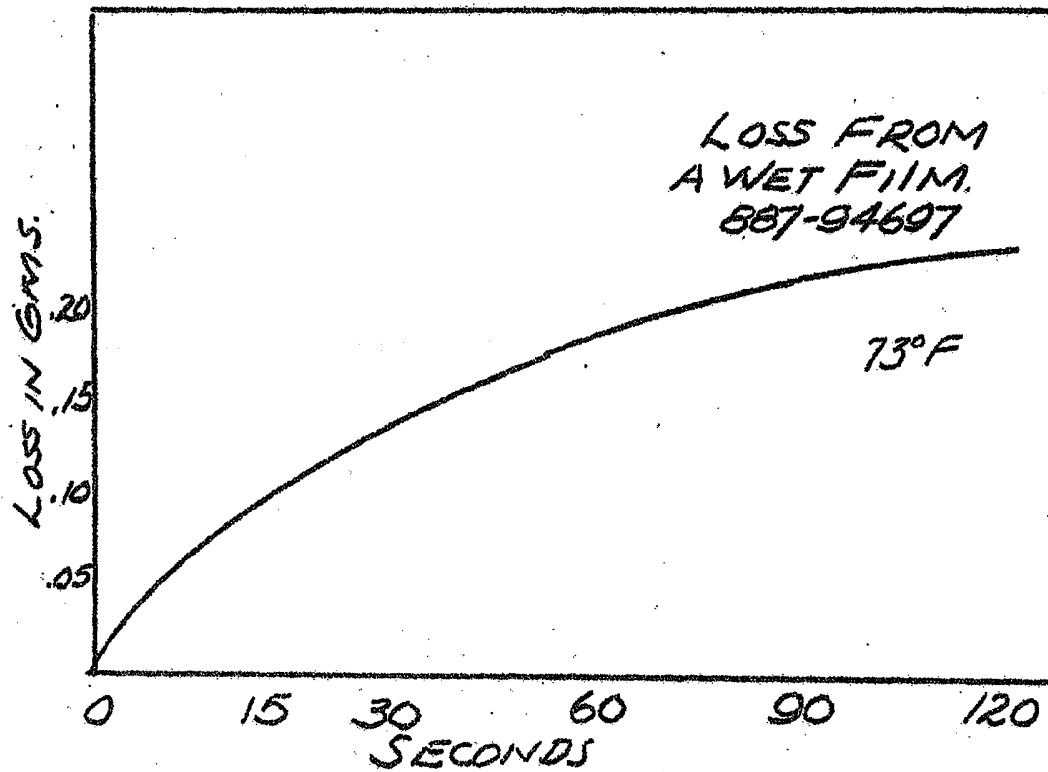
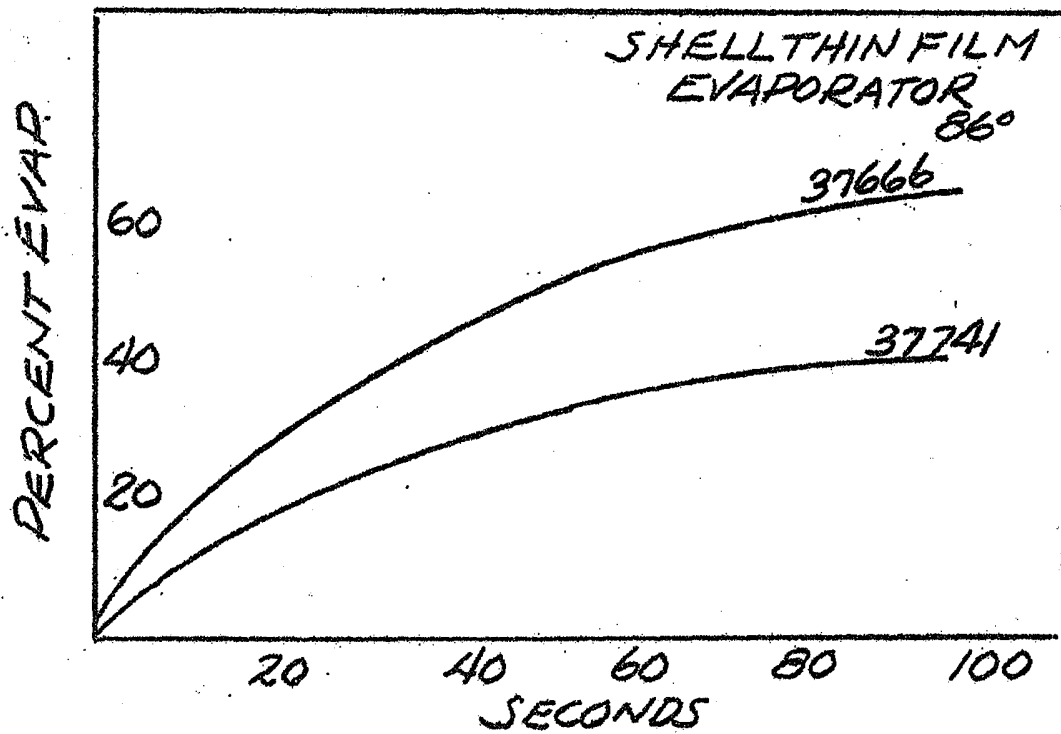
It was found that if the film wetness remained constant no change in color developed regardless of the solvent used to maintain the constant film characteristics under wide changes in environment.

An attempt was made to use the Shell Thin Film Evaporator to develop data for use in adjusting solvent structure to correct film wetness that changed due to temperature and humidity. There was no correlation between the Thin Film Evaporator results and applied film wetness. The loss of solvent in combination with "Lucite"® and the high degree of atomization had no relation to the solvent evaporating rates obtained by the Shell Thin Film Evaporator. The data shown are for reference use only.





21A



7. Environment

a. Temperature

The rate of solvent loss from the applied film on the panel is a function of the environment and temperature is the most critical element. To control the rate of dry it is necessary to maintain the temperature of the environment surrounding the applied film of the panel while it is flashing. It was found that the most reproducible results were obtained by maintaining a temperature in excess of any spray room temperature. 120°F was selected and found to be easy to maintain regardless of room temperature. With the controlled environment at 120°F for the flash period, a uniform metallic pattern was obtained as the aluminum particles orient under a standard rate of dry.

b. Humidity

The relative humidity is very critical at temperatures below 80°F if it increases above 30%. As the temperature rises, higher relative humidity can be tolerated and does not affect the wetness of the film. The relative humidity will affect the wetness of the applied film if it drops below 15% as the temperature rises over 85°F.

There appears to be a wide tolerance of relative humidity as it changes with temperature. In most situations the temperature and relative humidity increase or decrease in the same direction and prevent extreme conditions in the environment. It is impossible to outline the "comfort zone" for constant solvent evaporation with the equipment now available in the F. & P. Division and extremely costly to control a narrow "comfort zone." It is possible to avoid most of the effect of changes in relative humidity by maintaining the spray room at 80°F minimum as most high temperatures are accompanied with higher relative humidities.

c. Air Flow Rate

Temperature and relative humidity become more critical as the air flow rate increases. There is no advantage to maintaining air flow rates in excess of that required to remove the overspray. The present rate of 300 feet/minute is difficult to maintain and 150 feet/minute was found to be adequate for spray dust removal and easier to maintain at a constant rate. At the lower rate the film wetness varies less under temperature and relative humidity changes so panels are more uniform in color and TT.

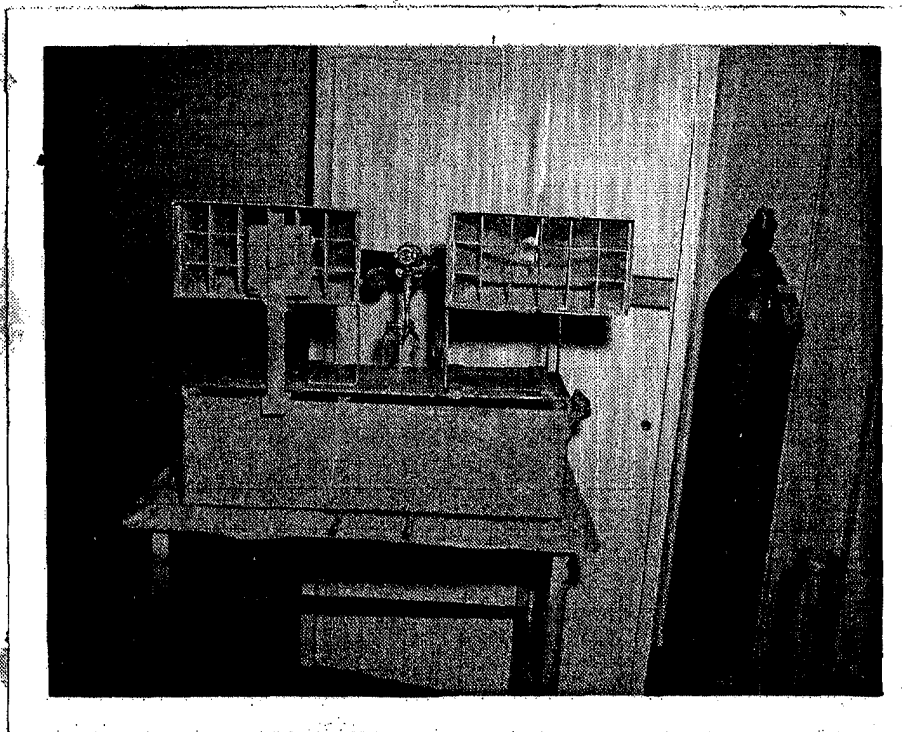
If the film wetness or wet film weight can be controlled within $\pm 5\%$ and rate of dry held constant, excellent reproducibility can be obtained.

Wet film weight can be maintained by:

- (1) Complete air-conditioning with a range of 5° and 20% relative humidity.
- (2) Changing solvents so the rate of vaporization is constant under a range of temperature and humidity.
- (3) Use a slow evaporating solvent free of H-30 to minimize difference in loss in combination with a controlled environment for the flash period. (Details discussed at end.)
- (4) Remove the H-30 from the formulas and substitute a slower evaporating solvent to use with controlled environment system.
- (5) Use a combination of two proposals.

C. Details of Controlled Environment System

The C.E.S. was developed late in 1961 as a means of avoiding the wide fluctuations in temperature and humidity experienced at Philadelphia Process Engineering when spraying "Lucite"® metallic panels.



The purpose of the C.E.S. is to control the environment of the applied film of a panel so its rate of dry is constant. The constant rate of dry allows the aluminum particles of a constant wet film to orient in a uniform manner so reproducibility of color and TT is at a maximum. The system operates at 120° which is easy to maintain by heating the spray room air. Raising the temperature avoids high humidity which reduces the reproducibility. No attempt was made to control the humidity as its effect in this range of temperature did not adversely affect reproducibility.

1. The Controlled Environment System operates at 120° for controlled flash temperature.
2. Uses a slow evaporating solvent H-79/H-47 equal parts. Minimum loss over range of room temperature.
3. Fixed velocity 150°/min. Easy to control.
4. Fixed reduction - 100 cc material
110 cc solvent
5. Filtered air gives cleaner panels.
6. No flash time before bake.
7. Six-pass system 1-1/2 min. flash for 24 coats.
8. System minimizes variance in color but does not eliminate it.
9. For maximum control air temperature of fan must be controlled.
10. Panels show a very light orange peel and are higher in TT than regular standards.
11. Limits of reproducibility over a range of 80° to 95°F.

ΔL	$\pm$	0.10
Δa	$\pm$	0.30
Δb	$\pm$	0.10
ΔTT	$\pm$	2.0

D. Future Studies

1. Air-less Spray

The air-less spray would decrease the variance but would not eliminate it as some solvent is required to reduce viscosity. The unit is impractical for panel preparation due to cleanup time required. Panels prepared had a good appearance and if a simple unit can be designed it may prove useful.

2. Steam Spray

This system appears to have a very good potential as it would be completely independent of temperature and humidity as all of the faster solvents would be evaporated. If used in conjunction with the C.E.S., a very high degree of reproducibility should result.

The panels appear darker and in the direction of the film obtained on the automotive production line.

Further work is planned to determine the feasibility of a steam system and its reproducibility.

E. Appendage

1. Test Memorandum
2. Report on Preparation of "Lucite"* Metallic Color Panels
3. Temperature-Humidity Plant Reports

Page 1
4/13/62

**SPRAY TECHNIQUE & PANEL
PREPARATION - SPARGER SYSTEM
"LUCITE" - ACRYLIC LACQUER**

PURPOSE - To provide a detailed procedure for preparing "Lucite" Acrylic Lacquer color panel in the most reproducible manner.

PRINCIPLE - The method consists of preparing panels under closely controlled air temperature and velocity. The temperature of the air in the C.E.S.* is normally above the temperature of the spray room, in order to reduce or eliminate the effect of fluctuations in room air environment.

* Controlled Environment System (Sparger System)

STATUS - This is a proposed control method and has been used extensively for Instrumental Color work at Flint. It has been evaluated for reproducibility over a wide range of temperature. It is the most reproducible method of preparing "Lucite" metallic panels at the present time.

SPECIAL APPARATUS AND EQUIPMENT

1. 4" x 6" aluminum panels undercoated with 881-94027,
Gray M. G. Sealer, reduced with 37767

100 cc 881-94027
125 cc 37767

Apply one double coat and air-dry minimum of five minutes.

2. Common sense strainer or 100-mesh screen.
3. Environment Control

See drawings PM-13119
PM-13120

Blueprints may be obtained from Process Engineering,
Philadelphia Plant.

4. Spray Gun

- a. Machine Spray - De Vilbiss AGA 502 with AV-15-E tip (Order AV-601-E Tip and gasket which includes the AV-Tip, AGA 404-E-Needle and 30 Cap. (Refer De Vilbiss Parts List 1820-A.)
- b. Guns should be inspected monthly for worn parts. The gun should be completely overhauled and new parts installed where necessary.
- c. Fluid Stem - 3/8" inside diameter.

5. Air gauge on gun - De Vilbiss H-6054, 0-100 pounds.
6. Air valve on gun - equipped with positive open and close.
7. Thinner H-8 (H-47/H-79 equal parts).
8. Oven ($260^{\circ}\text{F} \pm 4^{\circ}\text{F}$).
9. If necessary to clean panels, use VZ-1204. Do not oil or use rubbing compound.
10. Daylight lamp (TM-350).
11. Horizon Lamp.
12. Test Panel Reciprocating Unit.
 - a. Eclipse
 - b. 2 - GA-85 Gears for a 1-1 Ratio
 - c. 18-inch stroke
 - d. Panel speed - 822 inches/minute $\pm$ 25 inches/minute.
13. Spray booth lineal velocity of 150 feet/min. $\pm$ 25 feet/min. minimum.
14. Spray room maintained at a minimum temperature of 80°F .

DETAILED PROCEDURE

1. Standardizing Spray Gun
 - a. Adjust the air regulator to give an air pressure of 55#/sq.in. $\pm$ 2#/sq.in. at the gun with trigger wide open. Compressed air temperature should be between 75°F and 90°F .
 - b. Set the gun so that the ear of the cap is 11" from the panel. The center line of the gun should be perpendicular to the panel and in line with the center of the panel.

After gun is set, measure distance from ear of cap to top of Panel Reciprocating Unit and record so it can be checked daily.
 - c. Adjust the fluid flow to a rate of 100 cc of H-583/14 seconds.
 - d. Adjust fan to form a uniform 10-1/2" pattern.

- e. The above adjustments are a guide and should be checked by spraying six passes of standardized 868-0124 white base reduced with M-8 solvent at a ratio of 100 cc of 0124 to 125 cc of M-8.* The panel should be prepared with the spargers operating at 120°F. The wet film is the most critical property of a color panel and must be very closely controlled for wet film weight. The wet film of six continuous passes should weigh 0.62 grams $\pm$.03. The wet film weight can be changed by adjusting the feed or fan and some judgement is required to make adjustments so the feed rate and fan are as close to specification as possible. Minor adjustments are best made with the feed. The fan is limited by the formation of an hour glass figure or non-uniformity from top to bottom.
- f. After changing any one adjustment on the gun, all adjustments should be rechecked until all are in balance.

If unable to adjust gun to give the specified film weight, it will be necessary to change solvent reduction under extreme conditions by increasing the % of H-79.

As a final check, spray a panel of 867 line and check dry film build. It should be 2.0 mils to 2.2 mils.

Check wet film weight once per day.

Check feed rate and panel distance once per day.

Check fan pattern once per week.

STANDARDIZING CONTROLLED ENVIRONMENT SYSTEM

1. The C.E.S. should be placed so that panel travels 1/2" from the face of the spargers.
2. The temperature should be set at 120°F to obtain a temperature of 120°F at the panel. This can be measured by attaching a thermometer to the panel and completing a spray cycle. Adjust air temperature if necessary to get 120°F at the panel.
3. The average air flow over the face of the spargers should be 150 feet/minute. This setting should be made with a clean filter on the blower and the filter should be cleaned weekly to maintain uniform air flow. The dampers should be locked in place after adjusting for specified air flow.

* equal parts H-47/H-79

SPRAYING OF PANELS

1. Use undercoated panels with one end of the reverse side marked "Top."
2. Set panel in holder at 90° angle to center line of spray gun and so it passes in front of spargers at equal distances from top and bottom edges of spargers. The panels should be set in the same position at all times.
3. Spray as follows:
 - a. Reduce 100 cc of material with 110 cc of equal parts of H-47 and H-79. Avoid hot or cold solvent and material. Reduced sample should be between 75°F and 85°F.
 - b. Spray six single coats.
 - c. Flash 1-1/2 minutes with panel in holder passing behind spargers.
 - d. Repeat for number of required coats specified on formula.
 - e. Place in oven immediately and bake 20 minutes at 260°F.
 - f. Examine for color. See TM.....

CALCULATIONS

None

PRECAUTIONS

It is important that daily checks be made of all apparatus.

EXPERIMENTAL ERROR OF TEST

The equipment has been used for the I.C.A. commercialization program at Flint with the following results:

At one set of conditions:

	<u>Resolution</u>
ΔL	0.10
Δa	0.15
Δb	0.10
ΔTT	2

Range of Temperature and Humidity:

76°F - 20% R.H. to 95°F - 50% R.H.

Resolution

ΔL	0.20
Δa	0.50
Δb	0.20
ΔTt	4.0

This variance is less than the variance found in new standards and O.K. color panels.

DATE ISSUED

April 24, 1962.

SUPERSEDING

TM-349-F - 9/12/60.

REASON FOR REVISION

To use the sparger system of preparing color panels.

E. A. MILLER

EAM:IL

CC: C. F. KALE - WILMINGTON
H. R. STINE - FLINT
C. W. STAHL - "
R. W. ANDERSON - "
R. H. VINING - PHILA.

Philadelphia Plant
June 18, 1962.

W. H. EDWARDS

**COLORIMETER-CHART COLOR ADJUSTMENT SYSTEM (P-57)
REPORT ON PREPARATION OF "LUCITE"* METALLIC COLOR PANELS
PROCESS ENGINEERING**

In the preparation of "Lucite"* metallic color panels, it has been found that the present 867 Line is extremely sensitive to any change in drying conditions or in the wetness of the applied film. The film wetness is a function of many variables which can be controlled but the most important variable is the room temperature which cannot be controlled for the desired reproducibility. The high percentage of H-30, Acetone, in the material reduced for spray application and the high percentage in the reducing solvent result in wide variations in film wetness and color variation due to varying losses caused by changes in temperature. The present problem of reproducibility is that the variation in color due to environment changes exceeds the limit of variation required for production color control. Although the specifications of the present TM-349-F are followed, the color variation is excessive. This is a problem in production control and preparation of standards.

There are two solutions. One is to rewrite the T.M. with much narrower limits and the other is to adopt another method of preparing panels that allows a wider variation of ambient conditions. The details of each are outlined in this report.

There are certain basic concepts of a color control standard that must be adopted for 867 Line color control due to the fact that minor environment changes affect the color. The color standard can only be a standard for one set of conditions; therefore, the standard color panel, to have a true standard value, must show the following:

1. Temperature of the air
2. Velocity of the air at the panel
3. Relative humidity of the air
4. Film thickness or film weight
5. Solvent reduction
6. Wet film weight for a given number of passes

If these are known and can be reproduced within narrow limits and the following are in line with the test memorandum, excellent reproducibility should result:

(*) Du Pont Registered Trademark

7. Fluid flow
8. Panel distance
9. Fan pattern
10. Panel speed
11. Gun, cap, needle, and head
12. Number of passes
13. Flash time
14. Oven temperature for bake
15. Length of bake
16. Air pressure

The limits of the first three variables for the present method of preparing panels are not known but they appear to be very narrow. The best "guesstimate" is as follows:

1. Temperature of air $82^{\circ}\text{F} \pm 2^{\circ}$
2. Velocity of air 300 ft. per minute $\pm$ 50 ft. per minute
3. Humidity 30% $\pm$ 10%

These extremely narrow limits would require a very costly installation to accomplish the necessary control.

A second basic concept to be adopted to avoid the above costly installation is that a production control system need not use panels that match the customers' production line applications. Two customers using the same material will not apply it under the same conditions and will obtain different colors; therefore, the most important factor is to give them uniform material. This can be accomplished by using the best method available for color control although the color of the control panels will be different than the color obtained by the customer. If this is objectionable to Sales, it may be necessary to prepare a second set of panels for customer usage under conditions similar to those used in his plant. The same material would be used to prepare both control panels and customer standards but each would have a separate set of conditions on the back.

If a new control system could be adopted, it would overcome the present problem as panels now prepared for standards are held very close for film appearance. To obtain this film appearance, it is necessary to prepare panels on the wet side which is an area where reproducibility is very difficult and any slight change in environment brings about a change in color. Although these panels are prepared within the limits of the test method, they cannot be matched at higher temperatures without using a retarder.

It is proposed that the sparger or controlled environment system be adopted that produces panels that are on the dry side with a very slight orange peel that is only perceptible at specific angles and is much more reproducible over a wider range of conditions. These panels would not match the color obtained by the customer but the system would give us a wider range of reproducibility at a minimum cost. It is estimated that the cost per booth would be \$600 to \$800. It should be recognized that there will still be some minor color variance due to changes in room temperature. This temperature change affects the percent of H-30 lost between the gun and the panel which gives various degrees of film wetness. This variance could be reduced by increasing the percentage of H-79 for higher room temperatures.

To adopt this system, it would be necessary to have standards prepared with the same film characteristic in order to have maximum control to a given standard. This would require a complete revision of the present method of preparing standards and would also require all "Lucite" producing plants to have controlled environment equipment to use the new standards.

An alternate method would be to establish a master standard on the controlled environment system and use it as a guide to prepare standards with the present equipment. This could be accomplished by changing the ambient air in the spray booth or changing solvent used for reduction. The easiest way to accomplish this would be when new standards are prepared for a model year. The 1963 standards have been prepared but 1964 standards could be a realistic goal.

If the system warranted immediate installation for 1963 colors, it may be possible to use present standards with a minor off-set. A study is scheduled and an answer to the problem should be known in the near future.

Controlled Environment System
C.E.S.

A. Outline of System

1. Operates at 120° for controlled flash temperature.
2. Uses a slow evaporating solvent H-79/H-47 equal parts. Minimum loss over range of room temperature.
3. Fixed velocity 150"/min. Easy to control.
4. Fixed reduction -
100 cc material
110 cc solvent
5. Filtered air gives cleaner panels.
6. No flash time before bake.
7. Six-pass system 1-1/2 min. flash for 24 coats.
8. System minimizes variance in color but does not eliminate it.
9. For maximum control air to fan must be controlled.
10. Panels show a very light orange peel and are higher in TT than regular standards.
11. Limits of reproducibility - 867-95183
 $\Delta L \pm 0.20$
 $\Delta a \pm 0.30$
 $\Delta b \pm 0.15$
 $\Delta TT \pm 2.0$

B. Summary

1. The present 867 Line requires a new test memorandum for desired reproducibility.
2. To produce color panels under the new test memorandum will require installation of high cost equipment throughout the Division.
3. Alternate method would be to adopt the controlled environment system which gives a film with different characteristics.
 - a. New-type panels must be acceptable to Sales.
 - b. If not acceptable, two sets of standards could be adopted.
 - c. If present study shows that the prepared 1963 could be used with the C.E.S. using an off-set in color, then conversion of control units would only be necessary.
 - d. It would be possible to prepare new control standards to match C.E.S. standards and adopt system for 1963 colors.
4. If change is made, it must be on a Divisional basis and probably should be with a model year change.
5. The C.E.S. is an improvement on the present system and has proved to be adequate for I.C.A. color control. There will still be some minor variations in panels due to loss of H-30 between the gun and panel at varying amounts due to room temperature changes.
6. Automatic spray guns will have to be converted to a six-pass 1.5 minute flash 24-coat system.

C. Recommendations to Improve Present Metallic Panel Preparation

1. Request Sales Development Laboratory to supply the following on all standards at time of preparation:
 - Air temperature
 - Air humidity
 - Air velocity
 - Film thickness or weight
2. The above data should also be recorded when standards are prepared.
3. Adjust solvent for uniform standard preparation.
4. Reduce booth air velocity to 150' if spray dust removal satisfactory.
5. Investigate possibility of controlling temperature of air to fan with present air conditioner and use in conjunction with C.E.S.

6. Use volume reduction for samples to be sprayed.
7. All colors should be formulated to give the same film characteristics at constant conditions.

PROCESS ENGINEERING

E. A. Miller
E. A. Miller

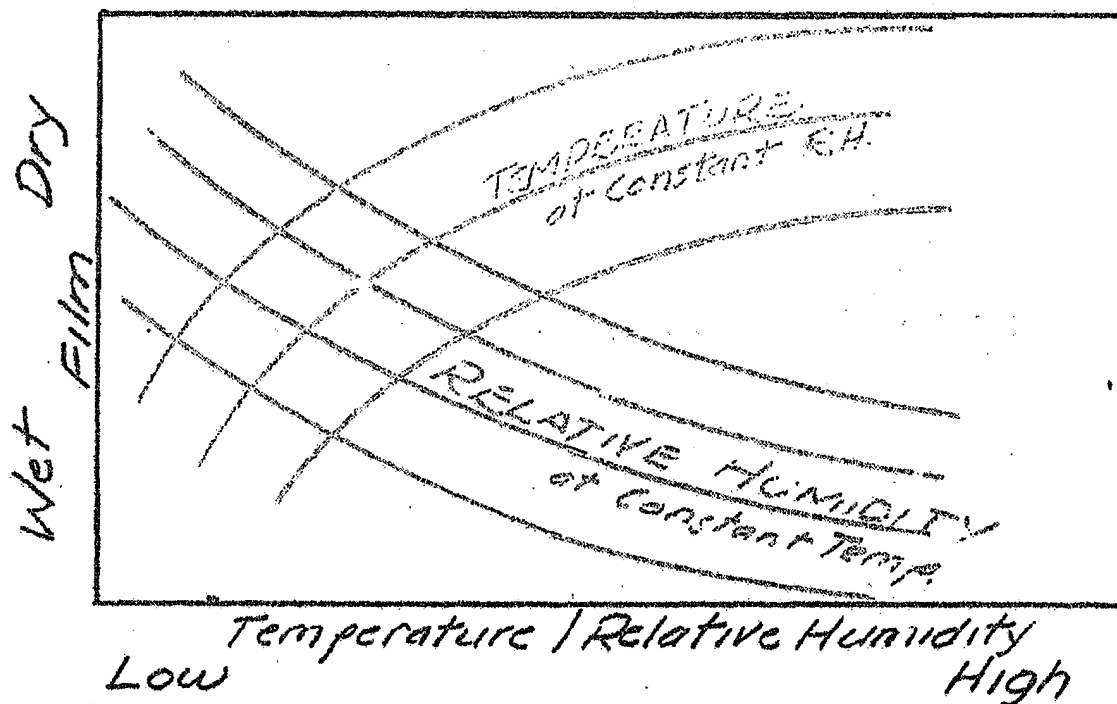
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SURVEY OF TEMPERATURE AND RELATIVE HUMIDITY

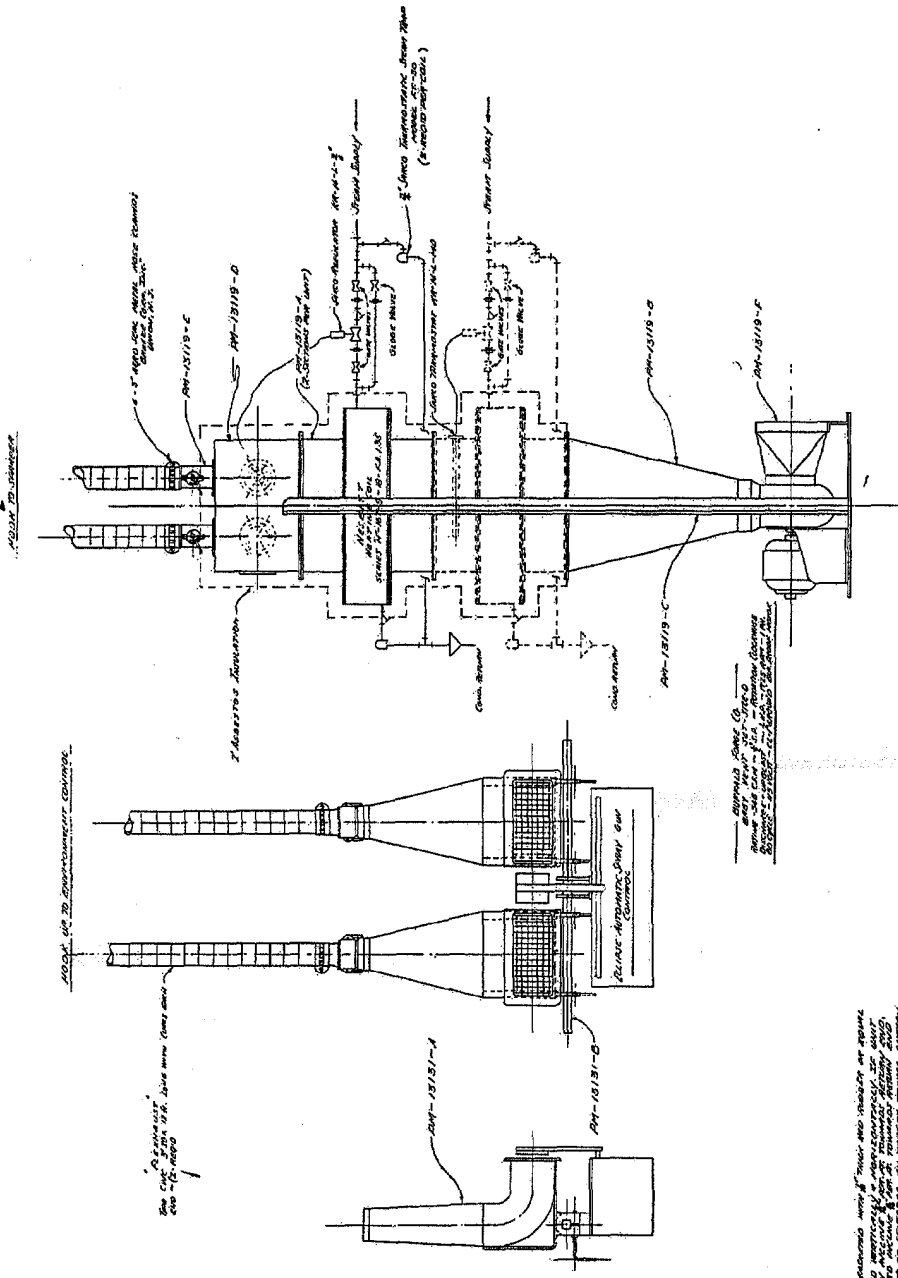
<u>PLANT</u>	<u>HIGHEST TEMP.</u> <u>" HUMID.</u>	<u>HIGHEST TEMP.</u> <u>LOWEST HUMID.</u>	<u>LOWEST TEMP.</u> <u>HIGHEST HUMID.</u>	<u>LOWEST TEMP.</u> <u>" HUMID.</u>
Tucker	95°F 95 R.H.	95°F 25 R.H.	77°F 95 R.H.	77°F 25 R.H.
So. San Fran.	72°F 80%	91°F 30%	67°F 67 R.H.	59°F 38% R.H.
Chicago	92°F 38%	93°F 32%	70°F 10%	70° 5%
Fort Madison	100°F 95%			
Flint	92°F 85%	92°F 37%	- 9° 85%	- 90 59%
Toledo	82°F 75%	82°F 25%	78°F 35%	78°F 20%
Phila.	100°F 98%	95°F 20%	70°F 95%	80°F 25%

	<u>Av.</u> <u>Max./Min.</u>	<u>Av.</u> <u>Max./Min.</u>	<u>1961</u>
Parlin	33/19 43/28 49/33 56/40 69/50 82/61 85/68 83/68 83/66 68/50 54/40 39/27	75/42 8/48 80/39 80/39 80/42 84/43 85/49 89/54 89/50 87/50 80/49 79/50	Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.

The "comfort zone" for good spray reproducibility under the present system appears to be 78°F to 83°F with a relative humidity between 20% and 40%. The higher the temperature the higher the tolerance for relative humidity. The most objectionable conditions are high temperature and low humidity and low temperature and high humidity.



It is impossible to define the limits of good reproducibility as no equipment is available to run a series of tests. The large volume of air required for a spray booth makes it impractical to control to the narrow limits required over the wide range of temperature and humidity experienced at each plant.



NOTE 1:
 1- ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
 2- ALL DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED.
 3- ALL DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED.
 4- ALL DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED.
 5- ALL DIMENSIONS ARE TO CENTER UNLESS OTHERWISE SPECIFIED.

ENVIRONMENT CONTROL		ADDN. TO DRAWING	
E. L. DU PONT DE NEMOURS & CO., INC.		PROCESS DIVISION	
PROCESS ENGINEERING GROUP		DATE: 6-14-62	
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SCALE: 1/8" = 1'-0"		PROJECT NO.: 13120	
NO.		REVISIONS	
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10	DATE	BY	APP'D

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3/26/62 by J. A. Antonelli

Solvents

DUP030002310