APPENDIX I

GLOSSARY OF TERMS

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GLOSSARY OF TERMS

1. *Air dry*

An air dry coating is one which can dry and cure at ambient or elevated temperature. Air pollution regulations in California and some other states require that if the coating is cured inside and oven, the temperature of the air in the oven shall be less than 194°F.

2. *Appearance (acceptable)*

For the coating film to have acceptable appearance, or finish, the film must be smooth and continuous. The *gloss* level and *distinctness of image* shall meet minimum requirements as specified in the Transfer Efficiency Test Protocol.

3. *Application viscosity*

The viscosity at which the coating is applied, as measured either on a Zahn #3 viscosity cup, or on a Krebbs Stormer viscometer. Both instruments are defined in this glossary

4. *Bake coating*

A coating which will only cure, or crosslink when it is exposed to an elevated temperature, usually above 250°F. Air pollution regulations in California and some other states require that if a coating is exposed to a temperature greater than 194°F, it is considered to be a bake coating.

In the work performed under this Transfer Efficiency Test Protocol contract, the regulatory definition is used.

5. *Coating*

See Organic Coating

6. *Coating additives*

Organic and inorganic chemical ingredients which are added to a coating formulation to modify the coating's application, chemical resistance, corrosion resistance and physical performance properties. Additives include, but are not limited to wetting agents, flow modifiers, drying agents, anti-fungicidal chemicals, plasticizers ,etc. Some additives are partially volatile, particularly when heated to elevated temperatures greater than 200°F.

7. Coating density

The mass of a unit volume of coating at a specified temperature. In this method it is expressed as the weight in grams per cubic centimeter (g/cc), or as the weight in pounds avoirdupois of one US gallon measure (lbs/gal) of the liquid at the laboratory ambient temperature.

Coating density can be calculated by one of the equations:

$$\text{Coating density (g/cc)} = \frac{\text{Wt. of Coating (g)}}{\text{Volume of coating (cc)}}$$

$$\text{Coating density (lbs/gal)} = \frac{\text{Wt. of Coating (lbs)}}{\text{Volume of coating (gal)}}$$

Coating density is measured using a pre-calibrated *Weight per Gallon Cup* which can be purchased from a laboratory supply house. Most MSDS report coating density as "Weight per Gallon", or WPG.

When the coating's density is used in transfer efficiency calculations, the weight per gallon is converted to metric units, (g/cc) by multiplying with the conversion factor, 1 lb/gal = 0.1198 g/cc.

8. Coating resins

Synthetically produced liquid or solid organic polymers. After formulating with solvents, pigments, additives and other ingredients they can be applied to a surface to form a uniform solid film, exhibiting unique chemical and physical properties. Typical resins include, but are not limited to alkyds, epoxies, polyurethanes, acrylics, etc.

9. Coating reservoir

When mentioned the Transfer Efficiency Test Protocol, it shall refer to a commercially available 5 gallon plastic pail with tight-fitting lid.

10. Coefficient of Variance (%)

This is defined by the following equation:

$$\text{Coeff. of Variance (\%)} = \frac{\text{Standard deviation}}{\text{Mean}}$$

$$\textit{Where} \qquad \textit{Mean} = \sum_{i=1}^{n} \frac{(X_i)}{n}$$

X_i = Value of a single measurement

n = Number of measurements

11. *Continuous use*

For purposes of the Transfer Efficiency Test Protocol, if a component, instrument or item of equipment has been used up to three times per week for more than one month, or if it has been used intermittently more than 30 times within a rolling six month period, it shall be considered to have been used continuously.

12. *Conversion Factor (K)*

The ratio between the liquid coating flow (as measured by accurately weighing an amount of liquid which passes through the *flow meter* , and converting the weight to volume by multiplying by the coating density), and the digital read-out on the flow meter (cc).

Conversion Factor (K)

$$= \frac{\textit{Total flow into plastic bags (g)}}{\textit{Total flow (cc) (Flow meter read-out)} * \textit{Density of coating (g/cc)}}$$

Mean Conversion Factor (K)

$$= \sum_{i=1}^{n} \frac{(\textit{Conversion Factor } (K)_i)}{n}$$

Where n = number of measurements taken

13. *Distance between gun strokes*

The distance by which the spray gun is moved down after it has completed one stroke and is being positioned for the next stroke. Usually the distance between strokes is one half the fan width[1].

14. *Distinctness-of-Image (DOI) gloss*

The sharpness with which pattern images are reflected by a surface[1].

15. *Distinctness of Image, (DOI) meter*

An instrument which measures the Distinctness of Image

16. *Dry film thickness (DFT)*

The dry film thickness of a coating is that which is measured after the coating has dried and cured for at least 24 hours. Ideally, it is the film thickness when the coating is totally cured. In practice, it is often inconvenient to wait until full cure is achieved, or no less than 24 hours.

DFT is measured using several types of instruments; both destructive and non-destructive.

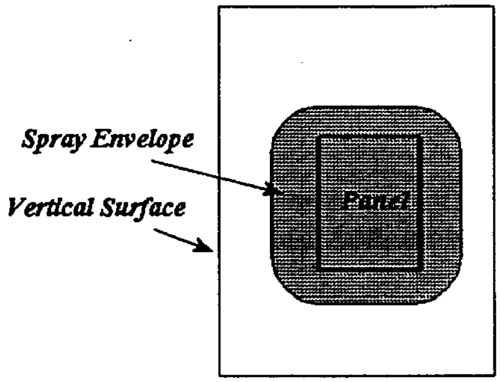
17. *Dry film thickness gage*

An instrument which measures the dry film thickness of the coating without destroying the coating film. Instruments can operate on the basis of magnetism (for ferrous metals), eddy currents (for both magnetic and nonmagnetic, metal substrates), or beta back scattering for non-metallic substrates.

18. *Envelope size*

The entire spray pattern which a spray gun projects on a vertical surface when it applies coating to a panel. The vertical surface is in the same plane as the panel. The envelope size captures the entire pattern, regardless of whether or not all of the coating is deposited on the panel. This is illustrated in Figure G-1.

Figure G-1
Illustration of Spray Envelope



19. *Finish (coating)*

See under *Appearance* in Glossary.

20. *Flow meter*

See under *Volumetric Flow Meter.*

21. *Gloss (gloss level)*

(1) A property of paints and enamels characterized by measuring the specular reflectance of the coating film using ASTM D523 Test for Specular Gloss[a]

(2) A property of paints and enamels[1] characterized by measuring the specular reflectance of the coating film using ASTM D523-89 (Reapproved 1994) Standard Method for Specular Gloss . The 60° specular gloss test is used for all gloss levels except for flat paints. A measurement of 65 or more characterizes the material as "gloss". Semigloss paints have readings of 30 to 65; flats when tested at an 85° angle have readings below 15.

22. *Gloss meter*

An instrument which complies with ASTM D523 Test for Specular Gloss[a] , and is capable of measuring the gloss of a coating film.

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1 EPA Glossary, Industrial Finishing, Vol. 66, No. 8, 1990, p 28.

23. *Field condition*

Application parameters which exist in a functioning production painting operation, such as in an automotive assembly plant. Parameters include, but are not limited to air and fluid pressures, speed of gun travel, whether the gun is operated by a spray painter or by means of a reciprocator or robot.

24. *Fluid delivery*

In the context of this project this refers to the actual delivery of coating as it leaves the spray gun. Fluid delivery can be monitored in three ways.

> The volumetric fluid flow meter directly measures fluid delivery. This is the most accurate direct measurement.
>
> The weight of coating deposited on one or more panels as a result of the coating
>
> The weight of coating used during the application of the coating.

Any changes in fluid delivery can be seen in the weight of coating deposited on a panel, or the weight of coating used during the application of the coating to a panel. By comparing any of the above parameters for a set of panels, it is possible to observe the consistency of the fluid delivery.

25. *Fluid delivery system*

The hardware through which the coating flows, from the coating reservoir all the way to the spray gun. The hardware comprises the rigid and flexible fluid lines, valves, pump, flow meter, regulators, etc.

26. *FM stop pulse (cc)*

The flow meter reading after liquid has passed through the volumetric flow meter.

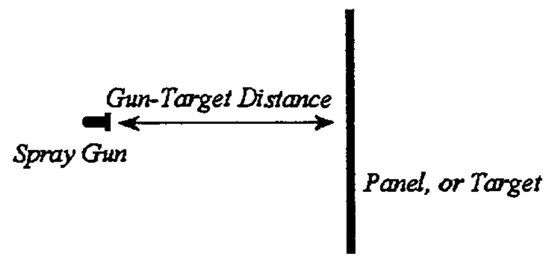
27. *FM start pulse (cc)*

The flow meter reading before liquid has passed through the volumetric flow meter.

28. Gun-target distance

The horizontal distance between the spray gun orifice and the target (or panel).

Figure G-2
Gun-Target (Panel) Distance



29. *Heater (in-line)*

Specially designed heat exchanger through which the coating passes as it flows toward the spray gun. The heat can be generated electrically, or by means of another heated fluid, such as water or a special oil. A thermostat control the temperature of the coating as it leaves the heater.

In some heated fluid delivery systems the coating only passes through the heater once, on its way to the spray gun. While the spray gun is idle, the coating in the fluid hose cools down. When the spray gun is triggered the cool coating must first be purged from the gun before coating at the required temperature can reach the gun Such designs are know was dead-end heating systems.

In the ideal heated fluid delivery system the coating can by-pass the spray gun, (when it is idle) and return via a recirculation hose back to the inlet of the heater. Such systems better ensure constant temperature of the coating at all times.

30. *High solids coating*

For purposes of the Transfer Efficiency Test Protocol, a coating which has a volume solids in excess of 52%, and has a VOC content, determined by EPA Method 24, at or below 3.5 lbs/gal, (420 g/L).

31. *Job number (#)*

This is the identification of a *test set* of panels. The results of each *test set* are recorded per job number, and saved in a computer spreadsheet under the same number.

For the most part one job number comprises only one set of panels. In few instances a job number might incorporate two or more sets of panels, where each set of panels is one *rack-equivalent*. For example, Job #3002 comprises two sets of panels. The first set of six panels is identified as AAC with individual panels marked 1 through 6. The second set of panels is identified as AAD panels with individual panels marked 1 through 6.

Refer to Table G-1 for an example of how this term is applied.

32. *Krebbs Stormer Viscometer*

An rotational viscometer which uses a paddle, rotating at constant speed within the coating. The energy required to maintain the constant rotational speed is a measure of the coating's viscosity. This instrument reports viscosity in Krebbs Units, (KU).

33. *Large commercial oven*

For purposes of the Transfer Efficiency Test Protocol, a gas-fired, gas-electric, or electrically heated oven permanently installed and large enough to accommodate at least six steel panels, with dimensions 16 x 20 inches, respectively.

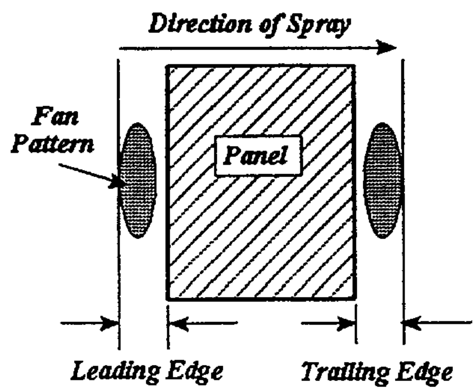
34. *Laboratory oven*[2]

An electrically heated, portable oven which can be placed on a laboratory bench. When used to dry coatings, adequate ventilation must be provided to prevent fires or explosions due to the presence of high concentrations of solvent. These ovens are specified by Type IIA or Type IIB of ASTM E-145.

35. *Leading edge*

The distance between the outer edge of the fan pattern and the left or right edge of the panel, as shown in Figure G-3. The *leading edge* refers to that edge of the panel at which the spray gun is initially triggered. The *trailing edge* refers to the edge of the panel at which triggering of the gun terminates.

Figure G-3
Leading and Trailing Edges



36. *Organic coating*[3,4]

A protective or decorative film applied in a thin layer to a surface. The term often applies to paints such as lacquers or enamels, but also is used to refer to films applied to paper, plastics or foil.

A liquid, liquefiable or mastic composition that is converted to a solid protective, decorative, or functional adherent film after application as a thin layer.

37. *Panels*

Steel panels with the following dimensions; small panels 6" x 4" x 16 gage, medium panels 16" x 20" x 16 gage.

38. *Pass (of spray gun)*

This is a single application of a coating over an area of the panel. For instance, if the coating is applied over an area only one time, this is one pass and one *stroke* If the spray gun applies coating twice over exactly the same area in the same horizontal plane, this is two passes, but still only one stroke. Similarly, if there are three applications over exactly the same area in the same horizontal plane, this is three passes, but still only one stroke.

39. Percent weight solids of coating

Determined by the equation:

$$\textit{Percent weight solids} = \frac{\textit{Wt. of solid coating (g)} \times 100}{\textit{Wt of liquid coating (g)}}$$

40. *Position #1, #2, #3, #4, ...*

The x-y-z coordinates of the spray gun relative to the position of the panel which is to be coated. For instance, in Position #1 the center of the spray gun orifice will be perpendicular to the upper right corner of the panel, but 1.75 inch to the right edge of the panel, *(leading edge)*. Position #2 will be in the same horizontal plane as Position #1, but 1.75 inch to the left of the left edge of the panel (*trailing edge*). Position #3 will be below Position #1, by the distance of one half (½)the width of the spray fan. Similarly, Position #4 is below Position #2. Position #5 is located directly below Position #3 by the same distance. Similarly for all other positions.

41. *Pressure pot*

A pressure pot is a closed, sealed container for the liquid coating, to which a pressure, usually less than 100 psi is applied to force the coating through the fluid hose to the spray gun. Dry, clean compressed air from the paint facility's compressor is used for this purpose.

42. *Pulse equivalent (cc/cog)*

The volume of coating (cc) which causes the flow meter gears to rotate from the center point of one cog to the center point of the adjacent cog.

43. *Pumps - High and low pressure*

A diaphragm pump is often used to force liquid coating through the fluid hose to a spray gun which is designed to atomize the coating at a pressure usually less than 250 psi. Spray guns which atomize coatings at low pressures include the conventional air atomizing, HVLP guns and their electrostatic counterparts.

A high pressure hydraulic pump is often used to force liquid coating through the fluid hose to a spray gun which is designed to atomize the coating at a pressure usually greater than 250 psi. Spray guns which atomize coatings at high pressures include the airless, air-assisted airless guns and their electrostatic counterparts.

44. *Rack (coating application rack)*

The coating application rack comprises a steel frame which will hold a steel panel in place.

45. *Rack-equivalent*

A *rack-equivalent* of medium-size panels comprises six panels. The first panel is placed in position on the coating rack. The coating is applied according to the specified criteria of the test. The panel is then removed and placed on a second rack which holds the panel in place until all six panels have been coated. A second panel is placed on the first rack in exactly the same location as for the first panel. The coating procedure is repeated until all six panels have been coated. Thereafter, the rack or racks which hold the coated panels are transferred to an oven where the coating is cured.

Refer to Table G-1 for an example of how this term is applied.

A *rack-equivalent* of small panels comprises 12 panels.

46. *Repeatable (results)*

In the context of this Transfer Efficiency Test Protocol Development project, repeatable results are those for which the *coefficient of variance* (COV (%)) calculated from the results of several measurements, is less than 2.5%.

47. *Rheology*

A branch of science dealing with the flow and deformation of matter.

48. *Robot (Spray Robot)*

A six-axis, fully automated and computerized machine that can be programmed to allow the arm, or extension of the robot to repeatedly follow the same path in 3-dimensional space.

49. *Robot arm*

The extension of the robot to which is attached the spray gun. This can move the spray gun into any x-y-z coordinate within a specified envelope. The gun can also be maneuvered to simulate the wrist action of a paint operator.

50. *Series of tests (or test series)*

A series of tests comprise more than one test in which all but one spray gun and/or application parameter might vary. The tests are conducted with the intention of determining a trend. For instance, 36 tests within the following table would be considered to fall within a series.

Table G-1

Effect of Fan Size on Transfer Efficiency
Rack-Equivalents Medium-Sized Panels

	8"	10"	12"
Conventional air atomizing	3	3	3
HVLP	3	3	3
Electrostatic	3	3	3
Air-assisted airless	3	3	3
Total	12	12	12

One series of tests = 36 *tests sets*
Each *test set* comprises one *rack-equivalent* of six panels
Each *test set* can be recorded under one or more *Job Number*(s), depending on the technician who conducts the tests.

51. *Set of panels, or test set*

More than one panel, all of which are coated at the same time using the same spray gun settings and application parameters. Usually a *set of panels* will comprise one *rack-equivalent*. In Table G-1 three sets comprising six-medium panels each, are coated with the conventional air atomizing spray gun with an 8" fan width.

52. *Spray booth*

A stationary enclosure in which coatings are applied. The booth, usually constructed of steel or galvanized sheets, can be open at one end, or can be totally enclosed. Air is drawn into the booth by means of blowers. Paint- and solvent-laden air passes through a filtering mechanism (dry filters or water curtain) allowing the paint particles to be trapped. The solvent-laden air passes through the filtering mechanism and is emitted into the air.

53. *Spray booth - dry filter*

Incoming air carries overspray paint particles into a bank of filters comprising porous non-flammable materials, thus entrapping the paint particles. The air which leaves through the stack of the booth and is essentially free of paint particles. VOCs in the air pass through the filters are emitted into the outside atmosphere.

54. *Spray gun*

A device which is designed to apply an organic liquid coating by forcing the coating under pressure through a small orifice, or orifices. Some spray guns are designed to allow the liquid coating to mix with pressurized air immediately before, or after being ejected from orifice(s).

Common spray gun types are as follows:

a. *Conventional air atomizing*

Coatings are atomized at fluid pressures of 30 - 80 psig, and air pressures of 30 - 80 psig.

b. *High volume, low pressure (HVLP)*

Coatings are atomized at air pressures of 0.1 - 10 psig, and fluid pressures less than 50 psig[2].

c. *Pressure regulated HVLP*

Air at approximately 80-100 psig is forced through one or more baffles, usually within the body of the spray gun, dropping the pressure to less than 10 psig. It is this low pressure air which atomizes the coating.

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2 This definition, particularly as regards the fluid pressure limitation, is not the same for all states, nor for all air basins within California.

d. *Turbine HVLP*

A turbine is used to generate low pressure air at pressures of 0.1 - 10 psig. Unlike the pressure-regulated HVLP guns, the air is drawn from the surrounding environment rather than from a compressor.

e. *Airless*

The coating is atomized by forcing the fluid through the a small orifice at high pressures, usually 1,000 - 3,000 psig. Typical orifice sizes vary from 0.011 - 0.074 inches. No air is used to assist in atomizing the coating.

f. *Air-assisted airless*

This spray gun is similar to the airless gun, except that the fluid pressures are typically 250 - 1,000 psig. Low pressure air is passed through special orifices on the cap of the gun to shape the fan pattern. The air does not atomize the coating.

g. *Electrostatic*

Spray guns which are designed to apply an electrostatic charge, usually 60 - 125 KV, to the atomized coating. The substrates to be coated must be conductive and connected to a ground. The coating particles are attracted to the grounded surfaces and are deposited thereon. Electrostatic spray guns are available in all types, conventional, HVLP, airless and air-assisted airless.

55. *Spray gun design*

A particular design of a spray gun type unique to one manufacturer. For instance, all manufacturers of HVLP spray guns (*spray gun type*) offer a unique <u>design</u> designated by a model and/or serial number. An HVLP spray gun from one vendor will have a different <u>design</u> from that of a competitor.

56. *Standard deviation*

$$S = \sqrt{\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1}}$$

Where S = Standard deviation
X_i = the ith value if X
$\bar{X}$ = mean of measurements
n = number of measurements

57. *Spray gun speed of travel*

The speed at which the gun travels either from left to right, or from right to left. The gun speed is measured in mm/sec.

58. *Stroke (of spray gun)*

Triggering of the spray gun for only one *pass* horizontally across the substrate. For this protocol, a stroke would be the application of coating to a panel while the gun moves one time from the extreme right to the extreme left of the panel, or visa versa. Throughout this application the spray gun is in the same horizontal plane.

> Scenario #1: If the gun applies coating one time over a specified area of the panel, this is one stroke and one pass. If the gun is then moved (vertically) down by a specified distance, and the coating is applied one time over the new area, (even if it overlaps the previous area), this is two strokes, but only one pass per stroke.
>
> Scenario #2. If, in the previous scenario the gun applies coating twice over the same area, first with the gun in the higher position, and then with the gun in the lower position, this is two strokes and two passes.

59. *Test series*

Refer to *Series of tests* in the Glossary.

60. *Test Set*

Refer to *Set of panels* in the Glossary.

61. *Trailing edge*

The distance between the outer edge of the fan pattern and the left or right edge of the panel. The *trailing edge* refers to that edge of the panel at which triggering of the spray gun terminates. (See *Leading Edge* in this Glossary).

62. *Transfer efficiency TE_m, TE_a and TE_d*

This is the ratio of the amount (weight or volume) of solid coating which is deposited on a substrate, to the amount (weight or volume) of solid coating which is used in the application. In the case of spray applications, the amount of coating used is the weight or volume of coating that is fed to the spray gun and is then atomized toward the substrate.

It is calculated by the equation:

$$\textit{Transfer Efficiency, } TE_m\ (\%) = \frac{\textit{Wt. of Solid Coating Deposited (g)} \times 100}{\textit{Wt. of Solid Coating Used (g)}}$$

Where Wt. of Solid Coating Used (g)

= Wt. Liquid Coating Used (g) x % Wt. Solids of Coating

The Transfer Efficiency Test Protocol allows for the spray gun to overshoot the edges of a panel rather than capture the entire envelope within the boundaries of the panel. It was intended to make a calculated correction to TE_m (to be titled TE_a), that would correct for the portion of the spray pattern that overshoots the edges. In fact, this concept was dropped when it was found that the calculations did not yield consistent results.

Similarly, it was intended to correct TE_m for variations in the dry film thickness of the applied coating (TE_d). The results of dry film thickness measurements showed that for some spray guns there was no consistency of film thickness across the face of the panel; therefore the concept of reporting TE_d was also dropped.

63. *Viscosity*

The force per unit area that resists the flow of two parallel fluid layers, past one another when their differential velocity is 1 cm/(s)/cm separation[5].

64. *Volumetric flow meter*

A mechanical device comprising two counter-rotating gears, each interlinked with the other. The coating flows through the meter forcing the gears to rotate.

Volumetric flow is measured by the number of (gear) cogs which rotate as the fluid passes through the meter.

65. *Zahn cup viscometer*

A cup type viscosity instrument containing an orifice. A Zahn cup[6] is one of many different types available and has a nominal volume of 44 mL although it may vary from 43 mL to 48 mL, and a nominal orifice diameter of 3.8 mm (0.15 inch).

Zahn cups are available with different orifices diameters. Zahn #1 has the smallest, followed by Zahn #2 and then Zahn #3. A Zahn #3 viscosity of 16 seconds might be equivalent to a Zahn #2 viscosity of 35 seconds. Actual conversions from one cup to another are dependent on the formulation and rheology of the coating.

66. *References*

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2. ASTM -E-145

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4. ASTM D-16-93a, Standard Terminology Relating to Paint, Varnish, Lacquer, and Related Products, Annual Book of ASTM Standards, Paints, Related Coatings, and Aromatics. Section 6, Volume 06.01, 1995

5. Raymond E. Serway and Jerry S. Faughn, College Physics, , Saunders Golden Sunburst Series, Harcourt Brace Jovonovich Publishing,Third Edition 1992.

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APPENDIX 2

CORRESPONDENCE REGARDING STATISTICAL ANALYSES

5/6/94

STATISTICAL LABORATORY -- DIVISION OF STATISTICS
STATISTICAL CONSULTING/PROGRAMMING REPORT

Ron Joseph

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Department: *O: State Air Resources Board* Status: *O*
Department Charge Number (Account/Fund or I.D.):
Major Professor: Consultant Name: *Neil Willits (NHW)*
Project Title: *Protocol development for spray gun testing*

O: State Air Resources Board

Nature of Consultation:
1. Statistical Consulting:
Appointment Date/Time: **940506 (Friday)** **9:00 am**
Task Description:
1. Advice 2. Modeling(chargeable) 3. Computations(Chargeable)--Computer/Analysis
Time with Client: **3.25 (a)** Time on Follow-up: **0.75 (a)**

2. Programming:
Estimated Time: Date Started: Date Completed:
Task Description:
Language: Package Title:
Time with Client: Time on Follow-up:

Abstract of Problem:

Ron is contracting with the Air Resources Board to look into methods that might be used for testing the efficiency of spray guns. The protocol that would come out of Ron's investigations would presumably be used by laboratories in the state to certify makes and models of spray guns as being sufficiently efficient for use in California.

Ron handed out a list that was a couple of pages long, of factors that can affect the efficiency of the guns. Since Ron's task is simply to recommend a *protocol* for doing this type of testing, many of these factors can be standardized for the purposes of his tests. Ultimately, they will need to be set according to either "good spray painting practice" or else "common spray painting practice", which may well vary from one type of gun to the next. This doesn't bother me, since the purpose of the protocol is to determine how efficient a gun is when it's used appropriately and not under a bizarrely inappropriate set of conditions. Factors that will be set according to common practice include the distance between the gun and the target, the distance between targets, the spray booth air flow, the speed the gun travels, and the fan width of the spray.

There are two aspects of the problem that Ron will need to address. The first is how replicable the measurements are from one trial to the next, across all sorts of conditions. They *won't* be concerned with gun to gun variability within a given manufacturer, since the response will be assumed to be quite uniform within a particular model. The second aspect Ron will need to address is whether certain factors need to be taken into account in developing the testing protocol. For example, the efficiency may depend on the temperature of the paint, the chemical formulation of the paint, or on the voltage used for an electrostatic spray gun. Also, the precision of the efficiency estimates may depend on the *range* in which the efficiency lies. (For example, there may be more variability in measuring the efficiency of a crummy spray gun than for a good one.) Within the scope of Ron's

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study, he can't afford to look at all of these questions simultaneously, so he's constructed a series of sub-experiments to look at individual questions of interest.

As I mentioned, one of the main purposes of this investigation is to determine how replicable the measurements are. In doing this it's going to be important to spread the replicate measurements of a given type over more than one day, dis-assembling and cleaning the gun between protocols, in order to provide true replication. He's also planning on doing some pseudoreplication, in which he doesn't take the gun apart, in order to see how replicable the results would be under unrealistically clean experimental conditions. I don't know how useful this data (i.e., the pseudoreplicates) will be, and he might want to reduce the numbers of replicates of this kind that he uses.

One of the components measuring efficiency is to determine the average thickness of the paint on the object, since they'll be aiming to achieve a nominal thickness. A good question is how to determine the average thickness, given that (1) it won't be uniform, and (2) it may be biased toward extra thickness toward the edge of the object. Ron generated a graph of paint thickness in various lattice locations on a painted object, and it showed *considerable* variability. From this, he eyeballed a fan width, namely the width at which the paint is acceptably thick. There are a number of statistical questions that could be raised here. One is how to estimate the fan width from data of this kind, for which (not surprisingly) the answer depends on what you're trying to estimate (i.e., what you want the fan width to do). I suggested that they might want something akin to a tolerance interval, so that within the fan you'd be say 95% sure that the thickness would be a certain amount or greater. (Frankly, I'm not sure that this is the right think to estimate, since in practice, a painter will let the fans overlap by 50% of the width on successive strokes. I'll think about this some more.) A second question is who many points would need to be sampled (and where on the object) in order to derive an average thickness estimate that was adequately accurate. To look at this second question, I suggested that he should measure the thickness at *lots* of points on a lattice, and then we could regress the overall average (i.e., the average calculated from *all* of the points) on averages based on various subsets of the points. It's entirely likely that the relationship between the two won't lie along a 45° angle, but may fall along some other line. In any event, we can probably develop linear relationships that would translate an average based on k points into an estimate of the overall average and we can also calculate the dispersion around this relationship, in order to determine how many points you need to use in the calculation of the estimate in order to achieve a certain precision.

When it comes to developing a protocol, the overall cost will be a consideration. Thus, while they'll *need* to test the efficiency for both water-borne and solvent-borne paint, and for various sizes of objects being painted, it's not clear what additional factors will need to be taken into consideration or how many tests will be available to accomplish this. The efficiency *will* depend on the orifice size, the fluid pressure and the air pressure, and a given manufacturer will recommend ranges for each of these variables. This will define a box in three dimensions, from which they'll want to choose a number of points at which to test a gun. If it was possible to use *lots* of points, they might choose all combinations of low, medium and high values for each of the variables (27 points in all). If that's not possible, then they might want to choose only the middle of the box and each of the vertices (7 points in all). Depending on how Ron's experiments come out, the may want to look at other factors, such as the fluid temperature, as well. The overall efficiency estimate would be based on those points, and could be taken either as the *best* efficiency achieved within the box, the worst, or else an average (an estimate of the integral of the efficiency over the box). It's a good question which of these is the most appropriate, but I think the consensus at our meeting was that the average would be the best one to use, in view of the fact that in practice, painters choose their own settings for the gun and while they'd probably be *close* to the manufacturer's recommendations, they wouldn't be right on the mark.

Ron said that he'd like to send (FAX) me the data on a bit-by-bit basis as he generates it, mostly so that in case a particular sub-question turns out to be answerable with a smaller sample size, he can divert some of his resources to some other questions. That's fine by me, as long as our contract with ARB is in force and this is okay with Steve.

8/16/95

Ron Joseph

STATISTICAL LABORATORY -- DIVISION OF STATISTICS
STATISTICAL CONSULTING/PROGRAMMING REPORT

Client Name: *Ron Joseph* Telephone: *(408)446-9736*
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Glenn Kasai (ARB, via phone) *(909)396-2771*
Department: *O: Ron Joseph and Associates* Status: *O*
Department Charge Number (Account/Fund or I.D.):
Major Professor: Consultant Name: *Neil Willits (NHW)*
Project Title: *Protocol development for spray gun testing*

O: Ron Joseph and Associates

Nature of Consultation:
1. Statistical Consulting:
Appointment Date/Time: **950816 (Wednesday)** **1:15 pm**
Task Description:
1. Advice 2. Modeling(chargeable) 3. Computations(Chargeable)-Computer/Analysis
Time with Client: **1.50 (a)** Time on Follow-up: **0.75 (a)**

2. Programming:
Estimated Time: Date Started: Date Completed:
Task Description:
Language: Package Title:
Time with Client: Time on Follow-up:

Abstract of Problem:

Ron and Marla dropped by (and we talked with Glenn via a conference call) to discuss the progress they're making on the development of a protocol for the testing of spray guns, so that they can be certified as acceptable for certain types of usage in various air basins that may have restrictions on this type of emission. Ron has done a series of tests on several different types of spray guns, and he's chosen several different manufacturers for each type of gun. For a given gun and manufacturer, he's tested between six and twelve panels (depending on the size of the panel), and for each panel he's measured the transfer efficiency, which is defined as the proportion of the paint that winds up on the target, but is actually measured by looking at the amount of paint sprayed, the thickness of the paint on the target, and the amount of overspraying (i.e., the width and thickness of the envelope of paint on the backdrop surface, around the edges of the object).

O

As it stands, these measurements have been taken using a distance between the gun and the object being sprayed of either 8, 10, or 12 inches. Other parameters, such as the speed of the robot arm (that holds the spray gun), the number of strokes it takes to paint the object, and the number of passes per stroke were determined so that the resulting surface is of acceptable quality. "*Acceptable quality*" is defined primarily in terms of the gloss of the surface, for which they're developing some quantitative measurement tools. (In the past, this has been assessed subjectively.) One problem they need to confront is that while all of the guns they tried did a pretty good job at a distance of 10 inches, some guns really worked a little better at 8 inches, while others worked a little better at 12 inches. Since they want to come up with a protocol that doesn't inherently disadvantage one type of gun versus another, it doesn't make sense to me to use a *fixed* set of test conditions for all guns. Instead, it makes more sense to allow a manufacturer to specify their own optimal conditions and then test the gun under those optimal conditions, as well as under conditions that involve slight deviations from those conditions. For example, if their optimal conditions are a distance of 8 inches, an arm speed of 400 mm per second, and a flow rate of (fill in an appropriate quantity here), then they would run one test of the gun under those conditions, two tests in which the distance was either increased or decreased by 20% (or some other small percentage), two tests in which the distance was 8 inches, but the arm speed was increased or decreased by 20%, and two tests in which the distance was 8 inches, the arm speed was 400 mm per second, and the flow rate was increased or decreased by 20%. The gun's overall performance could be taken as the average transfer efficiency under those seven sets of test conditions. For some additional parameters, such as the numbers of passes and strokes, they can follow the manufacturer's recommendations exactly, as long as those recommendations lead to painted samples of acceptable quality. Finally, in order to avoid conditions that are unrealistically restrictive, they'll probably want to set a minimum acceptable paint application rate. This general approach has several advantages:

• It makes the manufacturers think about the best (realistic) conditions under which their gun should be used. If their gun performs poorly in one series of tests, then they will want to rethink their recommended settings.

• In practice, a painter won't follow the manufacturer's recommendations exactly. By testing the gun under a range of *close to optimal* conditions, you better approximate how the gun will be used in practice.

• By looking at the gun's performance over range of settings for several different parameters, they'll get a sense of which of the parameters are most critical in determining transfer efficiency.

• Finally, if the manufacturers give careful thought to the best (most efficient) conditions under which to use the gun, they can include this information in their instructions for gun usage. While not all (few?) painters will actually *follow* these instructions, it *can't hurt* to provide the information and may result in somewhat more intelligent use of the guns in practice.

I offered to look at the data that Ron has collected so far, to determine the relative importance of item to item variability and trial to trial variability. (Between trials, a gun is taken apart and cleaned, making this more of a *true* replicate reading. Still, if trial to trial variability isn't all that large, it may be more cost effective to take measurements on larger numbers of objects during fewer trials. This type of question can be addressed using a variance components analysis. I should point out that in these experiments, we really can't look at the question of changes due to the choice of arm speed or application rate, since for a given gun those parameters were generally held constant.) We can also look at the effect of the distance to the target, and see whether (as I expect will be the case) the distance effect differs from one gun to the next. This will also allow the development of a relative ranking of the sprays guns that were tested, to get a sense of how much overlap they can expect based on tests that involve this number of replicate trials. Ron is planning on sending me the data on a disk in an Excel format.

9/21/95

Ron Joseph

STATISTICAL LABORATORY -- DIVISION OF STATISTICS
STATISTICAL CONSULTING/PROGRAMMING REPORT

Client Name: *(Ron Joseph)* Telephone: *(408)446-9736*
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Department: *O: Ron Joseph and Associates* Status: *O*
Department Charge Number (Account/Fund or I.D.):
Major Professor: *Marla Meuller* Consultant Name: *Neil Willits (NHW)*
Project Title: *Protocol development for spray gun testing*

O: Ron Joseph and Associates

Nature of Consultation:
1. Statistical Consulting:
Appointment Date/Time: **(950921) (Thursday)**
Task Description:
1. Advice 2. Modeling(chargeable) 3. Computations(Chargeable)-Computer/Analysis
Time with Client: Time on Follow-up: *(see attached)*

2. Programming:
Estimated Time: Date Started: Date Completed:
Task Description:
Language: Package Title:
Time with Client: Time on Follow-up:

Abstract of Problem:

I finally got unpacked enough that I got my hands on the material Ron had sent me about a month ago, and I ran the variance components analysis on the spray gun efficiency data. There are two types of analysis in the attached output: first a couple of analyses of variance (ANOVAs) to look at whether there are systematic differences between types of spray guns or spraying distances, and then the variance components analysis, which was run to assess the relative magnitude of the variability between different sets of objects being painted, and the variability between the items within a given set. In general, there were significant main effects of gun type and distance, and the interaction between these two effects was marginally significant ($p \approx .05$), leading me to conclude that while some of the guns may perform better at different distances, this certainly isn't one of the main features of the data. In the variance component analysis as I mentioned, the two random effects being considered were variation between sets of items, and variation within a given set. The former was much larger than the latter (the variance differed by more than an order of magnitude), which argues that in choosing between testing more sets of items as opposed to taking measurements on more items within a set, it's apt to be advantageous to opt for more sets of items, even if it means cutting down on the number of measurements within a set. Of course, this sort of conclusion is always subject to practical constraints, and to offer a concrete (i.e., numerical) suggestion about how many items within a set to measure, I'd need to have a guess as to how many times as much effort is involved in running an extra set of items, relative to measuring an extra item within a set. O

Finally, I should mention that one of the things that stood out in examining this data set was that occasionally, in doing replicate sets of items, the results were quite inconsistent between one set and the next. (For example, compare set AAP against sets AAQ and AAR.) This may be a large contributor to the fact that the "panel" variance component is so much larger than the residual (item) component, but unless they can figure out what (if anything) went wrong with those tests, this is a fact with which they're going to have to live. This *does* seem to be a sporadic phenomenon (i.e., most of the time replicate sets of items yield *quite* similar results), and on this basis alone, they might consider (in their protocol) always running at least three sets of items at a given distance, so that if one of the sets gives aberrant results, they can drop it from the subsequent calculations. Mind you, I'm not *recommending* doing this, but it's a possibility that they may want to consider.

```
NOTE: Copyright (c) 1989-1993 by SAS Institute Inc., Cary, NC, USA.
NOTE: SAS (r) Proprietary Software Release 6.10  TS019
      Licensed to UNIVERSITY OF CALIFORNIA/DAVIS, Site 0029107901.



NOTE: AUTOEXEC processing beginning; file is C:\AUTOEXEC.SAS.

NOTE: The SAS System for Microsoft Windows, Release 6.10 Limited Production
NOTE: Libref MAPS was successfully assigned as follows:
      Engine:        V610
      Physical Name: C:\WINSAS\MAPS

NOTE: AUTOEXEC processing completed.

     data rj0;
             infile 'c:\home\rj0.txt' firstobs=2 dlm='09'x missover;
             input job panel $ vendor $ type $ dist size $;

NOTE: The infile 'c:\home\rj0.txt' is:
      FILENAME=c:\home\rj0.txt,
      RECFM=V,LRECL=256

NOTE: 59 records were read from the infile 'c:\home\rj0.txt'.
      The minimum record length was 18.
      The maximum record length was 22.
NOTE: The data set WORK.RJ0 has 59 observations and 6 variables.
NOTE: The DATA statement used 1.04 seconds.


     proc sort;
             by panel;

NOTE: The data set WORK.RJ0 has 59 observations and 6 variables.
NOTE: The PROCEDURE SORT used 0.22 seconds.


     data rj1;
             infile 'c:\home\rj1.txt' firstobs=3 dlm='09'x missover;
             input panel $ refno deposit used tr_eff;

NOTE: The infile 'c:\home\rj1.txt' is:
      FILENAME=c:\home\rj1.txt,
      RECFM=V,LRECL=256

NOTE: 366 records were read from the infile 'c:\home\rj1.txt'.
      The minimum record length was 20.
      The maximum record length was 25.
NOTE: The data set WORK.RJ1 has 366 observations and 5 variables.
NOTE: The DATA statement used 0.27 seconds.


     proc sort;
             by panel;

NOTE: The data set WORK.RJ1 has 366 observations and 5 variables.
NOTE: The PROCEDURE SORT used 0.17 seconds.


     data both;
             merge rj0 rj1;
             by panel;

NOTE: The data set WORK.BOTH has 371 observations and 10 variables.
```

```
NOTE: The DATA statement used 0.33 seconds.

proc glm;
        where size ne 's';
        class type dist panel;
        model tr_eff = type dist type*dist panel(dist type);
        random panel(dist type)/test;
        means type/e=panel(dist type) tukey lines;
        title 'mixed model analysis of spray gun efficiency data';

NOTE: TYPE I EMS not available without the E1 option.
NOTE: Means from the MEANS statement are not adjusted for other terms in the model.  For adjusted means, use the LSMEANS statement.
NOTE: The PROCEDURE GLM used 2.62 seconds.

proc varcomp;
        class type dist panel;
        model tr_eff = type dist type*dist panel(dist type)/fixed=3;
        title 'variance component analysis of spray gun efficiency data';
run;

NOTE: The PROCEDURE VARCOMP used 0.59 seconds.
```

General Linear Models Procedure
Class Level Information

Class	Levels	Values
TYPE	8	AAA CONV ELEC HVLP1 HVLP2 HVLP3 TURB1 TURB2
DIST	3	8 10 12
PANEL	54	AAC AAD AAE AAF AAG AAH AAI AAJ AAK AAL AAM AAN AAO AAP AAQ AAR AAS AAT AAU AAV AAW AAX ABA ABB ABC ABD ABE ABF ABG ABH ABI ABJ ABK ABL ABM ABN ABO ABP ABQ ABR ABS ABT ACE ACF ACG ACH ACI ACJ ACK ACL ACM ACN ACO ACP

Number of observations in data set = 311

NOTE: Due to missing values, only 294 observations can be used in this analysis.

General Linear Models Procedure

Dependent Variable: TR_EFF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	48	23858.41769864	497.05036872	162.90	0.0001
Error	245	747.57616667	3.05133129		
Corrected Total	293	24605.99386531			

R-Square	C.V.	Root MSE	TR_EFF Mean
0.969618	3.630612	1.74680603	48.11326531

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TYPE	7	20873.55519326	2981.93645618	977.26	0.0001
DIST	2	1767.01239922	883.50619961	289.55	0.0001
TYPE*DIST	14	658.11936033	47.00852574	15.41	0.0001
PANEL(TYPE*DIST)	25	559.73074583	22.38922983	7.34	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TYPE	7	20101.71958525	2871.67422646	941.12	0.0001
DIST	2	1621.05698263	810.52849132	265.63	0.0001
TYPE*DIST	14	658.11936033	47.00852574	15.41	0.0001
PANEL(TYPE*DIST)	25	559.73074583	22.38922983	7.34	0.0001

General Linear Models Procedure

Source	Type III Expected Mean Square
TYPE	Var(Error) + 6 Var(PANEL(TYPE*DIST)) + Q(TYPE,TYPE*DIST)
DIST	Var(Error) + 6 Var(PANEL(TYPE*DIST)) + Q(DIST,TYPE*DIST)
TYPE*DIST	Var(Error) + 6 Var(PANEL(TYPE*DIST)) + Q(TYPE*DIST)
PANEL(TYPE*DIST)	Var(Error) + 6 Var(PANEL(TYPE*DIST))

General Linear Models Procedure
Tests of Hypotheses for Mixed Model Analysis of Variance

Dependent Variable: TR_EFF

Source: TYPE *
Error: MS(PANEL(TYPE*DIST))

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
7	2871.6742265	25	22.389229833	128.2614	0.0001

* - This test assumes one or more other fixed effects are zero.

Source: DIST *
Error: MS(PANEL(TYPE*DIST))

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
2	810.52849132	25	22.389229833	36.2017	0.0001

* - This test assumes one or more other fixed effects are zero.

Source: TYPE*DIST
Error: MS(PANEL(TYPE*DIST))

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
14	47.008525738	25	22.389229833	2.0996	0.0512

Source: PANEL(TYPE*DIST)
Error: MS(Error)

DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
25	22.389229833	245	3.0513312925	7.3375	0.0001

Tukey's Studentized Range (HSD) Test for variable: TR_EFF

NOTE: This test controls the type I experimentwise error rate, but generally has a higher type II error rate than REGWQ.

Alpha= 0.05 df= 25 MSE= 22.38923
Critical Value of Studentized Range= 4.667
Minimum Significant Difference= 4.3117
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 26.23292

Means with the same letter are not significantly different.

```
Tukey Grouping          Mean      N  TYPE

             A        56.752     18  TURB2
             A
             A        56.372     18  TURB1
             A
     B       A        54.132     18  HVLP3
     B
     B       C        51.630     18  HVLP2
     B       C
     B       C        51.489     84  HVLP1
     B       C
     B       C        50.099     60  ELEC
             C
             C        48.255     30  CONV

             D        29.723     48  AAA
```

Variance Components Estimation Procedure
Class Level Information

Class	Levels	Values
TYPE	8	AAA CONV ELEC HVLP1 HVLP2 HVLP3 TURB1 TURB2
DIST	3	8 10 12
PANEL	59	AAB AAC AAD AAE AAF AAG AAH AAI AAJ AAK AAL AAM AAN AAO AAP AAQ AAR AAS AAT AAU AAV AAW AAX ABA ABB ABC ABD ABE ABF ABG ABH ABI ABJ ABK ABL ABM ABN ABO ABP ABQ ABR ABS ABT ACA ACB ACC ACD ACE ACF ACG ACH ACI ACJ ACK ACL ACM ACN ACO ACP

Number of observations in data set = 371

NOTE: Due to missing values, only 354 observations can be used in this analysis.

MIVQUE(0) Variance Component Estimation Procedure

SSQ Matrix

Source	PANEL(TYPE*DIST)	Error	TR_EFF
PANEL(TYPE*DIST)	1398.16000000	199.60000000	419976.05687822
Error	199.60000000	330.00000000	45555.94358639

Variance Component	Estimate TR_EFF
Var(PANEL(TYPE*DIST))	307.19563856
Var(Error)	-47.75850263

Maximum Likelihood Variance Components Estimation Procedure

Dependent Variable: TR_EFF

Iteration	Objective	Var(PANEL(TYPE*DIST))	Var(Error)
0	837.63762621	783.32018024	3.52010304
1	806.18588823	398.28710067	3.57966428
2	780.40505325	205.76105681	3.69861592
3	765.13519447	109.47909071	3.93583814
4	763.59789025	87.32270906	4.07714269
5	763.59671659	86.78800440	4.08159755
6	763.59671657	86.79048971	4.08157670
7	763.59671657	86.79048971	4.08157670

Convergence criteria met.

Asymptotic Covariance Matrix of Estimates

	Var(PANEL(TYPE*DIST))	Var(Error)
Var(PANEL(TYPE*DIST))	281.7891328	-0.0060350
Var(Error)	-0.0060350	0.1109643

APPENDIX 3

CORRESPONDENCE REGARDING SETTING OF SPRAY GUN PARAMETERS

FAX FORM

RON JOSEPH & ASSOCIATES, INC.
12514 Scully Ave.
Saratoga, CA 95070
TEL: (408) 446-9736
FAX: (408) 446-9736

DATE: March 21, 1995

TO: GLEN MUIR
GRACO, INC.

PHONE: (612) 623-6316

FAX #: (612) 623-6777

FROM: RON JOSEPH

SUBJECT: **TASK #3 ESTABLISHING SPRAY GUN PARAMETERS - Revision #1**

Dear Glen,

Thank you for commenting on the first draft of this scenario. After our discussion this morning I have revised the document and would appreciate your review yet again.

The available parameters are as follows:

- Film build (mils)
- Appearance (Gloss and Distinctness of Image, DOI)
- Coating Viscosity
- Fluid flow rate (mL/min)
- Atomizing air pressure
- Gun-target distance
- Speed of gun travel
- Number of gun strokes
- Orifice size
- Fan size

1 **Scenario #1** Evaluates the following

Parameter	Fixed or Variable
Coating film build (mils)	Goal
Appearance	Goal
Coating viscosity	Fixed
Speed of gun travel	Fixed
Gun-target distance	Fixed
Fan size	Fixed
Number of strokes	Variable
Fluid flow rate (mL/min)	Variable
Atomizing air pressure	Variable
Orifice size	Variable

2 Application Goals

2.1 <u>Coating Film Build (mils)</u>

The film build will be specified in the protocol and must not be varied outside the specified tolerance limits. All spray guns will be expected to achieve the specified value.

2.2 <u>Appearance</u>

Appearance it terms of gloss and distinctness of image (DOI) will be specified. All spray guns will be expected to achieve an acceptable finish in terms of the specification.

3 Analysis of Scenario #1

3.1 <u>Coating viscosity</u>

A commonly used alkyd high solids air drying enamel coating which satisfies the VOC requirements of all affected states (3.5 lbs/gal or 420 g/L) has been selected. Therefore, it is reasonable to expect that all spray gun types should be capable of applying this coating to the specified film build.

Coating viscosity will be maintained constant regardless of the spray gun, because at the specified viscosity, 16.5 - 17.0 seconds on a Zahn #3 cup, the coating VOC is 3.5 lbs/gal, 420 g/L. Even though some spray gun types, such as HVLP may have more difficulty than others in meeting the film build and appearance requirements, they nevertheless are currently being used in industry to apply similar coatings.

3.2 Speed of Gun Travel

This parameter will be fixed at approximately 20 inches per second (*still to be defined*), as this is a typical speed at which spray guns are used in industry.

Some HVLP guns may find it somewhat difficult to keep up with this speed, in which case the operator will have the option to apply the coating in more than two strokes.

If the speed of travel is somewhat slow for guns such airless and air-assisted airless, the operator may apply the coating in one, rather than two strokes.

3.3 Gun-Target Distance

The gun-target distance will be standardized for all guns, and will probably be set at 10 inches. (*This is still being evaluated.*)

The rationale is as follows:

Most **HVLP** guns can apply the coating at this distance, although some vendors prefer to specify 6-8 inches. Therefore, it is acknowledged that some HVLP guns might exhibit a slight disadvantage when compared to other guns.

The **conventional** gun, which has always been the standard or benchmark for the industry, can effectively apply the coating at 10 inches.

For **electrostatic** guns, a 10 inch distance is the closest one would want to go without affecting the electrostatic wrap. As the gun gets closer to the part the effect of wrap diminishes. When the gun-target distance is larger than approximately 12 inches, other factors, such as the air velocity in the booth play a larger role in affecting the wrap.

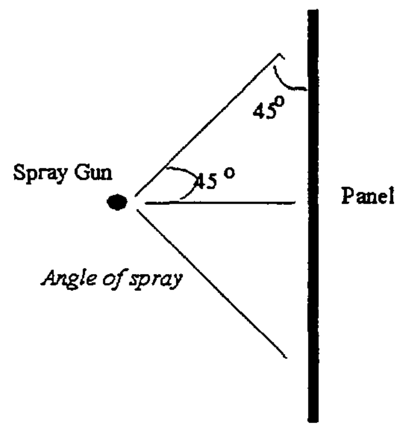
Both **air-assisted airless** and **airless** favor slightly larger distances, such as 12 inches.

Therefore, a distance of 10 inches is a realistic compromise for all guns.

3.4 Fan size

The overspray around the top and side edges of a panel is a major contributor to the resulting transfer efficiency value. Fan size is one of the most important parameters in this regard, therefore fan size will be fixed so that all guns can be judged equally.

If the gun-target distance is standardized at 10 inches, and the fan size is also standardized at 10 inches paint particles emerging from the extremes of the fan pattern will strike the target at approximately 45°. If the angle (from the perpendicular) is increased beyond this, unnecessary deflection of a particle striking the panel will take place. Although a smaller angle would increase the transfer efficiency, 45° represents a realistic scenario. *(A decision on what the standard fan size will be, must still be made. Transfer efficiency tests may need to be carried out before deciding on this value.)*



It is intended to measure envelope size so that calculations can be performed to correct for small differences in fan size.

3.5 Number of Strokes

The protocol will allow the number of strokes to be a variable. However, the operator will be required to attempt to achieve the application goals in two strokes. Only if the goals cannot be achieved in two strokes, will the operator have the option to apply the coating in one, or more than two strokes.

The rationale is that to the extent possible, all guns should be tested under similar conditions, hence the requirement for a standard two strokes. If the operator has free choice to select the fewest or the most number of strokes to apply the coating, then it is possible that he/she will favor a selection which will unrealistically increase the transfer efficiency of a gun, hence making the gun appear to more efficient than it really is.

3.6 Fluid flow rate

The fluid flow rate will vary for each gun. However, it must be understood that lower flow rates favor higher transfer efficiency values. Therefore, to prevent an operator from selecting an unrealistically low flow rate for a particular gun, the protocol will require the operator to attempt to accomplish the finishing goals in two gun strokes. Only if it can be demonstrated that the finish cannot be achieved within two strokes may the operator lower the flow rate.

It is understood that some guns, such as airless and air-assisted airless require high flow rates to be effective. For these guns it is feasible that the operator may need to apply the coating in one stroke.

3.7 Atomizing air pressure

This parameter which will remain variable, must be adjusted for each gun used. Atomizing air pressure will depend on the fluid flow rate.

Low atomizing air pressures favor higher transfer efficiencies; therefore, when testing a **conventional air atomizing** gun, the protocol will require the air pressure to be no less than 40 psig. Although this gun can atomize coatings at lower pressures, it is unusual for operators to spray below 40 psig, and the protocol would not provide a true estimate of the gun's efficiency.

The **air-assisted airless** gun also uses air, but at low pressures the air serves solely to shape the fan. At higher pressures the air can also affect atomization, but transfer efficiency will be adversely affected. Therefore, the protocol will require shaping air pressures less than 15 psig. (*This value is still negotiable.*)

3.8 Orifice size

In order to satisfy all of the fixed parameters, the orifice, and perhaps also the needle (where applicable) might need to be selected for each gun. The spray gun vendor would be allowed to make the most appropriate selection based on the vaules of the fixed parameters.

Glen, please review this draft, and make any comments. Moreover, please could you ask your colleagues at Binks, DeVilbiss-Ransberg, Nordson and any other vendors with whom you have contact, to comment on the above scenario.

Cordially yours,

Ron Joseph
Ron Joseph & Associates, Inc.

APPENDIX 4

DIXON CRITERIA FOR TESTING OF EXTREME OBSERVATION

NOTE

The following Appendix discusses how to test for outliers when a set of numbers is being evaluated. The test is relevant to the Transfer Efficiency Test Protocol, because there are instances in which one or two values in a set of numbers do not appear to fit with the remainder.

This document was taken from the following reference:

Quality Assurance Handbook for Air Pollution Measurement Systems, EPA-600/9-76-005

In this proptocol the Dixon Criteria for Testing of Extreme Observation will be used. Refer to Table F.1.

In this proptocol the Dixon Criteria for Testing of Extreme Observation will be used. Refer to Table F.1.

APPENDIX F

OUTLIERS

F.1 INTRODUCTION

An unusually large (or small) value or measurement in a set of observations is usually referred to as an outlier. Some of the reasons for an outlier in data are:

Faulty instrument or component part
Inaccurate reading of record, dial, etc.
Error in transcribing data
Calculation errors
Actual value due to unique circumstances under which the observation(s) was obtained--an extreme manifestation of the random variability inherent in the data.

It is desired to have some statistical procedure to test the presence of an outlier in a set of measurements. The purpose of such tests would be to:

1. Screen data for outliers and hence to identify the need for closer control of the data generating process.

2. Eliminate outliers prior to analysis of the data. For example, in developing control charts the presence of outliers would lead to limits which are too wide and would make the use of the control charts of minimal, if any, value. In most statistical analysis of data (e.g., regression analysis and analysis of variance) the presence of outliers violate a basic assumption of the analysis. Incorrect conclusions are likely to result if the outliers are not eliminated prior to analysis. Outliers should be reported, and their omission from analysis should be noted.

3. Identify the real outliers due to unusual conditions of measurement (e.g., a TSP concentration which is abnormally

large due to local environmental conditions during the time of sample collection). Such observations would not be indicative of the usual concentrations of TSP, and may be eliminated depending on the use of the data. Ideally, these unusual conditions should be recorded on the field data report. Failure to report complete information and unusual circumstances surrounding the collection and analysis of the sample often can be detected by outlier tests. Having identified the outliers using one or more tests, it is necessary to determine, if possible, the cause of the outlier and then to correct the data if appropriate.

It will be assumed in this discussion that the measurements are normally distributed and that the sample of n measurements is being studied for the possibility of one or two outliers. If the measurements are lognormally distributed, such as for concentration of TSP, then the logarithm of the data should be taken prior to application of the tests given herein.

F.2 PROCEDURE(S) FOR IDENTIFYING OUTLIERS

Let the set of n measurements be arranged in ascending order and denoted by

$$X_1, X_2, \ldots, X_n$$

where X_i denotes the ith smallest measurement. Suppose that X_n is suspected of being too large, and that a statistical test is to be applied to the particular measurement to determine whether X_n is consistent with the remaining data in the sense that it is reasonable that it is part of the same population of measurements from which the sample is taken. Consider the following TSP data from a specific monitoring site during August 1978.

Example F.1

TSP, µg/m³	ln TSP
40	3.69
88	4.48
71	4.26
175	5.16
85	4.44

One test procedure for questionable data is to use a test by Dixon,[1] see Table F.1,

$$r_{10} = \frac{X_n - X_{n-1}}{X_n - X_1} = \frac{175-88}{175-40} = \frac{87}{135} = 0.655. \qquad (1)$$

Referring to Table F.1 the 5% significance level for r_{10} is 0.642 and we would thus declare that the value 175 appears to be an outlier. The value should be flagged for further investigation. We do not automatically remove data because a statistical test indicates the value(s) to be questionable.

Suppose that we know that the data are lognormally distributed (or at least that the log normal distribution is a very good approximation), then we should examine the Dixon Ratio for this example. Using the logarithm, the Dixon ratio is

$$r_{10} = \frac{5.16 - 4.48}{5.16 - 3.69} = 0.46,$$

and this value is not significant at the 5% level. Hence on this basis the extreme value 175 is not questionable.

We still may wish to investigate the value further (data permitting) and we compare the data with those at a neighboring site. The corresponding data are given below.

Site 20 TSP, μg/m³	Site 14 TSP, μg/m³
40	42
88	53
71	56
175	129
85	64

Thus we see that the value 175 does not appear to be questionable in view of the corresponding value for a neighboring site. Both sites have high values on the same day, suggesting a common source of the high values. The only means to investigate these values further is to go to the source of the data collection and review the meteorological factors, comments in the site logbooks relative to local construction activity, daily traffic, and other possible causation factors.

TABLE F.1. DIXON CRITERIA FOR TESTING OF EXTREME OBSERVATION (SINGLE SAMPLE)*

n	Criterion	Significance level 10%	5%	1%
3	$r_{10} = \frac{x_2 - x_1}{x_n - x_1}$ if* smallest value is suspected;	.886	.941	.988
4		.679	.765	.889
5		.557	.642	.780
6	$= \frac{x_n - x_{n-1}}{x_n - x_1}$ if largest value is suspected.	.482	.560	.698
7		.434	.507	.637
8	$r_{11} = \frac{x_2 - x_1}{x_{n-1} - x_1}$ if smallest value is suspected;	.479	.554	.683
9	$= \frac{x_n - x_{n-1}}{x_n - x_2}$ if largest value is suspected.	.441	.512	.635
10		.409	.447	.597
11	$r_{21} = \frac{x_3 - x_1}{x_{n-1} - x_1}$ if smallest value is suspected.	.517	.576	.679
12	$= \frac{x_n - x_{n-2}}{x_n - x_2}$ if largest value is suspected.	.490	.546	.642
13		.467	.521	.615
14	$r_{22} = \frac{x_3 - x_1}{x_{n-2} - x_1}$ if smallest value is suspected.	.492	.546	.641
15		.472	.525	.616
16		.454	.507	.595
17	$= \frac{x_n - x_{n-2}}{x_n - x_3}$ if largest value is suspected;	.438	.490	.577
18		.424	.475	.561
19		.412	.462	.547
20		.401	.450	.535
21		.391	.440	.524
22		.382	.430	.514
23		.374	.421	.505
24		.367	.413	.497
25		.360	.406	.489

*Reproduced with permission from W. J. Dixon, "Processing Data for Outliers," Biometrics, March 1953, Vol. 9, No. 1, Appendix, Page 89. (Reference [1])

$x_1 \leq x_2 \leq \cdots \leq x_{n-2} \leq x_{n-1} \leq x_n$

Criterion r_{10} applies for $3 \leq n \leq 7$

Criterion r_{11} applies for $8 \leq n \leq 10$

Criterion r_{21} applies for $11 \leq n \leq 13$

Criterion r_{22} applies for $14 \leq n \leq 25$

This example points out several considerations in validating data and in particular in detecting and flagging outliers.

1. The use of a statistical procedure for detecting an outlier is a first step and the result should not be to throw out the value(s) if the statistic is significant but to treat the value(s) as suspect until further information can be obtained.

2. The statistical procedures depend on specific assumptions, particularly concerning the distribution of the data--normal, lognormal, and Weibull--and the result should be checked using the distribution which best approximates the data.

3. Often there are values at neighboring sites which can be used to compare the values. If the values at the two sites are correlated, as in the Example F.1, this approach can be very helpful.

4. The final resolution of the suspect values can be made by the collection agency, thus the importance of performing the data validation at the local agency.

Another commonly used test procedure,[2] requires additional computation and is given by

$$T_n = (X_n - \bar{X})/s \qquad (2)$$

where: X_n is the largest observed value among n measurements,
$\bar{X}$ is the sample average,
s is the sample standard deviation (i.e.,
$s = \{\Sigma(X-\bar{X})^2/(n-1)\}^{1/2}$).

For the data set previously given,

$X_n = 175$
$\bar{X} = 91.8$
$s = 50.2$

and hence $T_n = 1.66$, which is not significant at the 0.05 level, that is, it is less than 1.672 which is the tabulated value for this level from Table F.2. This test result is not in agreement with the previous one, however, both test results are borderline

TABLE F.2. TABLE OF CRITICAL VALUES FOR T(ONE-SIDED TEST OF T_1 OR T_n) WHEN THE STANDARD DEVIATION IS CALCULATED FROM THE SAME SAMPLE

Number of Observations n	Upper .1% Significance Level	Upper .5% Significance Level	Upper 1% Significance Level	Upper 2.5% Significance Level	Upper 5% Significance Level	Upper 10% Significance Level
3	1.155	1.155	1.155	1.155	1.153	1.148
4	1.499	1.496	1.492	1.481	1.463	1.425
5	1.780	1.764	1.749	1.715	1.672	1.602
6	2.011	1.973	1.944	1.887	1.822	1.729
7	2.201	2.139	2.097	2.020	1.938	1.828
8	2.358	2.274	2.221	2.126	2.032	1.909
9	2.492	2.387	2.323	2.215	2.110	1.977
10	2.606	2.482	2.410	2.290	2.176	2.036
11	2.705	2.564	2.485	2.355	2.234	2.088
12	2.791	2.636	2.550	2.412	2.285	2.134
13	2.867	2.699	2.607	2.462	2.331	2.175
14	2.935	2.755	2.659	2.507	2.371	2.213
15	2.997	2.806	2.705	2.549	2.409	2.247
16	3.052	2.852	2.747	2.585	2.443	2.279
17	3.103	2.894	2.785	2.620	2.475	2.309
18	3.149	2.932	2.821	2.651	2.504	2.335
19	3.191	2.968	2.854	2.681	2.532	2.361
20	3.230	3.001	2.884	2.709	2.557	2.385
21	3.266	3.031	2.912	2.733	2.580	2.408
22	3.300	3.060	2.939	2.758	2.603	2.429
23	3.332	3.087	2.963	2.781	2.624	2.448
24	3.362	3.112	2.987	2.802	2.644	2.467
25	3.389	3.135	3.009	2.822	2.663	2.486
26	3.415	3.157	3.029	2.841	2.681	2.502
27	3.440	3.178	3.049	2.859	2.698	2.519
28	3.464	3.199	3.068	2.876	2.714	2.534
29	3.486	3.218	3.085	2.893	2.730	2.549
30	3.507	3.236	3.103	2.908	2.745	2.563
31	3.528	3.253	3.119	2.924	2.759	2.577
32	3.546	3.270	3.135	2.938	2.773	2.591
33	3.565	3.286	3.150	2.952	2.786	2.604
34	3.582	3.301	3.164	2.965	2.799	2.616
35	3.599	3.316	3.178	2.979	2.811	2.628
36	3.616	3.330	3.191	2.991	2.823	2.639
37	3.631	3.343	3.204	3.003	2.835	2.650
38	3.646	3.356	3.216	3.014	2.846	2.661
39	3.660	3.369	3.228	3.025	2.857	2.671
40	3.673	3.381	3.240	3.036	2.866	2.682
41	3.687	3.393	3.251	3.046	2.877	2.692
42	3.700	3.404	3.261	3.057	2.887	2.700
43	3.712	3.415	3.271	3.067	2.896	2.710
44	3.724	3.425	3.282	3.075	2.905	2.719
45	3.736	3.435	3.292	3.085	2.914	2.727
46	3.747	3.445	3.302	3.094	2.923	2.736
47	3.757	3.455	3.310	3.103	2.931	2.744
48	3.768	3.464	3.319	3.111	2.940	2.753
49	3.779	3.474	3.329	3.120	2.948	2.760
50	3.789	3.483	3.336	3.128	2.956	2.768

Use $T_1 = \frac{\bar{X} - X_1}{s}$ when testing the smallest value, X_1.

Use $T_n = \frac{X_n - \bar{X}}{s}$ when testing the largest value, X_n in a sample of n observations. Unless one has prior information about largest values (or smallest values) the risk levels should be multiplied by two for application of the test.

TABLE F.2 (continued)

Number of Observations n	Upper .1% Significance Level	Upper .5% Significance Level	Upper 1% Significance Level	Upper 2.5% Significance Level	Upper 5% Significance Level	Upper 10% Significance Level
51	3.798	3.491	3.345	3.136	2.964	2.775
52	3.808	3.500	3.353	3.143	2.971	2.783
53	3.816	3.507	3.361	3.151	2.978	2.790
54	3.825	3.516	3.368	3.158	2.986	2.798
55	3.834	3.524	3.376	3.166	2.992	2.804
56	3.842	3.531	3.383	3.172	3.000	2.811
57	3.851	3.539	3.391	3.180	3.006	2.818
58	3.858	3.546	3.397	3.186	3.013	2.824
59	3.867	3.553	3.405	3.193	3.019	2.831
60	3.874	3.560	3.411	3.199	3.025	2.837
61	3.882	3.566	3.418	3.205	3.032	2.842
62	3.889	3.573	3.424	3.212	3.037	2.849
63	3.896	3.579	3.430	3.218	3.044	2.854
64	3.903	3.586	3.437	3.224	3.049	2.860
65	3.910	3.592	3.442	3.230	3.055	2.866
66	3.917	3.598	3.449	3.235	3.061	2.871
67	3.923	3.605	3.454	3.241	3.066	2.877
68	3.930	3.610	3.460	3.246	3.071	2.883
69	3.936	3.617	3.466	3.252	3.076	2.888
70	3.942	3.622	3.471	3.257	3.082	2.893
71	3.948	3.627	3.476	3.262	3.087	2.897
72	3.954	3.633	3.482	3.267	3.092	2.903
73	3.960	3.638	3.487	3.272	3.098	2.908
74	3.965	3.643	3.492	3.278	3.102	2.912
75	3.971	3.648	3.496	3.282	3.107	2.917
76	3.977	3.654	3.502	3.287	3.111	2.922
77	3.982	3.658	3.507	3.291	3.117	2.927
78	3.987	3.663	3.511	3.297	3.121	2.931
79	3.992	3.669	3.516	3.301	3.125	2.935
80	3.998	3.673	3.521	3.305	3.130	2.940
81	4.002	3.677	3.525	3.309	3.134	2.945
82	4.007	3.682	3.529	3.315	3.139	2.949
83	4.012	3.687	3.534	3.319	3.143	2.953
84	4.017	3.691	3.539	3.323	3.147	2.957
85	4.021	3.695	3.543	3.327	3.151	2.961
86	4.026	3.699	3.547	3.331	3.155	2.966
87	4.031	3.704	3.551	3.335	3.160	2.970
88	4.035	3.708	3.555	3.339	3.163	2.973
89	4.039	3.712	3.559	3.343	3.167	2.977
90	4.044	3.716	3.563	3.347	3.171	2.981
91	4.049	3.720	3.567	3.350	3.174	2.984
92	4.053	3.725	3.570	3.355	3.179	2.989
93	4.057	3.728	3.575	3.358	3.182	2.993
94	4.060	3.732	3.579	3.362	3.186	2.996
95	4.064	3.736	3.582	3.365	3.189	3.000
96	4.069	3.739	3.586	3.369	3.193	3.003
97	4.073	3.744	3.589	3.372	3.196	3.006
98	4.076	3.747	3.593	3.377	3.201	3.011
99	4.080	3.750	3.597	3.380	3.204	3.014
100	4.084	3.754	3.600	3.383	3.207	3.017

Source: Grubbs, F. E., and Beck, G., Extension of Sample Sizes and Percentage Points for Significance Tests of Outlying Observations, Technometrics, Vol. 14, No. 4, Nov. 1972, pp. 847-854.

situations. If the T_n is applied to the logarithms, the result is $T_n = \frac{5.16-4.41}{0.527} = 1.42$, which is not significant and which agrees with the Dixon ratio test. In many examples it will be obvious that a particular value is an outlier, whereas in Example F.1 this is not the case. A plot of the data is often helpful in examining a set of data.

After rejecting one outlier using either T_n or T_1 the analyst may be faced with the problem of considering a second outlier. In this case the mean and standard deviation may be re-estimated and either T_{n-1} or T_1 applied to the sample of n-1 measurements. However, the user should be aware that the test T_n or T_1 is not theoretically based on repeated use.

Grubbs[2] gives a test procedure (including tables for the critical values) for simultaneously testing the two largest or two smallest values. This procedure is not given here.

The use of the procedures given in Table F.1 requires very little computation and would be preferable on a routine basis. Grubbs[3] gives a tutorial discussion of outliers and is a very good reference to the subject. A recent text on outliers is also recommended to the reader with some statistical background.[4]

One other procedure for data validation which has an advantage relative to the previous two procedures (Dixon and Grubbs) is the use of a statistical control chart.[5,6] The control chart is discussed in Appendix H and the reader is referred to that Appendix for details in application. The TSP data for a specific site for the years 1975 to 1977 for which there are five measurements per month are used as a historical data base for the control chart and the data for 1978 are plotted on the chart to indicate any questionable data. These data are shown in Table F.3 (historical data) and in Table F.4 (1978 data). Figure F.1 (upper part) is the control chart with both 2σ and 3σ limits for the averages.

$$\bar{\bar{X}} \text{ (average of the } \bar{X}\text{'s)} = 56.5\ \mu g/m^3$$

TABLE F.3. TSP DATA FROM SITE 397140014H01 SELECTED AS HISTORICAL DATA BASE FOR SHEWHART CONTROL CHART (1975-1977)

Month-year	Mean ($\bar{X}$), $\mu g/m^3$	Range (R), $\mu g/m^3$	Month-year	Mean ($\bar{X}$), $\mu g/m^3$	Range (R), $\mu g/m^3$
1-75	54.6	67	10-76	34.6	50
5-75	63.8	39	11-76	53.4	29
6-75	59.0	25	12-76	52.2	44
7-75	63.0	23	3-77	40.4	28
8-75	68.2	54	4-77	63.6	57
10-75	41.8	26	6-77	45.4	31
11-75	68.4	81	7-77	53.4	19
12-75	57.6	39	8-77	58.6	26
1-76	82.4	87	9-77	46.0	12
4-76	90.2	117	10-77	45.6	33
5-76	43.8	48	11-77	49.8	54
7-76	72.6	80	12-77	30.4	22
9-76	73.4	83			

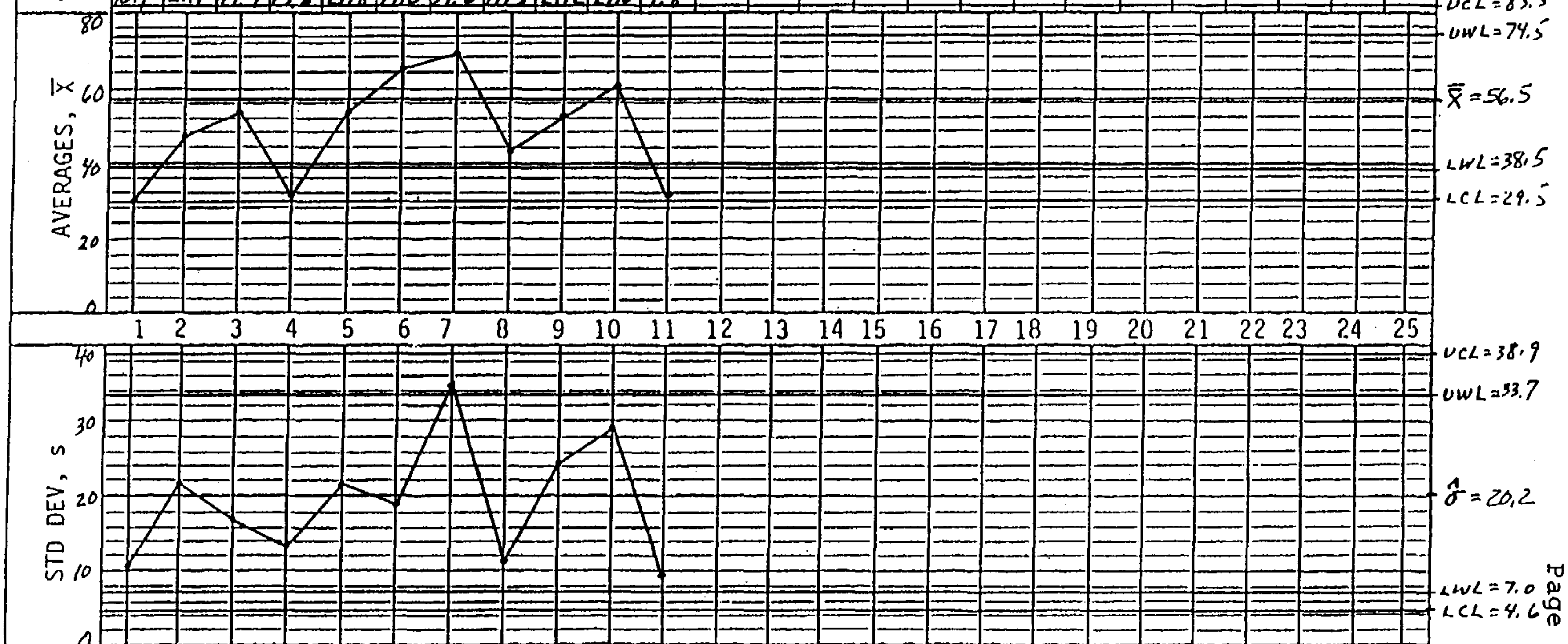
TABLE F.4. TSP DATA FROM SITE 397140014H01 FOR CONTROL CHART (1978)

Data set	Month	Mean	Range	s
1	1	30.6	27	10.4
2	2	47.4	60	21.7
3	3	54.4	39	17.2
4	4	31.8	29	13.6
5	5	53.6	46	21.8
6	6	64.8	46	19.0
7	8	68.8	87	34.6
8	9	43.2	31	11.3
9	10	52.4	59	24.2
10	11	60.8	71	29.0
11	12	31.6	22	9.8

$\bar{X}$ AND s CHART

PROJECT *Validation of TSP Data.* MEASUREMENT *Daily TSP at Site 397140014101* UNITS *$\mu g/m^3$*

DATE/mo	1	2	3	4	5	6	8	9	10	11	12
MEASUREMENT CODE 1											
MEASUREMENT CODE 2											
MEASUREMENT CODE 3											
MEASUREMENT RESULT 1											
MEASUREMENT RESULT 2											
MEASUREMENT RESULT 3											
SUM											
$\bar{X}$	30.6	47.4	54.4	31.8	53.6	64.8	68.8	43.2	52.4	60.8	31.6
s	10.4	21.7	17.2	13.6	21.8	19.0	34.6	11.3	24.2	29.0	9.8



COMMENTS (CORRECTIVE ACTION, ETC.)

Figure F.1. $\bar{X}$ and s control charts for TSP data.

$\sigma_{\bar{X}}$ (standard deviation of the mean) = 9.0 μg/m^3

$UWL_{\bar{X}}$ (upper 2σ limit) = 74.5 μg/m^3

$LWL_{\bar{X}}$ (lower 2σ limit) = 38.5 μg/m^3

$UCL_{\bar{X}}$ (3σ) = 83.5 μg/m^3

$LCL_{\bar{X}}$ (3σ) = 29.5 μg/m^3

Figure F.1 shows three averages below the $LWL_{\bar{X}}$ (2σ limit) and no values above the $UWL_{\bar{X}}$ (2σ limit). No values are below the 3σ limit $LCL_{\bar{X}}$ (3σ). Hence we do not suspect any averages to be significantly different from the historical average and which would suggest further investigation.

Figure F.1 (lower part) is the control chart for the standard deviation.

$\bar{R}$ (average range) = 47.0

$\hat{\sigma}$ = 0.43 (47.0) = 20.2

UWL_s (upper 2σ limit for s) = 33.7

LWL_s (lower 2σ limit for s) = 7.0

UCL_s (99.5 percentile) = 38.9

LCL_s (0.5 percentile) = 4.6

There is a single outlier on this chart and this sample (one month of data--5 values) should be checked for factors which might explain the high value for the standard deviation. See Example F.1 for further discussion of this example relative to action taken after the flagging or identification of the questionable value. The same data were used in that example.

The advantage of the quality control chart approach is that not only are questionable values within a month detected, but also if all of the values for a month are high relative to values for other months, they will be flagged. The latter can result from personnel changes, instrument problems, calculation errors, and such changes will go undetected when comparing a single possible outlier within a data set. It is recommended that both test procedures (Dixon or Grubbs and the control chart) be used if resources permit, if not use the control chart technique.

F.3 GUIDANCE ON SIGNIFICANCE LEVELS

The problem of selecting an appropriate level of significance in performing statistical tests for outliers is one of comparing two resulting costs. If the significance level is set too high (e.g., 0.10 or 0.20) there is the cost of investigating the data identified as questionable a relatively large proportion of the time that, in fact, the data are valid.[1] On the other hand, if the significance level is set too low (e.g., 0.005 or 0.001) invalid data may be missed and these data may be subsequently used in making incorrect decisions. This cost can also be large but is difficult to estimate. The person responsible for data validation must therefore seek an appropriate level based on these two costs. If the costs of checking the questionable data are small, it is better to err on the safe side and use $\alpha = 0.05$ or 0.10 say. Otherwise, a value of $\alpha = 0.01$ would probably be satisfactory for most applications. After experience is gained with the validation procedure, the α value should be adjusted as necessary to minimize the total cost (i.e., the cost of investigating outliers plus that of making incorrect decisions).

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3. Grubbs, F. E., Procedures for Detecting Outlying Observations in Samples, <u>Technometrics</u>, Vol. 11, No. 1, February 1969, pp. 1-21.

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APPENDIX 5

DATA ENTRY FORMS

Example of how all Data Forms are used

Note: the Cover Sheet and Data Forms 1-1 to 1-8 are completed by the technician while conducting a test. Data Forms 3 through 8 are generated by the Excel 5.0 spreadsheet computer program.

COVER SHEET

RATING EVALUATION FOR SPRAY GUNS

JOB NUMBER	**TSK463B**
DATE TESTS PERFORMED	**12/12/95**

NAME AND ADDRESS OF LABORATORY:

Ace Spray Gun Laboratory

Irwindale, CA

Phone:	(818) 81-9999
FAX :	(818) 81-8888

NAME OF TECHNICIANS:

Jack Jones

Barbara King

TYPE OF SPRAY GUN TESTED	**Conventional Air Atomizing**

NAME OF SPRAY GUN MANUFACTURER:

Saratoga Spray Guns Inc.

	B	C	D	E	F	G
54	JOB NO:	TSK463B	DATA FORM 1-1			
55			DETAILS OF SPRAY GUN EFFICIENCY EVALUATION			
56						
57						
58		Date	12/12/95			
59						
60		Panel ID	*(If more than one set of panels is run, enter the ID of each set)*		AAD, AAE, AAF	
61		**Description of Tests:**				
62		Three test set evaluations using six panels per set.				
63						
64						
65						
66						
67						
68		***Details of Coating and Calibration of***			**Enter Data Here**	
69		***Density and % Wt Solids***				
70		Name of Coating Manufacturer			Cardinal Industries	
71		Name of Coating			High Solids Air Dry	
72		Coating ID			#16440	
73		Coating Batch #			3.06	
74		Coating Temperature at Spray Gun Run (oF)			82	
75						
76		Coating Viscosity Zahn #3 (secs)			16 @ 82F	
77		Coating Viscosity Stormer (Krebbs)			58 @ 82F	
78		Coating Conductivity (uA)			N/A	
79		Coating %Wt Water (per ASTM 4017 - Karl Fischer)			N/A	
80		Was reducer added to adjust viscosity? (Y/N)			Yes	
81		Name of Solvent added			MPK	
82						
83				PAGE 1 OF 8		
84						

	B	C	D	E	F	G
88	JOB NO:	TSK463B	DATA FORM 1-2			
89			DETAILS OF SPRAY GUN EFFICIENCY EVALUATION			
90						
91		***Spray Gun Details and Settings***			**Enter Data Here**	
92		Name of Spray Gun Vendor			Saratoga Spray Guns Inc.	
93		Spray Gun Type (e.g. HVLP)			Conventional Air Atomizing	
94		Spray Gun Model Name			AA 200HS	
95		Spray Gun Model No:			Same	
96		Spray Gun Tip Size			413	
97		Spray Gun Orifice Size			0.013	
98		Spray Gun Cap Size			N/A	
99		Spray Gun Needle Size			N/A	
100		Gun-Target Distance (inches)			10	
101		Width of leading edge (inches)			1.75	
102		Width of trailing edge (inches)			1.75	
103		Fan Size (inches)			10	
104		Speed of gun (mm/sec)			250	
105		No. of Strokes			5	
106		Number of passes			1	
107						
108		***Air Flow Through Spray Gun***				
109		Air Flow through Gun (cfm)			Not Measured	
110		Air Temperature at Gun (oF)			76.6	
111		Air Pressure to Gun (psig)			20	
112		Air pressure at cap (for all guns) (psig)			Not Measured	
113						
114		Air valve opening (screw turns)			N/A	
115						
116		***Fluid Pressure to Spray Gun***				
117		Type of fluid pumping system (e.g. pump, pressure pot)			High Pressure	
118		Ratio of pump (if applicable)			15:1	
119		Fluid Pressure at Gun (psig)			~375	
120		Fluid valve opening (screw turns)			N/A	
121						
122		***Electrostatics of Spray Gun***				
123		Electrostatic Voltage at Tip (if applicable) (KV)			N/A	
124		Ground checked? (Y / N)			Yes	
125						
126		***Computer Set-up***				
127		*(Note: Other computer details are on Data Form 6, Sheet #2)*				
128		Computer program for particular coating application			TE3MED6	
129						
130		***Environmental Conditions***				
131		Ambient Temperature (oF)			76.6	
132		Ambient Relative Humidity (%)			46	
133		Spray Booth Air Velocity (fpm)			77	
134						
135				PAGE 2 OF 8		
136						

	B	C	D	E	G	I
3	JOB #	TSK463B		DATA FORM 1-3		
4			CALIBRATION OF COATING PROPERTIES			
5			Measurements for Coating Density			
6			(Refer to Appendix II, Section 1)			
7						
8		Date	12/12/95	Coating ID	#16440	
9		Calibration of cup volume (from cup vendor)			1.0000	
10		Measurement #1				
11		A	Weight of Empty Cup (g) #1		56.698	
12		B	Weight of Full Cup (g)		67.079	
13						
14		Measurement #2				
15		A	Weight of Empty Cup (g) #2		56.660	
16		B	Weight of Full Cup (g)		67.059	
17						
18		Measurement #3				
19		A	Weight of Empty Cup (g) #3		56.764	
20		B	Weight of Full Cup (g)		67.166	
21						
22			Measurements for Coating % Wt Solids			
23			(Refer to Appendix II Section 2)			
24						
25		Oven Temp.(F)	250	Time in Oven (mins):	30	
26						
27		ID-1	WEIGHINGS	SYRINGE	ALUMINUM DISH	
28			First (g)	18.850	1.161	
29			Second (g)	18.356	1.491	
30						
31		ID-2	WEIGHINGS	SYRINGE	ALUMINUM DISH	
32			First (g)	18.356	1.148	
33			Second (g)	17.687	1.595	
34						
35		ID-3	WEIGHINGS	SYRINGE	ALUMINUM DISH	
36			First (g)	17.687	1.138	
37			Second (g)	17.045	1.564	
38						
39		ID-4	WEIGHINGS	SYRINGE	ALUMINUM DISH	
40			First (g)	17.045	1.136	
41			Second (g)	16.486	1.508	
42						
43		ID-5	WEIGHINGS	SYRINGE	ALUMINUM DISH	
44			First (g)	16.486	1.161	
45			Second (g)	15.721	1.670	
46						
47					PAGE 3 OF 8	
48						

JOB # TSK463B

DATA FORM 1-4

Calibration of Flow Meter
Weighing of Plastic Bags

Pulse Equivalent (cc/cog) (from vendor's calibration) 0.12117

	WEIGHT OF PLASTIC BAGS		FLOW METER READINGS	
Bag #	Before (g)	After (g)	FM Start Pulse	FM Stop Pulse
1	10.006	50.216	0	273
2	10.018	15.659	0	39
3	10.037	15.056	39	72
4	10.078	16.305	0	42
5	10.089	16.429	42	84
6	10.063	16.392	0	42
7	10.014	16.269	0	43
8	9.977	16.293	0	42
9	9.973	16.367	0	44
10	9.973	16.221	0	43

B	C	D	E	G	I	K	L
JOB #	TSK463B			DATA FORM 1-5			
			RECORDING COATING USAGE DURING APPLICATION OF				
				COATING ON PANELS			
		1st SET	PANEL WEIGHT READINGS		FLOW METER READINGS		
		Panel ID	Wt. Uncoated Panel (g)	Wt. Coated Panel (g)	FM After Purge Pulse	FM after Panel is coated Pulse	
	1	AAD	1145.1	1156.6	79	322	
	2	AAD	1141.1	1152.3	79	321	
	3	AAD	1147.5	1159.2	80	317	
	4	AAD	1141.1	1152.4	80	314	
	5	AAD	1270.5	1281.6	80	318	
	6	AAD	1151.2	1161.4	79	313	
		2nd SET	PANEL WEIGHT READINGS		FLOW METER READINGS		
	1	AAE	1137.8	1148.7	74	308	
	2	AAE	1147.0	1157.7	75	314	
	3	AAE	1254.7	1265.5	75	315	
	4	AAE	1281.0	1291.9	74	315	
	5	AAE	1145.4	1155.4	77	311	
	6	AAE	1146.0	1156.4	77	309	
		3rd SET	PANEL WEIGHT READINGS		FLOW METER READINGS		
	1	AAF	1148.9	1159.3	79	313	
	2	AAF	1141.7	1153.0	79	322	
	3	AAF	1269.0	1280.4	78	313	
	4	AAF	1156.2	1167.5	79	320	
	5	AAF	1143.0	1153.9	79	312	
	6	AAF	1260.3	1271.8	79	318	
						PAGE 5 OF 8	

	B	C	D	E	G	I	K	L
150	JOB #	TSK483B		**DATA FORM 1-6**				
151				**DETERMINATION OF**				
152				**ACCEPTABLE APPEARANCE**				
153								
154		**SET #1**	**DOI "C" RECOGNITION**	**GLOSS 60°**	**AVERAGE GLOSS**	**AVEAGE DRY FILM THICKNESS**	**PASS/FAIL**	
155		AAD3	45	93	90	1.3		
156				89				
157				89				
158				89				
159		AAD5	40	85	87.5	1.5		
160				87				
161				90				
162				88				
163		**MEANS**	42.5		88.75	1.4		
164								
165		**SET #2**	**DOI "C" RECOGNITION**	**GLOSS 60°**	**AVERAGE GLOSS**	**AVEAGE DRY FILM THICKNESS**	**PASS/FAIL**	
166								
167								
168								
169								
170								
171								
172								
173								
174		**MEANS**	#DIV/0!		#DIV/0!	#DIV/0!		
175								
176		**SET #3**	**DOI "C" RECOGNITION**	**GLOSS 60°**	**AVERAGE GLOSS**	**AVEAGE DRY FILM THICKNESS**	**PASS/FAIL**	
177								
178								
179								
180								
181								
182								
183								
184								
185		**MEANS**	#DIV/0!		#DIV/0!	#DIV/0!		
186								
187		**CRITERIA FOR ACCEPTABLE APPEARANCE:**			DOI $\geq$ 40	Gloss 60 deg $\geq$ 85	DFT 1.0-1.5 mils	
188						PAGE 8 OF 8		
189								

JOB #	TSK463B		DATA FORM 1-7		
			MEASUREMENT OF DRY FILM THICKNESS		
	Panel ID:		SET#		
		COLUMNS			
	ROWS	1	2	3	4
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
				MEAN DFT	#DIV/0!
				STD. DEV	#DIV/0!
				COV (%)	#DIV/0!
	Panel ID:				
		COLUMNS			
	ROWS	1	2	3	4
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
				MEAN DFT	#DIV/0!
				STD. DEV	#DIV/0!
				COV (%)	#DIV/0!
				MEAN OF MEAN DFT	#DIV/0!

NOTE 1: TWO PANELS ARE REQUIRED PER TEST SET

NOTE 2: THREE TEST SETS COMPRISE A TEST SERIES.

THEREFORE, THIS FORM MUST BE COMPLETED FOR EACH TEST SERIES.

	B	C	D	E	F	G	H	I	J
2	JOB #	TSK463B		DATA FORM 1-8					
3			MEASUREMENT OF SPRAY ENVELOPE						
4									
5		1st SET							
6		Panel ID							
7									
8			1	2	3	4	5	Mean (in)	
9		Width (in)	19.5	19.7	21.0	18.9	19.0	19.6	
10		Height (in)	23.6	23.9	22.0	23.9	24.0	23.5	
11						Area of Envelope (in2)		460.7	
12									
13		2nd SET							
14		Panel ID							
15									
16			1	2	3	4	5	Mean (in)	
17		Width (in)	19.3	19.7	22.0	18.5	19.0	19.7	
18		Height (in)	23.9	22.0	22.5	23.9	23.8	23.2	
19						Area of Envelope (in2)		457.4	
20									
21		3rd SET							
22		Panel ID							
23									
24			1	2	3	4	5	Mean (in)	
25		Width (in)	19.2	19.7	19.5	18.9	19.0	19.3	
26		Height (in)	23.7	23.9	22.0	23.1	24.0	23.3	
27						Area of Envelope (in2)		449.5	
28									
29							PAGE 8 OF 8		
30									

	B	C	D	E	F	G
2						
3		DATA FORM 2-1				
4		DETAILS OF LABORATORY EQUIPMENT (*)				
5		(Page 1 OF 2)				
6						
7		**Scale #1 (For light weights):**				
8		Manufacturer:				
9		Model No:				
10		Seriel No:				
11		Range (g)				
12		Precision:				
13		Calibrated? (Y or N)		Date		
14						
15		**Scale #2 (For panels):**				
16		Manufacturer:				
17		Model No:				
18		Seriel No:				
19		Range (g)				
20		Precision:				
21		Calibrated? (Y or N)		Date		
22						
23		**Weight per Gallon Cup:**				
24		Manufacturer:				
25		Model No:				
26		Seriel No:				
27		Calibrated volume (mL)				
28		*(supplied by vendor)*				
29		Precision:				
30		Calibrated? (Y or N)		Date		
31						
32		**Volumetric Fluid Flow Meter:**				
33		Manufacturer:				
34		Model No:				
35		Seriel No:				
36		Calibrated volume (mL/cog)				
37		*(supplied by vendor)*				
38		Precision:				
39		Calibrated? (Y or N)		Date		
40						
41		**Gloss Meter:**				
42		Manufacturer:				
43		Model No:				
44		Seriel No:				
45		Specular Angle of Reflectance:				
46		*(such as 60 deg)*				
47		Precision:				
48		Calibrated? (Y or N)		Date		
49						
50	(*)	**NOTE:** This form need only be completed once per test series				
51						

	B	C	D	E	F	G
55						
56			DATA FORM 2-2			
57			DETAILS OF LABORATORY EQUIPMENT (*)			
58			(Page 2 OF 2)			
59						
60		**Dry Film Thickness Gage:**				
61		Manufacturer:				
62		Model No:				
63		Seriel No:				
64		Range (mils):				
65		Precision:				
66		Calibrated? (Y or N)				
67						
68		**Viscometer**				
69		Manufacturer:				
70		Model No:				
71		Seriel No:				
72		Precision:				
73		Calibrated? (Y or N)		Date		
74						
75		**Air Velocity Meter:**				
76		Manufacturer:				
77		Model No:				
78		Seriel No:				
79		Precision:				
80		Calibrated? (Y or N)		Date		
81						
82		**Large Commercial Oven:**				
83		Manufacturer:				
84		Model No:				
85		Approx. Dimensions:				
86		Range (oF)				
87		Temperature Calibrated? (Y or N)		Date		
88						
89		**Laboratory Oven:**				
90		Manufacturer:				
91		Model No:				
92		Range (oF)				
93		Temperature Calibrated? (Y or N)		Date		
94						
95		**Psychrometer:**				
96		Manufacturer:				
97		Model No:				
98						
99		***Computer Set-up***				
100		Type of Gun mover (e.g. robot, reciprocator)				
101		Name of Vendor of Gun Mover				
102		No of axes (such as 1, 2, 3, 6)				
103	(*)	**NOTE:** This form need only be completed once per test series				
104						

	B	C	D	E	G	H	I
2							
3				DATA FORM 3-1			
4				CALCULATING % WT SOLIDS			
5				(Page 1 of 2)			
6							
7		Job #			TSK463B		
8		Date			12/12/95		
9		Coating Manufacturer			Cardinal Industries		
10		Coating Name:			High Solids Air Dry		
11		Coating ID			#16440		
12		Coating Batch #			3.06		
13		Oven Temp. (F):		250	Time in Oven (mins):	30	
14							
15							
16							
17		ID-1	WEIGHINGS	SYRINGE	ALUMINUM DISH	%WT SOLIDS	
18			First (g)	18.850	1.161		
19			Second (g)	18.356	1.491		
20			Difference (g)	0.494	0.330	66.802	
21							
22		ID-2	WEIGHINGS	SYRINGE	ALUMINUM DISH	%WT SOLIDS	
23			First (g)	18.356	1.148		
24			Second (g)	17.687	1.595		
25			Difference (g)	0.669	0.447	66.816	
26							
27							
28		ID-3	WEIGHINGS	SYRINGE	ALUMINUM DISH	%WT SOLIDS	
29			First (g)	17.687	1.138		
30			Second (g)	17.045	1.564		
31			Difference (g)	0.642	0.426	66.355	
32							
33							
34		ID-4	WEIGHINGS	SYRINGE	ALUMINUM DISH	%WT SOLIDS	
35			First (g)	17.045	1.136		
36			Second (g)	16.486	1.508		
37			Difference (g)	0.559	0.372	66.547	
38							
39							
40		ID-5	WEIGHINGS	SYRINGE	ALUMINUM DISH	%WT SOLIDS	
41			First (g)	16.486	1.161		
42			Second (g)	15.721	1.670		
43			Difference (g)	0.765	0.509	66.536	
44							
45							
46					Mean % Wt Solids	66.611	
47					Std. Deviation	0.196	
48					% Coeff. of Variance	0.294	
49							

	B	C	D	E	G	H	I	J	K	L
52										
53					DATA FORM 3-2					
54					CALCULATING COATING DENSITY					
55					(Page 2 of 2)					
56										
57		Job #		TSK463B						
58		Date		12/12/95						
59										
60						Calculation of VOC for Solvent-Borne Coating:				
61		A	Weight of Empty Cup (g) #1		56.698	VOC (lbs/gal)			3.47	
62		B	Weight of Full Cup (g)		67.079	VOC (g/L)			415.38	
63		C	Weight of Coating (g)(C) = B-A		10.381	VOC (g/mL)			0.415	
64		D	Calibration Factor (*)		1.000					
65		E	Density of Coating (lbs/gal)		10.381					
66		F	Density of Coating (g/cc)		1.244					
67		G	Density of Coating (g/L)		1,244.1					
68										
69						Calculation of VOC for Solvent-Borne Coating:				
70		A	Weight of Empty Cup (g) #2		56.660	VOC (lbs/gal)			3.47	
71		B	Weight of Full Cup (g)		67.059	VOC (g/L)			416.10	
72		C	Weight of Coating (g)(C) = B-A		10.399	VOC (g/mL)			0.416	
73		D	Calibration Factor (*)		1.000					
74		E	Density of Coating (lbs/gal)		10.399					
75		F	Density of Coating (g/cc)		1.246					
76		G	Density of Coating (g/L)		1,245.8					
77										
78										
79						Calculation of VOC for Solvent-Borne Coating:				
80		A	Weight of Empty Cup (g) #3		56.764	VOC (lbs/gal)			3.47	
81		B	Weight of Full Cup (g)		67.166	VOC (g/L)			416.22	
82		C	Weight of Coating (g)(C) = B-A		10.402	VOC (g/mL)			0.416	
83		D	Calibration Factor (*)		1.000					
84		E	Density of Coating (lbs/gal)		10.402					
85		F	Density of Coating (g/cc)		1.246					
86		G	Density of Coating (g/L)		1,246.2					
87										
88		Signature of Operator				MEAN DENSITY		(lbs/gal)	10.394	
89						Relative Diff. (%) Sample 1 &			-0.173	
90		(*) Calibration Factor converts the weight of coating				Relative Diff. (%) Sample 1 &			0.202	
91		in the WPG cup from (g) to (lbs/gal).				Relative Diff. (%) Sample 2 &			0.029	
92		Units of the Calibration Factor = (mL.lbs)/(g.gal)				MEAN DENSITY		(g/cc)	1.246	
93		(**) VOC Content is used solely to confirm coating				MEAN VOC (**)		(lbs/gal)	3.470	
94		compliance with local regulations.								
95										

DATA FORM 4

CALCULATION OF COATING DEPOSITED ONTO PANELS

COATING USAGE

Job # TSK463B

Date 12/12/95

PANEL SET #1

	Panel ID	Wt. Uncoated (g)	Wt. Coated (g)	Wt Deposited (g)
1	AAD	1145.1	1156.6	11.5
2	AAD	1141.1	1152.3	11.2
3	AAD	1147.5	1159.2	11.7
4	AAD	1141.1	1152.4	11.3
5	AAD	1270.5	1281.6	11.1
6	AAD	1151.2	1161.4	10.2
		Mean		11.2
		Std Dev		0.5
		Coeff of Variance (%)		4.7

PANEL SET #2

	Panel ID	Wt. Uncoated (g)	Wt. Coated (g)	Wt Deposited (g)
1	AAE	1137.8	1148.7	10.9
2	AAE	1147.0	1157.7	10.7
3	AAE	1254.7	1265.5	10.8
4	AAE	1281.0	1291.9	10.9
5	AAE	1145.4	1155.4	10.0
6	AAE	1146.0	1156.4	10.4
		Mean		10.6
		Std Dev		0.4
		Coeff of Variance (%)		3.3

PANEL SET #3

	Panel ID	Wt. Uncoated	Wt. Coated	Wt Deposited
1	AAF	1148.9	1159.3	10.4
2	AAF	1141.7	1153.0	11.3
3	AAF	1269.0	1280.4	11.4
4	AAF	1156.2	1167.5	11.3
5	AAF	1143.0	1153.9	10.9
6	AAF	1260.3	1271.8	11.5
		Mean		11.1
		Std Dev		0.4
		Coeff of Variance (%)		3.7

DATA FORM 5
Calculation of Flow Meter
Conversion Factor (K)

Job No:	**TSK463B**	**Date**	12/12/95
Mean Coating Density (lbs/gal)	10.39		
Mean Coating Density (g/cc)	1.246		
Pulse Equivalent (cc/cog)	0.12117		

WEIGHT OF PLASTIC BAGS

Bag #	Before (g)	After (g)	Total Flow (g)
1	10.006	50.216	40.210
2	10.018	15.659	5.641
3	10.037	15.056	5.019
4	10.078	16.305	6.227
5	10.089	16.429	6.340
6	10.063	16.392	6.329
7	10.014	16.269	6.255
8	9.977	16.293	6.316
9	9.973	16.367	6.394
10	9.973	16.221	6.248

FLOW METER READINGS

Bag #	FM Start Pulse	FM Stop Pulse	Total Flow (1) (cc)	Total Flow (2) (g)	Conversion Factor K Bags:FM (3)
1	0	273	33.079	41.205	0.976
2	0	39	4.726	5.886	0.958
3	39	72	3.999	4.981	1.008
4	0	42	5.089	6.339	0.982
5	42	84	5.089	6.339	1.000
6	0	42	5.089	6.339	0.998
7	0	43	5.210	6.490	0.964
8	0	42	5.089	6.339	0.996
9	0	44	5.331	6.641	0.963
10	0	43	5.210	6.490	0.963
				Mean Conv. Factor K	0.981
				Std. Dev.	0.019
				Coeff of Variance (%)	1.925

(1) Total Flow (cc) = FM Stop Pulse - FM Start Pulse

(2) Total Flow (g) = Total Flow (cc) x Density of Coating (g/cc)

(3) Conversion Factor K (Bags:FM) = Total Flow (g) for Plastic Bags/Total Flow (g) for Flow Meter

DATA FORM 6

WEIGHT OF COATING USED DURING TE APPLICATION

COATING USAGE

Job Number	TSK463B
Date	12/12/95
Mean Coating % Wt Solids	66.611
Mean Coating Density (lbs/gal)	10.394
Mean Coating Density (g/cc)	1.246
Mean Flow Meter Conversion Factor (K)	0.981
Pulse Equivalent (cc/cog) (from vendor's calibration)	0.12117

PANEL SET #1

	Panel ID	FM Pulse after Purge Pulses	FM after Panel is coated Pulses	FM Measured Usage Pulses	Volume Liquid Coating Used (cc)	Corrected Volume Liquid Coating Used (cc)	Weight Liquid Coating Used (g)	Weight Solid Coating Used (g)
1	AAD	79	322	243	29.44	28.88	35.97	23.96
2	AAD	79	321	242	29.32	28.76	35.83	23.86
3	AAD	80	317	237	28.72	28.17	35.09	23.37
4	AAD	80	314	234	28.35	27.81	34.64	23.07
5	AAD	80	318	238	28.84	28.29	35.23	23.47
6	AAD	79	313	234	28.35	27.81	34.64	23.07
					Mean			23.47
					Std Dev			0.38
					Coeff of Variation (%))			1.62

PANEL SET #2

	Panel ID	FM Pulse after Purge Pulses	FM after Panel is coated Pulses	FM Measured Usage Pulses	Volume Liquid Coating Used (cc)	Corrected Volume Liquid Coating Used (cc)	Weight Liquid Coating Used (g)	Weight Solid Coating Used (g)
1	AAE	74	308	234	28.35	27.81	34.64	23.07
2	AAE	75	314	239	28.96	28.40	35.38	23.57
3	AAE	75	315	240	29.08	28.52	35.53	23.67
4	AAE	74	315	241	29.20	28.64	35.68	23.77
5	AAE	77	311	234	28.35	27.81	34.64	23.07
6	AAE	77	309	232	28.11	27.57	34.35	22.88
					Mean			23.34
					Std Dev			0.37
					Coeff of Variation (%))			1.60

PANEL SET #3

	Panel ID	FM Pulse after Purge Pulses	FM after Panel is coated Pulses	FM Measured Usage Pulses	Volume Liquid Coating Used (cc)	Corrected Volume Liquid Coating Used (cc)	Weight Liquid Coating Used (g)	Weight Solid Coating Used (g)
1	AAF	79	313	234	28.35	27.81	34.64	23.07
2	AAF	79	322	243	29.44	28.88	35.97	23.96
3	AAF	78	313	235	28.47	27.93	34.79	23.17
4	AAF	79	320	241	29.20	28.64	35.68	23.77
5	AAF	79	312	233	28.23	27.69	34.49	22.98
6	AAF	79	318	239	28.96	28.40	35.38	23.57
					Mean			23.42
					Std Dev			0.40
					Coeff of Variation (%))			1.72

DATA FORM 7

CALCULATION OF MEAN TRANSFER EFFICIENCY

COATING USAGE

Job No: TSK463B | Date 12/12/95

PANEL SET #1

	Panel ID	Wt Deposited (g)	Weight Solid Coating Used (g)	Transfer Efficiency (%) (TEm)
1	AAD	11.50	23.96	47.99
2	AAD	11.20	23.86	46.93
3	AAD	11.70	23.37	50.06
4	AAD	11.30	23.07	48.97
5	AAD	11.10	23.47	47.30
6	AAD	10.20	23.07	44.20
Mean TEm (%)		11.17	23.47	47.58
Std. Deviation		0.52	0.38	2.01
COV (%)		4.66	1.62	4.22

PANEL SET #2

	Panel ID	Wt Deposited (g)	Weight Solid Coating Used (g)	Transfer Efficiency (%) (TEm)
1	AAE	10.90	23.07	47.24
2	AAE	10.70	23.57	45.40
3	AAE	10.80	23.67	45.63
4	AAE	10.90	23.77	45.87
5	AAE	10.00	23.07	43.34
6	AAE	10.40	22.88	45.46
Mean TEm (%)		10.62	23.34	45.49
Std. Deviation		0.35	0.37	1.25
COV (%)		3.34	1.60	2.76

PANEL SET #3

	Panel ID	Wt Deposited (g)	Weight Solid Coating Used (g)	Transfer Efficiency (%) (TEm)
1	AAF	10.40	23.07	45.07
2	AAF	11.30	23.96	47.16
3	AAF	11.40	23.17	49.19
4	AAF	11.30	23.77	47.55
5	AAF	10.90	22.98	47.44
6	AAF	11.50	23.57	48.80
Mean TEm (%)		11.1	23.42	47.53
Std. Deviation		0.4	0.40	1.45
COV (%)		3.71	1.72	3.06

Grand Mean Transfer Efficiency TEm	**46.87**
Std. Deviation of the Grand Mean TEm	**1.19**
COV (%)	**2.55**

	B	C	D	E	F
3					
4			DATA FORM 8		
5		SUMMARY OF RESULTS FOR TEST SERIES			
6					
7					
8		JOB NUMBER			
9		DATE			
10		TYPE OF GUN TESTED (Subject gun)			
11		MAKE AND MODEL			
12		NAME OF SPRAY GUN MANUFACTURER:			
13					
14		TYPE OF STANDARD GUN TESTED			
15		MAKE AND MODEL			
16		NAME OF SPRAY GUN MANUFACTURER:			
17					
18					
19			**Subject Gun Tested**	**Standard Gun Tested**	
20		Panel ID's			
21		Gun-Target Distance (in) *(Close)*			
22		Grand Mean Transfer Efficiency (TEm)			
23		*(from Data form 7A or 7B)*			
24					
25		Panel ID's			
26		Gun-Target Distance (in) *(Middle)*			
27		Grand Mean Transfer Efficiency (TEm)			
28		*(from Data form 7A or 7B)*			
29					
30		Panel ID's			
31		Gun-Target Distance (in) *(Far)*			
32		Grand Mean Transfer Efficiency (TEm)			
33		*(from Data form 7A or 7B)*			
34					
35					

Blank Data Forms

COVER SHEET

RATING EVALUATION FOR SPRAY GUNS

JOB NUMBER

DATE TESTS PERFORMED

NAME AND ADDRESS OF LABORATORY:

Phone:

FAX :

NAME OF TECHNICIANS:

TYPE OF SPRAY GUN TESTED

NAME OF SPRAY GUN MANUFACTURER:

JOB NO:	0

DATA FORM 1-1

DETAILS OF SPRAY GUN EFFICIENCY EVALUATION

Date 1/0/00

Panel ID *(If more than one set of panels is run, enter the ID of each set)*

Description of Tests:

Details of Coating and Calibration of Density and % Wt Solids

	Enter Data Here
Name of Coating Manufacturer	
Name of Coating	
Coating ID	
Coating Batch #	
Coating Temperature at Spray Gun Run (oF)	

Coating Viscosity Zahn #3 (secs)	
Coating Viscosity Stormer (Krebbs)	
Coating Conductivity (uA)	
Coating %Wt Water (ASTM 4017 Karl Fisher)	
Was reducer added to adjust viscosity? (Y/N)	
Name of Solvent added	

JOB NO:	0

DATA FORM 1-2

DETAILS OF SPRAY GUN EFFICIENCY EVALUATION

Spray Gun Details and Settings	Enter Data Here
Name of Spray Gun Vendor	0
Spray Gun Type (e.g. HVLP)	0
Spray Gun Model Name	
Spray Gun Model No:	
Spray Gun Tip Size	
Spray Gun Orifice Size	
Spray Gun Cap Size	
Spray Gun Needle Size	
Gun-Target Distance (inches)	
Width of leading edge (inches)	
Width of trailing edge (inches)	
Fan Size (inches)	
Speed of gun (mm/sec)	
No. of Strokes	
Number of passes	

Air Flow Through Spray Gun	
Air Flow through Gun (cfm)	
Air Temperature at Gun (oF)	
Air Pressure to Gun (psig)	
Air pressure at cap (for all guns) (psig)	
Air valve opening (screw turns)	

Fluid Pressure to Spray Gun	
Type of fluid pumping system (e.g. pump, pressure pot)	
Ratio of pump (if applicable)	
Fluid Pressure at Gun (psig)	
Fluid valve opening (screw turns)	

Electrostatics of Spray Gun	
Electrostatic Voltage at Tip (if applicable) (KV)	
Ground checked? (Y / N)	

Computer Set-up

(Note: Other computer details are on Data Form 6, Sheet #2)

Computer program for particular coating application	

Environmental Conditions	
Ambient Temperature (oF)	
Ambient Relative Humidity (%)	
Spray Booth Air Velocity (fpm)	

JOB #	0

DATA FORM 1-3

CALIBRATION OF COATING PROPERTIES

Measurements for Coating Density
(Refer to Appendix II, Section 1)

Date	1/0/00	Coating ID	0
Calibration of cup volume (from cup vendor)			

Measurement #1

A	Weight of Empty Cup (g) #1	
B	Weight of Full Cup (g)	

Measurement #2

A	Weight of Empty Cup (g) #2	
B	Weight of Full Cup (g)	

Measurement #3

A	Weight of Empty Cup (g) #3	
B	Weight of Full Cup (g)	

Measurements for Coating % Wt Solids
(Refer to Appendix II Section 2)

Oven Temp.(F)		Time in Oven (mins):	

ID-1	WEIGHINGS	SYRINGE	ALUMINUM DISH
	First (g)		
	Second (g)		

ID-2	WEIGHINGS	SYRINGE	ALUMINUM DISH
	First (g)		
	Second (g)		

ID-3	WEIGHINGS	SYRINGE	ALUMINUM DISH
	First (g)		
	Second (g)		

ID-4	WEIGHINGS	SYRINGE	ALUMINUM DISH
	First (g)		
	Second (g)		

ID-5	WEIGHINGS	SYRINGE	ALUMINUM DISH
	First (g)		
	Second (g)		

JOB #	0

DATA FORM 1-4

Calibration of Flow Meter
Weighing of Plastic Bags

Pulse Equivalent (cc/cog) (from vendor's calibration) ______

	WEIGHT OF PLASTIC BAGS		FLOW METER READINGS	
Bag #	Before (g)	After (g)	FM Start Pulse	FM Stop Pulse
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

JOB #	0

DATA FORM 1-5

RECORDING COATING USAGE DURING APPLICATION OF COATING ON PANELS

	1st SET	PANEL WEIGHT READINGS		FLOW METER READINGS	
	Panel ID	Wt. Uncoated Panel (g)	Wt. Coated Panel (g)	FM After Purge Pulse	FM after Panel is coated Pulse
1					
2					
3					
4					
5					
6					

	2nd SET	PANEL WEIGHT READINGS		FLOW METER READINGS	
1					
2					
3					
4					
5					
6					

	3rd SET	PANEL WEIGHT READINGS		FLOW METER READINGS	
1					
2					
3					
4					
5					
6					

JOB #	0

DATA FORM 1-6

DETERMINATION OF ACCEPTABLE APPEARANCE

SET #

PANEL ID	DOI "C" RECOGNITION	GLOSS 60°	AVERAGE GLOSS	AVEAGE DRY FILM THICKNESS	PASS/FAIL
MEANS	#DIV/0!		#DIV/0!	#DIV/0!	

SET #

PANEL ID	DOI "C" RECOGNITION	GLOSS 60°	AVERAGE GLOSS	AVEAGE DRY FILM THICKNESS	PASS/FAIL
MEANS	#DIV/0!		#DIV/0!	#DIV/0!	

SET #

PANEL ID	DOI "C" RECOGNITION	GLOSS 60°	AVERAGE GLOSS	AVEAGE DRY FILM THICKNESS	PASS/FAIL
MEANS	#DIV/0!		#DIV/0!	#DIV/0!	

CRITERIA FOR ACCEPTABLE APPEARANCE:	DOI $\geq$ 40	Gloss 60 deg $\geq$ 85	DFT 1.0 - 1.5 mils

JOB #	0

DATA FORM 1-7
MEASUREMENT OF DRY FILM THICKNESS

Panel ID: ____________________ SET# [ ]

	COLUMNS			
ROWS	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				

MEAN DFT	#DIV/0!
STD. DEV	#DIV/0!
COV (%)	#DIV/0!

Panel ID: ____________________

	COLUMNS			
ROWS	1	2	3	4
1				
2				
3				
4				
5				
6				
7				
8				
9				

MEAN DFT	#DIV/0!
STD. DEV	#DIV/0!
COV (%)	#DIV/0!

MEAN OF MEAN DFT	#DIV/0!

	B	C	D	E	F	G	H	I	J
2	JOB #	0							

DATA FORM 1-8
MEASUREMENT OF SPRAY ENVELOPE

1st SET

Panel ID

	1	2	3	4	5	Mean (in)
Width (in)						#DIV/0!
Height (in)						#DIV/0!
				Area of Envelope (cm2)		#DIV/0!

2nd SET

Panel ID

	1	2	3	4	5	Mean (in)
Width (in)						#DIV/0!
Height (in)						#DIV/0!
				Area of Envelope (cm2)		#DIV/0!

3rd SET

Panel ID

	1	2	3	4	5	Mean (in)
Width (in)						#DIV/0!
Height (in)						#DIV/0!
				Area of Envelope (in2)		#DIV/0!

DATA FORM 2-1
DETAILS OF LABORATORY EQUIPMENT (*)
(Page 1 OF 2)

Scale #1 (For light weights):	
Manufacturer:	
Model No:	
Seriel No:	
Range (g)	
Precision:	
Calibrated? (Y or N)	Date
Scale #2 (For panels):	
Manufacturer:	
Model No:	
Seriel No:	
Range (g)	
Precision:	
Calibrated? (Y or N)	Date
Weight per Gallon Cup:	
Manufacturer:	
Model No:	
Seriel No:	
Calibrated volume (mL)	
(supplied by vendor)	
Precision:	
Calibrated? (Y or N)	Date
Volumetric Fluid Flow Meter:	
Manufacturer:	
Model No:	
Seriel No:	
Calibrated volume (mL/cog)	
(supplied by vendor)	
Precision:	
Calibrated? (Y or N)	Date
Gloss Meter:	
Manufacturer:	
Model No:	
Seriel No:	
Specular Angle of Reflectance:	
(such as 60 deg)	
Precision:	
Calibrated? (Y or N)	Date

(*) **NOTE:** This form need only be completed once per test series

DATA FORM 2-2
DETAILS OF LABORATORY EQUIPMENT (*)
(Page 2 OF 2)

Dry Film Thickness Gage:

Manufacturer:	
Model No:	
Seriel No:	
Range (mils):	
Precision:	
Calibrated? (Y or N)	

Viscometer

Manufacturer:	
Model No:	
Seriel No:	
Precision:	
Calibrated? (Y or N)	Date

Air Velocity Meter:

Manufacturer:	
Model No:	
Seriel No:	
Precision:	
Calibrated? (Y or N)	Date

Large Commercial Oven:

Manufacturer:	
Model No:	
Approx. Dimensions:	
Range (oF)	
Temperature Calibrated? (Y or N)	Date

Laboratory Oven:

Manufacturer:	
Model No:	
Range (oF)	
Temperature Calibrated? (Y or N)	Date

Psychrometer:

Manufacturer:	
Model No:	

Computer Set-up

Type of Gun mover (e.g. robot) ________

Name of Vendor of Gun Mover ________

No of axes (such as 1, 2, 3, 6) ________

(*) **NOTE:** This form need only be completed once per test series

DATA FORM 8

SUMMARY OF RESULTS FOR TEST SERIES

JOB NUMBER ______________________

DATE ______________________

TYPE OF GUN TESTED (Subject gun) ______________________

MAKE AND MODEL ______________________

NAME OF SPRAY GUN MANUFACTURER: ______________________

TYPE OF STANDARD GUN TESTED ______________________

MAKE AND MODEL ______________________

NAME OF SPRAY GUN MANUFACTURER: ______________________

	Subject Gun Tested	Standard Gun Tested
Panel ID's		
Gun-Target Distance (in) *(Close)*		
Grand Mean Transfer Efficiency (TEm) *(from Data form 7A or 7B)*		

Panel ID's		
Gun-Target Distance (in) *(Middle)*		
Grand Mean Transfer Efficiency (TEm) *(from Data form 7A or 7B)*		

Panel ID's		
Gun-Target Distance (in) *(Far)*		
Grand Mean Transfer Efficiency (TEm) *(from Data form 7A or 7B)*		

NOTE

The spreadsheet will generate all of the tables showing the results of the calculations. Hence no additional blank sheets follow this page.