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Research and development was required to lower the VOC of two component urethanes while avoiding problems created by high solids systems on aircraft. Without such research, there was very little hope to lower VOC content in this industrial segment.

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A discussion of newer technologies for aerospace to reduce or remove VOC and hazardous air pollutants requires a short history as a prelude. Prior to 1988, most finish coats on aircraft and ground support equipment were coated with a two component urethane. Military equipment was coated with a specification, Mil-C-83286, which had a VOC of 600 g/l (5 lbs. per gal.) as a normal figure. Commercial aircraft operated under different specification, but the VOC was at a similar value. In 1988, the specification, Mil-C-85285B, was issued which required VOC maximums of 420 g/l (3.5 lbs. per gallon) for aircraft and 340 g/l (2.8 lbs. per gallons) for ground support. These coatings began their inroads into the military market in late 1988. The savings in VOC were significant and even more than some realized when the square foot coverage was considered.

The following shows the calculations for actual VOC reductions on a typical cámouflage product.

Mil-C-83285, color 36375
32.3% solids volume
577 g/l (4.82 lbs.) VOC
618 sq. ft./gal. at 1 mil dry

Mil-C-85285B Type I, color 36375
52.3% solids volume
420 g/l (3.5 lbs.) VOC
840 sq. ft./ gal. at 1 mil dry

1000 gallons of Mil-C-83286 covers 518,000 sq. ft.
1000 gallons of Mil-C-83286 contains 4,820 lbs. of solvent
617 gallons of Mil-C-85285 Type I covers 518,000 sq. ft.
617 gallons of Mil-C-85285 Type I contains 2160 lbs. of solvent

Savings of 2660 lbs. of solvent

With these types of savings, great strides had been made and research continued to lower the VOC's, but the high solids had created some situations that meant higher solids may not be the most desirable resultant materials.

These main situations presented by the higher solids urethanes were:

1. Difficulty in controlling film thickness
    a. higher weight
    b. reduction in VOC savings
    c. outgassing

2. Shorter pot life

3. Higher viscosities giving rise to more orange peel, and exaggerated by newer high transfer efficiency guns.

4. Slow cure response at lower temperatures.

It was evident that higher and higher solids would only compound these problems. The logical approach was to use water to be able to lower application solids and still use high performance systems for aerospace systems. The use of exempt solvents such as 1,1,1 trichloroethane were not considered as a logical solution for long term research. Water was the only logical approach to lower VOC and still apply thin films.

The question became how low can we go? Two systems have been developed and tested to a proposal specification of Mil-C-83286 low VOC version. One material has a VOC of less than 250 g/l and its prototype have had limited applications on aircraft. The other material has approximately zero VOC, and is just in the final research phases with no large scale applications as of January 1995. The term "zero VOC' or approximately zero is based on theoretical calculations. The test methods involved in water determinations at this time have high enough percentage errors to yield fluctuating values. Some of these can even be negative values which would be wonderful, but not real.

The following graphs show how these results can vary. This is only presented to justify the use of theoretical VOC values in this presentation.

The following charts show the general characteristics and performance results to the proposed Mil-C-83286 low VOC draft specification. It must be noted that this is not a specification for use and has only been drafted as a guide to follow for development purposes, however, the majority of requirements exceed those of Mil-C-83286 and Mil-C-85285.

<u>Specification</u>	Two Component Urethane <u>Water Based at 210 g/l VOC</u>
Drying Time	
Set to Touch 2 hours	2 hours
Dry hard 8 hours	8 hours
Viscosity 15 to 30 seconds #4FC	25-30 seconds
Pot Life 4 hours minimum	4 hours
VOC 210 g/l max	210 g/l
Gloss Camouflage 85°/5 max	2
Gloss 20°/85 min	60° 85
Hiding Power .94 minimum	.98
Surface smooth and uniform	Uniform
Wet Tape 24 hours	No Effect
Impact Flexibility 20%	10% to 15%
Heat Resistance 4 hours @ 300°F	10% impact
Low Temperature Flexibility-2 inch mandrel	Passes 2 inch
Fluid Immersion	
Lube Oil Mil-L-23699 24 hours @ 150°F	H hardness
Hydrocarbon TT-S-735 Type III 14 days	F hardness
Hydraulic Fluid Mil-H-83282 14 days	H hardness
Hydraulic Fluid Mil-H-5606 14 days	H hardness
Skydrol 500B 14 days	F hardness
Distilled water 4 days @ 100°F	F hardness, Tr blisters
Jet Fuels 14 days	H hardness
Accelerated Weathering No Significant Changes	ΔE less than 1
Pencil Hardness (no requirement)	H

% Application Solids by Volume (no requirement)	39%

Specification	Two Component Urethane Water Based at Zero VOC
Drying Time	
Set to Touch 2 hours	2-3 hours
Dry hard 8 hours	10 hours
Viscosity 15 to 30 seconds #4FC	20 seconds
Pot Life 4 hours minimum	4 hours
VOC 210 g/l max	0
Gloss Camouflage 85°/5 max	3 @ 60° 3 @ 85°
Gloss 20°/85 min	88
Hiding Power .94 minimum	.98
Surface smooth and uniform	Smooth
Wet Tape 24 hours	No Effect
Impact Flexibility 20%	40%
Heat Resistance 4 hours @ 300°F	Passes 20%
Low Temperature Flexibility-2 inch mandrel	Passes 2 inch
Fluid Immersion	
Lube Oil Mil-L-23699 24 hours @ 150°F	H hardness
Hydrocarbon TT-S-735 Type III 14 days	H hardness
Hydraulic Fluid Mil-H-83282 14 days	2H hardness
Hydraulic Fluid Mil-H-5606 14 days	2H hardness
Skydrol 500B 14 days	F hardness, 30 days
Distilled water 4 days @ 100°F	3H hardness
Jet Fuels 14 days	2H hardness
Accelerated Weathering No Significant Changes	ΔE less than 1
Pencil Hardness (no requirement)	2H-3H
% Application Solids by Volume (no requirement)	50%

The information in the testing data shows these two separate two component urethane systems can perform to the majority of the desired requirements. Some fluctuation may occur as the products are commercialized and total field condition impacts are seen.

Areas of future work will concentrate on pot life and dry time controls at various humidities.

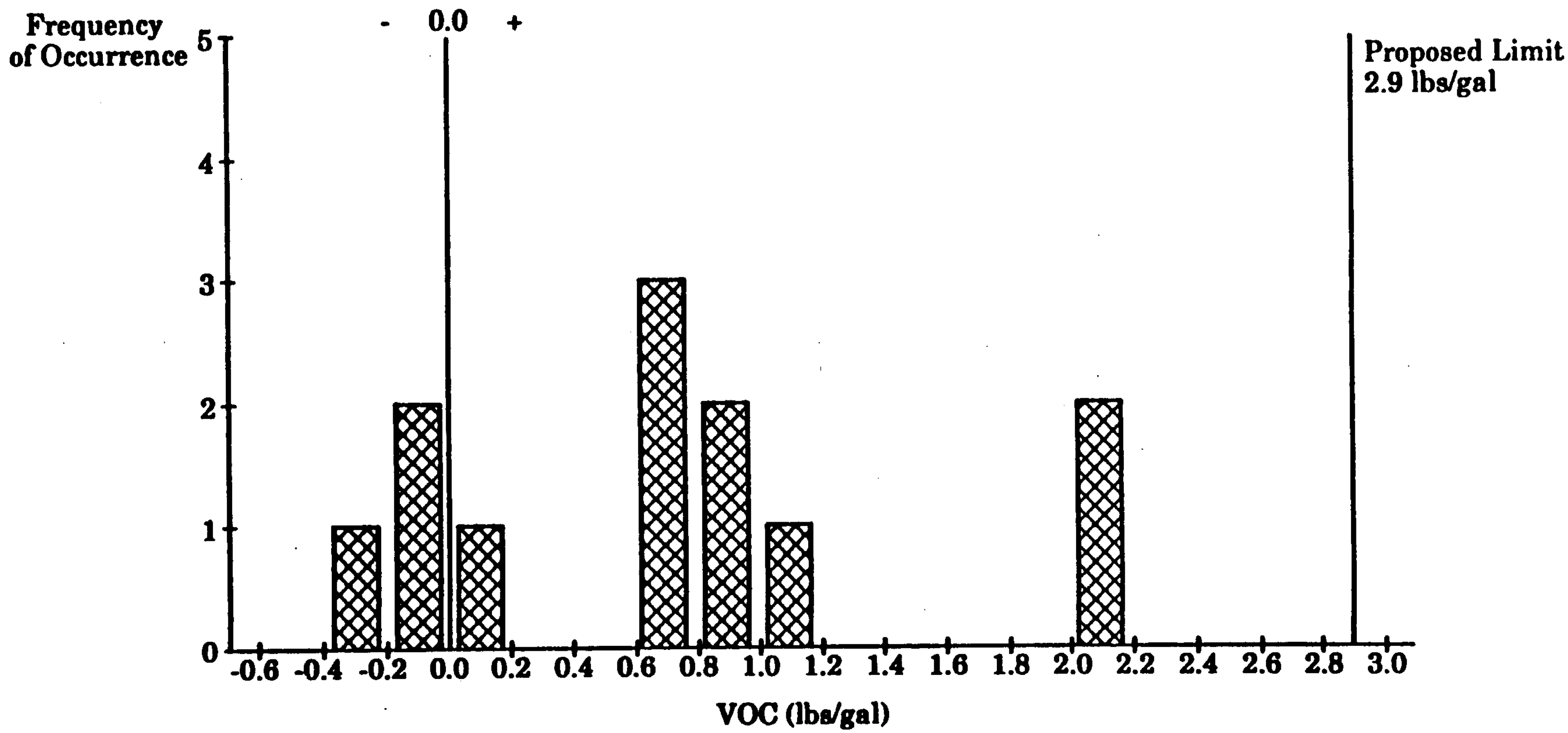

Figure 1 - Illustration of Method 24's lack of repeatability within a single laboratory for water-reducible primer. Note that some values are negative.

Source: Boeing Commercial Airplane Group

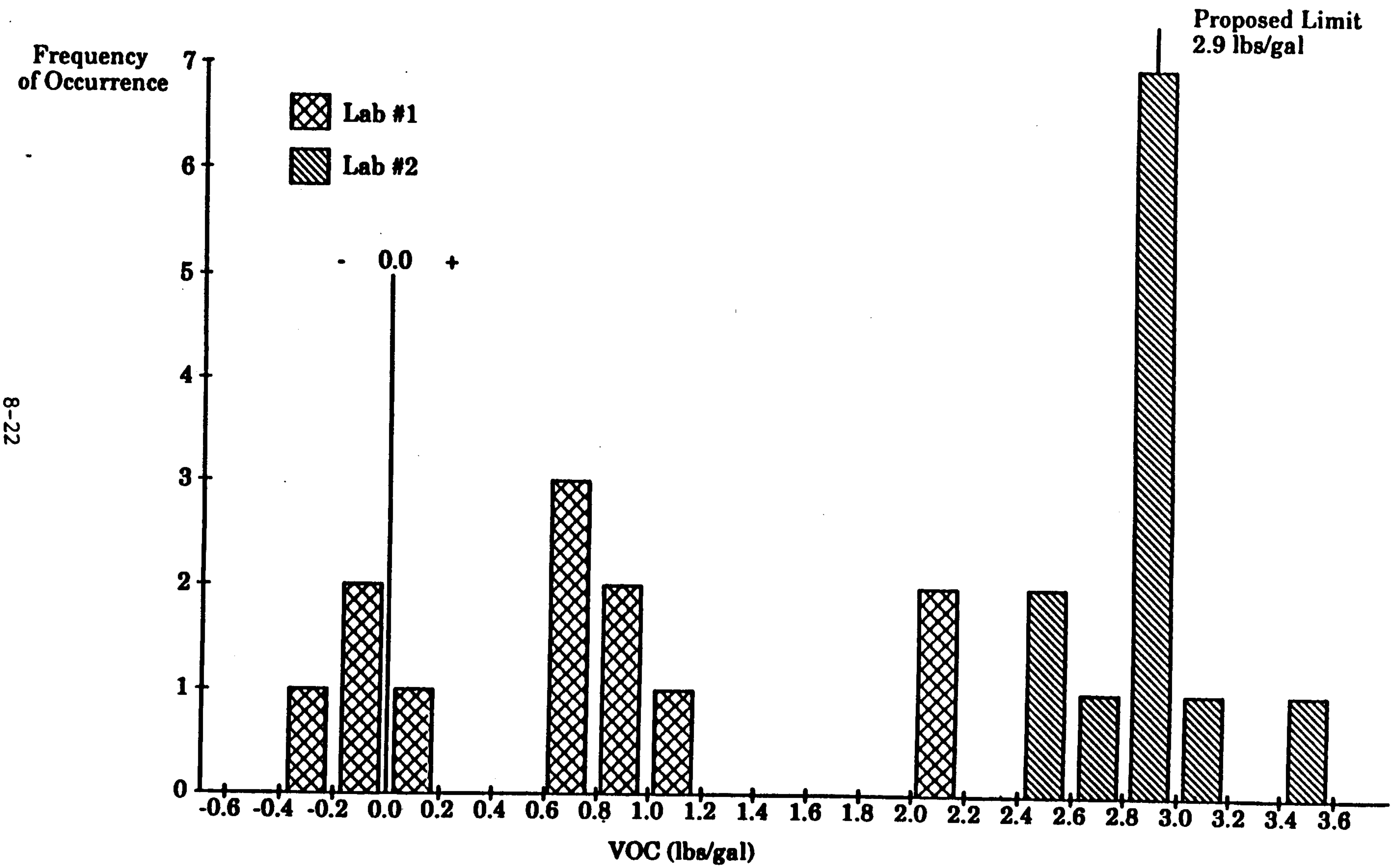

Figure 2 - Illustration of Method 24's lack of reproducibility between laboratories for water-reducible primer.