CHAPTER 5 STANDARD ALMEN AND AERO ALMEN STRIP TESTS

DN5A5 - AERO ALMEN TEST DATA

1. INTRODUCTION

All branches of the military are in various stages in the implementation of alternative coating removal processes in lieu of chemical stripping. Since coatings and substrates vary significantly from one service branch to another, as well as within each service branch, a broad variety of coating removal approaches are emerging.

Coating removal materials currently in use (or under evaluation for future use) include several types of plastic media, sodium bicarbonate, carbon-dioxide pellets, polymerized wheat starch, flash lamps, lasers, high pressure water and ice.

Systems used to deliver coating removal materials vary as well. Direct pressure and suction air blast equipment is being used and turbine wheel blasting is being evaluated for the various loose grain abrasive approaches to coating removal. Specially designed equipment has been developed for other approaches.

Parameters being used for each specific weapon system/transport system vary as well depending on the hardness and thickness of the substrate as well as the coating to be removed. Blast pressure, blast angle, blast distance, blast nozzle configuration, as well as hardness and size of coating removal materials are the major variables.

While specifications for equipment and coating removal materials have been, and continue to be developed, there will always be some differences in equipment and coating removal material performance from one manufacturer to the next.

The standard Aero Almen Strip test has been developed to provide a "benchmark" measurement test. Use of the Aero Almen test kit and procedures described in this chapter will allow each maintenance facility to measure the amount of energy being transferred to the substrate being cleaned for a given set of parameters.

Once a set of parameters has been established, periodic use of the Aero Almen Test Kit will ensure that the process is performing as expected. Any proposed changes to the process in an effort to increase productivity should also be evaluated with the Aero Almen Test Kit to ensure that the process meets established Almen Arc height guidelines.

Finally, the Aero Almen Test Kit is intended to provide a tool for an independent evaluator, such as the Federal Aviation Administration (FAA) or quality control inspector, to assess the conformance of a PMB operation to process specifications. The Aero Almen test also allows periodic, visual examination procedure, which will help in the detection of blast material contamination and excessive distortion of the surface being cleaned.

2. BACKGROUND

Chemical stripping methods, used historically to depaint aircraft surfaces, came under attack during the decade of the 1980s because of worker safety and environmental problems associated with the use and disposal of toxic chemicals. With chemical strippers, concerns about aircraft surface integrity were related to the corrosive, embrittling, and mechanical property degradation effects associated with the cleaning chemical's reaction with aircraft alloys. Further, chemical stripping agents had a potential adverse effect on a variety of sealants and were not compatible with the variety of composites that were being used increasingly in aircraft exteriors.

The use of soft, angular, loose grain abrasive materials in place of chemical strippers has reduced the worker safety and environmental problems, but has raised concerns about the effect of these abrasives on aircraft aluminum skins, composites and underlying structures. Of paramount concern is the effect of the energy transferred to the aircraft substrate as individual abrasive particles impact the surface in a direct pressure airstream or are propelled onto the surface via turbine wheel blasting.

Since loose grain abrasives have been used to "peen" aircraft components under tightly controlled process parameters for decades, and because techniques existed for measuring peening affect, the tools of the shot peening trade were adapted for use on thin skin aircraft parts. However, it is important to understand that the goal in shot peening is to change the surface of a metal part in a controlled and uniform way by imparting a layer of compressive stress. This compressive layer allows the part to withstand a greater cyclic load before failing in tension.

While the tools of the shot peening trade are useful for measuring the effect of loose grain abrasive depainting, one must understand that we are not measuring a uniform peening effect when depainting. Rather, we are measuring the "partial peening effect" as some abrasive particles impact the substrate as the coating is removed.

To better understand what is being measured, a brief general discussion of shot peening is provided.

3. WHAT IS SHOT PEENING

Shot peening is the bombardment of a metal surface with a very large number of hard spherical particles. As these particles impact the metal surface, they cause tiny indentations that actually move the grain structure of the metal and change the stress pattern in the metal part.

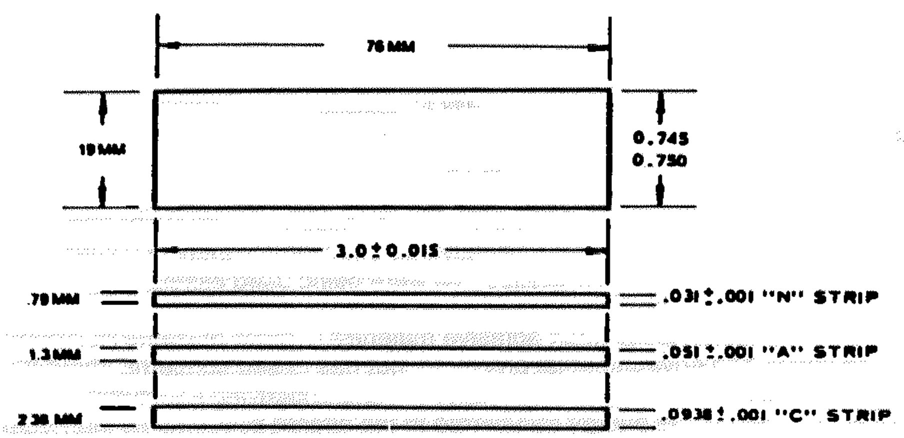
Shot peening is performed under tightly controlled process parameters so that the desired amount of cumulative energy is transferred and a uniform layer of compressive stress is obtained. For a given metal substrate and a given shot size, density and hardness, control of particle velocity governs the transfer of energy from the shot to the metal surface. Once the metal surface has been completely and uniformly covered, the process is complete.

4. HOW IS PEENING EFFECT MEASURED

The use of standardized "Almen Strips," "Almen strip holders," "Almen gauges" and "Almen arc height" measurement curves was developed in the 1930s in the automotive industry.

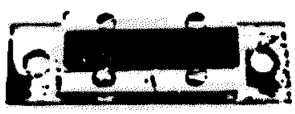
Historically, standard almen strips have been manufactured from 1070 automotive spring steel. These strips are 3.0 inches long, .75 inches wide and are available in three different thicknesses (032 inches, .051 inches and .094 inches) as shown in *SN 4(1)*. The traditional Almen strip is also described in MIL-S-13165.

SUB-NOTE 4(1) ALMEN STRIP DIMENSIONS

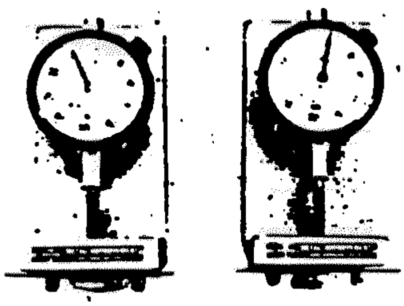


The Almen strip is securely attached to a metal plate fixture with four screws as shown in *SN 4(2)*. The Almen strip is then subjected to the uniform controlled blast stream for predetermined periods of time (normally 2.5, 5, 10, 20, 40, 80 ,160 seconds, and so forth.). After each period of exposure, the Almen strip is removed from the holder and the degree of curvature of the strip is measured using an Almen gauge. (See *SN 4(3)*). The curvature of the strip is a result of the layer of compressive stress as it begins to accumulate in the strip.

SUB-NOTE 4(2) TRADITIONAL ALMEN STRIP HOLDING FIXTURE

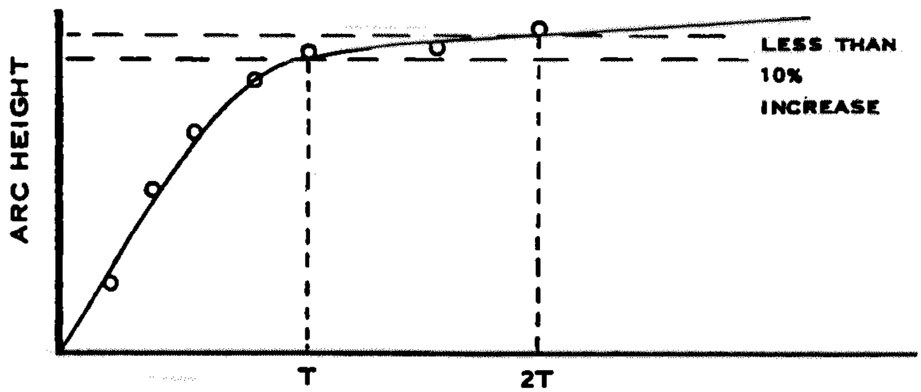


SUB-NOTE 4(3) TRADITIONAL ALMEN TEST GAUGE



Once the point is reached where a doubling of blast time yields less than a ten percent increase in the curvature of the Almen strip, surface saturation has occurred and continued peening yields little additional benefit. In very delicate peening applications, peening much beyond the saturation point can have a negative effect. *SN 4(4)* shows a typical Almen arc height curve.

SUB-NOTE 4(4) ALMEN ARC HEIGHT SATURATION CURVE



5. HOW DO WE PROVE IT WORKS

The Almen strip is a benchmark and nothing more than that. Engineers set peening requirements based on trial and error. First, the process is controlled using the almen strip and almen intensity curve. Next, parts are peened to the desired intensity. Finally, increase in fatigue life and fatigue strength associated with peening are measured in a laboratory and/or production environment and peening is then designed into the manufacturing process.

6. PEENING VERSUS PAINT REMOVAL

6.1 GENERAL

When peening, it is important to use a rounded media with a smooth surface. Uniformity of shot size and shot hardness also is critical to control of the process. Ideally, nothing is removed from the surface of the metal part being peened.

With general purpose paint removal or cleaning operations, the objective is to remove paint and other contaminants as quickly as possible at the lowest overall cost. Historically, hard, angular media such as silica sand and coal slag have been used on steel structures. Angular shaped particles are used because they clean much faster. Also, a broader gradation is normally used in cleaning operations. It has been shown that a broader gradation is more efficient in general purpose cleaning applications because the larger abrasive particles remove the heavier contaminants and the smaller particles complete the job rapidly by removing lighter contamination.

6.2 PEENING

When "peening" metal parts to impart a layer of residual compressive stress just below the surface, it is important to use a round shot, which is harder than the substrate being peened. As the harder shot impacts the softer substrate, it causes a small dimple or indentation in the surface of the substrate. Full coverage or saturation is achieved when there is a complete and uniform "dimpling" of the entire surface of the part.

Roundness of the peening material assures a smooth surface and a uniform dimpling effect. Angular particles can cause an uneven compressive layer and can result in stress risers or areas of potential fatigue crack initiation.

Aluminum alloys are typically peened with glass beads when low to medium peening intensities are desired. At lower peening intensities, glass beads will transfer energy into the aluminum substrate without breaking. As desired peening intensity increases, a point is approached where the "friability" of glass beads causes them to break rather that transfer the energy into the aluminum surface. See *SN 6.2(1).*

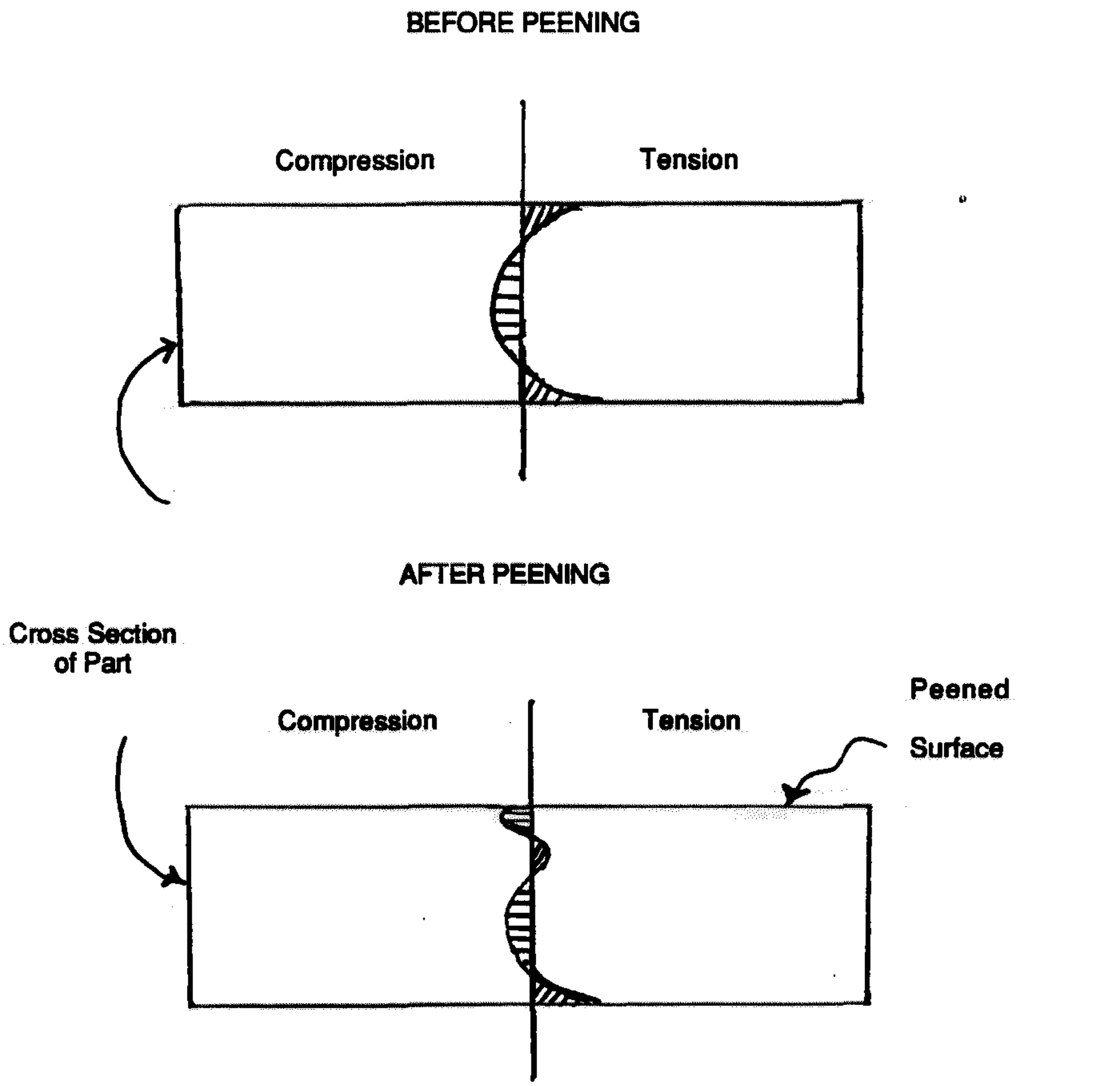
As substrate hardness and/or desired peening intensity increases, other shot materials which are less prone to breakage are used in the peening process. Cast steel shot, stainless steel shot, conditioned cut steel and stainless steel wire and ceramic materials are used at higher peening intensities on harder substrate materials.

In addition to uniform hardness and roundness, a narrow size gradation is crucial to the peening operation. The depth of the compressive layer is determined by the energy transferred into the surface of the part being peened by each individual particle. Uniform size and hardness equates to uniform energy transfer if all other parameters are controlled.

Typically, peening is undertaken on a fairly thick metal part with the objective of increasing that part's ability to withstand a cyclic load thereby increasing the life of the part or the design load.

Machining, forming and heat treating operations affect the stress pattern in a metal part. Typically, there are tensile stresses built up at or near the surface of the part during the manufacturing process. Peening creates a layer of compressive stress at or slightly below the surface as indicated earlier. The exhibits in *SN 6.2(1)* show a typical stress profile before and after peening a new metal part.

SUB-NOTE 6.2(1) ALMEN STRIP RESIDUAL STRESS PROFILES



6.3 PAINT REMOVAL/CLEANING

With paint removal, there is a different situation with which to contend. The substrate is aluminum (primarily 7075-T6 or 2024-T3) or one of a variety of composite materials increasingly being used in the aircraft industry. The coating, to be removed must be well adhered and hard enough to perform under severe conditions. By design the coating is difficult to remove and in certain cases, the coating is actually as hard or harder than the underlying substrate. Further, the substrate is very thin compared to the typical metal parts, which are peened to increase their fatigue life.

What is needed is a media that can remove the paint system without imparting any residual stress into the surface of the thin aircraft metal below. As the ideal material does not exist at this point, the second best material is one that provides an acceptable paint removal rate (economics and turnaround time) with the lowest possible effect on the substrate.

As a general rule, softer materials, such as polyester, require very high blast pressure (50-60 PSI) in order to attain minimally acceptable strip rates. At the other end of the spectrum, the hardest of the specified materials, melamine must be used at very low pressure (below 20 PSI) to avoid excessive peening of the substrate.

By directive, the order of priorities in the depainting process must be 1) protection of the workpiece, 2) maintenance of an acceptable turnaround time on critical weapons systems and cargo aircraft, 3) minimization of hazardous waste generated by the depainting process, and 4) overall economic cost control.

The conflict in the priorities is clear. The softer materials, which impart the least residual stress, are the unfilled polyesters; however, these materials are very slow, even at higher blast pressures. Also, at the higher blast pressures required to remove well-adhered paint systems, the breakdown rate of the polyester products is too high, resulting in inordinate raw material and disposal costs. Contamination of the media with sand or metal also becomes a greater concern because higher blast pressures are used with the softer polyester materials.

The harder materials (melamines) are too hard to be used on softer alloys (2024T-3 and 6061T-3), particularly in an operator-sensitive, hand-held production mode. A very short dwell time, even at low pressure, will result in the transfer of energy into the soft aluminum surface as measured by Almen intensity. Robotic control systems currently under development should eventually permit the use of harder loose grain blasting abrasives in aircraft coating removal operations.

DN 5A5 shows residual stress data (almen intensity) for a variety of loose grain materials. As can be seen, the lowest almen intensities are recorded with the polyester material Type I in MIL-P-85891AS and the highest almen intensities are recorded with the melamine material (Type III).

Chapter 3 discussed particle geometry in some detail. In order to remove military paint systems, an angular particle is required to chip away or erode away the coating. The softer, unfilled materials, such as the polyesters, acrylics and allylics are more angular with sharper points and flatter surfaces. These materials rely primarily on their sharp edges to remove paint. The alpha cellulose filled ureas and melamines are less angular in shape with much rougher surfaces. These materials chip away paint with their edges, but also do more abrading work because of their rough surfaces.

The argument for a broad gradation in general cleaning can not be made for aircraft coating removal because of the thin, soft nature of the substrate. Oversized particles must be avoided to maintain the integrity of the aircraft aluminum or composite material.

1. AIRCRAFT DEPAINTING INDUSTRY USE OF ALMEN STRIPS

As concerns about possible fatigue life and fatigue crack growth rates associated with depainting with angular, loose grain soft abrasive media emerged, the industry turned to the use of Almen strips in an attempt to find a benchmark. Initially, standard spring steel almen strips were used in an attempt to develop a standard. However, standard spring steel almen strips are so hard that the amount of energy transfered into the surface of the strip could not be accurately measured. Because of the differential in substrate YS abrasive media hardness, the abrasive shattered and the almen strip did not bend.

To gauge the depainting process, aluminum Almen strips were manufactured for a variety of test programs. Because they are the most popular aircraft skin alloys, 2024-T3 and 7075T-6 almen strips were used primarily.

Most of these strips were made from .032 inch thick aircraft aluminum sheet stock. However, the method of shearing the sheet stock varied. In some cases the strips were cut with the rolling marks parallel to the 3.0 inch length. In other cases, the rolling marks were parallel to the .75 inch strip width. Early test data confirmed an expected doubling of arc height on strips with the rolling marks parallel to the .75 inch dimension.

Several thousand aluminum Almen strips have been blasted with a variety of media over the past few years under varying process conditions (blast pressure, media flow rate, impingement angle, stand off distance, and so forth.) Of course, a change in the process parameters translates in a change in the amount of energy transfered to the Almen strip (and the actual aircraft skin being depainted).

Much work has been undertaken to correlate aluminum Almen strip arc height with fatigue crack growth rate and fatigue life. While not totally conclusive, this work has resulted in the general acceptance of certain blast media types on certain airframes, alloys and composites in the military and commercial aircraft sectors.

2. THE AERO ALMEN STRIP

Since the use of aluminum Almen strips has become an accepted practice in the aircraft depainting industry, a specified, commercially available aerospace Almen strip has been developed. Because 2024T-3 is softer and more sensitive to residual compressive stress than 7075T-6, 2024T-3 has been selected as the standard aluminum alloy for aerospace application and is called the Aero Almen Strip.

There is a sufficient data base available to document the "buffering affect" of cladding on Almen intensity. Therefore, the standard Aero Almen Strip is manufactured from "bare" alloy. It should be noted that the overriding concern with clad alloy is control of the amount of clad removed during the blast process (or how much corrosion protection is lost during blasting).

The Aero Almen Strip is manufactured from .032 inch thick bare aluminum, as this is a common thickness and can be easily compared to earlier data. The standard length and width dimensions are the same as spring steel Almen strips to provide consistency with existing Almen Gage measuring techniques.

3. AERO ALMEN STRIP FABRICATION

Aluminum Aero Almen strips can be sheared in a sharp foot or power operated shear to net dimensions, blanked to rough size, then milled to final dimensions or manufactured by following the methods and procedures and specification requirements outlined in this chapter. The strips may also be purchased commercially For in-house, use the main factor is consistency. The dimensions for width are critical for the strips to fit within the Almen strip holder. The length dimension is less critical since the actual measurement uses the central 1.5 inches of the Almen Strip and denotes its deformation.

3.1 MATERIAL

The only material authorized for use and comparable to existing data is 2024T-3 aircraft quality aluminum sheet per QQ-A-250/4. The sheet thickness is .032 inch and the material must be bare (nonclad). 2024-T3 .032-inch thick aluminum can be sheared to size easily to meet specification.

3.2 PHYSICAL APPEARANCE

The material must be free from warpage, creases, notable dents and gouges. (Inspected with a 30 power microscope)

3.3 MATERIAL HARDNESS

Hardness of the sheet stock shall be 75Rb ± 3

3.4 ALIGNMENT OF ROLLING MARKS

Rolling marks of the sheet stock must be parallel to the 3.0 inch length of the strip. (If visual inspection indicates a significant angle to the 3.0 inch length, the strip shall be rejected.

3.5 FLATNESS

A random sample of 8 Aero Almen Strips shall be tested for flatness in the "as received" condition using the Aero Almen Gage. If the average of the eight strips tested is greater than .0015 inch (absolute), the lot shall be rejected.

3.6 LOT SIZE

Aero Almen strips shall be manufactured and tested in lots of 500 each manufactured from the same sheet stock. Each lot of Aero Almen Strips shall be assigned a lot number by the manufacturer.

3.7 PACKAGING

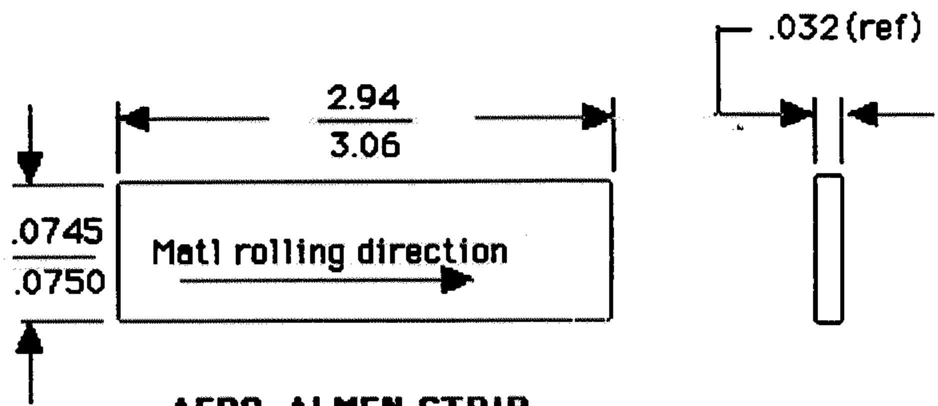
Aero Almen Strips shall be packaged and marked in accordance with (?) .

3.8 LENGTH, WIDTH AND THICKNESS TOLERANCE

The length of the Aero Almen strip shall be 3.0 inch ± .06 inch. The width of the Aero Almen strip shall be .75 inch ± .05 inch. The thickness of the Aero Almen Strip shall be .032 inch ± .001 inch. A lot may be rejected if any strip tested does not meet length, width and thickness requirements.

A dimensional drawing of the Aero Almen strip is in *SN 3.8(1)*.

SUB-NOTE 3.8(1) AERO ALMEN STRIP



AERO-ALMEN STRIP

Aluminum 2024-T3 bare .032 thick
per QQ-A-250/4

4. AERO ALMEN STRIP COATINGS

In order to be truly representative of the depainting process, the Aero Almen strips can be painted with the actual coating system to be removed from the aircraft. This coating system can then be artificially aged to simulate the condition of the aircraft to be depainted. Refer to Mil-P-85891-AS or Air Force TO 1-1-8 for artificial aging. Typically the aluminum material will be anodized or treated with a chromate conversion coating followed by application of an epoxy primer, such as MIL-P-23377. The top coat, such as a polyurethane MIL-C-83286, is applied in two cross coats and allowed to dry at room temperature for seven days. The panels are then baked for 96 hours at 190 to 210 degrees F. Aluminum panels are then sheared to size for use as Aero Almen Strips.

In order to verify the depainting process, almen strips <u>must</u> be painted prior to being blasted in accordance with the blasting and testing procedure outlined in Chapter 5.6. Testing with painted strips will ensure that dwell times and resultant almen arc heights are representative of the actual depainting process. Further, inspection with a 30 power microscope following blasting will allow an evaluation of the degree of paint removal.

If Aero Almen strips are to painted prior to shearing to size, care should be taken to insure the alignment of the sheet rolling marks with the 3.0 inch length of the finished strips.

The paint on the surface of the Aero Almen strip (and on the surface of the aircraft) acts as a buffer to the accumulation of residual stress. Prior testing has shown that until the paint system is removed, residual stress as measured by arc height intensity is minimal. If a given loose grain abrasive is not "hard enough" to remove the paint system, it is not "hard enough" to transfer a significant amount of energy into the substrate.

Certain manufacturers claim to have engineered loose grain abrasives, which will remove aircraft coatings rapidly but without high Almen arc height from extended dwell time once the paint has been removed. This can be tested by obtaining depainting speed on a scrap part and then blasting unpainted Aero Almen strips for a predetermined period of time and measuring the arc height.

To allow for controlled laboratory evaluation of strip rate and Almen intensity at the same time, commercially available Aero Almen strips can be painted and aged to specification. The manufacturer should be able to provide bare strips as well as strips painted in accordance with military and commercial OEM specifications.

5. AERO ALMEN STRIP PRODUCTION TESTING

In a production environment, residual stress data (Almen intensity) can be developed by directing the blast stream onto test strips using process parameters and nozzle traverse speeds that simulate the actual removal of coatings encountered in production depainting activities.

To ensure consistency from one production facility to another as well as comparability with historical data, a standard Aero Almen strip test kit has been developed for use at all production depainting activities. Use of the Aero Almen strip test kit (or its equivalent) is required to obtain valid test data.

1. INTRODUCTION

The Air Force Materials Laboratory has worked with equipment manufacturers to develop the standard test kit and to make this test kit as well as standard Aero Almen strips commercially available.

2. AERO ALMEN STRIP TEST KIT

The standard Aero Almen strip test kit contains the following components:

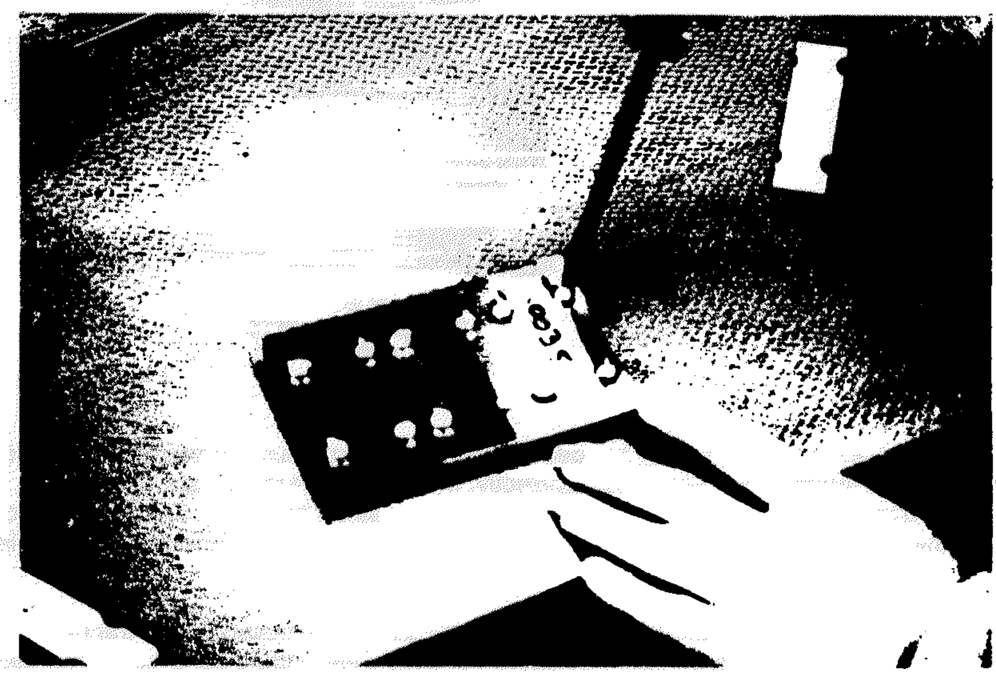
A. Almen strip holding fixture

This fixture consists of a metal base plate with holes drilled for machine screws to attach Aero Almen strips to the base plate.

The dimensions of the base plate are 4.5"x3"x.5". The base plate is made of low carbon commercial quality steel (see *SN 2(1)*).

The standard holding fixture can accommodate 3 Aero Almen strips. The photograph below shows the Almen strip holder without the almen strips attached:

SUB-NOTE 2(1) AERO ALMEN STRIP HOLDING FIXTURE



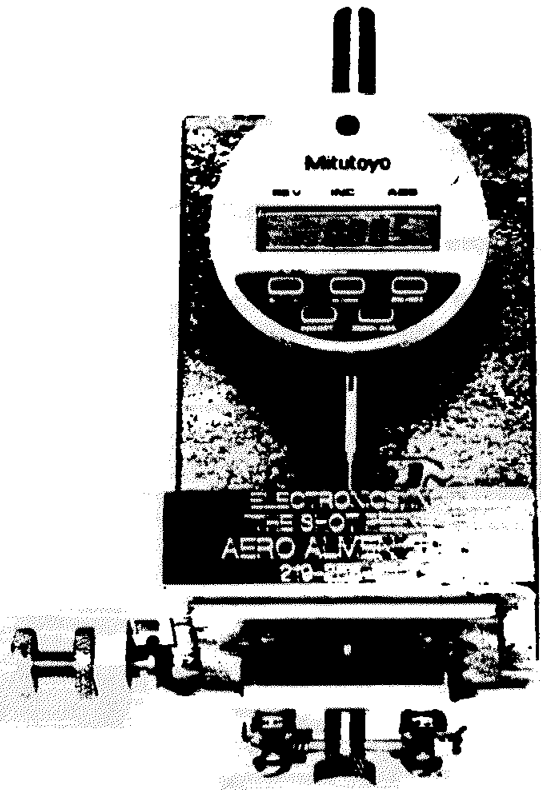
A larger plate can be utilized that will hold multiple rows of almen strips. Only one row of strips should be covered during a pass of the blast stream. Adjacent rows of almen strips can be masked with heavy, soft masking material to protect the adjacent strips from the blast stream.

The center points of the machined holes on the test plates are 1.562 inch apart for the long side of the strip and .94 inch for the width of the strip.

Strips should be attached firmly to the baseplate with the screwdriver, which is also included in the kit.

B. The Aero Almen Gauge is pictured in *SN 2(2)*. The gauge is similar to the standard Almen gage used for years to measure deflection / curvature in almen strips. The only major difference is that strip has an adjustible positioning screw to provide repeatable placement of a strip in the same location for accurate readings after repeated blasting cycles. The Aero Almen gauge also provides a spring mechanism for holding the aluminum Aero Almen strip in place while the deflection / curvature is being measured. With standard Almen strips manufactured from spring steel, a magnet holds the strip in place while the measurement is being taken.

SUB-NOTE 2(2) STANDARD AERO ALMEN TEST GAUGE



The Aero Almen gauge is initially "zeroed" by using the zero gauge. If the almen strip is perfectly flat and the instrument is "zeroed out" correctly, the reading on the gauge will be zero. Once a strip has been blasted, the strip is placed in the gauge strip holder with the non-blasted surface facing the needle of the gauge. The flat polished metal circular disc included in the kit is used to "zero out" the instrument.

The gauge measures in thousandths of an inch the additional distance that the needle must move beyond the zero point to touch the unblasted surface. Care should be taken to "center" the almen strip in the strip holder by aligning the end of the strip with the plate on the side of the Aero Almen gauge. The gauge is also calibrated to allow estimates to the nearest ten thousandth of an inch, but this degree of accuracy is not required for production testing.

C. The Aero Almen strip test kit also contains a protractor level device that can be used to measure angle of blast in degrees from the horizontal surface of the material being blasted. This will assist in developing data on angle of blast versus almen arc height. Of course, in a production environment, the angle to the surface must be estimated visually.

D. A 30 power microscope is included to permit (and encourage) visual examination of the surface following blasting. When testing different hardnesses of blast material, differences in actual "peening" effect can be seen with the microscope. Careful examination of the Aero Almen strips following blasting will also provide a good "double check" for the presence of hard particle contamination of the blast media. None of the plastic media products discussed in Chapter 3 of this handbook will cause deep gouges in the 2024-T3 Aero Almen strips. If visual examination with the 30 power microscope reveals any deep indentations, the blast media should be checked to be sure it is within specification for allowable hard particle contamination.

E. A tape measure is included for measuring distance from the nozzle to the workpiece.

F. A screwdriver is included for mounting and removal of Aero Almen strips from the Aero Almen block.

G. A supply of 100 Aero Almen strips is also included in the standard test kit.

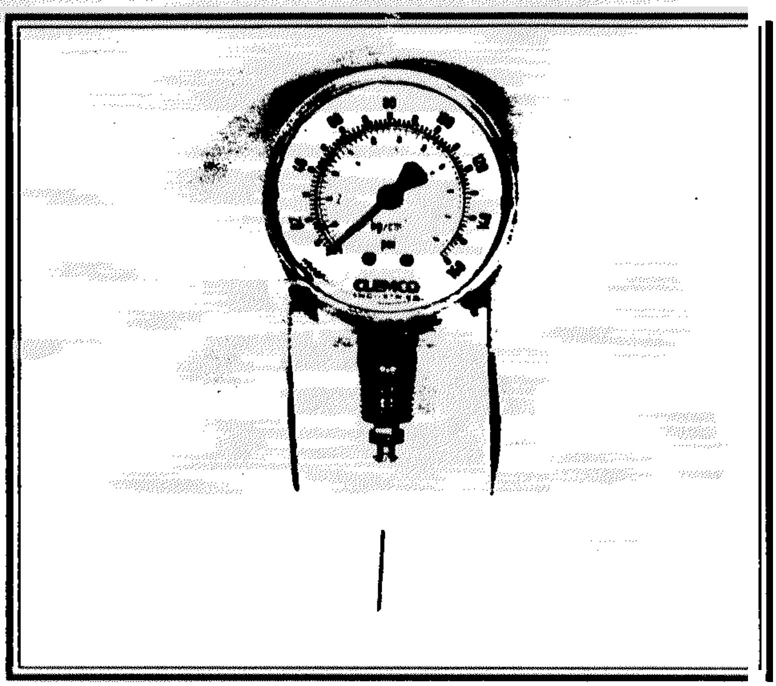
H. Each kit contains a needle gauge which is used to measure blast pressure just before the blast nozzle.

Depending on the length of the blast hose from the pressure vessel to the nozzle and the configuration of the blast hose and the blast equipment, there can be a substantial drop in pressure from the gauge at the pressure vessel to the blast nozzle.

Pressure at the nozzle can be measured by inserting the needle gauge through the blast hose just behind the nozzle. The needle should be inserted perpendicular to the blast hose and the end of the needle should be centered in the hose.

A photograph of the needle gauge is shown in *SN 2(3)*.

SUB-NOTE 2(3) — NOZZLE/HOSE LINE PRESSURE GAUGE



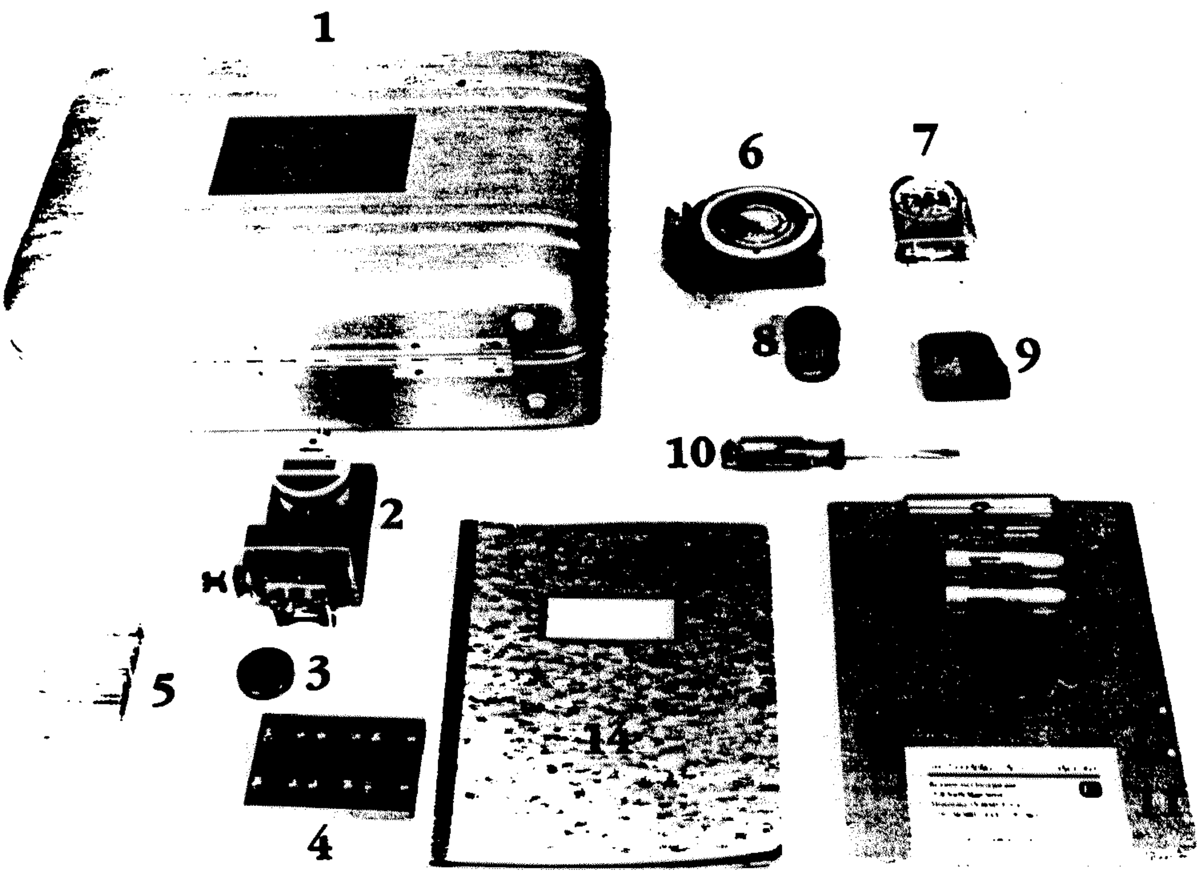
I. Each kit also contains Section 5 of the Design Handbook describing the blasting and testing procedure.

J. Each kit contains a stop watch to measure dwell time, determine bulk strip rates, and to time media mass flow rate tests.

K. A sturdy metal carrying case housing the Aero Almen test kit components is provided to withstand transport of the kit via commercial package shipper, Auto, or aircraft baggage handling processes.

Additional photographs showing the assembled Aero Almen test kit and individual components are on the following *SN 2(4)* and *SN 2(5)*.

SUB-NOTE 2(4) — AERO ALMEN TEST KIT



AERO ALMEN STRIP TEST KIT
PART # 999110

1.	Carrying Case	E.I. PART # 999111	8. Microscope	E.I. PART # 999118
2.	Aero Almen Gage	E.I. PART # 999112	9. Ruler	E.I. PART # 999119
3.	Zero Block	E.I. PART # 999113	10. Screw Driver	E.I. PART # 999120
4.	Aero Almen Strip Holder	E.I. PART # 999114	11. Clip Board	E.I. PART # 999121
5.	100 Aero Almen Strips	E.I. PART # 999115	12. Marking Pen	E.I. PART # 999122
6.	Angle Indicator	E.I. PART # 999116	13. Stop Watch	E.I. PART # 999123
7.	Needle Gage	E.I. PART # 999117	14. Instruction Manual	E.I. PART # 999124

DESIGN NOTE 5A4 AERO ALMEN STRIP TEST PROCEDURE

1. INTRODUCTION

The Aero Almen strip test kit is intended for use in all paint stripping facilities. The kit provides a way to check out and verify the dry stripping process.

For a given set of blasting parameters and media type and size, the kit will permit the measurement of "benchmark" residual stress imparted by the process.

Once a given set of PMB parameters is used to blast a set of Aero Almen strips the resulting baseline average Almen arc height is measured and documented. Alternative blast parameters, such as media type, nozzle size, media flow rate, pressure, stand-off distance, and blast angle can be used to develop better production capability by optimizing the stripping rate while maintaining the maximum Aero Almen arc height in accordance with the baseline levels measured.

The Aero Almen test allows the blast facility to quickly optimize a new blasting process and to develop and document various blast parameter combinations by measuring their relative blast effects. In this way a number of acceptable production blasting conditions could be made to allow a cost benefits analysis study to determine which method is most productive or cost effective since these two are most likely not the same condition.

The Aero Almen test kit is not intended as a means of approving dry stripping systems and media types. Approvals must come from the appropriate approving authorities in the Air Force and from the appropriate approving authorities in other branches of the service or the FAA for commercial applications.

2. TESTING PROCEDURE

The Aero Almen test consists of a verification of equipment and blast parameters followed by blasting applied using the known (measured) parameters and finally measurement and documentation of all parameters and of the test results.

The blast process parameters that must be measured are media flow rate, nozzle pressure, stand-off distance, and blasting impingement angle.

Equipment calibration consists of "zeroing" the Almen gauge, pre-measuring unblasted Almen strips for flatness, and final measurements of blasted strips after application of each set of PMB parameters.

3. MASS FLOW MEASUREMENT

For a given nozzle size and configuration and a given nozzle blast pressure, mass flow rate, measured in pounds per unit of time, will govern the velocity and impact energy of individual blast particles. A leaner mix (fewer pounds of media an hour) will result in greater individual particle velocity and more impact energy per particle. Conversely, a heavier mix (higher pounds of media per hour) will result in lower velocity and less impact energy per particle.

A leaner mix may result in a faster strip rate. As the strip rate increases, required dwell time decreases and almen intensity for one strip cycle could be lower for the leaner mix than for the heavy mix. For extended dwell times, however, the leaner mix should result in a higher almen intensity at saturation for a given set of process parameters.

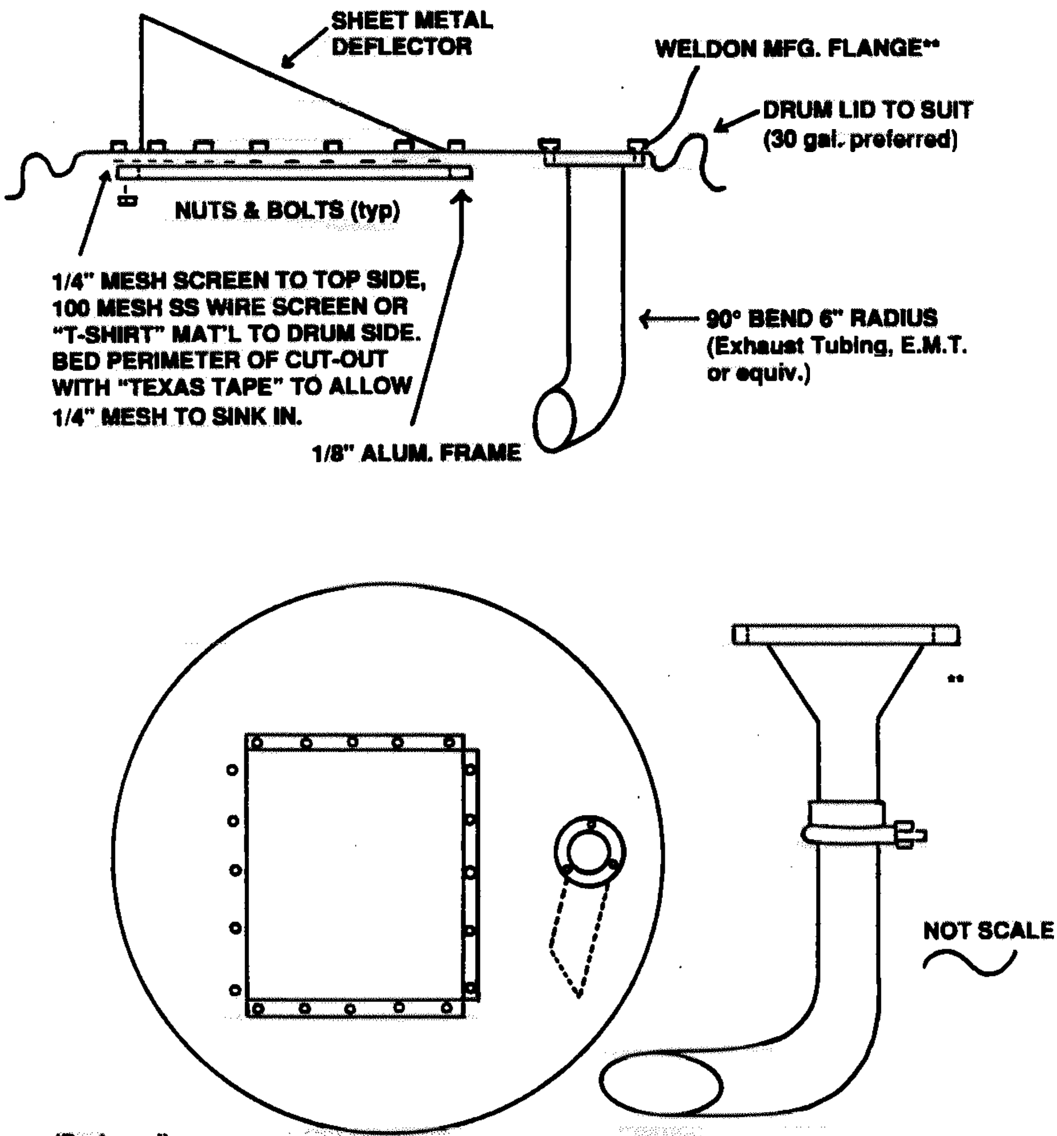
All of the direct pressure equipment in use for dry stripping has some type of a metering orifice to adjust the flow of media from the pressure pot. Some manufacturers have fixed size "grit stems" at the bottom of the pressure vessel while others have adjustable metering orifices. In conjunction with some of the robotic dry stripping approaches, computer controlled media metering is being used to ensure consistent media flow.

Media pulsing, or inconsistent media flow for a given set of process parameters, results in particle velocity and almen intensity changes, and should be avoided.

The first important piece of data required to verify the dry stripping process with the Aero Almen test kit is the mass flow rate. There are two suggested approaches to measuring mass flow rate. Either one can be used depending on the specific equipment setup being used.

The first method involves the use of a 30 gallon drum with a top with an opening and a sheet metal deflector and an exhaust tube (see *SN 3(1)*). The blast stream is started and the nozzle is then discharged into the drum for a given period of time. The material discharged into the drum can then be weighed and the mass flow in pounds per hour can be calculated. Three separate tests should be made to ensure consistent mass flow rates.

SUB-NOTE 3(1) MEDIA FLOW RATE CONTAINMENT SYSTEM



(Preferred)
**ALTERNATIVE CONSTR. USE MFG'D 2" HEADER FLANGE ADAPTER EXHAUST FITTING, CLAMP A 90° MANDREL BEND PIPE TO ADAPTER AFTER CHAMFERING (45°) EXIT END OF PIPE. BOLT TO LID USING APPROPRIATE EXHAUST FLANGE GASKET.

Alternatively, a pre-weighed sample of media can put into a cleaned out dry stripping system and the time required to discharge the pre-weighed sample can be determined.

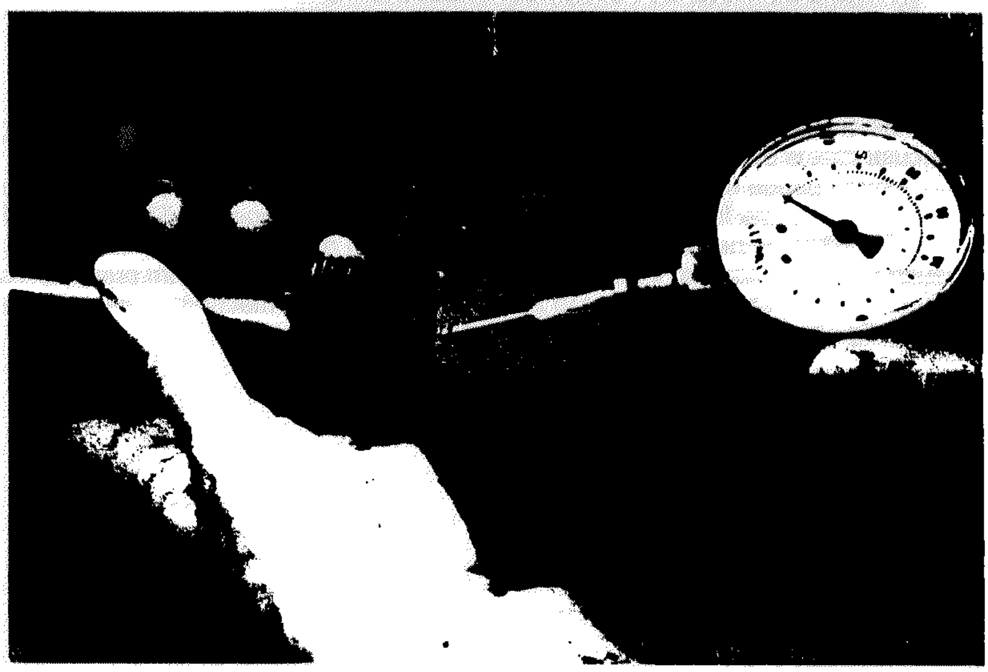
For a large production facility, the 30-gallon drum approach is preferred unless the system has just been cleaned out and is in a start-up mode. If a hand cabinet or a small walk-in booth is being evaluated, the second method may be preferred.

In either case, the Aero Almen Test Kit has a stop watch that can be used for timing the media flow. Raw data and calculated mass flow rate should be entered on the Aero Almen Test Kit Data Sheet.

4. NOZZLE PRESSURE

While mass flow rates are being determined, pressure at the nozzle should be determined using the pressure gauge included in the test kit. The needle should be inserted through the blast hose just behind the nozzle. The static pressure in the blast hose is measured by taking care not to allow the "dynamic" or moving air stream forces to be vented into the needle increasing the measured pressure value. The needle should be vented forward toward the nozzle and be perpendicular or canted forward toward the nozzle and should be centered in the blast stream (see *SN 4(1)*). Nozzle pressure (and pot pressure if available) should be entered on the data sheet.

SUB-NOTE 4(1) MEASURING NOZZLE/HOSE PRESSURE



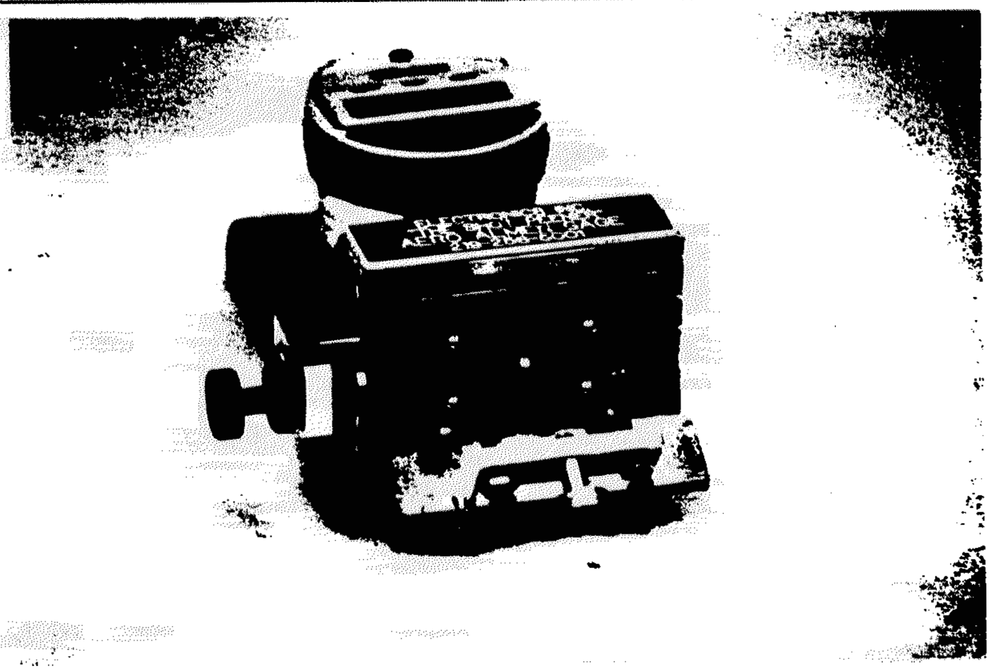
5. BLAST DISTANCE AND BLAST ANGLE

The Aero Almen strip holder should be placed on the floor of the blast room, booth, or cabinet for conducting tests. Depending upon equipment configuration, an approach should be taken to keep the Almen strip holder from moving during testing. The tape measure and the protractor included in the kit should be used to measure the approximate angle of blast and distance from the surface of the Almen strips (see *SN 5(1)*).

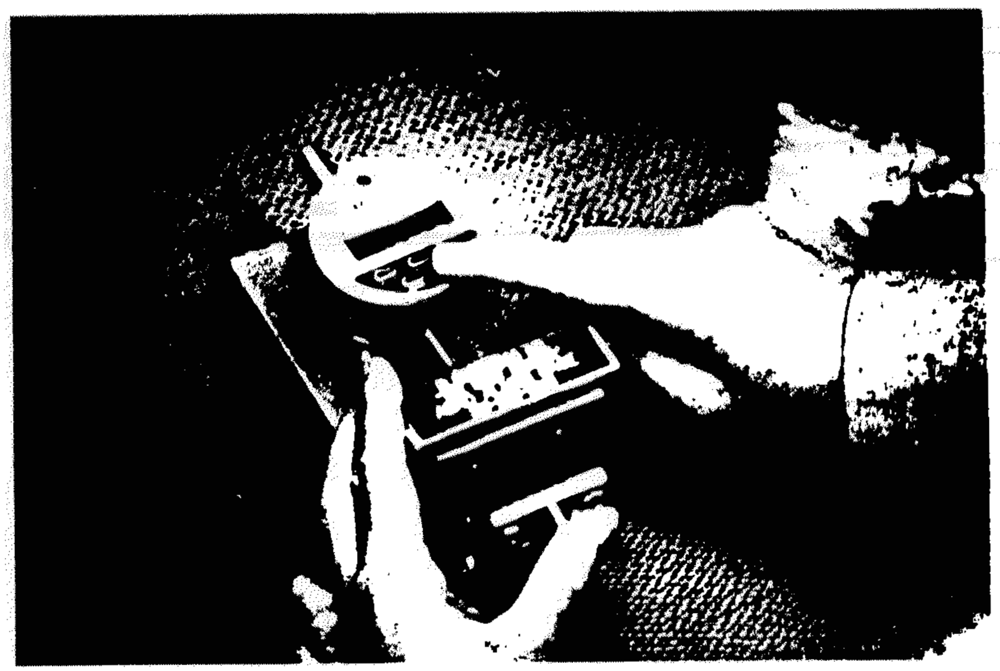
6. ZERO ALMEN GAUGE

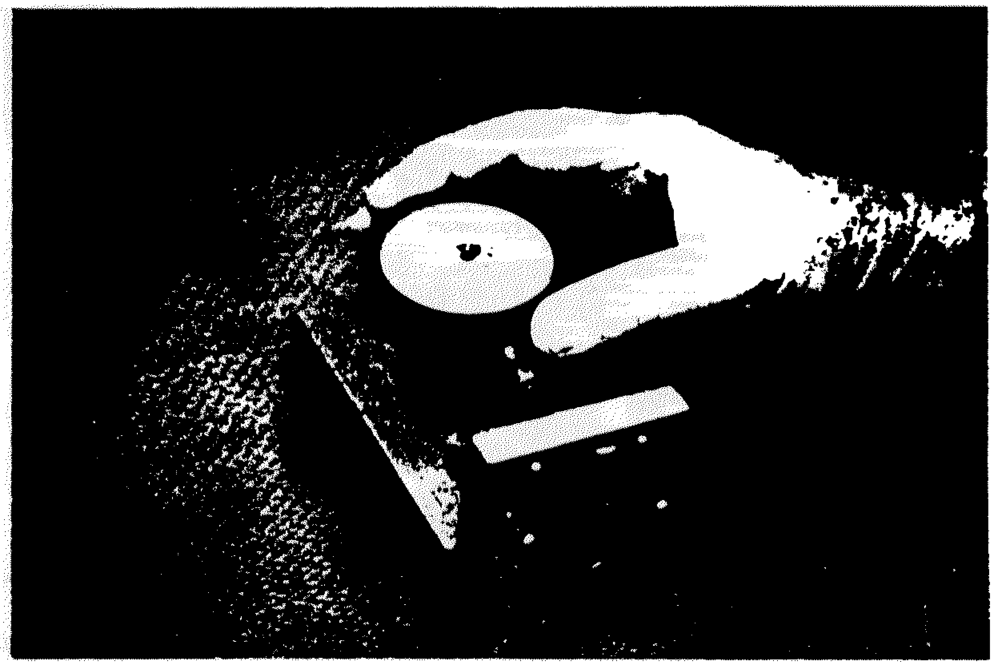
To calibrate or "zero" the Aero Almen gauge a machined flat plate shaped as a rectangular black or as a circular disk is used to locate the dial indicator plunger into the same plane as the four balls mounted in the gauge (see *SN 6(1)*). The zero block is placed in the Aero Almen gauge and pushed flat against the four balls with light finger pressure as shown in *SN 6(2)*. The Red "Zero/ABS" button is then depressed showing a 0.0000 measurement on the gauge. Make sure the gauge is reading inches, if mm are displayed depress the blue in/mm button to convert the reading to inches. The gauge is set to zero at this point. The mechanical gauge outer housing rotates to align the dial indicator with "0" (see *SN 6(3)*).

SUB-NOTE 6(1) ALMEN GAUGE BALLS AND DIAL INDICATOR PLUNGER



SUB-NOTE 6(2) ZEROING THE DIGITAL AERO ALMEN GAUGE

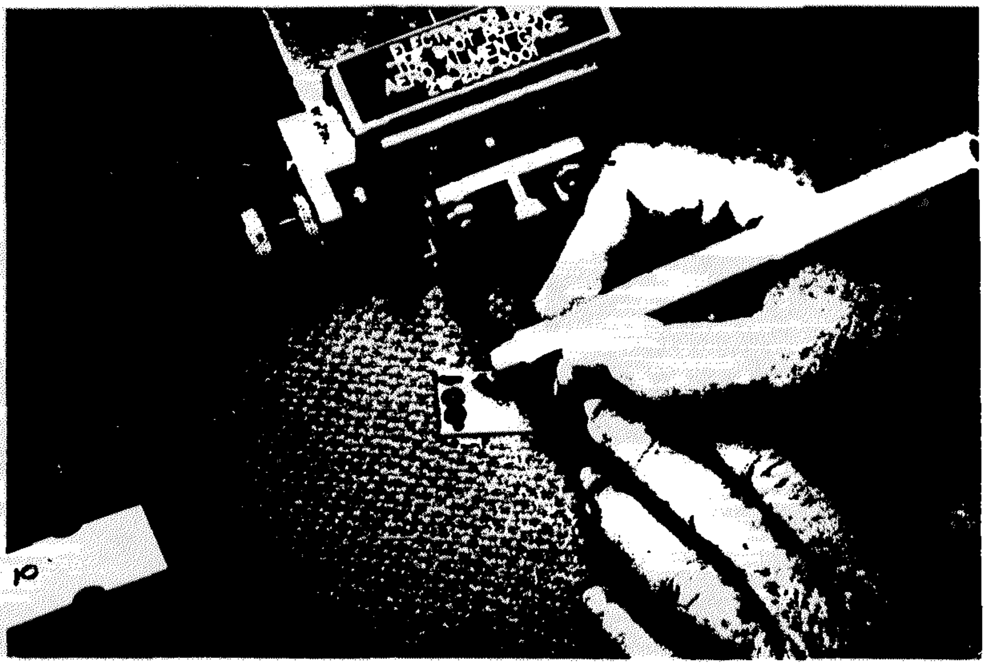




7. PRE-MEASURE UNBLASTED ALMEN STRIPS

Aero Almen strips are measured just prior to testing. The strip is placed into the holder with the painted surface facing away from the four Almen Gauge locating balls. With the Almen Gauge previously calibrated and zeroed, and the Almen strip located with one end touching the horizontal locating screw located on the left of the gauge, measure the flatness of the strip and print the reading on the bare unpainted surface which mates up to the left locating screw. Print the initial reading with an indelible or permanent marker as shown in *SN 7(1)*. Reject the strip if the Almen Strip reading is more than .0015 out of flat. The locating screw allows the Almen strip to be placed in the same position and orientation for the greatest accuracy in repeated pre and post blast measurements.

SUB-NOTE 7(1) PRE-MEASUREMENT OF UNBLASTED AERO ALMEN STRIPS



8. FIRST CYCLE ALMEN ARC HEIGHT

As stated earlier, in order to verify the process, painted Almen strips should be used for first cycle arc height tests. Use of painted strips will ensure that dwell time is not underestimated. If painted strips are not available, painted panels or scrap parts can be used to determine the proper nozzle traverse speed for one cycle.

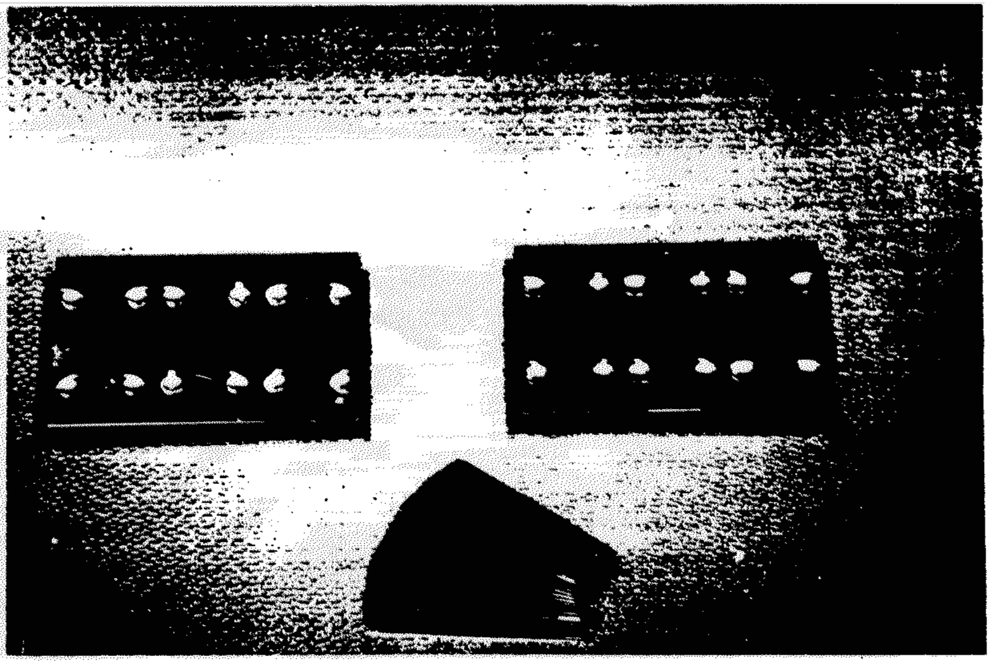
Almen strips should be attached to the Almen strip holder firmly using the screwdriver included in the kit (see *SN 8(1)*). Care should be taken to center the strips in the holder. Each Almen strip used in the test should be assigned a number. The number should be written on the nonblasted side of the strip and recorded on the data sheet.

The Almen strip holder, with Almen strips attached, should be placed on the floor of the stripping facility and secured appropriately.

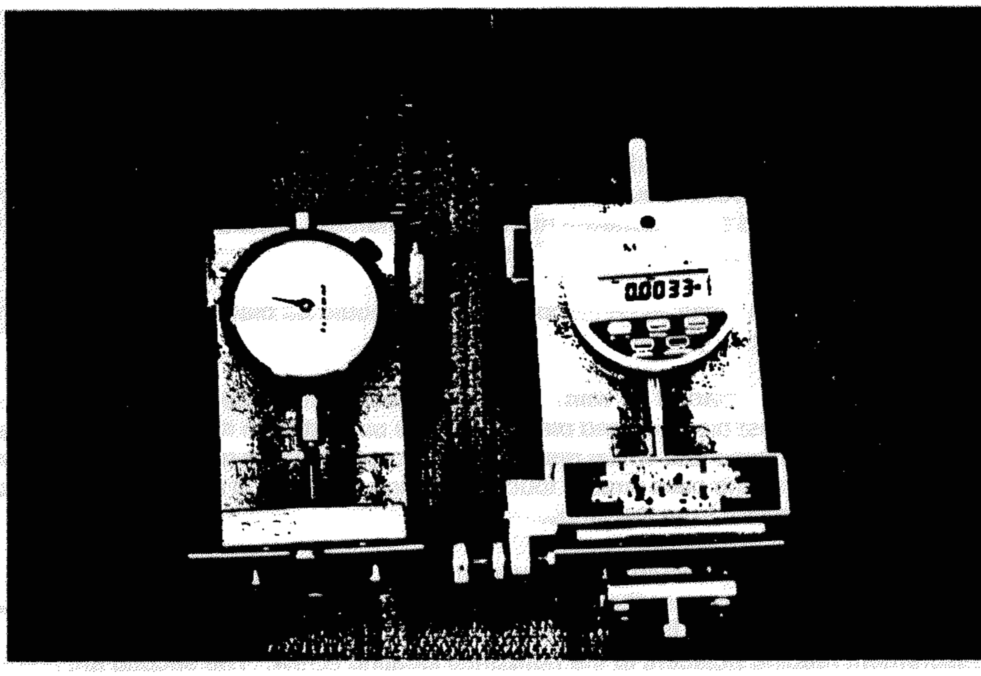
The system should be started up with the nozzle directed off to the side of the Almen strip holder. Using the desired blast distance and blast angle, the blast stream should be directed across the almen strips at a traverse rate which results in an acceptable paint removal. The stop watch should be started as soon as the blast stream touches the first Almen strip and stopped as soon as all paint has been removed from the strips.

The blasted almen strips should be removed from the holder and the arc heights measured using the Aero Almen gauge as described in *SN 8(2)*. The Almen arc height readings are made as described in the preblasted flatness measurements. The Almen strip is oriented with the previous measurement reading adjacent to the horizontal locating screw. The second arc height reading is written below the initial reading as shown in *SN 8(3)*. The value of the change in flatness between pre and post blast measurements is recorded as the standard Aero Almen arc height.

SUB-NOTE 8(1) AERO ALMEN STRIPS MOUNTED IN A HOLDING FIXTURE



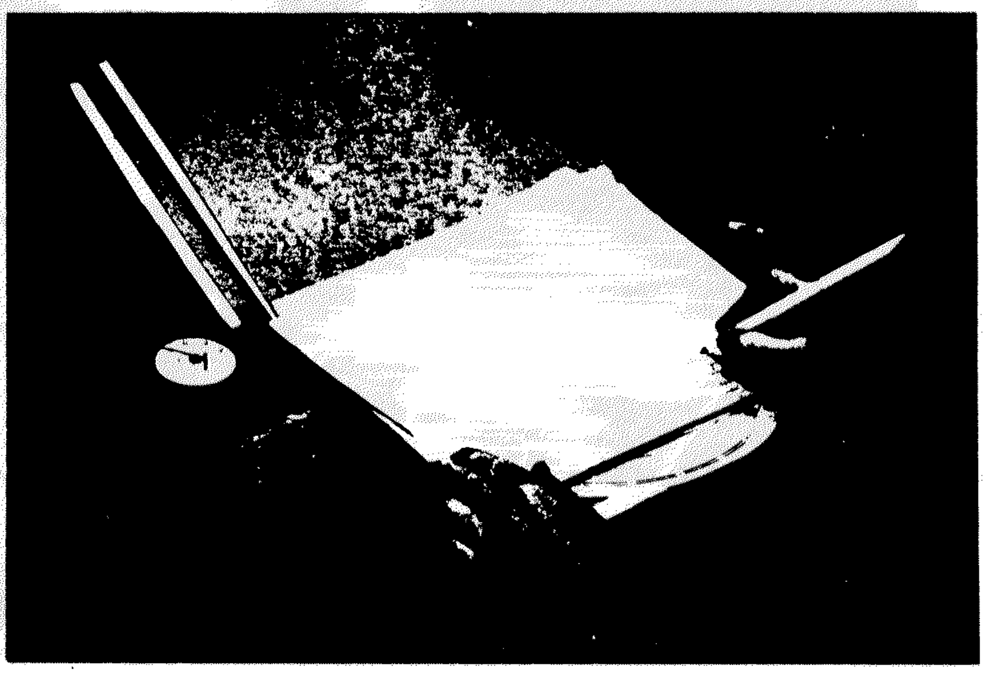
SUB-NOTE 8(2) AERO ALMEN STRIP GAUGES MANUAL AND DIGITAL



SUB-NOTE 8(3) POST BLAST AERO ALMEN ARC HEIGHT MEASUREMENT

The arc height for each of the three strips should be recorded on the data sheet (see *SN 8(4)*). If Almen Arc height readings are above the allowable level set for the specific coating removal application, a second set of strips should be subjected to the one cycle. Visual inspection with the 30 power microscope should be done to evaluate acceptability of paint removal and to look for any signs of media contamination or excessive surface distortion.

SUB-NOTE 8(4) RECORDING AERO ALMEN STRIP DATA



9. FOUR CYCLE AND EXTENDED DWELL TESTS

Next, new Almen strips should be numbered and attached to the Almen strip holder, and the Almen strips should be subjected to the equivalent of four blast cycles based on the traverse speed determined from the one cycle test. The blast stream should traverse back and forth twice with the traverse continuing until the entire blast pattern is off of the Almen strips at either end of the Almen strip holder.

Once again, the strips are removed from the holder, Almen arc height measurements are taken and recorded and the surface is evaluated using the 30 power microscope.

Extended dwell tests can then be conducted to determine the "worst case""Almen arc height. One Almen strip should be attached to the Almen holder and the blast stream should be moved back and forth over the strip for the equivalent of ten strip cycles.

Again, the strip is removed from the holder, and the arc height is measured and recorded and the surface can be evaluated.

One cycle, four cycle and extended dwell Almen arc heights can then be compared to the data base in *DN 5A5* of this chapter.

Tests should be conducted by the operator on duty at the time to ensure that the test is consistent with the actual paint removal operation. The process is operator sensitive, and the differences in blasting "technique" may affect arc height.

10. AERO ALMEN TEST KIT STORAGE

All materials used to conduct Aero Almen testing should be kept together in the storage case to prevent damage to equipment or loss (see *SN 10(1)*).

SUB-NOTE 10(1)	AERO ALMEN TEST KIT MATERIALS STORAGE

11. FREQUENCY OF TESTING

Tests should be conducted on a periodic basis every 4 hours or after any machine setting changes to ensure that blast pressure and media flow rates are being maintained and that residual stress as measured by arc height is within the expected range.

Additionally, tests should be conducted whenever media supplier is changed or when the type or size of media to be used is changed.

12. AERO ALMEN TEST KIT DATA SHEET

The form shown below , or one of similar content, should be completed in full for every test which is conducted:

AERO ALMEN TEST KIT DATA SHEET

Facility ____________________ Operator ____________________

Equipment Designation ____________________

Date __________ Mass Flow Rate- Test #l __________
Test #2 __________

Shift __________ Time __________ Test #3 __________
Average __________

Media Type __________ Media Size __________

Nozzle Pressure __________ Blast Angle __________ Blast Distance __________

First Cycle Test Strip #1 Code # __________ Arc Height __________
#2 Code # __________ Arc Height __________
#3 Code # __________ Arc Height __________

Four Cycle Test Strip #3 Code # __________ Arc Height __________
#2 Code # __________ Arc Height __________
#3 Code # __________ Arc Height __________

Extended Dwell Test Code # __________ Arc Height __________

Visual Observation Comments (degree of paint removal, evidence of peening effect on 1 cycle, 4 cycle and saturation tests, evidence of media contamination, and so forth.)

1. INTRODUCTION

Paint removal resulting from impingement of an abrasive blast medium on aluminum substrates causes concern about the residual "peening" effects and possible degradation to aluminum skins and underlying structure. Laboratory tests to determine the peening effects on the mechanical properties of aluminum and composite aircraft skins have demonstrated the susceptibility of thin structure to be significantly damaged by blasting effects. Chapter 4 documents some of the concerns and data generated evaluating residual blast effects on aircraft materials.

The aircraft depainting industry has been using a modified Almen strip to measure the residual energy imparted to a substrate after blasting off the paint coating. The Aero Almen strip is made from bare 2024-T3 aluminum sheet .032 thick. The strip is sheared to .75 by 3.0-inch dimension with the rolling marks aligned parallel to the 3.0 dimension then mounted on a flat plate fixture. Finally the strips are blasted with abrasive media using parameters simulating the conditions used to depaint the aircraft. The strips are peened by the blast media resulting in stretching of the top surface and cold working this surface to a depth of up to .002 inch. The residual energy stays in the test strip and causes the strip to arc up when removed from the test fixture. The strip is mounted in a standard Almen strip test gauge for measurement. The amount of arc height over the central two-inch span is called the Almen arc height. This height is primarily dependent on velocity, density, angle, and number of particles striking the surface of the test strip during the depainting cycle.

Several thousand Almen strips have been blasted with various media types, blast pressures, mass flow rates, impingement angles, and stand-off distances to document the intensity of the blast stream and to measure residual or peening effects. The same blasting process parameters used on aircraft materials gave test data on the mechanical degradation to the static and dynamic properties of the subject material. This engineering data was used to develop acceptable blast parameters for the various depainting applications and ends up as blast guidelines for process specifications used to strip flight hardware in depot depainting facilities.

The Aero Almen strip is the commercially available test strip that is equivalent to laboratory test strips in use for several years. The Aero Almen strip data base reflects a wide range of blasting parameters including those currently used on military and civilian aircraft and documents the intensity of the residual blasting effects from a variety of different abrasive blast media on flight structure.

Aero Almen strip data are used to show conformity of the facility equipment and operator training to authorized depainting process specifications and prescribed blasting parameters. The aluminum strip gives a sensitive and repeatable measure of the blast stream energy absorbed by a substrate but does not directly measure or infer the effect of the residual stress on the flight structure.

Almen strip data does not replace the required engineering determination of allowable peening effects on any aircraft structure. This data must be generated by the responsible engineering group then approved by the system manager in the Air Force or a similar person in the other services.

Almen strip data does give a good correlation between similar material applications and may be used as an engineering aid in selecting appropriate media types and blast parameters for new engineering depaint process specifications. Once the media type and blast parameters are selected for a given aircraft material, type, temper, and thickness the fatigue, crack growth rate, and other pertinent mechanical tests must be completed to demonstrate acceptable performance. Much of this work has been completed and has resulted in general acceptance of plastic/soft abrasive media. The general use of plastic media on.032 thick or greater aluminum substrates has been evaluated by the military and by commercial airframe manufacturers, such as Boeing. Accepted practice in blasting booths is to allow a process that generates Almen arc heights of less than .006 inches on metal substrates. On structural composite components, such as rudder and stabilizer surfaces, the Air Force permits blasting with lower pressure at the nozzle (below 25 psi) so long as the operator demonstrates control of process so no visual fiber damage on composite surfaces is observed. Testing by the Air Force and Navy laboratories have concluded that the depainting of composites surfaces results in a minor surface effect degradation of the composite structure which can be controlled by skilled operator depainting technique. General guidance documents such as the Air Force T.O. 1-1-8, "Application of Organic Coatings on Aerospace Equipment," authorize plastic media blasting within guidelines. The Boeing Company has written guidance in document number D6-55564, "Requirements for Alternative Paint Stripping Processes," describing allowable .006 inch Almen arc height data recommended for depainting .032 or thicker structure (see Chapter 6 for details).

2. DATA BASE ANALYSIS

A great deal of Almen arc height data has been generated over the past four years for a variety of plastic media products as well as other materials being used for aircraft coating removal applications. It should be noted, however, that much of the data developed to date have been developed for marketing rather than technical reasons.

The Data Base Appendix (Chapter 5.8) contains data on some of the work done by Battelle Memorial Institute on Types I, II, and III plastic media. This data base is supplemented by preliminary production data developed by Wright Patterson AFB in recent Type V testing in Sacramento. Only Almen arc height data on 2024-T3 Bare strips are included.

At this juncture, the only supplier data included has been taken from the Battelle report conducted for DuPont. As further details of supplier test data become available, this information will also be incorporated in the Design Handbook.

3. HARDNESS

Data developed thus far clearly shows that media hardness is the major determinant of residual stress measured by Almen arc height on 2024-T3 bare Almen strips. As the hardness of the blast media increases, the Almen arc height also increases.

SN 3(1) shows Almen intensity vs. media type for one strip cycle with all other parameters held constant. *SN 3(1)* is based on information developed by Battelle in their follow-on studies.

SN 3(2) shows similar data developed by Wright Patterson during the preliminary production testing.