Procedures for Using Standard Almen and Aero Almen Strip Tests Parts I & II

Adapted from AFSC Design Handbook DH-1-13 February, 1992 (unpublished)

Part I

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.

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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 best 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 1980's 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 many 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 hard-

ness, control of parade 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 1940's in the automotive industry by a General Motors engineer, John O. Almen.

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.

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.

4(2) Traditional Almen strip holding fixture

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. SAN 4(4) shows a typical Almen arc height 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 than 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.
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 6061 T-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 record with the melamine material (Type III).

Chapter 3 discussed particle geometry in some detail. In order to remove military paint systems, an angular particle I was required to chip away or erode away the coating. The softer, unfilled materials, such as the polyesters, acrylics and allyls are more angular with sharper points and flatter surfaces. These materials rely primarily on their sharp edges to remove paint. The alpha cellulose filled urea's 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.

**Part II**

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 transferred 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 transferred 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 effect 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 see 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.

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 3.00 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.

3.8(1) Aero Almen Strip

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 1-18 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 must 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 be 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.

In the next issue:
Part III Standard Aero Almen Test Kit and Part IV Aero Almen Strip Test Procedure.

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**News Release**

Turco® Introduces HAP-free, Drop-in Replacement Paint Strippers to Aircraft Market

Turco Products, Inc., a subsidiary of Elf Atochem North America, Inc., is introducing a new line of paint strippers designed to reduce VOC’s (Volatile Organic Compounds) and eliminate HPA’s (Hazardous Air Pollutants) during aircraft paint removal operations. The new water-based strippers are drop-in replacements for methylene chloride-based paint strippers that are the current industry standard.

"The NESHAP (National Emission Standards for Hazardous Air Pollutants) recently issued by the EPA, severely restricts the use of methylene chloride-based products for depainting operations within the aviation industry," said Nancy Storoz, Aviation Specialist. "With our new technology we're able to meet our customers changing needs in this critical market."

Field use of the new paint strippers by military and commercial customers indicates that the new paint strippers offer performance equal to methylene chloride-based products at a cost savings. Because the new products are true drop-in replacements, they require no investment in new equipment. Mechanical paint strippers, sold as alternatives to current methylene chloride-based technology, require significant investment in equipment and training.

The new water-based paint strippers are available from Turco. T-6776 LO, acid-activated, and T-6813, alkaline-activated, are formulated for commercial and military use. Additional information on these products is available from Elf Atochem on request.

Elf Atochem North America, Inc., a $1.6 billion diversified chemicals manufacturer headquartered in Philadelphia, PA., is an affiliate of Elf Atochem S.A., a $10 billion chemicals manufacturer, which is part of the Elf Group (NYSE: ELF) headquartered in Paris, France. Turco Products, Inc., is a wholly owned subsidiary of Elf Atochem and the world’s leading manufacturer of chemical products for the aircraft industry. ■

Let’s Hear From You...

We will be starting our Letters to the Editor column in the next issue—any questions or comments on this newsletter or the aircraft paint stripping industry in general, plus press releases on new services and products, can be sent to our editor:

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