Report No. FAA-CT-81-163

SYMPOSIUM ON NEW SAFETY CONSIDERATIONS FOR EMERGENCY EVACUATION SLIDES

OCTOBER 28-29, 1980

PROCEEDINGS

DECEMBER 1980

Document is available to the U.S. public through
the National Technical Information Service,
Springfield, Virginia 22161.

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER

Atlantic City Airport, N.J. 08405

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
ATLANTIC CITY, NEW JERSEY 08405

Dear Attendee:

We wish to thank you for attending the Emergency Evacuation Seminar and were very pleased with your excellent participation. Since a large majority of you requested copies of the presentations, and a list of the attendees, we have compiled and enclosed proceedings of the seminar.

We enjoyed meeting with you in this useful and interesting program and look forward to similar meetings at the Technical Center in the future.

Sincerely,

Wayne D. Howell

Wayne D. Howell
Chief, Fire Safety Branch

Enclosure

TABLE OF CONTENTS

Director, Joseph M. Del Balzo
Welcoming Remarks

I would like to welcome you to the FAA Technical Center and I was going to say I'd like to welcome you to our, the Technical Center, symposium on Evacuation Slides. You know the more I thought about that, that's not true, it's not our, the Technical Center symposium, because when you look around, you see that there are slide manufacturers here, there are airframe manufacturers here, the airlines are represented, the regulators are represented, and we don't fall into any one of those categories. The job that we are doing here, our mission in this case is a simple one, we want to be sure that whatever tests and standards get written and proposed for more effective heat resistant slides, have their basis on realistic testing that represents what happens in the real world. You know, it's not enough to devise a laboratory procedure so that you can test the material in this case because as it turns out evacuation slides don't get used in a laboratory; they get used in an aircraft after a crash. So whatever we do here, in terms of testing, and with the recommending of standards, should show some correlation to what actually happens in a real world and I think what you are going to see during that next two days shows that we have been successful in doing just that. We have been able to show a correlation between small scale testing and full scale testing. So it's not our symposium, it's kind of your symposium. When I look around and again I tell myself no one has a lock on safety, you know, despite what you read, safety is everybodies concern. It's not a concern just of Congress, it's not a concern just of NTSB, it's not a concern just of the regulators, I think safety is an issue that concerns us all. Let's look at what happens in a case of evacuation slides. A problem was recognized, and quickly we saw various organizations and people go into motion. Slide manufacturers prepared better heat resistant materials and they furnished that material to us for testing. We reacted quickly by devising test methods and providing people with test results. And I think what you are going to hear during these next two days are significant results that got accomplished in a timely manner. It didn't take an NTSB mandate. It didn't take nasty letters from consumer groups critizing the regulatory agency. All it took was an understanding of a real world problem and the willingness and cooperation of people to address that problem. To me that's a sign that there is something good in the aviation business, I'm not sure it could happen any place else. That's a subject I get emotional about because I think safety is something that we are all concerned about, and you can't help but be offended when you read the attacks on aircraft safety in the various publications. It just isn't so, I think this is a good indication. So again, I welcome you to the symposium, it's certainly timely, it's going to provide for some good discussions, and I think you will see some good outputs at the end of the two days. Have a good two days!

HISTORY OF THE INFLATABLE EVACUATION SLIDE

JAMES SUMMER

Staff engineering consultant with Eastern Aero Marine Co., Miami, Florida, 25 years experience on evacuation slides on all aircraft beginning with first commercial sale in 1956. Worked with American Safety and Air Cruisers in past. B.S. M.E. - Stevens Institute of Technology working on Ph.D in Science - New York University.

HISTORY OF THE INFLATABLE EVACUATION SLIDE

Mr. Chairman, gentlemen. When Sam Zinn called and asked if I would be interested in attending this workshop and possibly giving this presentation, I answered, yes I would be interested in attending; however, since I was no longer employed by a current manufacturer of slides, I would have to speak to my employer before giving a firm yes I will attend.

When I spoke to the general manager, he said you better discuss this with Sam. Sam Oroshnik is the owner of Eastern Aero Marine, my present employer. I finally caught up to Sam and told him of the workshop. He looked me in the eye and said, "Jim, you know we do not presently manufacture slides; however, that has been your field for so long, of course you can attend — we owe it to the industry." So here I am.

In the early days of air transport, the aircraft were relatively small and low to the ground, and in case of emergency evacuation requirements it was just a large step to the ground. As the aircraft became larger, the height of the doorsill to the ground increased, so a knotted rope was provided at the exit for emergency evacuation purposes. Additional increases in aircraft size and doorsill height rendered the knotted rope practically useless.

About this time, someone watched the coal man delivering coal from the truck down through the cellar window, via a metal coal chute, and thought the idea could be applied to emergency evacuation of an aircraft; and the fabric escape chute was born.

These chutes were fabricated from coated fabrics, had a flat sliding surface with turned up sides to contain the evacuee, hardware at the upper end to attach the chute to the doorsill, and several sets of webbing handles on each side at the lower or ground end. The chutes were stowed on, or adjacent to, the door. In case of emergency, the door was opened, the hardware on each side of the chute was attached to the mating hardware on the doorsill, and the remainder of the chute was thrown/pushed out of the aircraft. It was expected that two husky men would be the first to leave the aircraft by shimmying down the hanging chute. These two men would grab a set of handles on opposite sides of the chute and walk away from the aircraft until the chute was fully extended. They would then throw their weight against the handles to hold the chute taut and two additional men would slide down the chute and grasp the remaining handles and assist in holding the chute taut for the remainder of the evacuees.

The fabric chute was an improvement over the knotted rope but still had many drawbacks such as, the length of time required to engage the chute, and position the holders, the pileups that occurred at the end because evacuees rarely landed on their feet, the inability of the holders to maintain a nearly constant sliding angle, the hesitancy of evacuees to use the chute and the improbability of having the holders support the chute with an engine fire overhead.

Just about this time (early 1950's), there was a man named Jim Boyle whose name was synonymous with inflated products. He had basically started the inflatable airline rafts and vests as we know them today. He also fabricated the fabric chutes so he was aware of the problems associated with their use. Being an inflatable engineer, he started to think about using an inflatable structure to replace the fabric chute and the required chute holders. He then set about to develop the idea.

The material available at that time was natural rubber-coated cotton or the newly developed nylon fabrics which could be purchased in a 36-inch usable width. If a tube was made of this width fabric, it would be approximately 12 inches in diameter. That would not be wide enough to slide on; however, if two widths of fabric were joined together, a tube of approximately 24 inches in diameter could be fabricated. A tube of this diameter would be wide enough to slide on and would support the actuated loads. Since it is difficult to maintain position on a curved surface, a longitudinal tube was placed along the longitudinal axis on either side of the support tube to form a trough and to prevent the evacuee from sliding off the side of the tube. These tubes were approximately 12 inches in diameter to get the full utilization from the 36-inch-wide fabric. Hemispherical ends on the support tube would be unstable, so square ends were installed. This type construction provides four points about 3 inches from the bulge at the center of the ends. The sill end was installed at an angle to compensate for slide angle and fuselage curvature. At the runway end, the lower two points of the square end did not provide any stability, so they were removed and a 12-inch-diameter tube, 30-inches long was installed perpendicular to the axis of the support tube. A fabric girt was installed at the sill end with the same hardware as was used on fabric chutes. This girt was of two-piece construction and was laced together so the slide could be detached from the aircraft while inflated for use as a flotation deVice in a water ditching.

Handles were installed at the runway end to permit use as a fabric chute should the inflation system malfunction. Additional handles were placed on the top of the slide to permit reentering the aircraft and lines were fastened along the sides of the structural tube for flotation device hand holds.

A piece of webbing was attached to each rail tube, approximately one-third the length of the slide from the sill end. These webbings terminated in hooks for attachment near the top of the door. They also had adjusting sliders for adjusting the webbing length for various aircraft attitudes. These webbings were used to position the slide if it did not position itself properly after inflating and to take the shock load of an evacuee entering the slide.

Since natural rubber has a high friction factor and prevented evacuees from sliding, single side coated nylon fabric strips were cemented onto the sliding surface with the uncoated or nylon side up. The width and lengths of these strips were adjusted to obtain the required exit velocity.

The idea worked and the inflatable slide was born. An acceptable method for inflating the slide still had to be developed and I will discuss this when I talk about inflation systems.

Jim finally filed a patent application on May 4, 1954, and was awarded patent number 2,765,131 on October 2, 1956. This started the inflatable slide industry as we know it today and all slides manufactured since, in my opinion, infringe on this patent's basic claim which states ...an elongated, flexible walled, fluid-distensible slideway structure supported by the aircraft structure on one end and the ground on the other.

The first commercial sale of an inflatable slide was during 1956 for the military version of the 1049 aircraft.

This slide had a volume of 110 cubic feet, was approximately 275 inches long and inflated in 25 seconds. Adjusting the regulator and adding tighter controls to the aspirators reduced the inflation time to 13 seconds.

The 707 was the second sale followed closely by the DC-8 and CV-880/990. All these slide designs had one thing in common. Each slide was designed exactly the same; and only the length, and consequently, the inflated volume, stored gas requirements, and inflating times varied.

SLIDE IMPROVEMENTS

Although the slides were performing as originally designed — to get people off the aircraft in a hurry — experience showed that a large portion of the evacuations were of a precautionary nature. If an evacuee was injured and the aircraft was intact (no fire, etc.), the law suits piled up and the industry trend was to design a slide which would buckle under the weight of an evacuee and let them scramble/crawl off with no minor injuries, so the second generation of slide evolved in 1960 to 1962.

These slides were fabricated as a rectangular tubular structure having a fabric sliding surface and a built in breakpoint. The fabric sliding surface reduced the possibility of a catastrophic failure due to a spiked heel puncturing the sliding surface.

In previous slides, the sliding surface was on an inflated tube. If, in this case, a spiked heel punctured the sliding surface it also punctured the inflatable structure and the air integrity and, consequently, the structural support of the slide was lost.

This breaking effect of the slide and gentle deposit of the evacuee on the ground took valuable time and slowed the possible evacuation rate, so a third generation of slide evolved about 1965.

This third generation of slide had a curved or hooked runway end. It was strong and did not buckle and, when necessary, incorporated decelerating devices at the runway end to rotate an evacuee from a prone position to a sitting position and provided an exit velocity of slightly faster than a walk. This generation of slide is the current model, although it has been modified to permit two lanes of evacuees and to incorporate features which permit its use in a raft mode.

INFLATION SYSTEM REVIEW

An inflatable anything, slide in particular, is utterly useless if there is no means to inflate it within the allowable parameters of time, pressure, and temperature. This is exactly what Jim Boyle found after he had designed a useful inflatable slide. He tried to inflate it with a CO_2 bottle. Although he could get a satisfactory pressure in about 30 seconds in an ambient temperature 70° Fahrenheit (F), it took several minutes at minus 40° F. If he used a large enough charge of CO_2 to inflate in 20 seconds at minus 40° F, he had difficulty in dumping the excess gas at 120° F. He also had higher pressures during the discharge cycle and relief valve dumping cycle than the original slide was designed to operate at properly. If he increased the size of the relief valve to maintain the maximum slide design pressure, the weight and bulk of the relief valve was prohibitive.

He next tried stored air/nitrogen which was available, at that time, at a storage pressure of 2100 PSIG at 70° F. The slide could be inflated throughout the desired temperature range in less than 20 seconds, but again, the weight and bulk of the relief valve was excessive and the storage vessel was so large that no payload would be left on the aircraft.

One day he chanced upon a steam ejector for removing gas from a mine shaft and thought, if I can replace the steam with a stored gas system, the ejector might just make the slide feasible. So he looked around and finally located one of these ejectors. A regulator was installed in the discharge line of an air reservoir/discharge valve assembly and the exit to the steam ejector was mounted into the slide. A trial inflation was performed and it worked. The slide inflated in approximately 25 seconds and the weight of stored gas required was less than 50 percent of the gas required if no ejector was used.

Armed with this data, Jim approached Walter Kidde, who supplied all his CO_2 inflation equipment, to see if they would develop a smaller ejector which he called his aspirator.

They designed a unit which performed satisfactorily for about 3/4 of the inflation cycle. The slide pressure would reach about 2 1/2 PSIG and then decay down to approximately 3/4 PSIG at the end of the inflation discharge cycle. After many discussions with Walter Kidde on how to improve the aspirator and finally being told he did not know how an aspirator should work, he gave up on Walter Kidde and asked the Garrett Corporation for help. Jim had just sold his company, Air Cruisers Company, to the Garrett Corporation. They developed the jet pump (aspirator) which Air Cruisers used on the first inflatable slides, and with minor modifications, still use on their narrow body slide designs as well as on their aspirated raft designs.

This jet pump, installed in the first slides, inflated a 110 cubic-foot-volume slide to a usable pressure in 23 to 25 seconds using a 300-cubic-inch cylinder charged to 3000 PSIG at 70° F. Before the sixth ship set had been delivered, minor improvements/inspection tests had been incorporated into the jet pump/regulator and the inflation time had been reduced to 13 seconds, maximum.

The lesson learned from this experience was the aspirator/jet pump is part of the slide and must be controlled by the slide manufacturer.

This system was essentially the same type eventually used on the 707, DC-8, and CV-880 with minor modifications, and inflated these slides in less than 7 seconds. The DC-8 and CV-880 always purchased the inflation system with the slide. The 707 equipment started in this manner, but eventually the cylinder and valVe assembly was purchased from Air Cruisers vendors and the slide from Air Cruisers. Problems continually arose as to responsibility of failures etc., and finally, inflation equipment and slide was purchased as a unit and the majority of installation problems disappeared.

In 1958, Air Cruisers demonstrated a 707 slide inflation using a gas generator. Although the slide reached operating pressure in the allowable time, the pressure in the slide decayed as the gas from the generator cooled to ambient temperature.

Cool gas generators (which contained a liquid in the storage vessel) plus a gas generator were then developed to replace the gas storage vessel in the inflation system. These units reduced the weight and bulk of the inflation system and did not detrimentally affect inflation time; they did, however, increase both the initial cost and maintenance costs of the inflation system and also frequently produced costly damage to the inflatable slide.

Cool gas generators have been eliminated from the inflation systems on all L-1011 evacuation equipment and have been superseded by a stored gas system on 747 slide/rafts.

The latest design of jet pump/aspirator has produced inflation times in the 2- to 5-second range (depending on slide volume), regardless of the primary gas system used.

A solid grain gas generator is being developed which replaces the gas storage vessel and regulator valve. The generator delivers a non-toxic, breathable gas; it will, when matched with the latest jet pump/aspirator designs, duplicate the performance of the gas storage system. In addition, this type generator will reduce routine maintenance costs; it will, however, have a higher initial cost than the stored gas system which it is designed to replace. Preliminary trade offs indicate that when compared to air systems using composite-type stored gas vessels, the weight and bulk of the solid grain gas generator system is approximately the same, its cost is approximately 15 percent higher and the related nonrecurring costs are considerably higher (due to the fact that no production orders have been placed for the gas generator to date) whereas, several composite cylinders are in production and presently commercially available.

MATERIALS

Early slide designs, for such aircraft as 707's and DC-8's, were fabricated from natural rubber-coated nylon fabric. As neoprene coatings became available, second and later generation slides, such as the 727, 737, 747, etc., were fabricated from neoprene-coated nylon fabrics. With the advent of polyurethane coatings, some of the later model slides used on a retrofit slide program and later wide-bodied jets (such as the DC-10, L-1011, and A-300) have been fabricated from polyurethane-coated nylon fabric.

Neoprene-coated fabrics have proven far superior to the natural rubber-coated fabrics and their life expectancy has exceeded that of polyurethane-coated fabrics. Although polyurethane-coated fabrics are purchased to an approved specification, occasional substituting of an ester for an ether derivative polyurethane compound, or vice versa causes a rash of inflatables which no longer hold air and/or develop mold infestation, particularly in hot humid operational conditions. In addition, the isocyanate used in the majority of polyurethane adhesives is sensitive to water: i.e., during the cementing operation, moisture from the humidity of the air is absorbed by the isocyanate, and when the seam is exposed to stress at hot, humid operational conditions, it will fail through cement deterioration. To reduce this absorption of moisture, the cementing area must be dehumidified and maintained at an absolute humidity of 50 percent or less at 70° F.

STRUCTURAL CLOTH

Early inflatable equipment was fabricated from cotton, coated with an elastomer such as natural rubber, and later, neoprene. The fibrous surface and low strength of the cotton cloth required heavy denier cotton threads and thick coatings in order to obtain the required strength and air-holding properties for any given inflatable design.

As synthetic fibers became available, nylon was substituted for the original cotton cloth. The greater strength of nylon permitted the use of smaller denier yarn for the same strength coated fabric and the less fibrous nature of the nylon yarn permitted use of a thinner elastomeric coating. The result was a large weight and bulk savings over the cotton based fabrics.

A new cloth, made from "Kevlar," is now available which is lighter, stronger, more puncture and tear resistant, and less flammable than nylon. This material also can be natural rubber, neoprene and/or polyurethane coated to obtain the desired air-holding properties.

Since "Kevlar" does not burn, it does not require additional quantities of flame retardants to be added to the coating compound, as is the case with nylon fabrics. In addition, "Kevlar" retains a high percentage of room temperature properties when tested at 355° F (180° C), whereas nylon fabrics retain less than 10 percent of room temperature properties at 300° F and melt at 320° - 340° F. At 500° F, "Kevlar" still retains approximately 50 percent of room temperature properties; its strength gradually decreases from this value until at 800° F it retains 0 degrees of room temperature strength.

With the knowledge that several parachute systems, presently in service, utilize canopies and risers of "Kevlar," American Safety built a slide, to their approved drawings for the 737 forward door slide, using neoprene-coated "Kevlar" fabric. Simulated aircraft evacuation by 200 evacuees was performed on this slide and it was packaged and deployed 40 times.

During the packing/deployment cycles, the packaged slide was externally loaded by randomly being weighted with 150 pounds of sandbags, or being vacuum packed. During these external loadings, the slide was randomly exposed to ambient temperature conditions of either 160° F, test site ambient temperature or minus 40° F for 24-hour periods. After each 24-hour period, the slide was inflated at atmospheric temperature within 5 minutes of removal from the temperature chamber. After the twentieth and fortieth deployment, the slide was proof-tested at a minimum of three times the operating pressure.

The "Kevlar" slide passed this test program.

Being aware of FAA interest in flammability and toxicity of burning materials, and in anticipation of more stringent requirements for flammability and toxicity in the near future, samples of neoprene-coated nylon air-holding fabrics, neoprene-coated dacron sliding-surface fabrics, poly-urethane-coated nylon air-holding fabrics, neoprene-coated "Kevlar" air-holding fabrics, and neoprene-coated "Kevlar" sliding-surface fabrics (used in the fabrication of evacuation slides) were submitted to FAA CAMI Oklahoma City for toxicity testing, and to FAA NAFEC Atlantic City for radiant heat flux testing. A copy of the toxicity testing report letter, dated February 21, 1979, is included with this talk as Attachment 1, Exhibit B.

Testing performed by NAFEC on the above samples and on the Kevlar 737 slide will be presented in a separate talk.

The demonstrated higher strength, lower weight and bulk, less toxicity, and greater resistance to heat flux of neoprene-coated "Kevlar" fabrics, when compared to various coated nylon fabrics, makes it an excellent candidate for the coated fabric for use on evacuation equipment.

A table listing typical values for coated "state-of-the-art" fabric properties vs. coated "Kevlar" fabric properties is shown in this section.

Comparison of these proterties shows that the "Kevlar" fabrics are lighter in weight, have less bulk, are more tear resistant, have a greater grab-strength and are more flame resistant than the "state-of-the-art" fabrics.

When the 1-inch strip method tensile test values are compared, it is seen that the "Kevlar" fabrics are approximately twice as strong as the "state-of-the-art" fabrics when this method is employed. Although the grab method does not show as great an advantage of "Kevlar" fabrics over "state-of-the-art" fabrics, the 1-inch strip method more accurately reflects the relative strengths of the fabrics tested. This is due to the fact that since "Kevlar" fabrics do not stretch appreciably, when the grab method test is used, the load on the "Kevlar" fabric is applied only to the cords located directly in the machine chuck. When this same method is used on nylon and dacron fabrics, the load is spread out over the entire width of the sample being tested; thus the cords adjacent to the cords located directly within the machine take a portion of the load.

Although the tear strength values are only slightly in favor of "Kevlar," the manner in which a tear propagates is far less catastrophic with "Kevlar" than with "state-of-the-art" fabric. The low elongation in "Kevlar" produces a tear in which one thread at a time fails; if the load drops below this value, the tear stops propagating. With "state-of-the-art" fabrics, their higher elongation characteristics spread the load over many threads and, when a tear starts, the threads adjacent to the start of the tear cannot withstand the remaining load and the tear propagates catastrophically.

The differences in flame extinguishing times and char lengths show far greater superiority in the "Kevlar" fabrics over the "state-of-the-art" fabrics.

TABLE I.

	AIR-HOLDING FABRIC		SLIDING SURFACE FABRIC	
	NYLON	KEVLAR	NYLON	KEVLAR
TENSILE STRENGTH (LB/IN)				
GRAB METHOD (WARP X FILL)	260 x 240	290 x 290	240 x 240	480 x 480
1- INCH STRIP METHOD (WARP X FILL)	180 x 160	290 x 290	190 x 190	480 x 480
TRAPEZOIDAL TEAR (LB/IN) (WARP X FILL)	16 x 15	18 x 18	20 x 19	35 x 33
WEIGHT (OZ/YD^2)	8.2 ± 0.5	7.0 ± 0.4	7.5 ± 0.5	6.5 ± 0.5
THICKNESS (INCHES)	0.012	0.011	0.015	0.011
VERTICAL FLAME TEST				
SELF EXTINGUISHING TIME (SECONDS)	10.0	0	12.0	0
CHAR LENGTH (INCHES)	6.0	1.0	6.5	1.0

SLIDING ANGLES

A review of potential sliding angles revealed that the optimum line-of-sight sliding angle for normal sill heights is approximately 36 degrees. For other than normal sill heights, the line-of-sight angle increases or decreases as the sill height increases or decreases, respectively.

As the line-of-sight sliding angle increases beyond approximately 45 degrees, the speed of sliding increases fairly rapidly. At approximately 48 degrees, evacuees have a tendency to hesitate before entering the slide due to its steep appearance.

As the line-of-sight sliding angle decreases below approximately 31 degrees, the speed of sliding decreases until, at approximately 28 degrees, evacuees may have to assist their descent by pushing with their arms and legs. As the line of sight sliding angle decreases below approximately 22 degrees, evacuees using the slide can run off it in the manner of a ramp.

Each particular evacuation slide must be tailored to meet a compromise set of usable line-of-sight sliding angles, based on the expected variation of sill heights for its related aircraft door.

INSTALLATION REVIEW

The first inflatable slide designs separated the gas storage system from the inflatable slide; both items were stored near, but not on, the aircraft door. During an emergency evacuation situation, the aircraft door was opened, and the slide was removed from its storage compartment, installed in the girt attaching fittings, manually deployed and, finally, the inflation cycle was manually activated. The elapsed time from the start of door opening until the slide was inflated in an operational position ranged between 15 and 25 seconds. To permit separation of the slide from its inflation gas storage system, a quick disconnect was installed in the hose assembly which connected the gas storage system to the inflatable slide.

Experience with this type of installation revealed that the time required for first occupancy was too long. In addition, the quick disconnect in the hose assembly caused many problems, such as: improper assembly, inadvertent disassembly of the quick disconnect during handling/installation in emergency operation, and failure of the quick disconnect during use.

To reduce readiness time and improve the reliability of the entire slide system, the inflation gas storage system was mounted directly on the inflatable slide, the quick disconnect in the hose assembly was eliminated and the slide assembly was mounted to the interior of the door. The container holding the packaged slide assembly acted as the structural attachment to the door. The girt bar was manually installed and removed from the floor fittings for each normal (non-emergency) door opening. During emergency use, opening the door released the container latch which permitted the slide to be extracted from the container. As the door was fully opened, the slide fell into position outside the aircraft. The inflation cycle was then manually activated.

These modifications shortened the elapsed time (from the start of door opening until the slide was in operational position) to a nominal 15-second time interval. Readiness time was further reduced to approximately 10 seconds by rigging the inflation cycle activation cable to automatically activate as the slide package fell free of the container and below the door sill.

Several additional modifications have been incorporated into the latest door mounted installation such as:

1. Automatic engagement/disengagement of the girt bar as the door is opened and closed during non-emergency use. An emergency operation handle/switch is then activated for emergency conditions requiring use of the slide system.

2. Use of a decorative container (no structural load capability) in conjunction with a backboard (to which the slide assembly is mounted). The backboard takes the structural loads and contains provisions for door mounting.

In use, as the door is opened, either the contained cover releases from the door mounting or the slide assembly releases from a retained backboard. In either instance, the slide falls free of the container and, when it has fallen below the door sill, the inflation cycle is automatically activated as the slide continues to fall.

These latest modifications have little or no effect on readiness time but do reduce the possibility of human error in attaching the girt bar to the floor fittings and also reduce malfunctions due to damage to the hard container.

GALE BRADEN

Air Safety Investigator - Human Factor Specialist, NTSB Crash Injury Investigator, FAA-CAMI - 10 years other general investigative work - 14 years investigated Continental DC-10 in Los Angeles which brought about the purpose of this seminar. (Document not available.)

REGULATORY REQUIREMENTS (FAR)
FOR EMERGENCY EVACUATION SLIDES

HENRI BRANTING

Aerospace Engineer, Office of Airworthiness, FAA Headquarters - 18 years involved in writing regulatory rules for aircraft crashworthiness and fire protection. B.S. - C.E. Virginia Polytechnic Institute.

REGULATORY REQUIREMENTS (FAR) FOR EMERGENCY EVACUATION SLIDES

I would like to discuss briefly, emergency evacuation slides from the standpoint of rules and FAA's rulemaking process: what led up to the rules which are in effect today; what the next likely rulemaking will be; and how you, the interested public can take part in it. Following this, I will be glad to answer any questions or hear whatever comments you may have.

TSO C-69 is the technical standard order for emergency evacuation slides. It was issued originally in 1961. C-69 spells out the requirements which a manufacturer must meet to produce a slide, in effect, as a packaged off-the-shelf piece of equipment. It covers detail design, materials, functioning, and performance.

As issued, the TSO was used originally in conjunction with CAR 4b, the civil air regulations, which contained the airworthiness standards for transport category airplanes. CAR 4b later became Federal Aviation Regulations Part 25. Taken together, TSO C-69 and Part 25, contain the airworthiness requirements which must be met for producing a slide and installing it on a particular airplane.

These rules, for some time, have required that emergency exits more than 6 feet above the ground be equipped with slides, and 15 years ago this did not necessarily mean inflatable self-supporting slides. C-69, incidentally, still keeps the requirements for the old noninflatable hand-held slides, as well as the requirements for inflatable slides. The TSO is being completely revised and will be discussed later in the symposium.

The basic rule on the books today, which requires that an airplane be equipped with inflatable self-supporting slides was first incorporated into FAR, section 25.809 by Amendment 25-15 in 1967. This 1967 rule required that except for overwing exits, all passenger exits more than 6 feet above ground be equipped with a self-supporting slide which is automatically deployed and erected within 10 seconds after the exit is opened. Slides at passenger entry doors and service doors which serve as exits were required to be automatically deployed, but inflation could be activated by some other means, such as by a lanyard.

This rule, by virtue of Part 25, applied only to a limited number of airplanes; the Boeing 737 and stretch versions of older models such as the 200 series of the 727 and the 50 series of the DC-9. However, Part 121 which contains the air carrier operating regulations, also was amended upon adoption of this rule and extended these slide requirements to the United States (U.S.) airline fleet as a whole on a retroactive basis. As a result, except for airplanes such as the wide bodies which were certificated to more recent and more rigid standards, these 1967 requirements are the baseline for escape slides in the U.S. fleet.

In 1972, Amendment 25-32 revised the 1967 standard essentially by deleting the exception which had been granted passenger entry doors and service doors, and requiring that all floor level exits have fully automatic slides. It also required that these passenger and service doors be equipped with a means of disarming the slide when the doors are used in non-emergency conditions. The wide body transports were designed to these 1972 requirements.

The requirements for usability in 25-knot winds and for functional and reliability testing were added in 1978 with Amendment 25-46 under the Airworthiness Review Program.

Amendment 25-47, issued under the Operations Review Program in 1979, in effect, clarified the intent of the basic rule by stating that the slide must be of such length that it can be used safely after any one or more of the landing gears has collapsed.

In summary, Part 25 today requires that, except for overwing exits, each floor level passenger exit, more than 6 feet aboveground must be equipped with a fully automatic slide which is erected within 10 seconds after deployment is begun. Passenger entry and service doors must have a slide disarming means. The slide must be self-supporting and safely usable with gear legs collapsed; usable in 25-knot winds with the assistance of only one person; and subjected to specified functional and reliability testing.

The next rulemaking slated for evacuation slides is the development of standards for radiant heat resistance, to improve protection against fuel fires. This was recommended recently by the SAFER Committee, and is being given a priority treatment. Research and development on heat resistance has progressed well over the past 2 years and will be discussed in detail later in the symposium.

The rulemaking process is set up to give the interested public an opportunity to participate and have a say in the development of regulations. For the case at hand, this is, in effect, the procedure through which the results of the R&D will be translated into an industry standard.

From a technical standpoint, we are in a good position to proceed with rulemaking on heat resistant slides. The basic safety benefits have been confirmed by full-scale tests, a small-scale test has been developed for materials selection and qualification, and suitable materials have been found for slide construction. A notice of proposed rulemaking, or NPRM, will be issued in early 1981.

The NPRM on slides most likely will propose that the small-scale radiant heat test discussed here today be established as a standard, and that materials used in the construction of slides be required to meet certain limits when tested by that test.

Based on the information available to date, heat resistant slides appear to be a safety improvement which should be implemented as soon as practicable for the airline fleet. Insofar as applicability is concerned, the NPRM will probably propose that the new requirements become effective for airplanes for which a new application for type certificate is made, and, after a reasonable grace period, airplanes currently in production and airplanes which are already in service. This likely would involve changes in Part 25, Part 121, and the evacuation slide TSO.

When the FAA initiates rulemaking, a docket is established and the NPRM is published in the Federal Register which invites the general public to comment and express views. The docket is the rulemaking file and is open for public inspection at FAA headquarters in Washington. The NPRM states the proposed rule, word for word, and gives the background and reasoning behind the proposal.

Rule proposals often prompt a wide response from the public. Parties responding to NPRM's typically include private individuals, manufacturers, aircraft operators, consumer groups, trade unions, trade associations, foreign industries and governments, and many others. All of these comments go into the public docket, and they contain a wealth of information for anyone who is interested.

While we believe we are in a good overall position for rulemaking, there are a couple of technical areas in which your comments will be particularly welcome. One of the areas concerns the establishment of the grace period for production airplanes and in-service airplanes. It would be well if this period could fit in reasonably with the lead times for manufacturers and the maintenance schedules of the operators, in order to minimize the economic impact. The other area concerns defining a process specification or some other simple and practical means for demonstrating compliance for in-service slides which may not readily offer material samples for testing.

This is a brief outline of standards for evacuation slides from a regulatory standpoint. The development work on which rulemaking is to be based will be the subject of presentations later in the symposium.

Does anyone have any questions or comments on rulemaking?

FAR 25.809

FOR EXITS 6 FEET ABOVEGROUND (EXCEPT OVERWING)

APPROVED SLIDE (TSO OR EQUIVALENT)

AUTOMATICALLY DEPLOYED AND ERECTED WITHIN 10 SECONDS

DISARMING MEANS FOR SLIDES AT ENTRY AND SERVICE DOORS

SELF-SUPPORTING ON GROUND AFTER GEAR COLLAPSE

SAFELY USABLE LENGTH

USABLE IN 25-KNOT WINDS WITH ASSISTANCE OF ONE PERSON

FUNCTIONAL AND RELIABILITY TESTED

NPRM

RADIANT HEAT TEST FOR MATERIALS SAMPLES

ACCEPTANCE LIMITS

APPLICABLE TO

NEW APPLICATION FOR TYPE CERTIFICATE

AIRPLANES IN PRODUCTION

AIRPLANES IN-SERVICE

PROPOSED EMERGENCY EVACUATION SLIDE AND SLIDE/RAFT PERFORMANCE STANDARDS (TSO)

RICHARD JOHNSON

Aerospace Engineer, Crashworthiness Branch, FAA-TC recently transferred from Office of Airworthiness, FAA Headquarters. 12 years experience with FAA. 10 years experience with Boeing and Pratt Whitney. B.S. Aero Engr. - Purdue University.

PROPOSED EMERGENCY EVACUATION SLIDE AND SLIDE/RAFT PERFORMANCE STANDARDS

BY DICK JOHNSON,
FEDERAL AVIATION ADMINISTRATION

INTRODUCTION.

I plan to briefly discuss two areas that should be of interest to most of you. These areas concern new TSO procedural changes that the FAA recently adopted, and of course new proposed TSO performance standards for slides and slide/rafts. By the way, any comments you may have at this time, I'll be happy to answer at tomorrow's open session.

TSO PROCEDURES (SLIDE #1).

As it relates to slide and slide/raft devices and all other products under the TSO system, I want to make sure that everyone is aware of new TSO procedural changes that we adopted in June and which became effective in September of this year. Amendment 21-50 covers these changes which essentially relocates the technical order system under Part 37 to Part 21 of the FAR's and accordingly accomplishes several things. First, it takes the TSO standard out of the regulatory area and administratively, allows for a rapid issue of new as well as upgraded revisions. Revisions to a TSO standard will no longer have to be issued under a notice of proposed rule making procedure. Instead, rulemaking steps will be eliminated entirely, and the total processing of standard from the initial recommendation to final issue will be handled by one office. I think the most important aspect is that the TSO procedural change will more effectively allow the use of voluntary industry standards such as the 8000 series specifications currently developed by the SAE committees. The new procedures covering the development and issue of TSO's are covered under Advisory Circular 20-110. As provided under this circular, the FAA will issue annually an index of current TSO standards including a list of proposed standards that are to be issued within the succeeding 12 months. When the proposed standards are ready for publication, a notification will appear in the Federal Register and the proposals will be sent through a TSO mailing list to all interested parties in which case a period of 90 days will be allowed for comments. Upon the receipt and review of such comments, the FAA will draft and reissue the final standards. This brings us up to the development of new proposed slide TSO will be promulagated in accordance with these procedures.

MILESTONES (SLIDE #2).

Here's where we stand on the proposed slide standards. First, recognizing the obsolesence of the 1961 slide requirements under TSO-C69, we plan to issue a proposed revision later this year. Taking into account the provisions for slide/rafts developed in 1971, the proposal will also include requirements for combination devices. A proposed draft will be issued for comments late this year, and in early 1981 (not to exceed June), we expect to publish the final standard under TSO-C69, Revision A.

PROPOSED STANDARDS (SLIDE #3, #4).

The proposed TSO requirements we intend to issue this year should be somewhat familiar to many of you, since they reflect many of the performance provisions that have been applied to the approval of slide devices on the current wide-body airplanes. The standard will contain two sections relating to slide requirements, Part I, and raft mode requirements, Part II. These are some of the highlighted areas, starting with a demonstrated slide strength requirement of one evacuee per second per row which is intended to show the non-collapse capability of slide when positioned at its critical angle. While not identified here, there will also be related sections covering penetration of the sliding surface and slide durability. With respect to flammability the FAA is proposing an upgraded 8 inch per minute verticle burn test which will be appropriate to current flammability requirements established for interior cabin materials. I'd like to point out that from a fire standpoint the FAA is looking at improved fire protective coatings that will be discussed later today and which could result in a further upgrading under future revisions of the TSO. The evacuation rate requirement interfaces with the 90 second rule and is based up acceptable emergency demonstration rates on a single lane slide. The 10 second inflation time, reflects the airworthiness FAR 25.809. As slides have grown in size the effect of wind on deployment, as supported by in service evacuation incidents has been found to be significant. A 25 knot wind is not uncommon, and as applied redently to new transport designs under FAR 25, a demonstrated wind requirement has been proposed in the TSO. The last item concerns the ability of the slide to deploy each and every tune it's called upon. Five consecutive deployment and inflation tests will be required to demonstrate the overall reliability of slide. Part II of the Proposed standard covers the raft portion of the combination slide/raft device. Here are some of the general requirements. There will be no limit to the overall slide/raft occupancy except from a portability standpoint, it must be transportable by not more than 2 people and of course be seaworthy. The rated area per occupant as defined under capacity will reflect the present life raft requirements of 3.6 ft^2/person. In addition, an optional rated area of 3.09 ft^2/person based on a defined trapezoid space or on a demonstration will be allowed. An 8 inch back support height and 14.7 inch width will be required under these optional ratings. The bouyancy and freeboard requirement will be simplified providing for two tubes capable of supporting the rated capacity with a 12-inch freeboard and one tube capable of supporting the same capacity with a 6-inch freeboard. A measurable freeboard will also be required under conditions of overload with one tube deflated. As previously mentioned, not more than two persons must be shown to carry the device for use at other exit locations. And again, an inflation time of 10 seconds commensurate with the slide mode will apply. Unlike current life raft requirements, a single inflation source, appropriate to the slide, will be allowed. Sea anchor and mooring line strength will be increased over the existing life raft requirements to 1,000 pounds or 40 pounds per person. Functional water tests will include a demonstration of rated and overload capacities. Under open sea conditions (27-knot winds and 10-foot waves), they will also include a demonstration of canopy, equipment, raft stability and boarding from a simulated aircraft sill installation.

TSO REVISION PROGRAM

AMENDMENT 21–50, JUNE 2, 1980

- RELOCATES FAR 37 UNDER FAR 21
- EXPEDITES TSO ISSUE
- ALLOWS USE OF INDUSTRY STANDARDS

ADVISORY CIRCULAR 20–110, JUNE 2, 1980

- PRESENTS INDEX OF EXISTING TSO'S
- PROVIDES LIST OF PROPOSED TSO'S
- CONTAINS PROCEDURE FOR PUBLIC PARTICIPATION

PROPOSED SLIDE STANDARD

- 1961 – ISSUED SLIDE STANDARD TSO-C69
- 1971 – DEVELOPED GUIDANCE FOR SLIDE/RAFT APPROVAL
- 1980 – PROPOSED SLIDE AND SLIDE/RAFT STANDARDS
- 1981 – ADOPT NEW STANDARDS TSO-C69A

PROPOSED SLIDE STANDARD

SLIDES PART I

REQT'S	PROPOSED	EXISTING
• STRENGTH	1 PERSON/SEC/WAVE	3 PERSONS
• FLAMMABILITY	8 IN. VERT. TEST	4 IN. HOR. TEST
• EVACUATION	60 PERSONS/MIN.	30 PERSONS/MIN.
• INFLATION	10 SEC.	25 SEC.
• WIND	25 KNOTS	______
• RELIABILITY	5 DEPLOYMENTS	______

PROPOSED SLIDE STANDARD

RAFT MODE PART II

REQT'S	PROPOSED	EXISTING
• CAPACITY	3.6 FT^2/PERSON	3.6 FT^2/PERSON
	3.0 FT^2/PERSON	———
• FREEBOARD	12 IN. (2 TUBES)	12 IN. (2 TUBES)
	6 IN. (1 TUBE)	———
• PORTABILITY	2 PERSONS	———
• INFLATION	10 SEC.	60 SEC.
• MOORING LINE	1000 LBS.	500 LBS.
	40 LBS./PERSON	———
• SEA PERFORMANCE	27 KNT. WINDS	———
	10 FT. WAVES	———

A DISCUSSION OF INFLATION AUGMENTATION

ROBERT GRAHAM

Director of Marketing and Sales, Tech Development, Dayton, Ohio. 4 years experience in Marketing Inflation Systems and Highspeed Turbine Machinery. B.S. Aero Engr., Drexel University M.B.A. Marketing - Drexel University.

A DISCUSSION OF INFLATION AUGMENTATION DEVICES

BY ROBERT G. GRAHAM,
DIRECTOR OF MARKETING & SALES

TECH DEVELOPMENT, INC., DAYTON, OHIO

The purpose of this paper is to discuss some of the aspects of inflation augmentation devices which are used on current aircraft emergency evacuation slides. In particular, it will cover the inflation augmentors used to inflate the escape slides of the Boeing-747. These are compressed airdriven turbofans manufactured by Tech Development, Inc., (TDE) of Dayton, Ohio.

As a way of introduction, TDI, is a diversified manufacturer of turbomachinery and pneumatic equipment used in aeronautical research, air transportation, energy production and conservation, defense, and industrial OEM. TDI's current products include propulsion simulations for wind tunnel research of new aircraft configurations; turbofans, as just mentioned for inflation of aircraft emergency escape slides; turbine-driven air motors for OEM industrial drives; pneumatic starters for large industrial diesel and stationery gas turbines; turbomachinery research and development for energy production; and aerospace and defense applications.

TDI has recently moved into a new 50,000-square-foot facility located in Dayton, Ohio. All functions are at this one facility, which includes engineering, administration, manufacturing, and test. The test facilities at TDI are designed to handle a wide variety of pneumatic devices including turbomachinery, aspirators, and ejectors. Two compressors are available, plus suitable storage tanks, to generate a large supply of 3,000 psig air for use in experimental and production testing. TDI has one of the few test facilities in the United States U.S. capable of testing and generating a performance map of inflation turbofans and aspirators against varying back pressure.

One of the company's principal product lines are items called propulsion simulators. These are used in the wind tunnel testing of scale model aircraft to duplicate the same pressure, thrust and flow effects on the model aircraft as an actual engine would on the full-size airframe. These devices come in two principal categories; ejector-type devices similar to inflation aspirators and rotating devices somewhat similar to the B-747 inflation escape slide turbofan. Because of TDI's extensive experience with propulsion simulators, there was a technology base which could be drawn upon to develop the compressed air-driven turbofan for the B-747 slides.

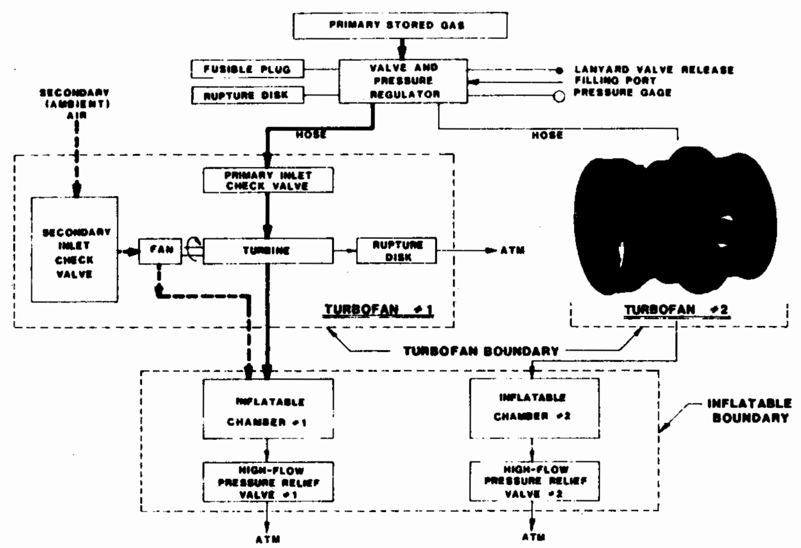
The TDI inflation turbofan for the B-747 escape slides, which are built by the B.F. Goodrich Company of Akron, Ohio, have been in production since 1974. Since that time, over 8,000 inflation turbofans have been manufactured by TDI. A typical B-747 utilizes from 16 to 23 of these turbofans in a complete shipset of slides; the number varies according to the configuration of the B-747 purchased by the airline customer and the number and types of slides on the individual aircraft. TDI designates its turbofan the "Model 840." There are two versions of this turbofan at present. One is the Model 840A, which has a closure plate over its inlet and which is used in the raft version of the escape slides. The other is the Model 840B, which has only an upstream flapper valve in the inlet and is used on all normal slide only configurations.

Figure 1 is a schematic of a typical inflation subsystem utilizing either the 840A or 840B turbofans. In Figure 1, the turbofan is placed in the inflation subsystem very similarly to an aspirator. It is driven by high-pressure compressed air at pressures of

Figure 1

TDI MODEL 840 INFLATION TURBOFAN

- TYPICAL ARRANGEMENT OF TURBOFAN INFLATION SYSTEM FOR A DUAL CHAMBERED SLIDE



INFLATION SYSTEM SCHEMATIC DIAGRAM

300 to 400 psig supplied by a pressure regulator, which reduces the 3,000+ psig of the stored gas vessel. The compressed air is fed into a plenum in the turbofan outer housing. This supplies a nozzle ring wherein the pressurized air is reduced to essentially atmospheric pressure at the nozzle discharge, but thereby creating a high-velocity airflow. This high-velocity airflow is directed onto the turbine blades, which are mounted on a ring around the tips of the fan blades. This high-velocity air imparts an impulse to the turbine blades, turning the wheel at speeds up to 30,000 rpm. The fan, which is rigidly attached to the turbine ring surrounding it, pumps air from the surrounding atmosphere and forces this air into the inflatable through the fans' exhaust nozzles. The expended high-velocity driven air is also dumped into the inflatable through the fans' exhaust nozzle.

Figure 2 gives a summary of the turbofan's performance and of the dimensions of this device.

Figure 2

TDI MODEL 840 INFLATION TURBOFAN

- PERFORMANCE

  Drive (Primary) Airflow Required

  Pressure - 350 psig
  Flow - 0.9 lbs./sec.,(705 scfm)

  Induced (Secondary) Airflow

  Flow - 4.8 lbs./sec.,(3763 scfm) at zero backpressure
  Fan Speed - 34,000 rpm
  Augmentation Ratio - 5.3 to 1

- SIZE

  Inlet Diameter - 7.5 inches
  Length - 8.5 inches
  Weight - 5.8 lbs. (Model 840B)
  7.6 Lbs. (Model 840A)

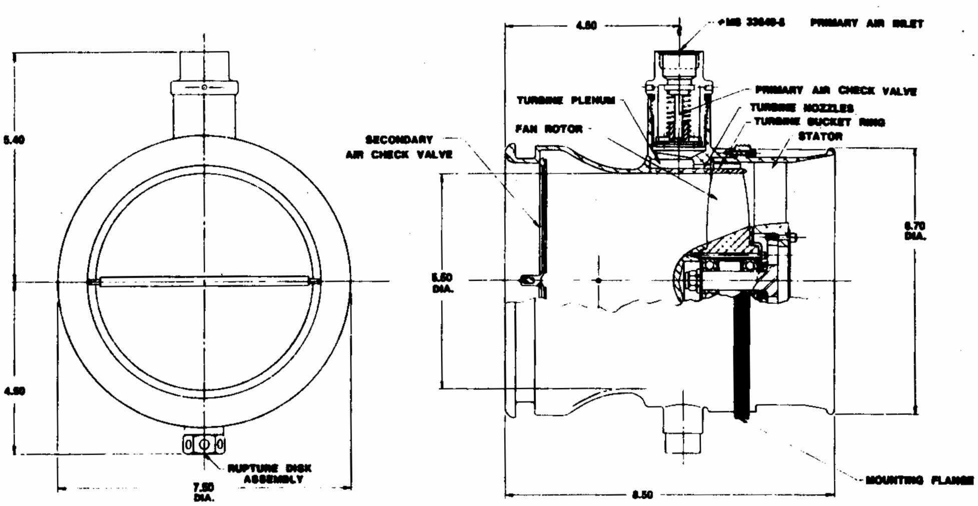
Figure 3 shows the overall configuration of a Model 840B fan and the components just discussed above. The secondary air check valve, which is commonly called the "flapper" valve, upstream of the turbofan is called out in figure 3. Near the end of the inflation cycle, the compressed air supply is nearly expended, which results in the fan slowing down. Also, at the same instant, the back pressure within the inflated slide is rapidly rising, creating a greater pumping workload on the fan. At the end of the cycle, the back pressure has risen great enough and the fan has slowed down in speed a sufficient amount, that the back pressure forces the secondary air check, or flapper valve, to close, sealing the compressed air within the inflatable. This whole process, from the start of the inflation cycle to the closing of the flapper valve, occurs in less than 6 seconds.

Questions are sometimes asked regarding the containment of the high-speed rotating elements within the turbofan and of the inherent safety of a turbofan. The turbofan has two built-in safety features. The first is the high strength walls within the turbofan itself, these alone would prevent any parts of the rotating elements from piercing the wall of the turbofan and damaging or injuring anything in the immediate proximity of the fan. Secondly, should a failure occur, it would most likely be generated by an overspeeding turbine. The turbine bucket ring surrounding the fan blades will fail in such a manner that the bucket ring acts as if it were a pair of brake shoes, expanding and rubbing the walls of the turbofan. This immediately brings the entire rotating assembly to a full stop. The best proof if the record of use of these units. In addition to the production testing of each and every turbofan by TDI, there have been thousands of operational cycles performed with the fans in use by the airlines of the

Figure 3

TDI MODEL 840 "B" INFLATION TURBOFAN

- INTERNAL COMPONENTS & INSTALLATION FEATURES



world. In all these thousands of operational cycles, there has never been one single reported failure of the turbofan subassembly. In fact, the only failure that TDI has been able to achieve has been in laboratory testing, the sole purpose of which was to drive to destruction. Even in these cases, it was difficult to achieve failure.

Up to this point, this paper has only discussed turbofans which are used as inflation augmenting devices. The second, and probably the most numerous device used as an augmentor, is an aspirator. Aspirators are being utilized on evacuation slides on aircraft as small as a Falcon Fanjet to aircraft as large as a DC-10 or L-1011. Aspirators are a cost-effective way of achieving augmentation, however, they do require larger packing volumes and are slightly less efficient than turbofans. The design technology of aspirators is fairly well understood and these are manufactured by several concerns. Two of the newest aircraft, which will be using aspirator-augmented inflation cycles, are the Boeing 757 and 767 aircraft. One new requirement, which is being demanded of aspirators recently, has been a positive closure capability for nonraft versions of the evacuation slides. Figure 4 illustrates the characteristics of aspirators designed to meet requirements such as the B-757 and B-767 applications.

The aspirators were designed by TDI to be fabricated of a fiberglass reinforced polycarbonate plastic. This particular concept incorporates a novel design for achieving full circumferential positive closure to prevent the intrusion of sea water into the aspirator after the inflation cycle.

The internal configuration of this aspirator concept is shown in figures 5 and 6. Figure 6 shows the three operating conditions of the aspirator. Condition A in figure 6 shows the aspirator at rest; the piston, item 2, is fully forward, pressing against the entire circumference of the flapper valve, item 4, which seats against a lip, item 3, inside the inlet of the aspirator. The piston is held forward by a steel spring, item 5, which has been sized to load the piston and resist the pressure found at a depth of 10 feet of water acting against the flapper valve, item 4. At the start of the inflation cycle, high-pressure air is emitted through the check valve, item 1, and enters the plenum chamber, item 8. Immediately, the high-pressure air drives the piston rearward as shown in condition B. This compresses the spring, places the spray nozzles, which are part of the piston, in a proper axial position, to emit high-pressure air into the interior of the aspirator. Once the piston translates to the rear, the flapper check valve is unloaded and opens, as shown in condition B. This allows outside air to flow into the aspirator, this flow being induced by the interaction of the high-pressure air spraying from the array of spray nozzles inside the aspirator. At a point approximately 1 1/2 seconds into the inflation cycle, the back pressure in the inflatable has built to a level (1 to 2 psig) which forces the flapper valve, item 4, to close and seat itself against the lip inside the inlet, creating condition C. There is still sufficient high-pressure air coming into the supply plenum from the pressure regulator to maintain a differential pressure on the piston, forcing it to remain fully retracted. A consequence of this mode is that the high-pressure driven air is still spraying into the aspirator and tops off the amount of air within the inflatable. At a point where the regulated air pressure drops to approximately 30 psig, the air pressure acting on the piston can no longer resist the spring force and the piston moves forward, again locking the check valve, item 4, preventing it from opening. This is again condition A.

The above explanation of a positive closure aspirator is just one of many concepts being utilized to achieve positive closure within an aspirating device. Other manufacturers achieve positive closure by other methods.

Figure 7 is a comparison of inflation augmentors, specifically fans versus aspirators. Each escape slide application for an inflation augmentor has to be separately examined in order to determine which is the optimum device to use; a fan or an aspirator. The key items are cost, packing volume, weight, and, efficiency. These elements can be traded off, one against the other, for a specific application to determine the best device to utilize.

Figure 4

FIBERGLASS REINFORCED PLASTIC ASPIRATOR DESIGN FEATURES

	Model 1380	Model 1380 Upscaled
APPLICATION & PERFORMANCE		
Aircraft	B757	B767
Slide Size	200 ft^3	250 ft^3
Time to Inflate to 2 psig (2 aspirators)	3 sec.	2 sec.
Bottle Size Required at 3000 psig	700 in^3	900 in^3
Backpressure at zero secondary flow	3 psig	3 psig
ASPIRATOR CHARACTERISTICS		
Maximum Diameter	5.44 in.	7.50 in.
Length Over All	10.57 in.	14.50 in.
Weight Estimation	3.1 lbs.	5.9 lbs.

Figure 5

TDI POSITIVE CLOSURE ASPIRATOR CONCEPT

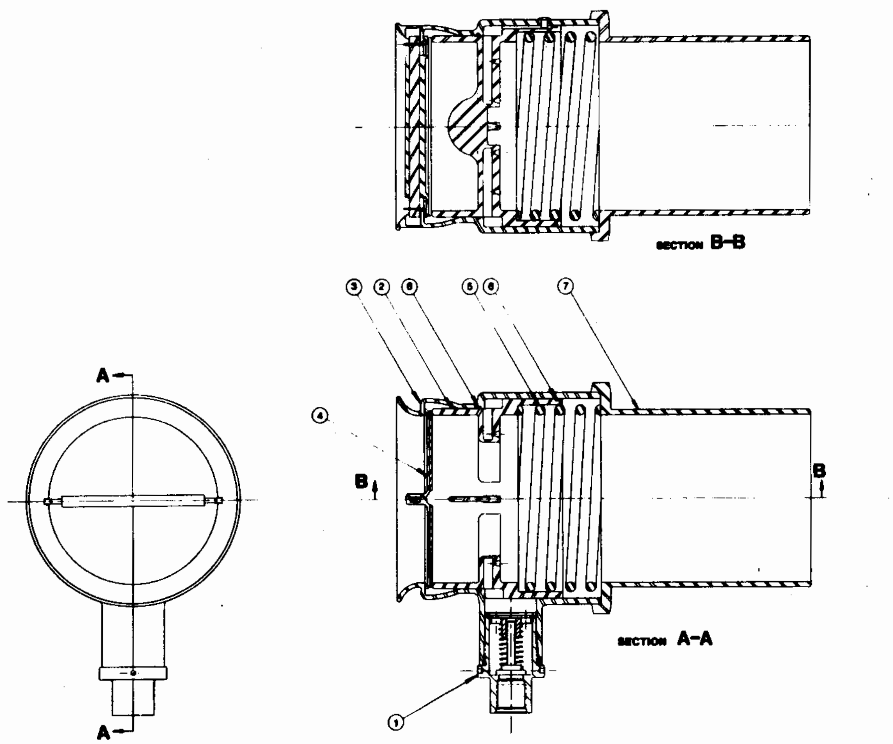


Figure 6

POSITIVE CLOSURE ASPIRATOR OPERATING SEQUENCE

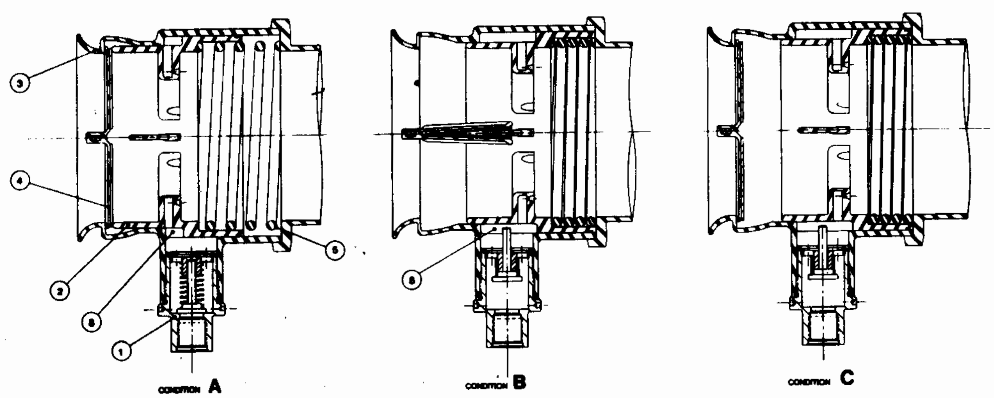


Figure 7

COMPARISON OF INFLATION AUGMENTORS

FANS vs. ASPIRATORS

FANS	ASPIRATORS
COMPACT - used where packing volume is critical	SIZE - approximately twice as large as fan for same pumping capacity
EFFICIENT - have greater augmentation ratio, therefore require smaller compressed air bottle	COST - less expensive than a fan of comparable capacity
STURDY - greater case strength and internal structure to resist packing deformation	WEIGHT - slightly lighter than a fan of comparable capacity
	EFFICIENCY - slightly less efficient than a fan of comparable capacity

SUMMARY: The requirements of each individual application will decide the suitability of using either a fan or an aspirator.

747 SLIDE DEVELOPMENT AND SERVICE EXPERIENCE

BENJAMIN WERNER

Project Engineer, 747 Freighter Mechanical and Emergency Systems, Boeing Aircraft Co. 40 years service with Boeing Co. Involved in evacuation slide work since 1967. B.S. Civil Engr. University of Wisconsin, Registered Professional Engineer.

747 SLIDE DEVELOPMENT AND SERVICE EXPERIENCE

The 747 evacuation system development began back in 1966 and it was a big step up from previous evacuation slide systems. Among the initial design decisions were that the main entry doors were to be "double wide" (type A, at least 42 inches) to accommodate two exiting passengers at a time, and that the door would be opened in an emergency by a power assist system. The initial evacuation system itself consisted of inflatable escape slides mounted in each main entry door, in the No. 3 (overwing) door, and at the upper deck door.

By the way, the first development slide we tested came from PICO. The original system, delivered in 1970, utilized a cool gas inflation system which was a pioneering development and represented the first application of modern solid propellant technology aboard passenger aircraft. At the time this new concept was selected, the system was by far the lightest and most compact, capable of inflating the 350- to 450-cubic-foot 747 escape slides.

The 747 is unique among wide-body transports in having an upper deck available for passenger use, and an entirely different slide system is used there. It is a single lane slide and on early airplanes the cool gas inflation system and slide are mounted on a pallet on tracks. The pallet is locked in front of the upper deck door after the door has been closed prior to takeoff. In emergency use, the door is opened manually, the slide/chute assembly is manually rotated through the door opening, and the slide is then automatically inflated.

Now I would like to refer to some statistics. Chart 1 — As of now the 747 evacuation system at Boeing has been subjected to almost 11,000 deployment/inflation cycles conducted during development, integration, verification, and certification of slides and slide rafts. Included are several hundred tests of the slide rafts in the water environment for verification and deployment and inflation acceptability under simulated ditching conditions. Also included here were some very early tests in 1967 of Shenandoah Pacific deployable stairway and a Goodyear inflatable ramp stair tube.

Other elements of the 747 evacuation system, consisting of emergency lighting provisions, aisles, cross-aisles, exit approachways, and exits were tested in conjunction with the escape devices on the 747 to determine total timing and system performance.

Chart 2 — Evacuation testing involving live test subjects, to date, has included participation of over 40,000 people.

The charts I have just shown you cover evacuation system testing, including slide/rafts.

As other wide-body aircraft were developed, combination escape slide/rafts became available. These appeared to offer an opportunity for substantial airplane weight saving, without comromise of either evacuation slide or liferaft capability. Following a design competition and a qualification program involving both land evacuation and seaborne life raft tests, slide/rafts were committed to production 747's to be delivered after approximately mid-1975, and to all 747SP's. Since that time, all 747 main entry doors (1, 2, 4, and 5) and 747SP doors 1, 2, 3, and 4 have been equipped with combination escape slide/rafts. The slide/rafts are automatically deployed in the same manner as the earlier escape slides. The eight slide/rafts provide adequate raft capacity for all but moderate to high density airplane configurations. For those airplanes, a small number of supplemental life rafts are installed.

The No. 3 door ramp and off-wing slide have been retained on the later 747 airplanes equipped with slide/rafts.

The slide/raft system differs from the escape slides in several respects. Slide/raft inflated volumes range from 318 to 382 cubic feet- considerably smaller than the escape slides. This made possible the consideration of the more straightforward stored gas inflation systems, using highly efficient turbofan type air pumps and composite gas storage bottles. A mixture of dry nitrogen and carbon dioxide is used as the stored gas, in order to maintain inflation efficiency at low system temperatures.

The slide/rafts average about 30 feet in overall length, and have a seating (or sliding) width of about 5.6 feet between the large upper floatation tubes. Demonstrated normal rated capacity as rafts varies from 36 to 48 passengers, and overload capacity from 47 to 62. They have been proven stable on the water at 50 to 100 percent of capacity in winds of 17 to 27 knots and waves from 5 to 8 feet in height.

Concurrent with the development of the stored gas inflation system and its incorporation with the slide/rafts in production airplanes, similar inflation systems were developed for the 747 off-wing slide and for the 747 and 747SP upper deck slides. Using the same turbofans and mixed stored gas as the slide/rafts, these systems developed a deployment and inflation capability of ambient temperatures as low as -40 percent F.

At about this time, a new upper deck slide, required to be reliably deployed in winds of 25 knots and used with a power deployment system was developed for airplanes with 24 or more upper deck passengers.

Now I will change to the subject of in-service and emergency evacuation statistics before I show you our most recent 747 slide developments of 1980. Chart III — The first 747 went into revenue service in January of 1970 and, to date, 35 emergency evacuations have taken place with a total of 6,248 persons evacuated. Of that total, 42 or 0.653 percent received serious injuries as defined by NTSB Regulation 430.2. To our knowledge, there are no fatalities as a result of evacuation in these 35 events.

I am pleased to state that for the past 3 1/2, years the four emergency evacuations that have occurred, had 100 percent slide-system deployment success and no injuries for over 1,000 persons using the evacuation system.

Also, I am able to report that the majority of 747 in-service evacuations have been precautionary, with 10 of the total number attributed to hijack attempts or bomb threats involving no malfunction of airplane systems.

The next chart (Chart IV) breaks down the 35 in-service evacuations into the 245 individual slide deployments that were attempted and shows their relative success.

On the next two charts (Charts V and VI), I am showing the hypothetical deployment probability at each end of the current 245 deployment attempts. Successful deployment probability is improved 77 to 86 percent by attempt number 246.

Now, I would like to bring you a more vivid picture of 747 slide development — a movie.

The first sequence is our 43 passenger upper deck evacuation demonstration we ran for FAA certification last January 19, for a JAL 747SR. The new development here was that we ran the test in two phases for safety reasons. The first phase deployed the slide and the second phase was run later with the slide already deployed and safety nets and pillows in place.

The second sequence shows our new type A door development slide for the 280-inch stretched upper deck. This airplane is scheduled to be delivered in the 1983 time period.

DEMONSTRATION FOR FAA CERTIFICATION

JANUARY 19, 1980

INTRODUCTION.

This test was a demonstration of the capability to evacuate 43 revenue passengers plus four crew members in order to obtain FAA certification for an increased number of passengers on the upper deck. By submitting the petition, the capacity of the upper deck was increased to 45, using the 5-percent rule. 43 + (43) (.05) = 45.

The upper deck evacuation was conducted in two phases for this program. Phase I established preparation time (time from initiation of evacuation procedures to first person ready to jump the escape slide). Phase II established the evacuation time and rate (time from first person ready to jump to last person on the ground). The sum of the times established in the two phases was the total time required for evacuation of the upper deck (initiation of test to last person on the ground).

Data obtained during the two phases of the evacuation demonstration showed that all evacuation demonstration requirements had been met pursuant to obtaining FAA certification for transport of 37 upper deck revenue passengers for the JAL airplane and for up to 45 passengers at some later date, if necessary.

TEST SUMMARY MOVIE.

(3 Different Viewpoints of Phase I)

1. Phase I used ten test subject passengers to verify that the passengers are ready (out of their seats and ready for use and to establish the preparation time.

2. Normal hangar lights were used so as not to risk tearing the escape slide during deployment on the infrared light racks required when hangar lights are off.

3. During both phases, the normal airplane lighting system was deactivated and the airplane emergency lights only were used.

(3 Different Viewpoints of Phase II)

1. The Phase II test group consisted of 43 test subject passengers.

2. The flight crew also participated, bringing the total number of evacuees to 47 in Phase II.

3. This phase was conducted under darkness of night simulation.

The elapsed time for Phase I was 13.8 seconds, that being the time from initiation of the test to the time the first crew member was out of the door and ready to use the slide.

The time from the first crew member out the door until the last person was on the ground was 60.9 seconds obtained in Phase II. Combining Phase I and II, the total elapsed time for the evacuation was 74.7 seconds.

747 STRETCH UPPER DECK
EMERGENCY ESCAPE SLIDE
DEVELOPMENT TESTING

APRIL-SEPT. 1980

INTRODUCTION.

The 747 Stretch Upper Deck is a 747 with the upper deck extended 280 inches aft. The primary escape route is by a pair of class A doors located at station 690, one door on each side. The secondary escape route is by an aft straight stairs. The crew service doors at station 400 and the forward stairs are deleted.

Normal door sill height is 306 inches. In a nose-down condition, the door sill height is 225 inches and in a tail-down condition, sill height is 400 inches. The escape slide can be deployed and used in all these conditions. A total of 42 deployments have been made of the prototype slide.

TEST SUMMARY MOVIE.

1. The first deployment shown is at the normal sill height of 306 inches. (Two views — sound and high speed film).

2. The second deployment shown is the low sill height which is 225 inches. (Two views — sound and high speed film).

3. Next is a deployment from the high sill height of 400 inches. (Again two views — sound and high speed film).

4. This slide is designed for winds to 25 knots. Fourteen wind deployments were made, the most critical wind direction was found to be 90°. The wind deployment shown was made in winds of 30 knots at 90°.

5. Six deployments were made at a cold chamber in Seattle. The deployment was at -18° F. with the pressure vessels at -1° F.

6. Last, the sliding characteristics at the normal sill height (306 inches) are shown.

CHART I

Summary of System Deployment Tests

747 EVACUATION SYSTEMS

	NUMBER OF TESTS	
• **MAIN DECK SYSTEMS**		
DEVELOPMENT	4350	
VERIFICATION	588	
DEMONSTRATION	3999	
		8937
• **UPPER DECK SYSTEMS**		
DEVELOPMENT	1102	
VERIFICATION	286	
DEMONSTRATION	553	
		1941
TOTAL		10878

CHART II

Summary of 747 Evacuation System Testing

EXERCISES INVOLVING LIVE TEST SUBJECTS

	NO. TESTS		NO. PEOPLE
● MOVEMENT INSIDE AIRPLANE AND THROUGH DOOR (NO ESCAPE DEVICE)	8		728
● MISC EXPERIMENTAL ESCAPE DEVICES	8		1 170
● EVACUATION EXERCISES AND JUMP TESTS (MAIN DECK SLIDE)			
• DEVELOPMENT	1520	19 866	
• VERIFICATION	25	3 270	
• DEMONSTRATION	9	2 431	
			25 567
● EVACUATION EXERCISES AND JUMP TESTS (UPPER DECK SYSTEM)	363		4829
● EVACUATION EXERCISES AND JUMP TESTS (SLIDE/RAFT)			
• DEVELOPMENT	344	4 800	
• VERIFICATION	89	1 802	
• DEMONSTRATION	51	1 152	
			7 754
TOTALS	2417		40048

CHART III

1970-1980
SUMMARY OF 747 IN-SERVICE EMERGENCY EVACUATION EVENTS

TOTAL EVENTS	35
PERSONS EVACUATED	6248
SERIOUS INJURIES	42 (.653%)

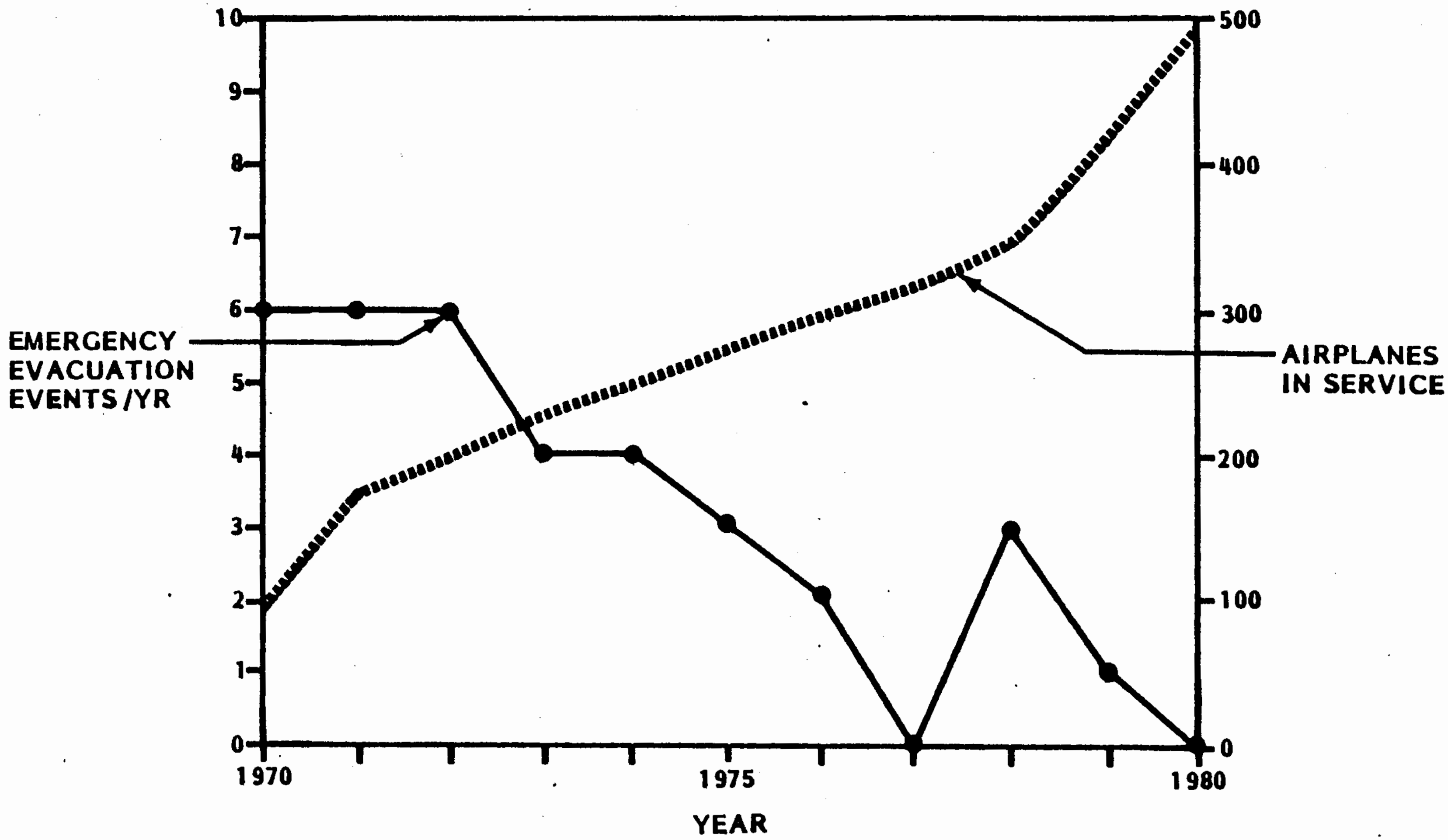


CHART IV

1970-1980
SUMMARY OF 747 IN-SERVICE EMERGENCY EVACUATION SYSTEM EXPERIENCE

IN THE 35 EVENTS
245 INDIVIDUAL SLIDE DEPLOYMENTS WERE ATTEMPTED

EVENTS	TOTAL	L.H.SYSTEMS	R.H.SYSTEMS
ATTEMPTED	245	117	128
UNSUCCESSFUL	49	26	23
PERCENT UNSUCCESSFUL	20%	22%	18%

EVENTS	DOOR 1	DOOR 2	DOOR 3	DOOR 4	DOOR 5	UPPER DECK
ATTEMPTED	47	57	43	48	47	3
UNSUCCESSFUL	10	5	15	7	11	1
PERCENT UNSUCCESSFUL	21%	9%	35%	15%	23%	33%

CHART V

SUMMARY OF 747 IN-SERVICE EXPERIENCE

HYPOTHETICAL EMERGENCY DEPLOYMENT # 0

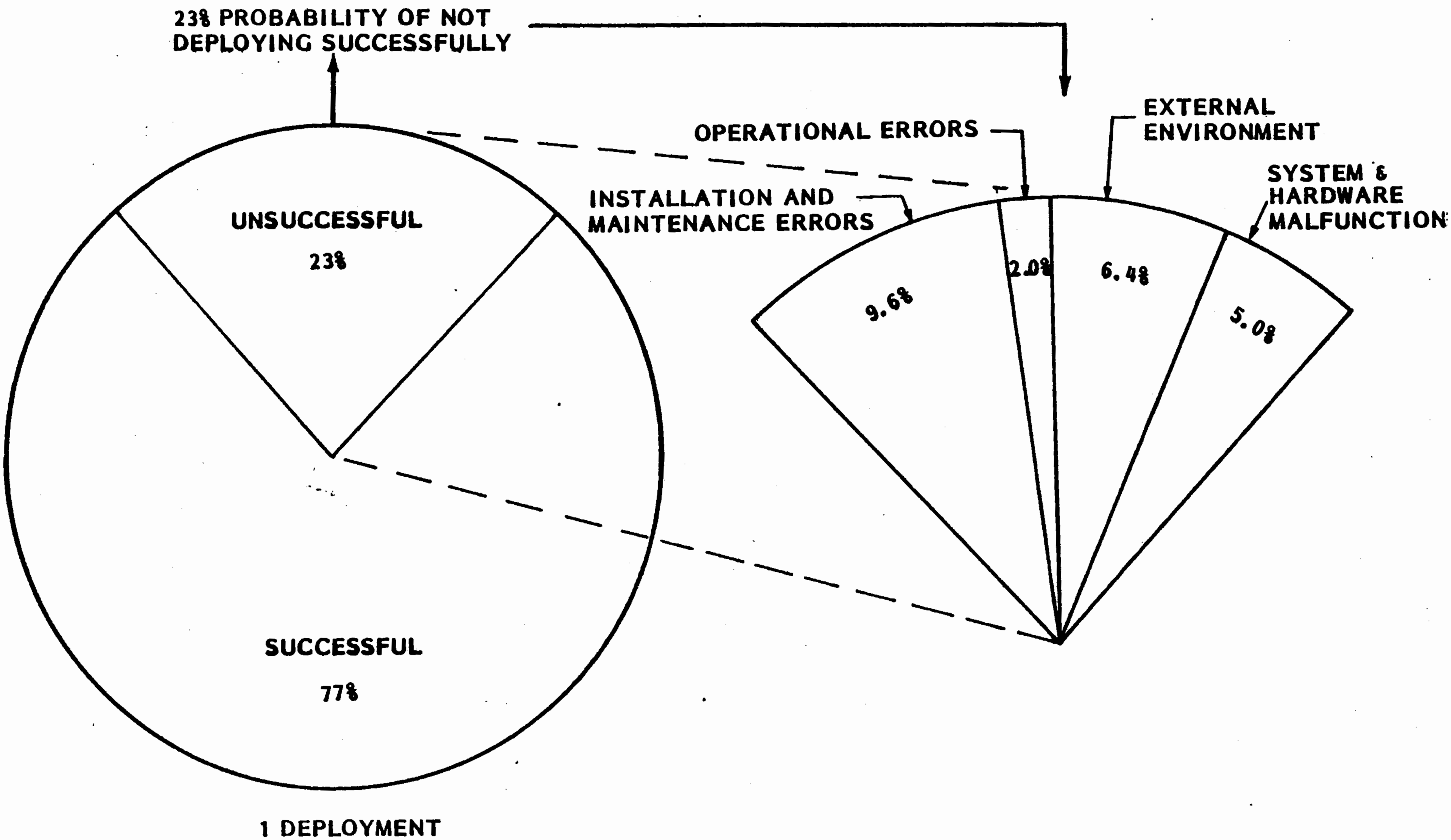
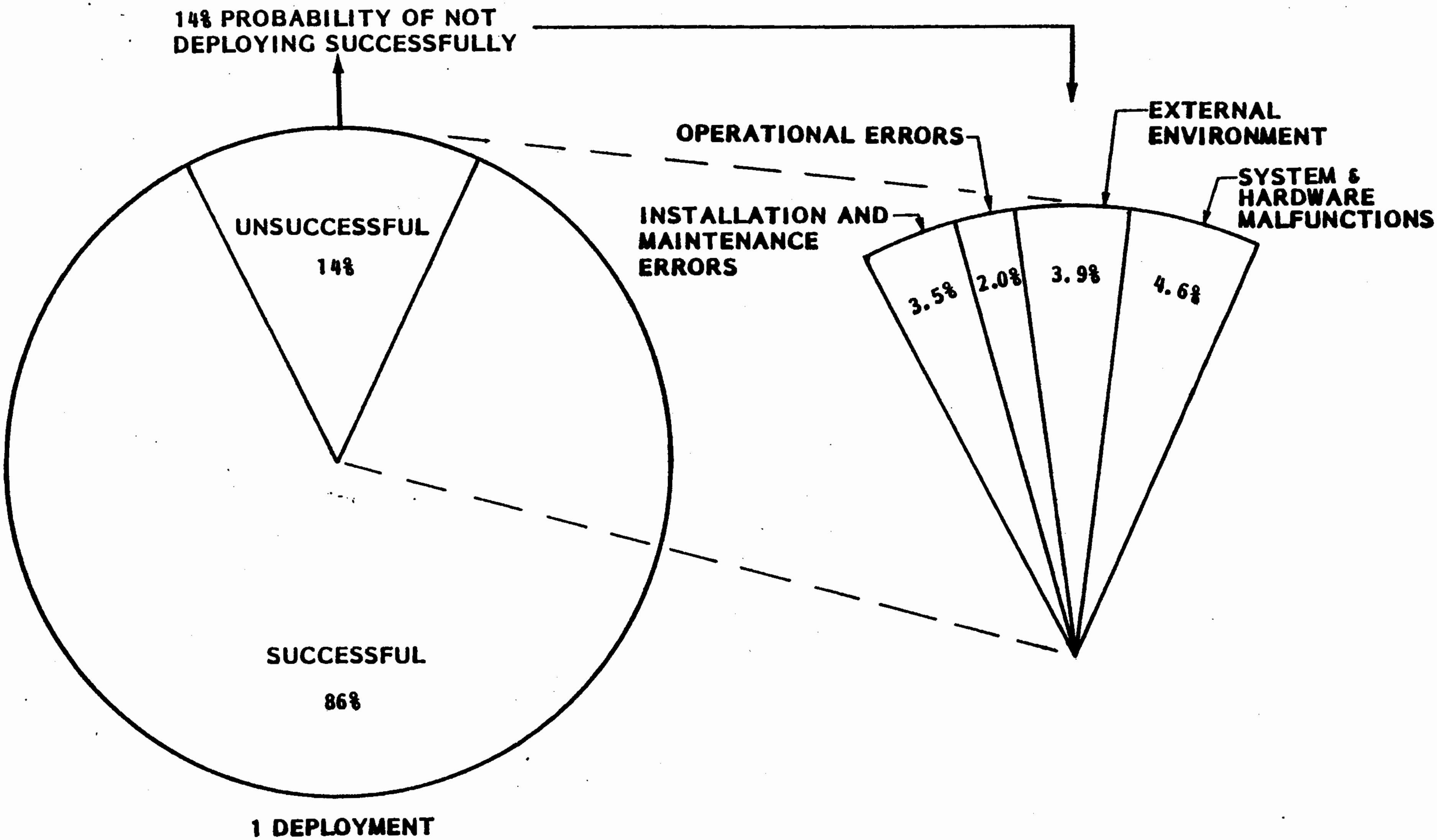


CHART VI

SUMMARY OF 747 IN-SERVICE EXPERIENCE

HYPOTHETICAL EMERGENCY DEPLOYMENT # 246



CONCLUSIONS

- CURRENT EVACUATION SYSTEM ON 747 IS DOING ITS JOB
- DEVELOPMENT TIME FOR NEW SYSTEMS IS A 3 TO 4 YEAR JOB
- EVACUATIONS IN LESS THAN 90 SECONDS IS A FACT
- NECESSITY OF LONG SLIDE LIFE IN HEAT ENVIRONMENT IS QUESTIONABLE
- SLIDE DEVELOPMENT IS COSTLY
- CONSIDER SAFETY IN DEVELOPMENT TESTING I.E. 2 PHASE APPROACH

THERMAL RADIATION RESISTANT PAINT-ON COATING EVALUATION

G. STANLEY SIMS

Senior Product Chemist, B.F. Goodrich with past 5 years experience on Inflatable Products. Produced heat reflective aluminized coating for slides under contract with FAA-TC. B.S. Chemistry - University of Akron.

THERMAL RADIATION RESISTANT PAINT-ON COATING EVALUATION ("Aluminized Coating Study for In-service Slide Materials")

Narrative: By: G. S. Sims

SCOPE/INTRODUCTION.

The primary purpose, and one of the major results of B. F. Goodrich's (BFG) study of aluminized coating, was confirmation of what most everyone knows: "That aluminized coatings reflect thermal radiation and will provide some protection for the substrate material." Particularly when the radiant heat is in the relatively long wavelength region of the spectrum, the near infrared, as emitted by aircraft fuel fires. We have attempted to quantify the degree of protection, while at the same time modifying the coatings to improve the reflectivity ratio and heat capacity.

As part of a program to improve the thermal radiation resistance of in-service inflatable evacuation slides, radiant heat reflective elastomer coatings, which can be applied as a brush-on or spray-on paint, were evaluated. These included presently available coatings as well as development of new coatings.

These coatings were selected and designed to be most reflective in the wavelength region of 2.1 to 2.5u, which according to the literature, corresponds to radiation emitted from JP-4 aircraft type fuel fire, and to be effective at a maximum radiant heat intensity of 2.5 Btu/ft^2-sec. Although most of the work or evaluations today are being carried out in a heat flux range of 1.5 - 2.0 Btu which apparently is more commensurate with human tolerance. The heat flux of 2.5 Btu, which is about 20 times the intensity of a mid-July noonday sun in Chicago, may be too hot to expect people to evacuate into or through. Besides these thermal parameters, the coatings are required to be compatible with state-of-the-art slide materials presently in service and not significantly alter the material physical properties accordingly, per the applicable FAA, TSO, or FAR regulations.

Our radiant heat tests and type samples which were the primary means for relative coating evaluation progressed through three phases.

The first samples were 3-inch-diameter tubes fabricated from the paint-on coated slide materials and with metal plugs in the ends. They were inflated and exposed to a heat flux of 2.5 Btu/ft^2-sec. The heat source was the "coffee pot" Aminco heater used in the NBS Smoke Chamber. The time-to-failure was taken at initial pressure drop. These tests were practically identical to those run by the FAA in their early evaluations of thermal radiation resistant slide materials. Reproducibility was a major problem and short failure times made it difficult to distinguish between actual differences in sample materials and ordinary experimental error.

In the second phase or series of tests, we continued to use the tube-type samples, but reduced the heat flux to 2.2 Btu/ft^2-sec. The reproducibility was slightly improved as well as the ability to detect significant differences between materials.

The third phase involved a new test apparatus in which a material sample disk is clamped over the open end of a metal cylinder, the cylinder pressurized, and the sample exposed to the same radiant heat source as in the earlier tests. Reproducibility was improved as the problem of sealing the inflated material tube ends was eliminated.

COATING BASE POLYMER VEHICLE.

Three polymer vehicles of the elastomer category and which are common to today's slide materials were evaluated. These included polyurethane, neoprene, and hypalon-based coatings. In addition, a silicone paint-on coating was tested. It was theorized that silicone rubber, which is noted for its high temperature resistance, would be effective in improving the material's total heat resistance.

Initially "off-the-shelf" and "in-house" compounded reflective coatings as well as commercially available reflective elastomer paints were evaluated. The coatings were applied to polyurethane and neoprene slide fabric control samples.

The control samples (those without any paint-on reflective coating) had failure times in the 13 — 15 second range as shown in table I. These were tested per the inflated tube. There appeared to be little difference between the polyurethane or neoprene coated fabrics, and only a slight difference between fabrics coated on both sides versus coated on one side only. Material #2, was used throughout this study as the base control, yellow polyurethane/nylon material on which most paint-on reflective coatings were evaluated. Number 1 was used as the yellow neoprene/nylon control material.

REFLECTIVITY, RATIO — STD YELLOW — WHITE — ALUMINIZED COATINGS.

The low reflectivity ratio for these aviation yellow colored materials should be noted, .11 to .37 at 2.5u. A plot of the reflectivity ratios versus the wavelength of the incident light for the yellow, white, and aluminized coatings is shown in figure 1. The yellow materials, sample "A," which are highly reflective in visible light, become very absorbent at the longer wavelength of the spectrum, dropping to less than 0.2. This partially accounts for the short failure times as large amounts of heat energy are absorbed rather than reflected.

These yellow coat compounds, specifically the polyurethanes, besides having low infrared reflectivity, have low heat capacities and melt temperatures; they can withstand only small amounts of absorbed heat before they deteriorate.

The glossy white coated material, "B," also very reflective in visible light, has a reflectivity ratio of only slightly more than 0.4 at 2.5u. As will be shown in the next table, the white coatings also have short failure times as compared to the aluminized paint-on coatings. The aluminized paint-on coatings, "C," which in spite of having a dull appearance, had a reflectivity ratio of nearly 0.9 at 2.5u.

COMMERCIALLY AVAILABLE REFLECTIVE COATINGS.

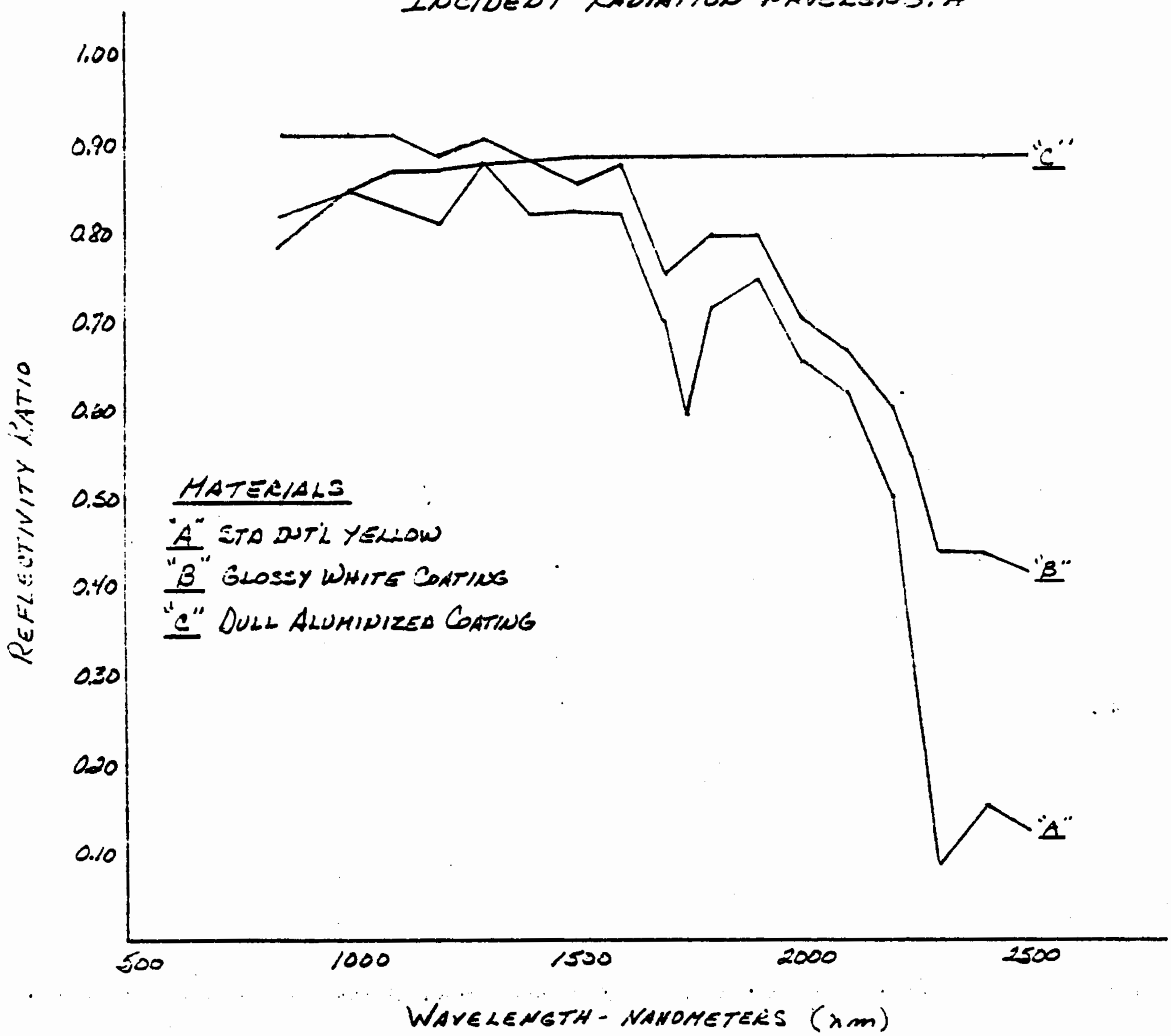
Initially, several commercially available "off-the-shelf" elastomer coatings based on each of the three polymers, were evaluated. They were pigmented with aluminum flake or white oxide powders.

ALUMINIZED POLYURETHANE COATINGS.

The aluminized urethane paint-on coatings, samples 9, 13, and 16, were used with the #2 urethane nylon control material. The failure times ranges from 16.3 to 24 seconds. The control material, remember, failed after 13 seconds. These samples were tested at 2.5 Btu/ft^2-sec which accounts for the relatively short failure times (as compared to some of the data many of you are more familiar with, which is being obtained on samples run at 1.5 or 2.0 Btu/ft^2-sec.). It would appear that the #9 coating was the most reflective and resistant to radiant heat, but if the results are normalized by dividing the failure time by the material weight

COMPARISON COATED SLIDE MATERIALS

REFLECTIVITY RATIO
VS.
INCIDENT RADIATION WAVELENGTH



gain in the T/Δ W ratio you can see that the coatings, if applied in equal weight, would have about the same results.

The ratios varied only from 10.9 to 11.6 for the three Al/polyurethane samples. These samples were brush coated which made it a little difficult to control the weight or uniformity. Number 9, for example, had a weight increase of about 2.0 oz/yd^2 maximum weight gain. These heavier coatings act as a greater heat sink with higher failure times as compared to the lighter weight or thinner coatings.

WHITE METAL OXIDE COATINGS.

A white urethane coating, sample #14, (which was based on the sample recipe as #13, but with white pigment loading rather than aluminum) failed in 8 seconds. It was expected to fail in less time than the aluminum sample because of the lower reflectivity ratio, which was 0.5 as compared to 0.87, but it also failed before the yellow control which was even less reflective. (Apparently even the low amount of heat absorbed was enough to melt the coating.)

The white hypalon coatings, sample #11, had a longer failure time but with a weight increase nearly twice that of the white polyurethane. Therefore, the T/ΔW ratio's are about the same, 5.5 and 5.8. It also showed no improvement over the control material which it was coated over and in this case, was the neoprene nylon material. The base control material also failed at 14.5 sec. Neither white paint-on coating improved the radiant heat resistance of the base materials.

ALUMINIZED NEOPRENE COATINGS.

An aluminized neoprene coating, sample #8, was also tested with the neoprene nylon base control. The failure time at 22 seconds is about a 50 percent improvement. As you can see, the T/Δ W ratio of 14.7 compares favorably with the urethane coatings in these early tests.

It was noticed in these early tests that the mode of failure for the neoprene and hypalon coatings was embrittlement followed by lifting and cracking open of the coating to expose tle base control material. The polyurethane coatings on the other hand softened and flowed still retaining some reflectivity in the melt state.

POLYURETHANE VERSUS NEOPRENE WITH NEOPRENE BASE CONTROL MATERIAL.

In that one of the major objectives is to select or formulate one reflective coating which may be used as a universal paint-on coating for all slide materials which from all available information is either neoprene or polyurethane, we also tested a neoprene base material coated with the paint-on aluminized polyurethane and compared it with a paint-on neoprene.

The two paint-on coatings were about equal. The failure time for #12 was the highest but the coating weight was also high as reflected in the TΔW ratio.

The adhesion of the neoprene coating to the base polyurethane materials was very poor. It was even low when painted on the neoprene based samples with peel adhesion values less than #3/inch width. Adhesion of the hypalon coatings was even worse and would probably require some type primer system.

The urethane coatings had good adhesion to both polyurethane and neoprene base materials. Peel values were in the #4-4-1/2 range.

COMMERCIAL PAINTS.

Many commercial paints, although with a polyurethane elastomer base, air cured to a hard plastic state rather than a soft flexible coating. Some of them had excellent reflectivity and heat resistance but were not suited to this application because of their brittleness.

SILICONE BASE COATINGS.

A silicone solution coating loaded with a highly reflective aluminum pigment was evaluated with unexpected poor results. (See table IV.) The reflectivity ratios were low .65 as compared to the other aluminized coatings. The failure times were very low — as you can see at 10 seconds. The adhesion of the coating to the base material was very poor and was not improved with the recommended primer system. Due to the time frame constraints of this initial study, we did not continue this investigation.

Development of a silicone radiant heat reflective coating will require a much more in-depth investigation; particularly in basic silicone compounding and adhesion properties.

FORMULATION OF REFLECTIVE COATINGS.

Based on the polyurethane coating's higher level of adhesion (than neoprene or hypalon) on both base urethane and neoprene slide materials and the improved resistance to radiant heat it provided for the slide materials, it was selected for further study and modification. A BFG coating, which was one of the commercially available aluminized urethane coatings was chosen simply because of availability and our knowledge of the basic formulation.

The areas of modification were to include evaluation of a new reflective aluminum pigment, incorporatmon of endothermic intumescent reactants, crosslinking by ambient room temperature cure systems and higher melt temperature thermoplastic urethane resins.

The concept of crosslinking the polymer for improved heat resistance, also, was evaluated in some of the neoprene coatings.

METALIC (ALUMINUM) PIGMENTATION.

Substitution of a brighter small, rhombic aluminum powder for the aluminum flake did not improve the reflectivity ratio as seen in table V, .73 versus .88 for the control coating. The failure time was even less than the noncoated material. Apparently the temperature rise rate was much higher than with the flake. A brighter, larger, flake pigment was also tested in the same coating recipe. The data is not shown here but samples did not last any longer than the control aluminized coating in spite of a reflectivity ratio of 0.95. Therefore, there is some question whether improving the reflectance ratio from the .80 - .90 range to 0.95, actually is worthwhile in attempting to improve the radiation resistance in this near infrared region.

WHITE (METAL OXIDE) PIGMENTATION.

We did not as I mentioned earlier do any further work with the white pigments because of the low reflectivity ratios and poor results obtained with the white urethane and hypalon coatings.

INTUMESCENT PIGMENTATION.

Even though a large portion of the infrared radiant heat energy is reflected, most of the base materials and paint-on coatings absorb a sufficient amount to experience rapid temperature rise. With reflectivity ratios in the 0.90 range, the material temperature rise rate, still, in some samples approached 60 degrees C/minute during test and in some cases the temperature at failure was as high as 175 degrees C.

Improving the coating and material heat resistance requires that the specific heat (that is the amount of energy required to increase the material temperature) must be increased as well as the melt temperature and heat of fusion (the amount of energy absorbed in the change of physical state).

It was thought that possibly the total coating heat capacity could be increased by incorporating some endothermic reactants. The intumescent-type reactants which decompose to release moisture and gases absorb large amounts of energy which normally would cause a temperature rise. Hopefully a reactant with a high heat of absorption and low enough decomposition temperature matching the softening temperature of the coatings could be located.

After a literature search, four common reactants as shown here in table VI, were selected. These had decomposition temperatures in the range of 110 degrees C to 327 degrees C.

It was also felt that those reactants which liberated moisture which would be turned into steam would be more effective.

The four reactants were added to both an aluminized and white polyurethane coating. The aluminum and aluminum/intumescent coatings were used as a base coat. The various combinations of standard aluminized and aluminized/intumescent, with and without the white intumescent base coat, are shown in table VII.

From the test data, it can be seen that the aluminum and aluminum/intumescent topcoats have excellent reflectivity with values in the .85 - .90 range. This would indicate that any difference in failure times is a matter of how effective the paint-on coating is in improving the heat resistance of the material.

The best failure time of 24 seconds was obtained with a single topcoat of aluminum/intumescent which was the hydrate of $CaSO_4$, however, at some sacrifice in weight. This is shown by the $T/\Delta W$ ratio of 21.6 as compared to the standard aluminum control sample with a failure time of 18.3 seconds and a $T/\Delta W$ ratio of 29.0.

It was interesting to note of the intumescents tested the best results were obtained with the one which had a decomposition temperature closely matching the melt temperature of the particular urethane resin we were using. It did not have the highest heat of absorption.

The two coat systems did not nor did the intumescent reactants themselves really improve the total heat resistance. The one higher value was more than likely due to the increased weight and mass. In general, the trade off of increased weight for a slightly improved resistance to radiant heat does not warrant use of the intumescent into the paint-on coating.

This is further illustrated in some sprayed samples (table VIII) comparing lightweight and relatively heavyweight coatings of the standard control aluminized coating and with the best intumescent, -1, $CaSO_4$ hydrate. (The standard coating has been modified with a flame retardant system and fungicide). These samples were tested per the "disk" method. As you can see, no real improvement in protection was gained with the reactant and also very little improvement with the heavier coated material. Comparing #40 or #42 with #41 or #43.

CURE SYSTEMS.

Besides increasing the heat capacity of a material with endothermic reactants, the total heat resistance can also be improved by increasing the coating melt temperature. This can be accomplished in most elastomers by vulcanization or curing. The resulting crosslink network, primary and even secondary bonds, can be formed by adding curing agents or cure systems which are activated at elevated or even at ambient room temperatures.

Most of the coatings evaluated so far relied primarily on evaporation of solvent, leaving a thermoplastic coating with a low degree of crosslinking.

NEOPRENE CURE SYSTEMS.

The most desirable crosslinking with improved heat resistance for neoprene coatings occurs with selected curing agents during vulcanization at high temperature. It, of course, is not really practicable to paint a slide then run it through a cure.

Normally room temperature curing agents such as isocyanates, amines, polyamides, carbonates, etc., used with neoprene do not provide good heat resistant coating compounds.

Here you can see, table IX, that two out of three neoprene coatings showed no improvement with addition of isocyanate when compared to the nonaccelerated #12 sample. The #5 sample did show slightly more than a two-fold improvement over the base control material. This sample, however, as well as the other two made the material stiff and boardy. The sample without the isocyanate curing agent, #12, remained soft and pliable and had only slightly less than two-fold improvement over the 14.5-second failure time for the base control material.

POLYURETHANE CURE SYSTEMS.

The polyurethanes, on the other hand, contain functional groups which react at room temperature with some curing agents and with formation of primary chemical bonds resulting in improved heat resistance.

The addition of a curing agent to the standard urethane coating, sample #7, (see table I), improved the heat resistance by a factor of 5; up to 92 seconds from 18 seconds for the control sample. This coating, however, also resulted in a stiff and boardy material. It did show a significant improvement as compared to the room temperature cured neoprene coatings.

Further evaluations with other curing agents and at various mixed ratios are in progress. It should be possible to optimize the degree of crosslinking and heat resistance without making the coating and material too stiff.

HIGH MELT TEMPERATURE THERMOPLASTIC URETHANES.

Use of thermoplastic urethanes with a higher degree of crystalinity and softening temperatures also can improve the total heat resistance. A higher melt temperature resin, sample #45, was substituted in the base control coating with a 25 percent improvement in failure time. The samples were spray coated and also tested per the disk method. The samples were slightly stiffer due to the higher modulus of this particular resin. In tests and 1.5 Btu the 7602E paint-on coating did not fail after 600 seconds and lasted 65 seconds at 2.0 Btu. These tests were with present-day urethane/nylon base slide materials.

RADIANT HEAT RESISTANCE VERSUS COATING WEIGHT.

We finally made a comparison of spray coated samples in which the coating weight or thickness was varied (Table XII) There actually is only a slight difference in failure time between sample #40 with a .50 oz/yd^2. The difference can mostly be attributed to experimental error in the test procedure. Apparently in this weight range little protection is gained by "putting on" a little more coating.

One sample, #44, had only a 2.4 percent weight gain or 0.18 oz/yd^2 but still lasted 26 seconds, 2-1/2 times longer than the standard yellow control material. This was not much more than an overspray with a high percentage of "windows" in the coating.

We have also tested the 7620 paint-on coating at 1.5 Btu/ft^2-sec on a urethane/nylon material and it lasted over 600 seconds.

CONCLUSIONS.

From this short study and the coatings evaluated, we did derive some conclusions:

1. The air-drying or room-temperature curing polyurethane paint-on coatings were slightly more radiant heat resistant than the air-drying or room-temperature curing neoprene coatings. Again this only holds for the room-temperature cure systems as it is well known that the vulcanized neoprenes are more heat resistant. But in this application, the paint-on coatings cannot be baked on or cured at high temperatures.

2. The polyurethane coatings adhere to dissimilar elastomer coated fabrics better than neoprene or hypalon.

3. Coatings with high reflectivity ratios, 0.80 - 0.90 in the near infrared wavelength region of the spectrum provide the best resistance to fuel fire radiant heat. (This is based on comparison of laboratory and fullscale fuel fire radiant heat tests and spectrophotometric reflectivity tests).

4. Aluminized coatings are more reflective in the near infrared than white oxide pigmented or standard aviation yellow coatings.

5. Aluminum "flake" provided the highest reflectivity.

6. The intumescent or endothemic reactants, which we evaluated, did not significantly improve the radiant heat resistance of paint-on coatings.

7. Light or ultra thin reflective coatings in spite of "windows" in the coating do significantly improve resistance to radiant heat.

8. The standard aluminized polyurethane paint-on coating, KE7620, increased failure times by 2-1/2 to 3 times. These results were obtained in laboratory tests at 2-2.5 Btu/ft^2-sec. At 1.5 Btu the failure time was in excess of 600 seconds. The base material was a present, state-of-the art, standard yellow polyurethane/nylon slide material.

9. Resistance to radiant heat is not totally a function of reflectivity but also related to the heat capacity and melt temperature of the coating. These properties can be improved by introducing some degree of crosslinding into the polymer.

We are continuing our evaluations and efforts to improve the total heat resistance of the paint-on coatings with higher melt temperature urethane resins and also optimizing the room temperature cure systems for both polyurethane and neoprene coatings.

TABLE I

TEST RESULTS - TYPICAL "SLIDE" MATERIALS

SAMPLE	BASE MATERIAL NYLON FABRIC ELASTOMER COATING	- COLOR	REFLECTIVITY @ 2.5μ	TUBE * FAILURE TIME SECONDS TO PRESSURE DROP
#1	NEOPRENE	YELLOW	.37	14.5
2	POLYURETHANE (1 SIDE)	YELLOW	.12	13.0
3	POLYURETHANE (2 SIDES)	YELLOW	.11	14.9

* HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE II

TEST RESULTS - PIGMENTED ELASTOMER PAINT-ON COATINGS

SAMPLE	PAINT-ON COATING ELASTOMER	PAINT-ON COATING COLOR	CONTROL BASE MATERIAL NYLON FABRIC ELASTOMER COATING	REFLECTIVITY @ 2.5 μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO $T/\Delta W$
#8	NEOPRENE	ALUM	#1 NEOPRENE	.66	22.0	14.7
9	POLYURETHANE	ALUM	#2 POLYURETHANE	.73	24.0	11.6
11	HYPALON	WHITE	#1 NEOPRENE	.62	14.5	5.5
13	POLYURETHANE	ALUM	#2 POLYURETHANE	.87	18.0	11.6
14	POLYURETHANE	WHITE	#2 POLYURETHANE	.50	8.0	5.8
15	POLYURETHANE	ALUM	#1 NEOPRENE	.85	20.7	14.7
16	POLYURETHANE	ALUM	#2 POLYURETHANE	.79	16.3	10.9

* HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE III

TEST RESULTS - COMPARISON NEOPRENE AND POLYURETHANE COATING ON NEOPRENE BASE MATERIAL

SAMPLE	PAINT-ON COATING ELASTOMER	COLOR	CONTROL BASE MATERIAL NYLON FABRIC ELASTOMER COATING	REFLECTIVITY @ 2.5μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO $T/\Delta W$
#8	NEOPRENE	ALUM	#1 NEOPRENE	.66	22.0	14.7
12	NEOPRENE	ALUM	#1 NEOPRENE	.79	26.0	11.6
15	POLYURETHANE	ALUM	#1 NEOPRENE	.85	20.7	14.7

*HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE IV

TEST RESULTS - SILICONE RADIANT HEAT REFLECTIVE COATING

SAMPLE	PAINT-ON COATING ELASTOMER	COLOR	CONTROL BASE MATERIAL NYLON FABRIC ELASTOMER COATING	REFLECTIVITY @ 2.5μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO $T/\Delta W$
#35	SILICONE	ALUM	#2 POLYURETHANE	.65	10.0	4.5
36	SILICONE	ALUM	#2 POLYURETHANE	.66	9.5	5.3

*HEAT FLUX @ 2.2 BTU/FT^2-SEC

TABLE V

TEST RESULTS - COMPARISON OF ALUMINUM PIGMENTS

SAMPLE	PAINT-ON COATING ELASTOMER	PAINT-ON COATING COLOR	CONTROL BASE MATERIAL NYLON FABRIC ELASTOMER COATING	REFLECTIVITY @ 2.5μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO T/ΔW
#19	POLYURETHANE	ALUM	#2 POLYURETHANE	.88	18.3	29.0
34	POLYURETHANE	ALUM	#2 POLYURETHANE	.73	12.0	10.8

*HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE VI

PHYSICAL PROPERTIES - INTUMESCENT MATERIALS

INTUMESCENT	DECOMPOSITION TEMPERATURE	RELATIVE HEAT OF ABSORPTION	DECOMPOSITION PRODUCTS	BASE MATERIAL
-1	160^{o} - $199^{o}C$	63	H_2O	$CaSO_4$ $2H_2O$
-2	$327^{o}C$	82	H_2O	Al_2O_3 $3H_2O$
-3	$166^{o}C$	100	H_2O + CO_2	$NaHCO_3$
-4	110^{o} -138^{o} $-277^{o}C$	140	H_2O	$CuSO_4$ $5H_2O$

TABLE VII

TEST RESULTS - INTUMESCENT PIGMENTED COATINGS

SAMPLE	REFLECTIVE COATING TOP COAT	REFLECTIVE COATING BASE COAT	REFLECTIVITY @ 2.5μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP (1)	RATIO T/ΔW
#19 CONTROL	AL	————	.88	18.3	29.0
20	AL/INTUM -1	————	.89	24.0	21.6
21	AL/INTUM -2	————	.88	17.0	11.2
22	AL/INTUM -3	————	.88	16.8	16.3
23	AL/INTUM -4	————	.89	14.7	14.7
24	AL	WHT	.89	15.7	14.5
25	AL	WHT/INTUM -1	.88	17.0	17.0
26	AL	WHT/INTUM -2	.90	18.2	15.8
27	SAME AS SAMPLE #26				
28	AL	WHT/INTUM -3	.89	15.5	12.9
29	AL	WHT/INTUM -4	.89	20.0	18.9
30	AL/INTUM -1	WHT/INTUM -1	.87	15.0	16.0
31	AL/INTUM -2	WHT/INTUM -2	.85	17.0	14.8
32	AL/INTUM -3	WHT/INTUM -3	.87	21.3	11.2
33	AL/INTUM -4	WHT/INTUM -4	.86	20.3	14.4

*TESTED AT 2.2 BTU/FT^2-SEC HEAT FLUX

TABLE VIII

TEST RESULTS - COMPARISON INTUMESCENT AND STANDARD COATINGS

SAMPLE	PAINT-ON COATING ELASTOMER	COLOR	INTUMESCENT	% Δ WEIGHT PAINT-ON COATING	DISK* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO T/Δ W
#40	POLYURETHANE KE7620	ALUM	NONE	6.6	30	57.7
41	POLYURETHANE KE7620	ALUM	NONE	13.7	33	32.4
42	POLYURETHANE KE7620-1	ALUM	-1	6.7	27	50.9
43	POLYURETHANE KE7620-1	ALUM	-1	21.6	32	20.0

*HEAT FLUX @ 2.2 BTU/FT^2-SEC

TABLE IX

TEST RESULTS - NEOPRENE COATINGS WITH ADDITION OF CURING AGENT

SAMPLE	PAINT-ON COATING ELASTOMER	COLOR	CURING AGENT ADDED	REFLECTIVITY @ 2.5 μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO T/ΔW
#4	NEOPRENE	10 PTS ALUM	ISOCYANATE	.78	26.7	7.9
5	NEOPRENE	20 PTS ALUM	ISOCYANATE	.74	32.0	15.4
6	NEOPRENE	30 PTS ALUM	ISOCYANATE	.81	19.7	5.2
12	NEOPRENE	30 PTS ALUM	- - - - - -	.79	26.0	11.6

* HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE X

TEST RESULTS - POLYURETHANE COATINGS WITH ADDITION OF CURING AGENT

SAMPLE	PAINT-ON COATING ELASTOMER	COLOR	CURE AGENT ADDED	REFLECTIVITY @ 2.5 μ	TUBE* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO $T/\Delta W$
#7	POLYURETHANE	ALUM	ISOCYANATE	.83	92	35.1
13 CONTROL	POLYURETHANE	ALUM	- - - - - -	.87	18	11.6

* HEAT FLUX @ 2.5 BTU/FT^2-SEC

TABLE XI

TEST RESULTS - EVALUATION OF HIGHER MELTING TEMPERATURE POLYURETHANE RESIN

SAMPLE	PAINT-ON COATING ELASTOMER	%Δ WEIGHT W/PAINT-ON COATING	DISK* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO T/ΔW
#45	POLYURETHANE-KE7602E	11.1	41	50.0
39 CONTROL	POLYURETHANE-KE7601-1	12.0	33	37.1

*HEAT FLUX @ 2.2 BTU/FT^2-SEC

TABLE XII

TEST RESULTS - SPRAY COATED SAMPLES

SAMPLE	PAINT-ON COATING ELASTOMER		COLOR	% Δ WEIGHT W/PAINT-ON COAITNG	DISK* FAILURE TIME-T SECONDS TO PRESSURE DROP	RATIO T/ΔW
#38	POLYURETHANE	KE7601-1	ALUM	4.7 (0.34 OZ/YD^2)	32	91.4
39	POLYURETHANE	KE7601-1	ALUM	12.0 (0.89 OZ/YD^2)	33	37.0
40	POLYURETHANE	KE7620	ALUM	6.6 (0.52 OZ/YD^2)	30	50.0
41	POLYURETHANE	KE7620	ALUM	13.7 (1.02 OZ/YD^2)	33	32.4
44	POLYURETHANE	KE7620	ALUM	2.4 (0.18 OZ/YD^2)	26	144.4
2 CONTROL	NO PAINT-ON		YELLOW	——————	10	——

*HEAT FLUX @ 2.2 BTU/FT^2- SEC

KEVLAR ARAMED FIBER YARNS, WEAVE DESIGN, FABRICS

JOHN MORTON

Technical Service Specialist, Du Pont Co., Wilmington, Delaware. 27 years service with Du Pont, with experience in fabric design and weaving of synthetic materials. Last 8 years has been assigned to Devlar development beginning with its concept to introduction to industry. B.S. Textile Engineering, North Carolina State University.

KEVLAR ARAMID FIBER
YARNS, WEAVE DESIGN, FABRICS

The Kevlar aramid fiber proposed for use in aircraft escape slides is a continuous filament yarn made with many small filaments in the yarn bundle. A 200-denier yarn has 134 small filaments of 1.5 denier each. This is necessary because the high modulus of Kevlar 29 (10X that of nylon) would make a yarn with larger filaments more rigid approaching steel wire.

The term "denier" is a weight per unit length (grams per 9,000 meters). The lower the denier the smaller the yarn. Nylon is available as small as 7 denier but the lowest denier of Kevlar is 200. The other deniers of Kevlar 29 are 400, 1,000, and 1,500 so the two yarns of Kevlar used for escape slides are 200 denier for the inflated tube and 400 for the sliding surface.

Kevlar has a breaking tenacity about 2.5X that of nylon which says a fabric could be made of Kevlar at 40 percent the weight of nylon fabric and have the same fabric strength. This is easily accomplished in heavier fabrics, but with the 200 denier limitation the lightest practical weight for coated fabrics is 2.2 ounces per square yard in a plain weave.

The plain weave has more binding points than any other weave design. The more binders in a weave the more stable the fabric. Since weight savings are so important in aircraft, the fabrics made for initial evaluation were plain weave constructions. When other weaves are used (fewer binders) the fabric drape (flexibility) and tear strength improve but more ends and picks are needed to stabilize the fabric. This increases fabric weight and strength. The best tear strength in coated fabrics is with a 2 x 2 basketweave made with twisted yarns. With 200 denier Kevlar such a cloth would weigh about 3 ounces per square yard instead of the 2.2 ounces per square yard for the plain weave.

Fabrics can be designed for strength, tear, modulus, thickness, weight, flex resistance, etc., but not all of these properties can be built into a single fabric.

FIBER DENIER : WEIGHT IN GRAMS OF 9000 METERS

DENIER IS A WEIGHT PER UNIT LENGTH.

THE HIGHER THE DENIER THE BIGGER THE YARN

KEVLAR 29 ARAMID FIBER IS AVAILABLE AS 200, 400, 1000 AND 1500 DENIER.

YARNS OF KEVLAR ARE SPUN AS MULTIFILAMENT. THE INDIVIDUAL FILAMENTS ARE VERY SMALL BECAUSE THE FIBER MODULUS IS VERY HIGH.

AN INDIVIDUAL FILAMENT IS ONLY 1.5 DENIER (REFERRED TO AS 1.5 DPF - DENIER PER FILAMENT)

THE AVAILABLE YARNS OF KEVLAR 29 ARE :

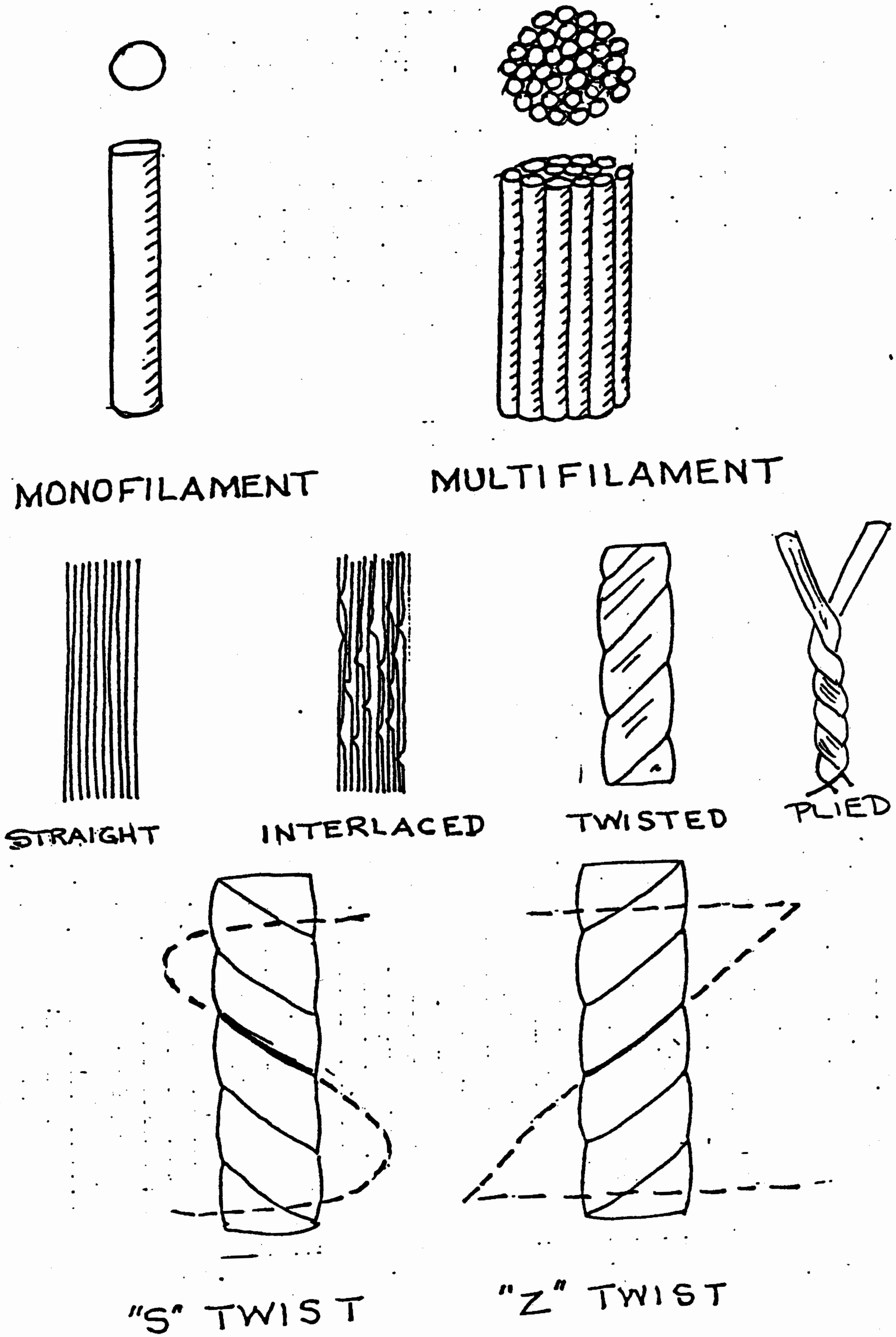
*200-134-0 KEVLAR 29 TYPE 964

400-267-0 KEVLAR 29 TYPE 964

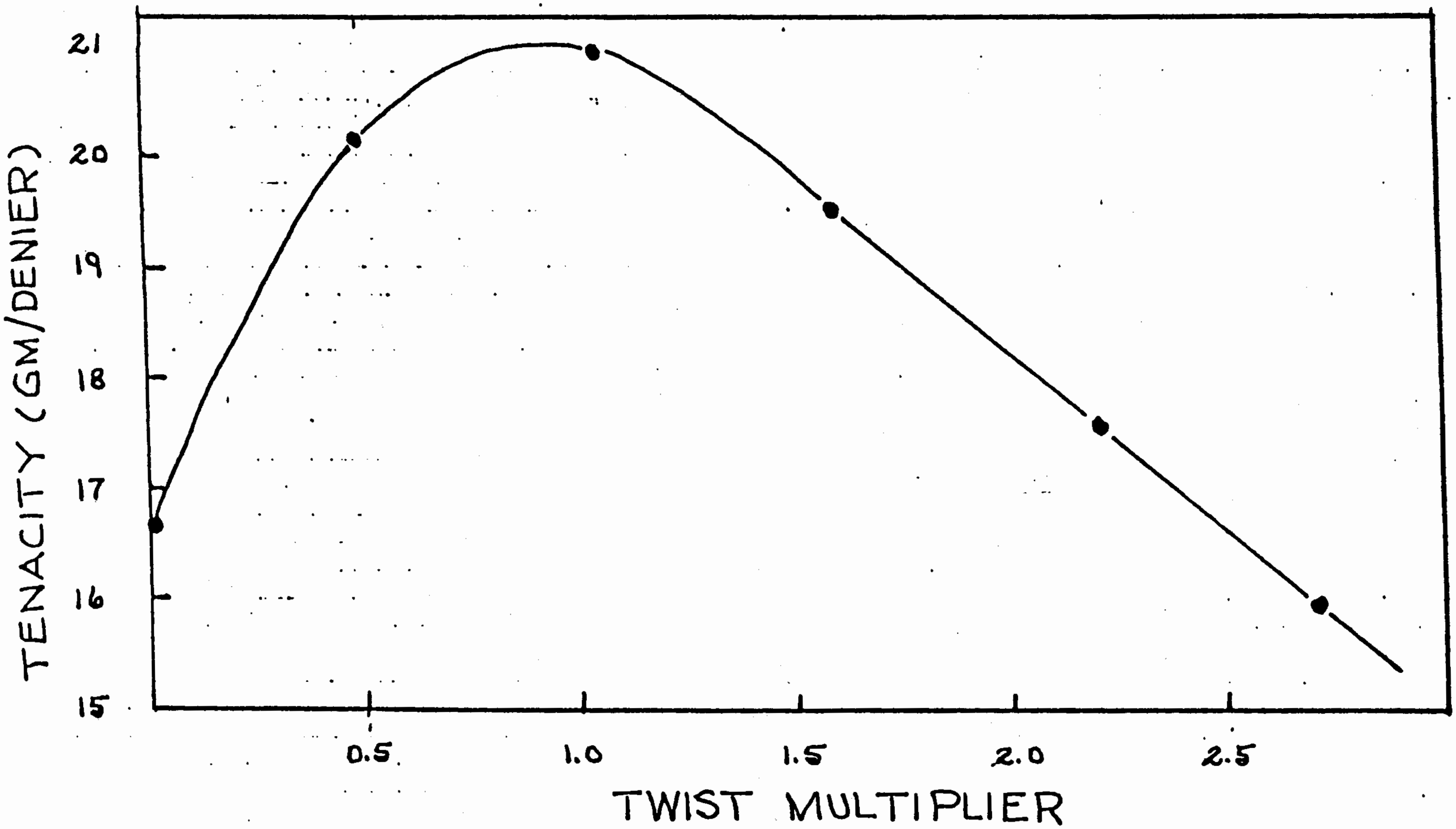
1000-666-0 KEVLAR 29 TYPE 964

1500-1000-0 KEVLAR 29 TYPE 964

200 = DENIER
134 = NUMBER OF FILAMENTS IN THE YARN BUNDLE
0 = TURNS PER INCH OF TWIST


MONOFILAMENT
MULTIFILAMENT
STRAIGHT
INTERLACED
TWISTED
PLIED
"S" TWIST
"Z" TWIST

THE EFFECT OF TWIST ON THE TENSILE STRENGTH
KEVLAR 29 ARAMID



$$\text{TWIST MULTIPLIER} = \frac{\text{TURNS/INCH} \times \sqrt{\text{DENIER}}}{73}$$

TWIST MUTIPLIER

A TWIST MULTIPLIER (T.M.) IS A MEASURE OF THE HELIX ANGLE IN A TWISTED YARN. YARNS OF DIFFERENT DIAMETERS WITH THE SAME T.M. WILL HAVE DIFFERENT TURNS PER INCH TO MAINTAIN THE SAME HELIX ANGLE.

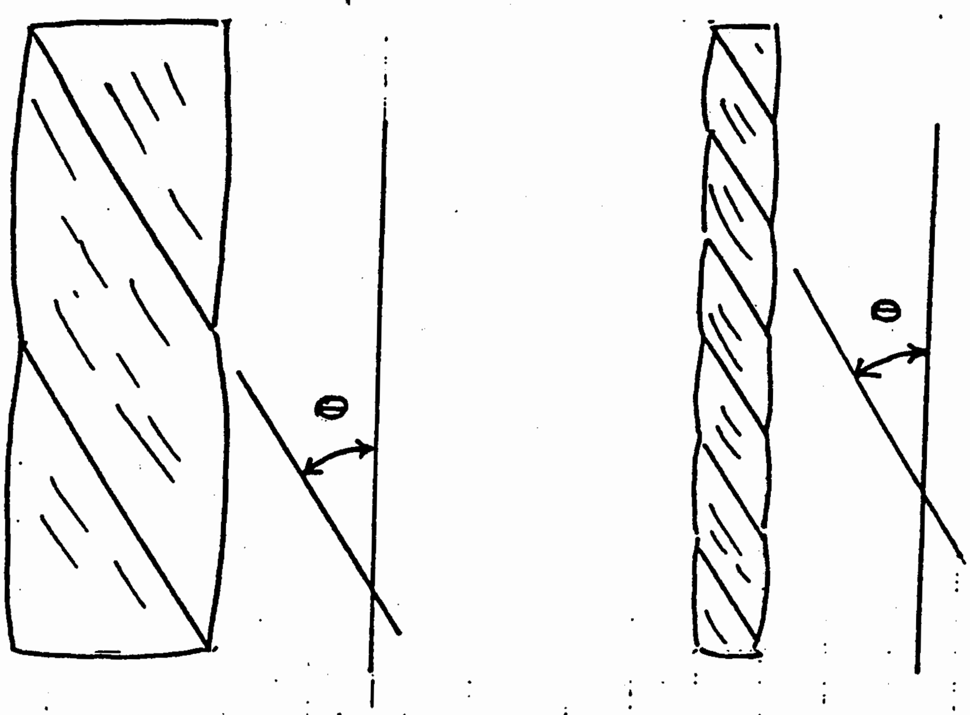
YARNS OF KEVLAR ARAMID FIBER ARE TWISTED BEFORE TESTING FOR TENSILE STRENGTH. THE TWIST MULTIPLIER USED IS 1.1.

THE EQUATION FOR T.M. FOR CONTINUOUS FILAMENT YARN IS:

$$T.M. = (TPI \times \sqrt{DENIER}) \div 73$$

FOR 1500 DENIER AT A T.M. OF 1.1 THE TPI = 2

FOR 200 DENIER AT A T.M. OF 1.1 THE TPI = 5.7



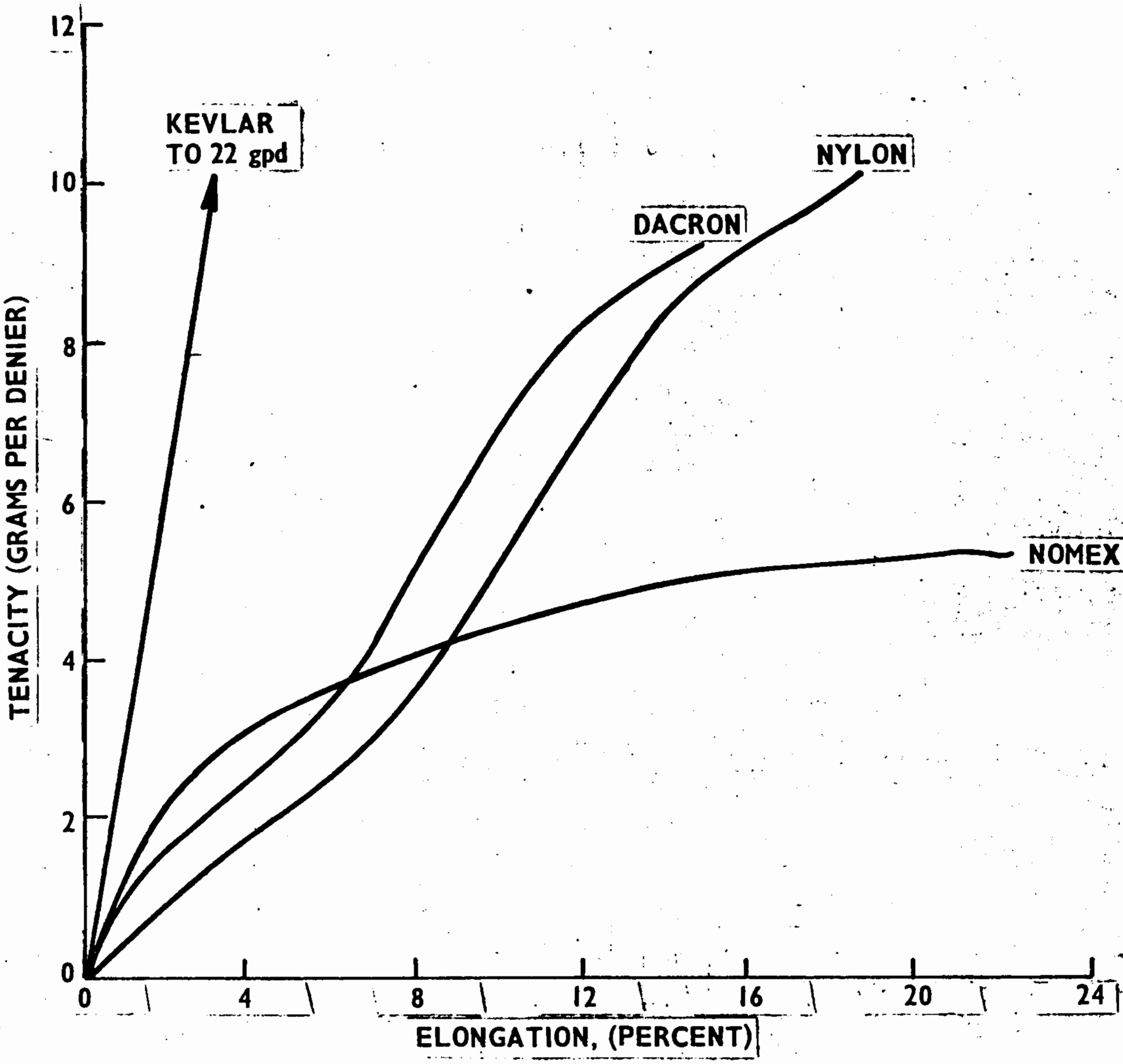
PHYSICAL PROPERTIES OF FIBERS

IN AIRCRAFT ESCAPE SLIDES

	NYLON	"DACRON"	"NOMEX"	"KEVLAR"
Specific Gravity, g/cc	1.14	1.38	1.38	1.44
Tenacity, g/den.	9.2	9.5	5.3	22.0
Elongation at Break, %	18.3	14.5	22.0	4.0
Initial Modulus, g/den.	50	115	140	500
Melting Point, °F.	473	482	* 700	** 800

* "NOMEX" does not melt. It degrades at temperatures above 700°F.

** "KEVLAR" does not melt. It chars at about 800°F.


KEVLAR
TO 22 gpd
NYLON
DACRON
NOMEX
TENACITY (GRAMS PER DENIER)
12
10
8
6
4
2
0
0
4
8
12
16
20
24
ELONGATION, (PERCENT)

EFFECT OF SPECIFIC GRAVITY ON YARN DIAMETER

MOST YARN NUMBERING SYSTEMS ARE BASED ON A WEIGHT PER UNIT LENGTH. THE DENIER SYSTEM USED ON CONTINUOUS FILAMENT YARNS IS THE WEIGHT IN GRAMS OF 9000 METERS. THUS A 200 DENIER YARN OF NYLON AND A 200 DENIER YARN OF FIBERGLASS WILL EACH WEIGH 200 GRAMS FOR A 9000 METER LENGTH BUT THE YARN DIAMETERS WILL BE VERY DIFFERENT.

THIS TABLE SHOWS THE NUMBER OF 200 DENIER YARNS THAT WILL LIE SIDE BY SIDE IN ONE INCH OF WIDTH.

FIBER	SPECIFIC GRAVITY GRAMS/CC	MAX. YARNS
NYLON	1.14	126
DACRON	1.38	138
NOMEX	1.38	138
KEVLAR	1.44	141
FIBERGLASS	2.56	188

IF A FABRIC OF NYLON WITH A GIVEN TEXTURE IS TO BE MADE WITH THE SAME DENIER YARNS OF "KEVLAR" THE EFFECT OF DENSITY MUST BE CONSIDERED.

EXAMPLE: PLAIN WEAVE, 200 DENIER NYLON, 40 x 40.

COVER FACTOR: ACTUAL ENDS/INCH ÷ MAX
$40 \div 126 = 0.317$

TO CONVERT TO KEVLAR WITH THE SAME COVER (TEXTURE) USING 200 DENIER YARNS:

ENDS/INCH = $0.317 \times 141 = 44.7$

THE CURRENT STANDARD IN THE TEXTILE INDUSTRY TO REPORT BREAKING STRENGTHS OF CONTINUOUS FILAMENT YARNS IS IN GRAMS/DENIER. TO CALCULATE BREAKING STRENGTH IN POUNDS:

(GRAMS/DENIER X DENIER) ÷ 454 GRAMS/LB.

BREAKING TENACITY OF DU PONT INDUSTRIAL FIBERS

	NYLON	"DACRON"	"NOMEX"	"KEVLAR"
GRAMS/DENIER	9.2	9.5	5.3	21

"KEVLAR" IS 2X AS STRONG AS NYLON AND "DACRON" AND 4X AS STRONG AS "NOMEX".

ASSUME THAT ALL OF THESE FIBERS ARE AVAILABLE AS 200 DENIER. THE BREAKING STRENGTH OF EACH YARN IN 200 DENIER WOULD BE:

BREAKING STRENGTH (POUNDS)

NYLON	"DACRON"	"NOMEX"	"KEVLAR"
4	4.2	2.3	9.2

THESE NUMBERS SHOW THAT A FABRIC OF "KEVLAR" OF THE SAME WEIGHT AS ONE OF NYLON WILL BE TWICE AS STRONG. ALSO, A FABRIC OF "KEVLAR" THAT IS ONE-HALF THE WEIGHT OF ONE OF NYLON WILL BE AS STRONG.

TENSILE STRENGTH OF KEVLAR 29 ARAMID

TESTED ON INSTRON MACHINE WITH T.M. OF 1.1

GM/DENIER	YARN DENIER	BREAK STRENGTH (lbs)
21	200	9.25 (7.4)*
21	400	18.5 (14.8)
21	1000	46.25 (37)
21	1500	69.4 (55.5)

* NUMBERS IN ( ) ARE THE BREAKING STRENGTHS AFTER WEAVING - ASSUMING AN 80% EFFICIENCY.

RULE OF THUMB METHOD TO CALCULATE FABRIC BREAKING STRENGTH:

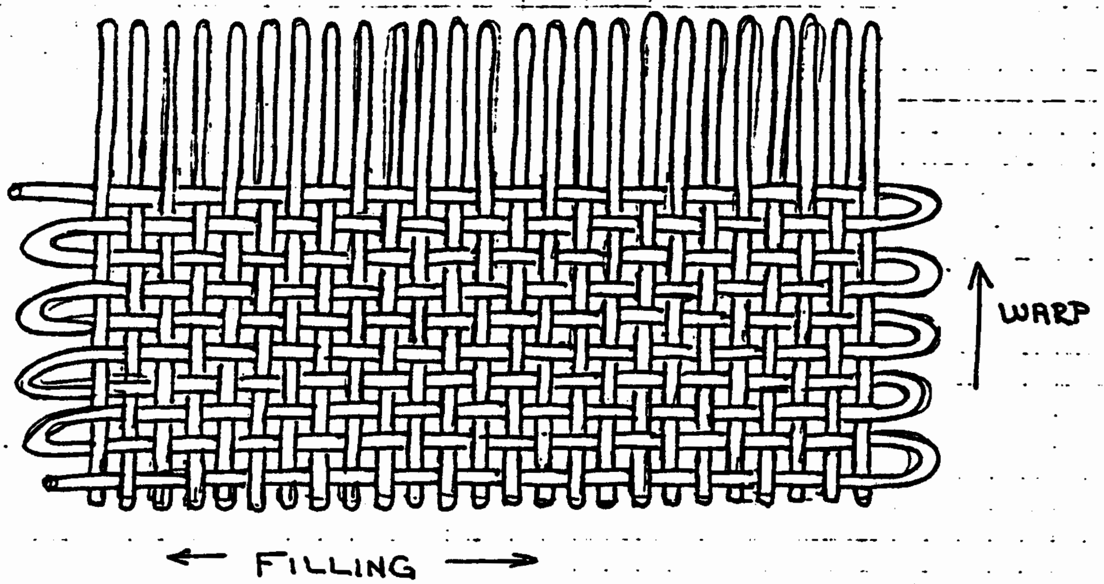
MULTIPLY YARNS/INCH BY BREAKING STRENGTH OF YARN AFTER WEAVING.

EXAMPLE: 40 ENDS/INCH OF 200 DENIER

$$40 \times (9.25 \text{ lbs.} \times 0.80) = 296 \text{ lbs/INCH}$$

THIS METHOD GIVES AN APPROXIMATION WHICH FOR A SIMPLE PLAIN WEAVE IS USUALLY LOW.

FABRIC NOMENCLATURE



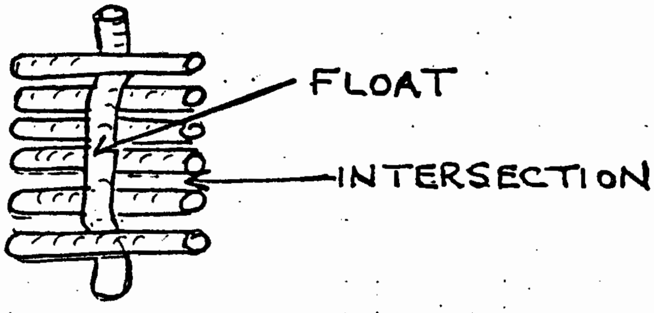
THE WARP THREADS ARE CALLED <u>ENDS</u>

THE FILLING THREADS ARE CALLED <u>PICKS</u>

THE EDGE OF THE FABRIC IS THE <u>SELVAGE</u>

FABRIC CONSTRUCTION IS GIVEN AS
ENDS x PICKS PER INCH

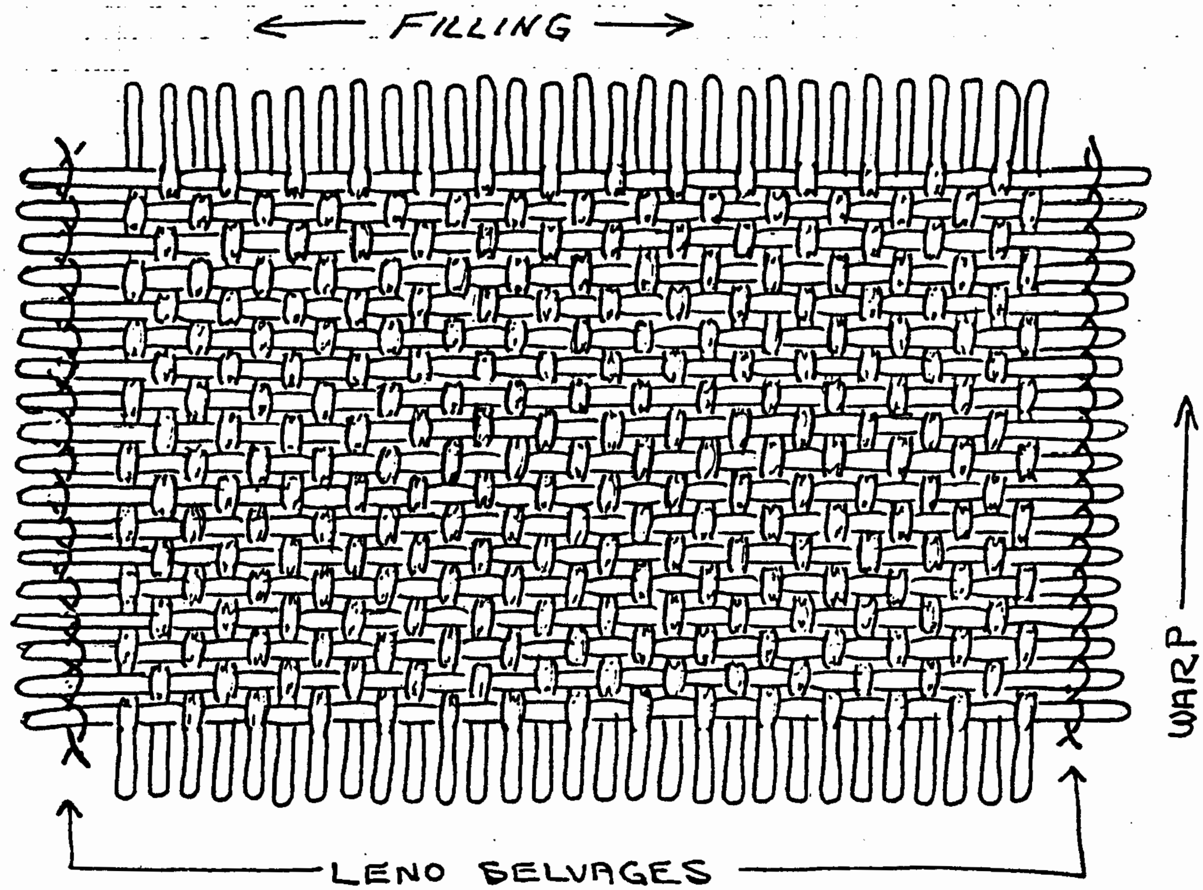
WEAVE (DESIGN) IS THE WAY THE FIBERS INTERLACE



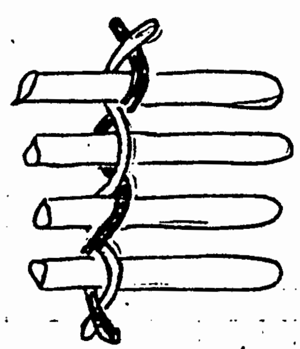
BALANCED WEAVE: SAME YARN IN WARP AND FILLING WITH SAME NUMBER OF ENDS AND PICKS

UNBALANCED WEAVE:

FABRIC FROM SHUTTLELESS LOOM



EACH PICK IS CUT. THE EDGE OF THE FABRIC IS CALLED "FEATHERED EDGE".



LENO SELVAGE

FABRIC DESCRIPTION

STYLE NUMBER

WARP YARN
FILLING YARN
Ends/Inch
Picks/Inch
WEAVE DESIGN
FABRIC WEIGHT (OUNCES/YARD^2)
FABRIC WIDTH (INCHES)

THICKNESS (MILS)
BREAKING STRENGTH (LBS/INCH)
TEAR STRENGTH (LBS)

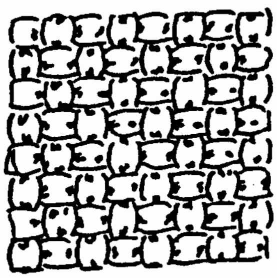
EXAMPLE:

FABRIC STYLE 740 FROM CLARK-SCHWEBEL

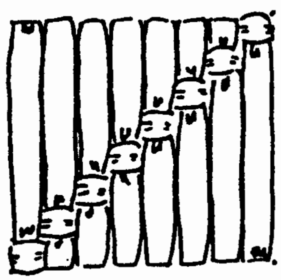
WARP YARN: 200-134-4tpi Z KEVLAR 29 ARAMID
FILLING YARN: 200-134-4tpi Z KEVLAR 29 ARAMID
CONSTRUCTION: 40 X 40
WEAVE: PLAIN
WEIGHT: 2.2 oz/yd^2
WIDTH: 56 inches

THICKNESS: 4.5 mils
BREAKING STRENGTH: 300 lbs/inch.
TEAR STRENGTH (TRAP TEAR) ≙ 20 lbs

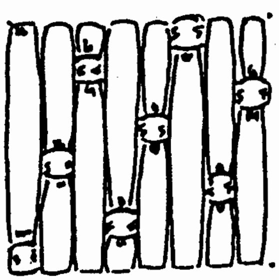
THE THREE BASIC WEAVE TYPES



PLAIN

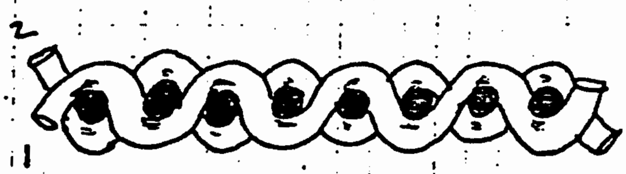


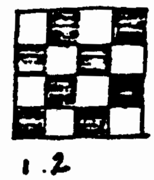
TWILL

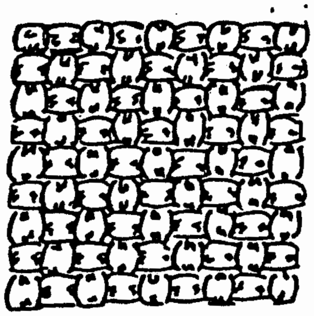


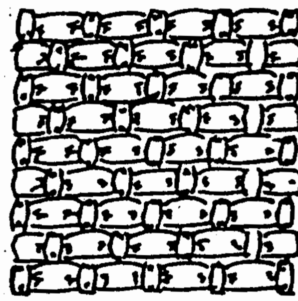
SATIN

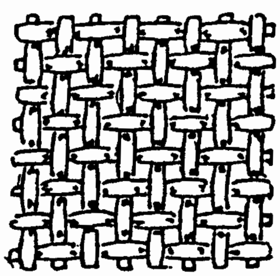
THE PLAIN WEAVE

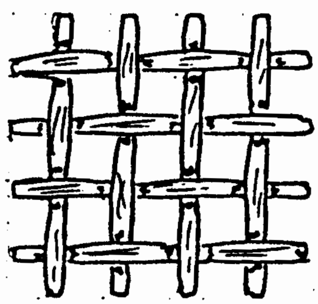




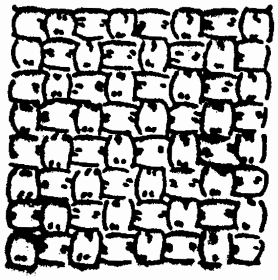






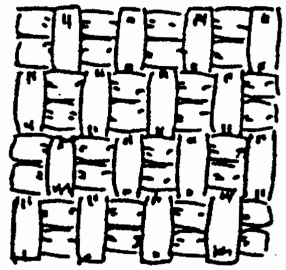


SOME WEAVES IN THE PLAIN WEAVE FAMILY

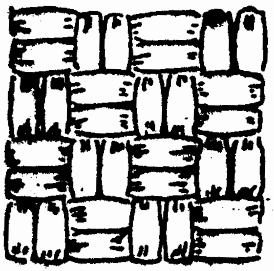


PLAIN

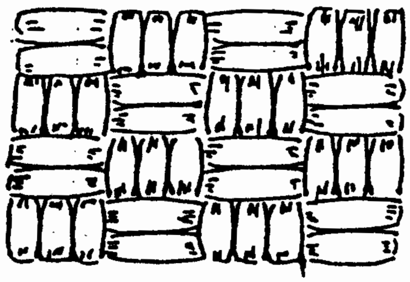
OXFORD



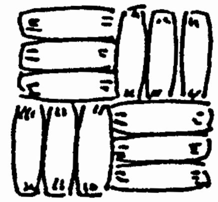
LOUISINE



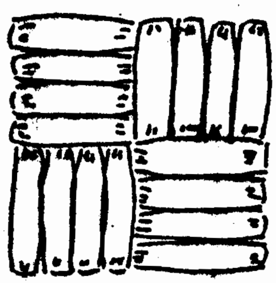
2x2 BASKET



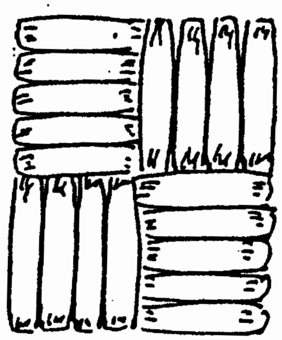
3x2 BASKET



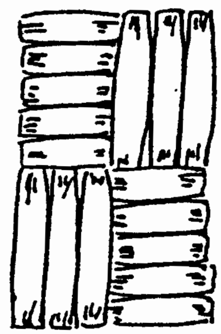
3x3 BASKET



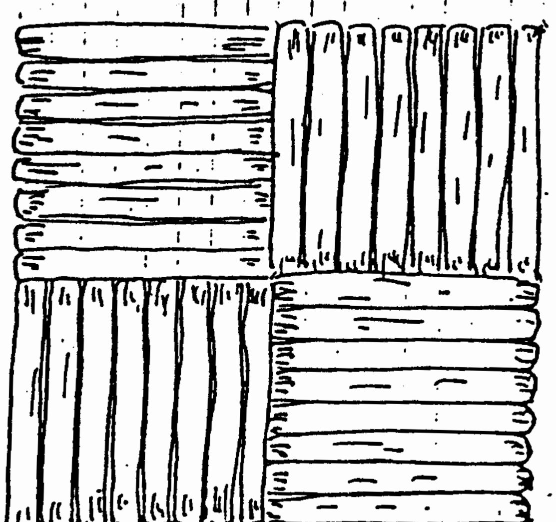
4x4 BASKET



4x5 BASKET

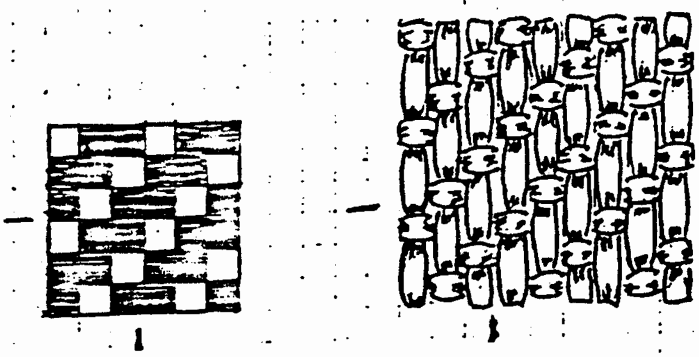


3x5 BASKET

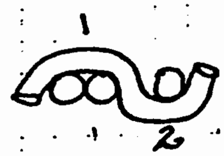


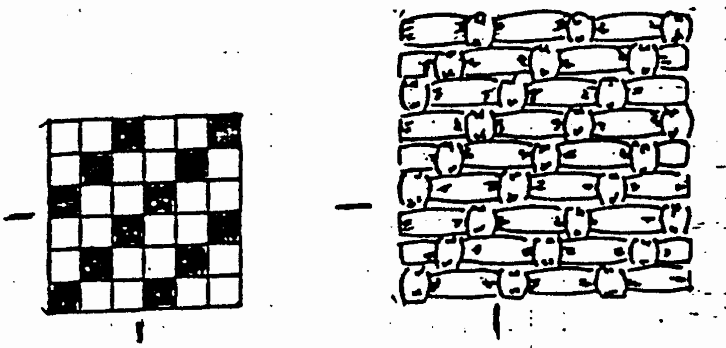
8x8 BASKET

EXAMPLES OF TWILLS

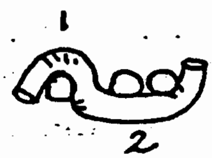


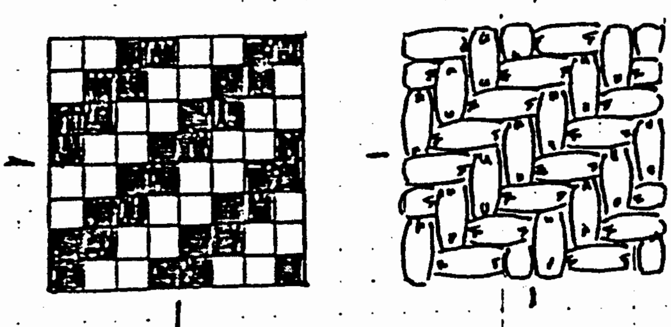
$\frac{2}{1}$ RIGHT HAND TWILL



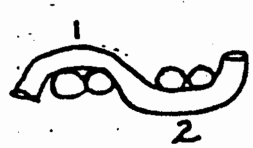


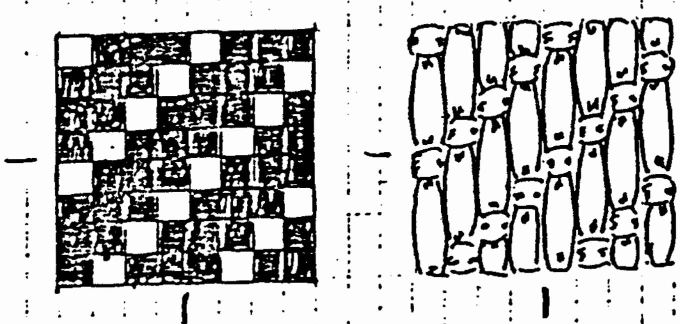
$\frac{1}{2}$ RIGHT HAND TWILL



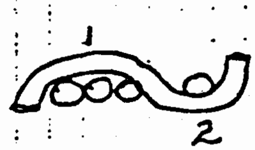


$\frac{2}{2}$ RIGHT HAND TWILL



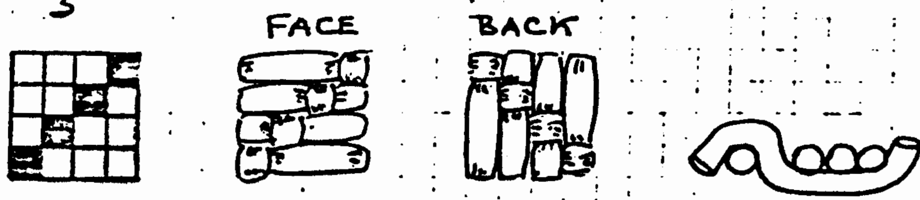


$\frac{3}{1}$ RIGHT HAND TWILL

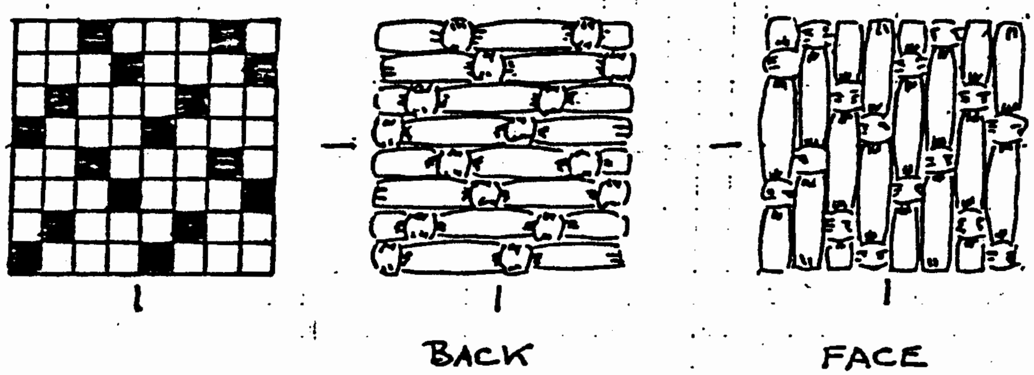


4 HARNESS SATIN – "CROWFOOT"

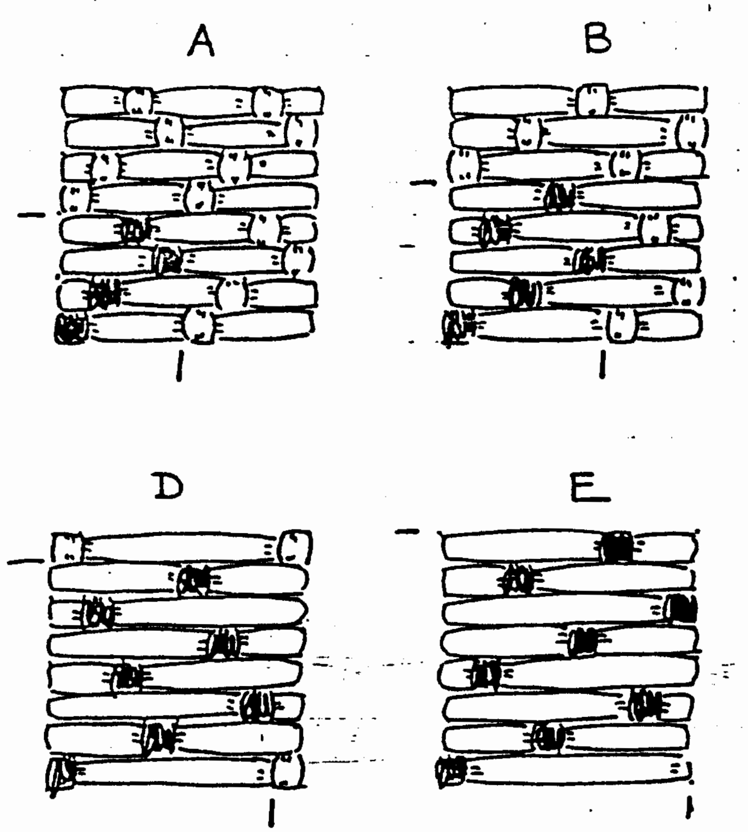
$\frac{1}{3}$ TWILL



4 HARNESS SATIN



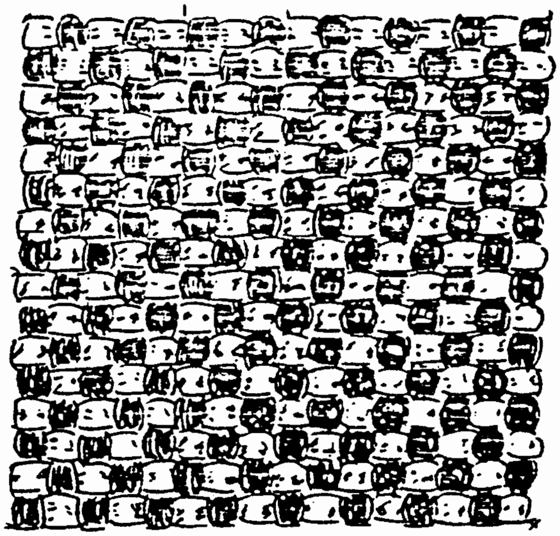
SATINS



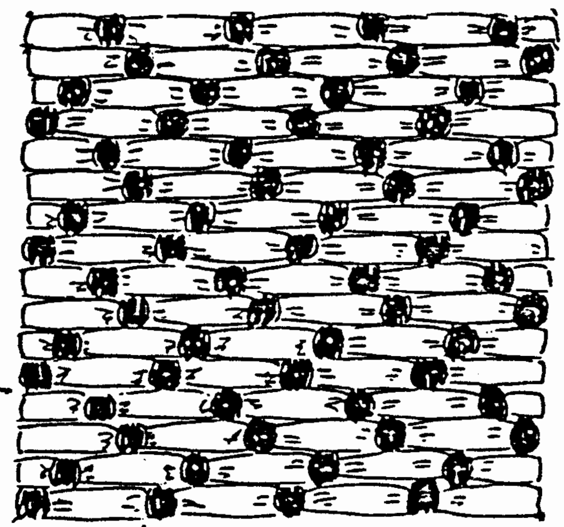
8 ENDS AND 8 PICKS OF :

A	CROWFOOT	16 BINDERS
B	5 HARNESS SATIN	13 BINDERS
C	6 HARNESS SATIN	11 BINDERS
D	7 HARNESS SATIN	10 BINDERS
E	8 HARNESS SATIN	8 BINDERS

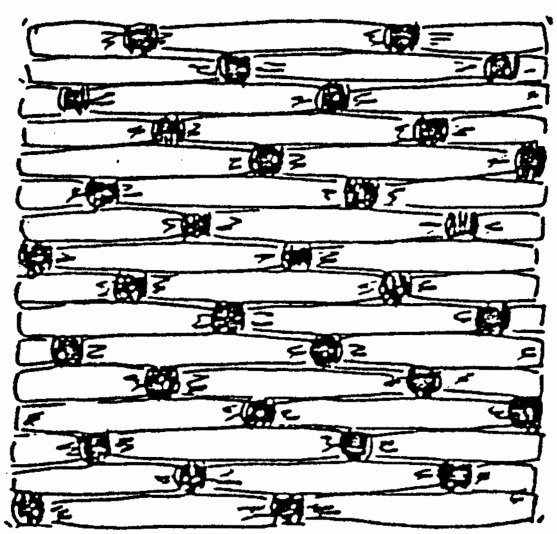
PLAIN

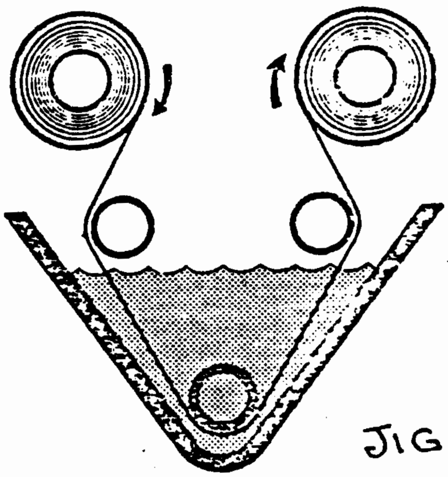


4 HARNESS SATIN

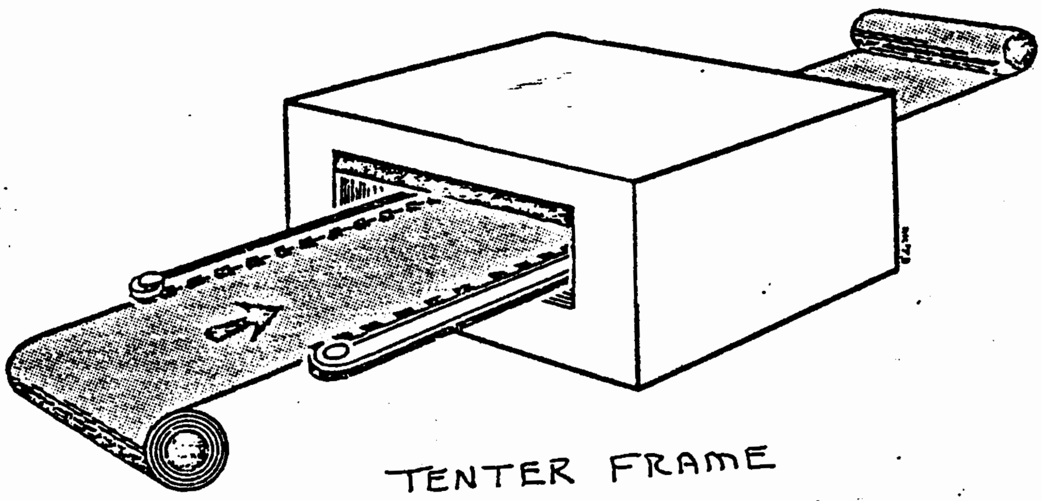


8 HARNESS SATIN

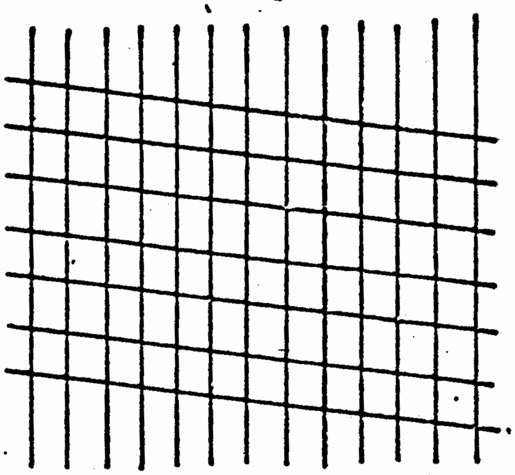




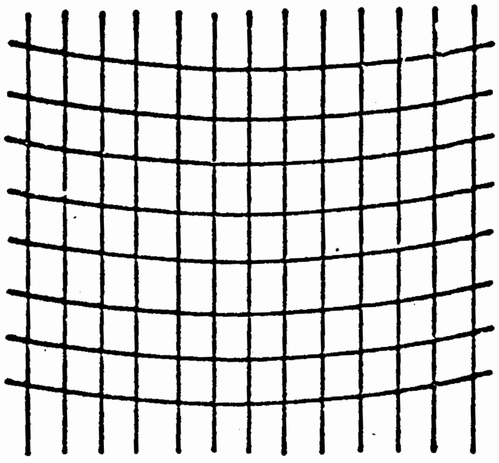
JIG



TENTER FRAME



Skew



Bow

FABRICS OF KEVLAR 29 EVALUATED IN ESCAPE SLIDES

- WARP & FILLING: 200-134-4Z KEVLAR 29
  PLAIN WEAVE
  CONSTRUCTION: 40 x 40
  FABRIC WEIGHT: 2.2 OZ/YD²

  TENSILE STRENGTH: 300 LBS/inch
  TRAP TEAR: ≙ 20 lbs

- WARP & FILLING: 400-267-0 KEVLAR 29
  PLAIN WEAVE
  CONSTRUCTION: 32 x 32
  FABRIC WEIGHT: 3.5 OZ/YD²

  TENSILE STRENGTH: 500 lbs/inch
  TRAP TEAR: ≙ 40 lbs

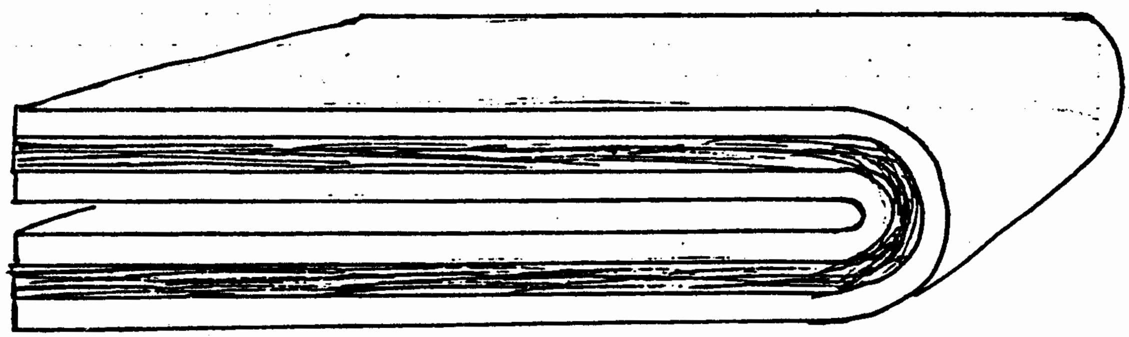
AN EXPERIMENTAL FABRIC WAS TESTED FOR INCREASED TEAR.
WARP & FILLING: 200-134-4Z KEVLAR 29
2x2 BASKET
CONSTRUCTION: 50 x 50
FABRIC WEIGHT: 2.7 OZ/YD².

COATED FABRIC HAD TRAP TEAR OF 30 lbs

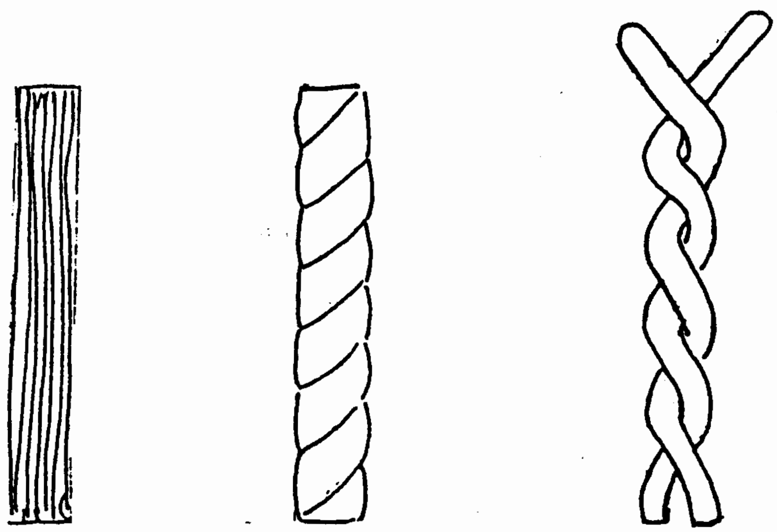
EXPERIMENTAL FABRICS OF 400 DENIER YARNS WERE MADE TO EVALUATE EFFECT ON TEAR OF TWIST.

	ZERO	5 TPI	7 ½ TPI
TRAP TEAR (lbs)	40	65	75

A RIPSTOP WEAVE MADE OF 400 DENIER 5 TPI YARN SHOWED A TRAP TEAR OF > 100 lbs.



COATED FABRIC



NO TWIST TWISTED SINGLE TWO PLY

FACTORS THAT CONTRIBUTE TO FLEX LIFE IN COATED FABRICS:

- ELONGATION OF FIBER
- TIGHTNESS OF WEAVE
- TYPE OF COATING

FACTORS FOR INCREASED TEAR STRENGTH

- FIBER TENACITY
- YARN SIZE
- CONSTRUCTION
- TWIST
- WEAVE

FACTORS FOR IMPROVED FLEX RESISTANCE

- PLIED YARN
- WEAVE
- CONSTRUCTION
- FIBER MODULUS

FACTORS INFLUENCING FABRIC WEIGHT

- YARN SIZE
- CONSTRUCTION

FACTORS FOR TENSILE STRENGTH

- FIBER TENACITY
- YARN SIZE
- CONSTRUCTION

REASSESSMENT OF GIRT STRENGTH REQUIREMENTS FOR SLIDE/RAFT DEVICES

BURT CHESTERFIELD

Chief, Evacuation Research Unit, FAA - CAMI, Oklahoma City, Okl. 13 years experience in Evacuation Research and Escape and Survival. 12 years with the Air Force in Accident Investigation. B.S. M.E. - Montana State University. Registered Professional Engr.

REASSESSMENT OF GIRT STRENGTH REQUIREMENTS FOR SLIDE/RAFT DEVICES

Presented by
Mr. Burt Chesterfield

FAA/CAMI/AAC-119B
Oklahoma City, Okla. 73125

The March 1, 1978, aborted takeoff and fire on Continental Airline's DC-10 at LAX was a classic case of a slide/raft being subjected to use under extreme loading and attitude conditions. The escape device, located at the right aft exit (R4), was positioned at a shallow angle (approximately 27°) which was too steep to be used as a ramp, yet too shallow to provide a rapid flow to the ground.

Passengers on the DC-10 leaving LAX were mostly retirement age tourists. The shallow sliding angle caused evacuees to pile up at the bottom of the slide. As the slide/raft began to sag from the weight at such a shallow angle, it became necessary to scoot or scramble off the device. Passengers were able to jump onto the slide, but apparently could not get off the bottom of the slide as fast as others were entering from the aircraft. Statements from aircraft passenger questionnaires indicated that a number of passengers bailed out over the sponson on the side away from the fire. The slide girt fabric eventually tore laterally from asymmetric overload, dropping the slide/raft to the ground. This "torsional loading" was referred to by the NTSB in their account of the failure of the slide/raft at exit R4.

CAMI's Protection and Survival Lab in Oklahoma City, launched a study into slide/raft girt strength, performance under asymmetric loading and load testing requirements after the DC-10 mishap. The Protection and Survival Lab's Evacuation Research Unit, using 50-pound sandbags, conducted initial proof-load testing on three DC-10 26-foot slide rafts in accordance with TSO C-69 escape slide criteria. Loads on each end of the girt bar were measured by a pair of triaxial load cells mounted near the floor level, Type A exit, in CAMI's Evacuation Simulator. Both horizontal and vertical loads were recorded. Vector analysis provided resultant magnitudes shown in table 1. Loading tests at twice the TSO C-69 criteria were then accomplished with symmetric loading on each sliding lane. No failures occurred with twice-the-current-TSO-criteria loading (six 170-pound passengers per lane or the equivalent of one passenger per lane per second for 6 seconds). In order to insure all sandbags remained on each lane, each slide/raft was positioned at relatively shallow angles of 25° and 30°.

Final testing was conducted to determine ultimate loads and failure modes of girt assemblies at shallow angles. Slide/rafts were loaded asymmetrically by placing sandbags alternately on one lane of the double lane sliding surface and in the adjacent sponson. Total sandbag weights for measured loads are shown at the top of table 1. Of course, not all of the sandbag weight went into the girt. Much of the load was being supported directly by the ground as each slide/raft began to stretch and sag. On each of the three slide/rafts tested, the predominant failure mode was the tearing loose of the stitching on the webbing loops which form the raft quick release feature. Each failure occurred first on the more heavily loaded side of the girt, as was expected. Once failure was initiated, the addition of only two or three more sandbags rendered the device unusable. A simultaneous failure in the form of a 7-foot longitudinal tear in the sliding lane occurred on the third slide/raft. All failures occurred at well above the loads applied for the twice-the-current-TSO-criteria.

The NTSB recommended that the FAA issue an Airworthiness Directive (AD) requiring the strengthening of the girt fabric on this particular slide/raft design. Although an AD was never issued, the manufacturer of the slide/raft has an improved girt kit available for retrofit, and current production slide/rafts receive the new girt. CAMI will conduct additional ultimate load testing of the new girt kit in the same manner as initial production girts were tested.

The NTSB also recommended that TSO C-69 be amended to require critical angle performance testing of escape equipment. Recommendations on performance improvement under shallow angle loading criteria will be offered through the Notice of Proposed Rulemaking (NPRM) activity on C-69A scheduled for early 1981.

Table I. Slide/Raft Girt Strength Tests

(Loads in pounds)

	Existing* TSO Criteria		Twice** TSO Criteria		Asymmetric Loading to Failure		
					Slide/Raft Nr. 1 (prototype)	Slide/Raft Nr. 2	Slide/Raft Nr. 3
	25°	30°	25°	30°	25°	25°	30°
Total Sandbag Weight	1100	1100	2100	2100	2350	3500	3650
Girt, Left Side	345	182	481	593	618	768	770
Girt, Right Side	314	206	490	662	182	539	489

*Actual TSO criteria is 510 pounds/lane or 1020 pounds on both lanes. Sandbags were applied to the next 50 pound increment above the TSO criteria for each lane, thus sandbag weight is shown as 1100 pounds (550 pounds/lane).

**Twice TSO criteria would be 1020 pounds/lane or 2040 pounds total. Sandbag weight for the next higher 50 pound increment was used in each lane, thus sandbag weight is shown as 2100 pounds (1050 pounds/lane).

HEAT RESISTANCE OF ALUMINIZED COATINGS AND ADVANCED MATERIALS

LOUIS BROWN

Project Engineer, Evacuation Slides, FAA-TC.
7 years experience in Fire Safety with
FAA-TC involving Evacuation Slides and
Full-scale Fire Tests on DC-7 Fuselage.
B.S. M.E. Drexel University.

HEAT RESISTANCE OF ALUMINIZED COATINGS AND ADVANCED MATERIALS

BY LOU BROWN - FAA TECHNICAL CENTER

BACKGROUND.

On March 1, 1978, a Continental Airlines DC-10 overran the departure end of runway 6R at Los Angeles International Airport and caught fire following a rejected takeoff. During the emergency evacuation of the aircraft, the slide/rafts were exposed to thermal radiation. The National Transportation Safety Board's (NTSB) report indicated that the slide/raft located at the forward right door "1R" failed, due to radiant heat only and not from direct flame contact.

DISCUSSION.

As a result of this accident, the FAA Technical Center initiated a quick response study to investigate the behavior of slide materials when exposed to radiant heat. A letter report on this study, FAA-NA-78-41-LR, was published in June 1978. The quick-response study, however, did not encompass testing of complete slides. It did give us a clue that aluminized coatings provide improved radiant heat resistance for slide materials.

A comprehensive test program was undertaken in January 1979, to further develop our laboratory test rig into a valid standard test method, to test complete slides exposed to a large fire and examine failure modes, to contract a retrofit study for a reflective coating applied to in-service slides, and to evaluate any new slide materials that become available.

Included in the tables are a photograph of the Lab Test Apparatus, Lab Test Results, Laboratory Repeatability Tests, Fire Pit Diagram, Full-Scale Test Results, and Lab/Full-Scale Test Comparison at 1.5 Btu/ft^2-sec.

CONCLUSIONS.

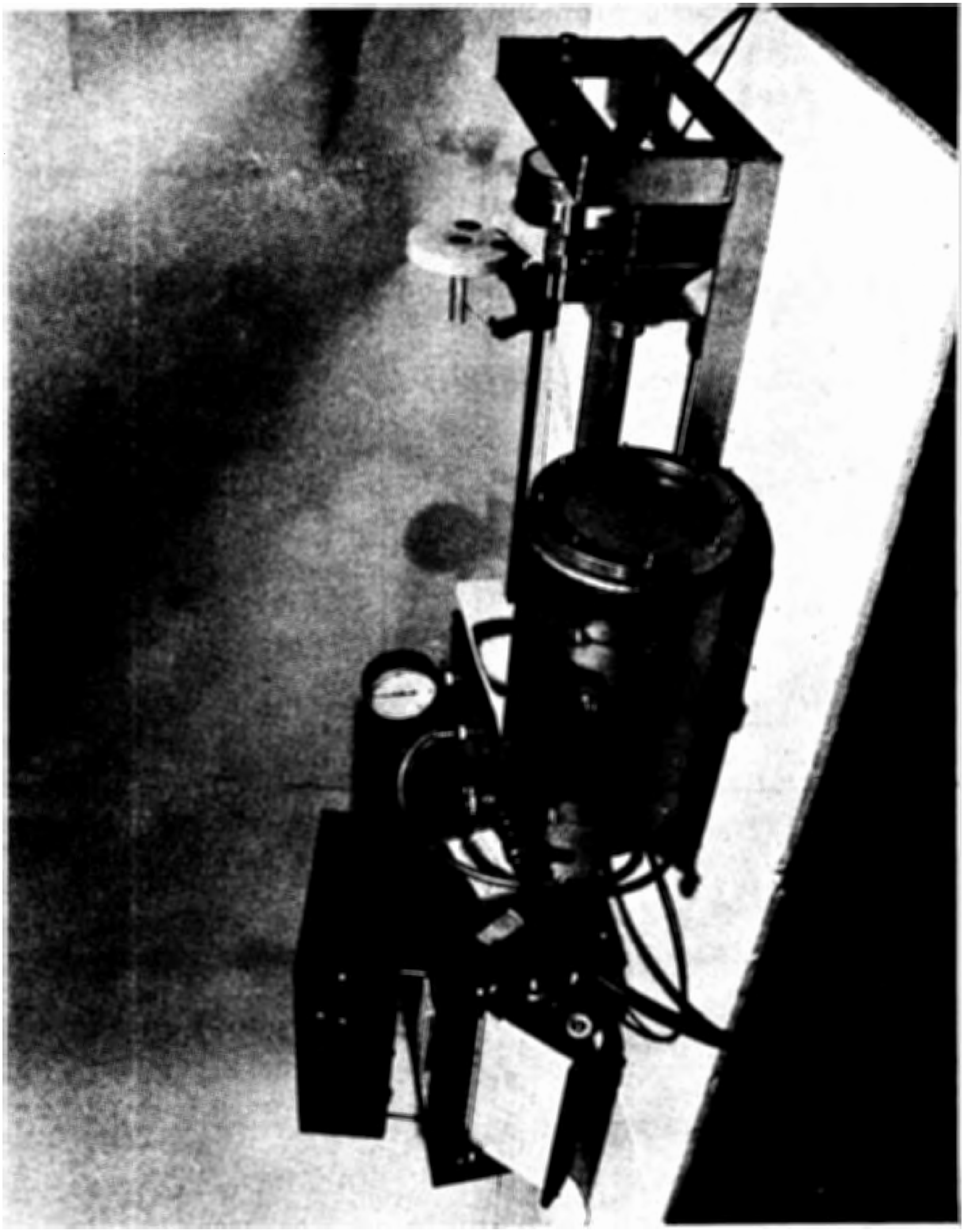
1. In-service slides can fail prematurely when exposed to radiant heat alone (no flame impingement).

2. Aluminized coating significantly improves radiant heat resistance of new and in-service materials.

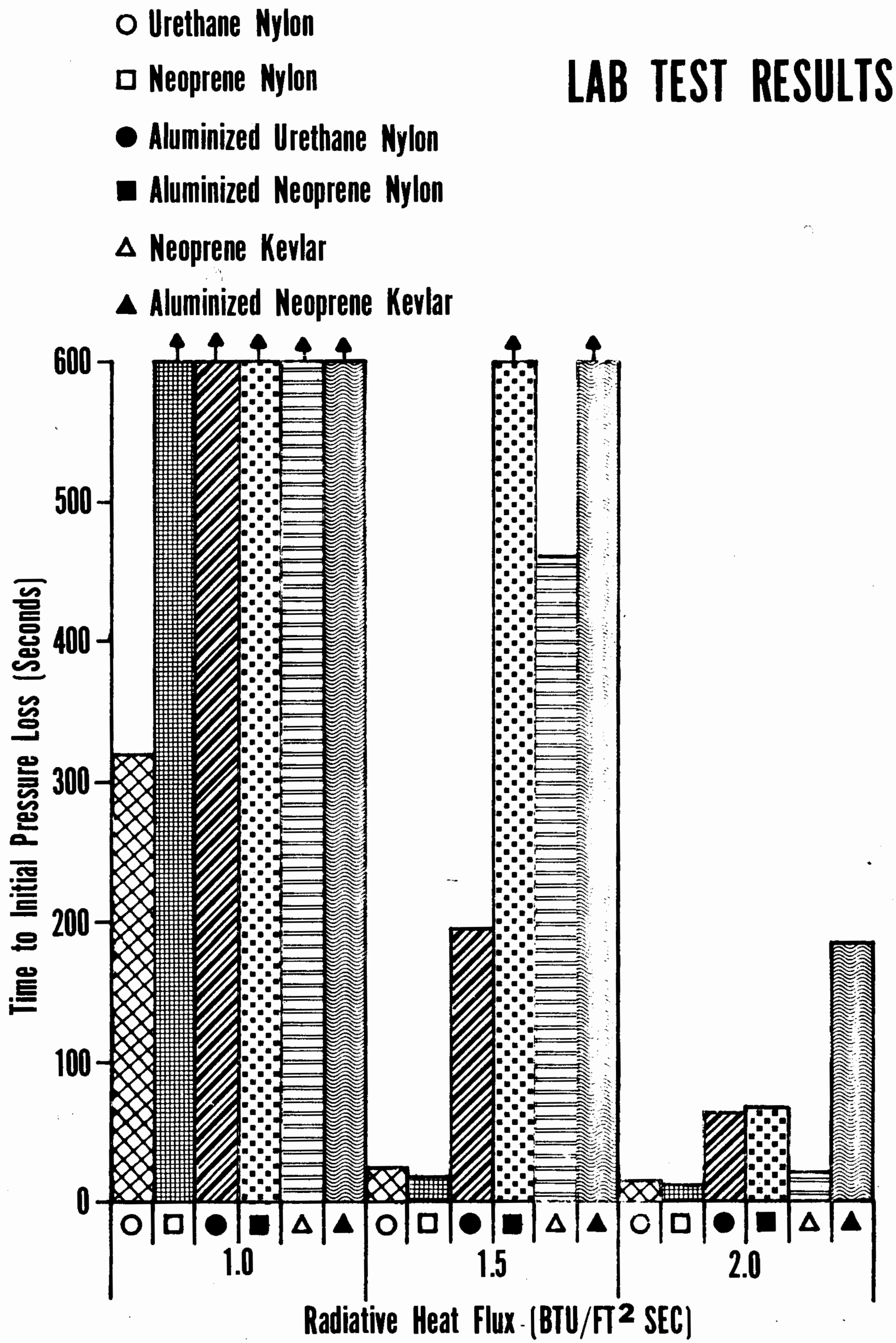
3. New materials exist which are resistant to radiant heat.

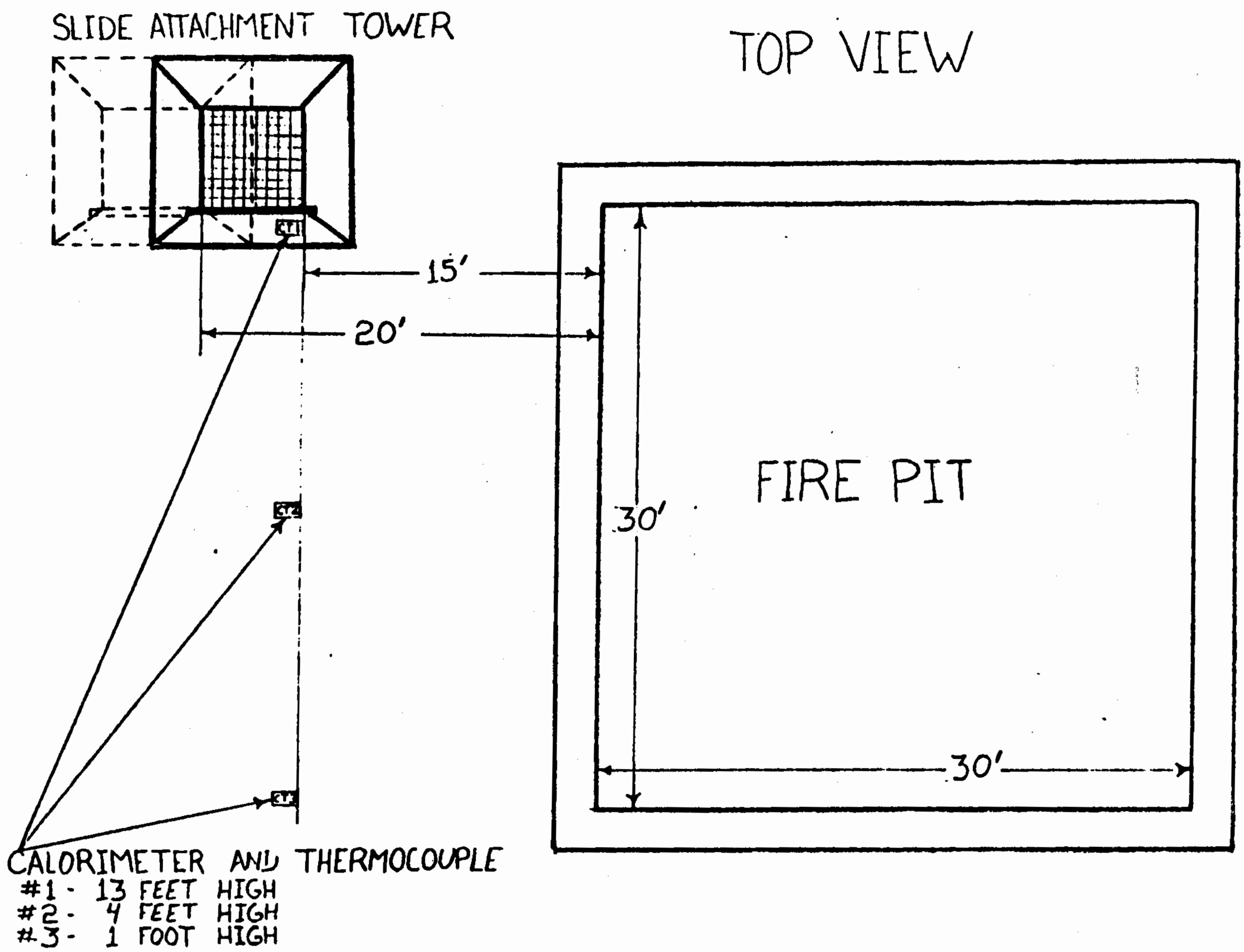
4. Present adhesive fabrication limits potential improvement of new and aluminized materials.

5. Laboratory Test Apparatus is a valid procedure for evaluating slide materials. Correlation was demonstrated with full-scale test results.



LAB TEST RESULTS




SLIDE ATTACHMENT TOWER
TOP VIEW
15'
20'
FIRE PIT
30'
30'
CALORIMETER AND THERMOCOUPLE
#1 - 13 FEET HIGH
#2 - 4 FEET HIGH
#3 - 1 FOOT HIGH

SUMMARY OF FULL–SCALE TEST RESULTS

DISTANCE FROM FIRE (feet)	SLIDE TYPE	AVERAGE HEAT FLUX BTU/FT^2 SEC	TIME (Initial Press. Loss) (sec.)	TIME (Visual Collapse) (sec.)	PLACE OF FAILURE (Seam or Nonseam)
15	URETHANE NYLON	1.5	27	27	NONSEAM
15	ALUMINIZED URETHANE NYLON	1.6	71	75	SEAM
15	ALUMINIZED URETHANE NYLON	2.1	26	32	SEAM
15	NEOPRENE NYLON	1.5	23	23	NONSEAM
15	NEOPRENE KEVLAR	1.77	44	44	SEAM
15	ALUMINIZED NEOPRENE KEVLAR	1.86	68	68	SEAM
20	URETHANE NYLON	1.0	80	110	SEAM
20	NEOPRENE NYLON	1.15	58	58	SEAM
20	ALUMINIZED NEOPRENE NYLON	1.0	100	100	SEAM
25	URETHANE NYLON	0.6	OVER 250	OVER 250	NONE

LAB/FULL—SCALE TEST COMPARISON

1.5 BTU / ft^2—sec.		URETHANE NYLON		NEOPRENE NYLON	
		YELLOW	ALUMINIZED	YELLOW	ALUMINIZED
FULL SCALE	(seconds)	25 — 30	70 — 75	23 — 28	NA
LAB SCALE	SEAM (seconds)	35 — 40	70 — 75	30 — 35	365 — 370
LAB SCALE	NON—SEAM (seconds)	20 — 25	195 — 200	20 — 25	+600

Panel Discussion

Ed Thomas, AGA

I've got sort of a joint question for Henri Branting and Dick Johnson. As I understand it there is going to be a revision to TSC C69 come out within the next couple of months which will cover an addition to slides and slide rafts and I presume it will have some requirements in there on heat resistance. My second part of my question is, directed to Henri, do I understand that early in 1981, there will be a proposed rule coming out to change Part 25 and Part 121, with consideration for retrofit of slides and I guess my question is, does the retrofit aspects, would they say, you have to install slides that meet the new TSO requirements or is there something about improving the heat resistance of existing slides in service or just exactly what is it going to cover and the last part of my question is, your, as I understand it, your asking for time frames and I was wondering whether if you had thoughts, with in the FAA on the time frames that you were talking about.

Dick Johnson

Ed, in response to the first part of your question, the TSO requirements will reflect the self-extinguishing tests on materials, the coating of slides as far as TSO of you are concerned could be considered in future revisions of the standards but as we see it now we just have the 8" per minute burn length.

Henri Branting

Yes, back to the standards for the heat resistance, this would be a change to FAR 25 and 121. We haven't really arrived at a decision on whether the new materials are going to the new slides say for the production airplanes but probably the inservice airplanes would have some sort of treatment for the slides, it wouldn't necessarily, I can't see retrofiting all the slides, installing all new slides on airplanes. I don't think that would be justified by cost. What we are picturing right now is a bonded coating to the slides that are already inservice. How long that would take, I don't know, this is a grace period that we are going to have to come up with. Has this answered your question?

Ed Thomas

I think so. I'll tell you when I see the NPRM's.

Henri Branting

Right, the NPRM that comes in early 1981, probably around March, and it would propose probably the 121 and 25 rule changes, and as I mentioned in the little talk I gave we are going to have to come up with some reasonable grace period to allow the inservice airplanes to be retrofitted. Now this doesn't mean retrofitted with new slides, probably it means that the slides are going to have to be treated some how and we would like as much as possible to fit this, to give the operators a chance to let them apply this coating at their next, whenever they repack the slides and inspect the slides, we don't know just what that is yet.

Ed Thomas

Have you established any requirements for the coating?

Henri Branting

No, this is one of the things, I believe I mentioned this as one of the problems we are going to have to put a little time on, because you can't obviously go out and cut a patch out of a slide and test it. We are going to have to find some way that we know if the slide has been treated with a certain treatment that it will meet the standards that we are looking for. The standards will be based on the tests that the Technical Center has developed. Then we are going to have to find some way to show that an inservice slide meets that test and you can't cut the slide up to do that.

Jack Grant from Quantas

Now treat this with care because I made inquiries many years ago why the aluminized coating was dispensed with and why it wasn't on wide body aircraft slides, and I was told by the airframe manufacturer that if they coated it, it would not fit in the present vessel. So you say you are going to require the airline to paint their slides but that might mean new vessels.

Henri Branting

Well Jack, I guess this is one of the things we are going to have to look at during when we are making the proposal we will see what sort of response we get form the public or from the airlines especially and whatever information we can get between now and March we are going to have to take that into consideration. Right now there is no definite proposal that has been shaped up, right now we are right at the end of the R&D and now we are getting ready to put this into the form of a rule proposal. Some questions like this are going to have to be answered. We don't have the answers yet. I don't see that it will be that difficult but we will just have to get around to it.

My name is Hal Hoder, I represent Chem Tech Rubber and Uretek. I am a manufacturer of the materials that go into the slides and I'm directing my question to Mr. Sims and Mr. Brown, who seem to have done an extensive amount of work related to the application of the aluminum coating on present day fabrics and I think the thing I would like to know is, if you have any data on excessive amounts of aluminum compound applied to it in irrespective of the weight increase. You mentioned something about three quarters of an ounce up to an ounce, have you done any work with two to two and a half ounces per square yard of aluminum pigmentation on top of the coating without taking into consideration the negative aspects of the weight buildup and what has that done for the radiant heat resistance?

Stan Sims

We have run samples and I think I had that in the data yesterday when we were up around two ounces or slightly over two ounces per square year and of course you have a larger heat sink so you have longer failure times but the increase in failure times did not warrant putting that much material on, in other words, the idea is to stay as light as you can and as I said we could increase in sample, laboratory test we could increase the failure time from the base material say two and a half to three times. We may go four times, maybe four and a half times with a real heavy coating but of course you increase the bulk and the weight so there is no reason to put that much on. We did not see any deteriorating effects of the material itself by say adding two more ounces of material.

Hal Hoder

I guess what I'm asking Stan is at the removal rather than increase the overall weight of the material if we would remove some of the undercoating, the standard undercoating as we have now, and replace it with an additional mass of aluminum do you have any thoughts as to whether or not that would be a step in the right direction?

Stan Sims

Yea, right that's the way to go.

Hal Hoder

Okay, thank you.

Sam Hayden of the FAA eastern region and I would like to ask questions concerning where the regulations say or TSO says something about that the color be international orange for high visibility on the rafts? Now, do you coat the whole thing with aluminum coating or do you still retain the high visibility, international orange/yellow on top?

Dick Johnson

This question came up a number of times, it is still being rustled with it gets into the priority which is most important international yellow, to be rescued at sea, or aluminized coating to protect you from a foreign environment but it will be rung out and we will make that decision I think when the rule goes out as a notice and it will be spoken to. It will be spoken to in both the TSO requirements and the rule.

Jack Grant

The canopy is not coated?

Dick Johnson

No, the canopy is not coated.

Jack Grant

Well that's what you see.

Dick Johnson

You only see the canopy if you have bad weather then you put the canopy up, otherwise the canopy is down.

M. Eastburn, American Airlines

I'm concerned about priorities, we've got a product that is an inflatable product that is vulnerable to all kinds of hazards in an accident environment subject to puncture from any different causes, wreckage, heels, stones, pebbles, abrasion on concrete during use, and for Dick Johnson and Henri Branting have you evaluated all the slide failures, the types of failures we've had, where our priorities should be? It seems to me that this is the first slide that we have had in an accident where it's been failed by heat flux. When you look at that one compared to the many many other failures that we have had are we spending our efforts in the right direction?

Henri Branting

In answer to your question, I don't know if any systematic study has been made but I think if you look at the problem with the failure of slides it's going to be a whole lot more serious if there is failure due to fire if you have the fire near the people going inthe slide than if it's punctured by a heel or something like that. If there isn't fire around there you can still use that slide as a hand held slide, right now the fire is what we are looking at. I think that is the biggest threat.

M. Eastburn

If you loose a slide, you loose a slide, regardless of what cause, your diverted from that exit to another exit.

Henri Branting

Yes, what I'm saying is if you fail the slide with people on it because of fire then you could loose people, it wouldn't necessarily be that case if it were punctured by some other; failed for some other reason.

M. Eastburn

Well, as we saw on the DC 10 at Douglas development program when you fail a slide with people in it you can have a serious injuries, there going to be people laying right there below the door sill.

Henri Branting

Well I can't argue with what you are saying yet I think what I'm trying to say is that the fire we consider is the priority mode of failure right now, its the most serious.

M. Eastburn

So then you have not evaluated all the types of failures?

Henri Branting

No, not in this particular incident, no.

M. Eastburn

Question for Jim Summer, Jim if you considered anything in your work on tear progation and ways of preventing it?

Jim Summer

Mack, to me, one of the biggest problems with slides over the years, and this is supposed to be a safety device, is the amount of people that get hurt due to the slide being punctured, years ago it used to be with spiked heels, it can be a cleet on a shoe, something sharp on a belt, and by my recollection from both evacuation demonstrations and actual aircraft accidents, there has probably been 50 to 100 times the amount of people hurt due to damage to the slide, as is done from people getting off the slide and turning an ankle at the bottom and to me the big thing was how do you try to keep that slide so that if it accidently punctured, a little tear in it, so that it doesn't catastrophically deflate. So that was the basic reason why I started to look into Kevlar as the fabric for a slide. If you test a piece of nylon fabric, in fact, I demonstrated this to Boeing when they were coming around on the 757. I asked the engineers, have you ever seen the laboratory tests of the strength, the tear, and the fire, on the materials for which your specifying a value or are you only taking data that your laboratory people give you? They admitted that they had never seen these fabrics being tested. So I said good, come on up to the lab. So I took some nylon, I took both single and double ply nylon, and I had some Kevlar and I took the Kevlar and I ran a grab strength. A grab strength is a four inch wide strip of material about six or eight inches long and you clamp it with a one inch jaw, now the minute you start putting load on the nylon regardless of what is is the sample curls around the jaw, because you are loading not only the one inch under the jaw but your spreading the load out to the edges and when failure goes it doesn't stay exactly under the jaw, it stretches maybe two to two and a half inches wide. So then I tested the Kevlar for them. The tear generally broke directly under the jaw. Then I took and showed them what tear strength was. Ran a strap tear, now if you take the two ply material you get a big jagged failure in the material and the spec says you read the top three or the top five peaks, thats your tear strength, but inbetween that time that the peak occurs it drops down very low. You run the single ply nylon you get a lot of little breaks in it but the curve keeps going down so that if you have a sixteen pound tear on a single ply to start with by the time you go off the end of the material you are down to maybe six or eight pounds. And I showed them on the Kevlar that when you do the same test and it tears if you get enghteen pounds you get eighteen pounds completely across the sample. I said so that if you get a puncture the Kevlar will stand up much better than a nylon will and they said can you demonstrate that and I said sure. So I had a tubular frame that had twisted on me for the 767 and I told the inspector, hey, get that tubular frame bring it up to pressure in this case 3psi, put a boy scout knife on the end of a five or six foot stick, and when it's ready call me. So they did that, and we went down I didn't think anything would happen but to play it safe, I ducked behind the fence, I stood there, you know, and I jabbed when it was at 3 psi. We just heard a little air leak out. The fellows said jab it again. So stood there and I jabbed it another three or four times and the air just slowly leaked out of that frame. So we went over and we checked the lengths of the cuts and the first cut I believe was something over an inch and a half long and the rest of the cuts were 5/8 to 3/4 inches long, you know, I watched what I did then, the first time I didn't. So they they said, hey could you demonstrate that on a nylon, I said yea, I don't have anything in engineering and I walked around the shop and I found a tubular frame that was in the same stage of construction as the one we had just tested. It was for a smaller slide, however, so we checked the diameters, at pressure, and it was a little smaller than what the Kevlar unit was so we agreed to get the same stress center because theoritically were using the same strength materials, grab strength now, and did the same thing. I think we brought that up to about 3 3/16 psi to get equal stresses. I said now stand back and I jabbed that with the pen knife, I didn't quite get the knife all the way into it, it took off and went around the building, the only thing that stopped it from going further was the manometer we had hooked up to it. Now we went back and we measured that and the knife puncture was just about 1/2 inches when it catastrophically failed. And to me, I think the main feature we should be looking at in slides is to try to stop a little puncture, a little tear, from propagating catastrophically and dumping people on the ground and breaking their backs, legs, because once if you have two or three people on that slide and it blows you're sending three people to the hospital. The fact that it works a little better than the nylon in a flame case, forget about the aluminum was just incidental you know. If you run the flame tests, were talking exposed flame now not radiant heat, the requirement is that I think its six inches in a vertical test your allowed to burn. Now if you take any of the neoprene and/or polyurethane coated nylon, and you take the bunsen burner and you put it underneath it there is an inch and a half starting point. You put your flame torch under there, and just like that, you have a big "V" burned out of the material. So when you take the flame away it is already burned out beyond where the flame is by six inches. You check your data, and you are allowed six inches of damage and it is eight inches of damage, but with that initial burning you've burned that material up to six to seven inches. But as long as it didn't pass eight inches you've passed the test. You do the same thing with the Kevlar and all the time the flame test is going on the part that is supposedly burning is right in the flame. When you pull the flame away you have a little area that burned out maybe a 1/2 inch and the original 1 1/2 inch to start it and when you try to tear it apart, your failure is less than one inch. So that you had the double gain, in that case.

Hal Hoder

Jim, was that nylon that you punctured was that two ply or was that single ply?

Jim Summer

That happend to be a two ply and I showed the fellows, now you saw the way that test specimen pulled in the test machine. You examine that failure and see if you can find that saw tooth on that failure. It's just as if you cut it with a knife. So test results they sound good, people that don't know what's happening believe the values that they get, but it's really meaningless.

Henri Branting

I'd like to make a comment on that flame test, the SAFER committee went over this about the materials that melt away from the bunsen burner flame and the ASTM right now is working on this, it would like to somehow change the FAR 25 to correct for this. There are materials that get through just by simply melting away from the flame, we know this. We would like to do something about it.

Ted Eidson, Bell Helicopter

With respect to Jim's comments on the tear propagation, I would like to ask Stan Sims if you have seen any failures of the type that the Kevlars that Jim spoke of?

Stan Sims

As far as tear propagation, there is no doubt that Kevlar does have better resistance, or a good resistance to tear propagation, particularily in inflatables when they are punctured at the same time we have been able to duplicate it with some of our modified nylon fabrics and I think we can prevent catastrophic failure that may have occurred several years ago with the old type nylon fabrics, coated with noeprene or urethane.

Jim Summer

But again, I think they have to consider that the fact that you are trying to get as light a piece of equipment on the aircraft as you can and you may be able to do it with a nylon but it is going to cost you weight, in other words, you may get by with a seven ounce Kevlar with some kind of coating on it, to pass some kind of a puncture test, but to duplicate with a nylon you are going to cost eight or nine ounces. So that its going to cost you maybe fifteen to twenty five percent more weight doing it with nylon than it would do with Kevlar.

Jack Fleischer, Viking Technical Rubber

Jim, I'd like to ask you regarding the results you spoke about yesterday you mentioned the loss regarding tensile strength over a period of flexing but you didn't speak about what happens with tear strength when you starting with presupposing you want to deal with low weight so you are using your two ounce Kevlar and you coat that and you go through your forty flexes then would that two ounces of Kevlar fabric, what happened with your tear which started at the coating perhaps between fifteen and twenty pounds value? Whats going to happen to the tear in that instance?

Jim Summer

We tested that and I don't quite remember the results we got but if my memory serves me correctly at the end of the forty tests that we performed, we still had a higher tear starting with eighteen pounds than what the TSO requires which is thirteen by thirteen pounds.

Jack Fleischer

Yes sir but is that a safe enough value to have in a much more expensive fabric when today you can have nylon constructions that certainly go thirty five to fifty pounds of tear? What you are recommending is taking a big step backwards to end up with something which is just...

Jim Summer

Now, now hold it there Jack, hold it there, you have to consider the materials that slides are being manufactured from now. They are being manufactured to meet the TSO requirements essentially of thirteen by thirteen. Now single ply nylon that people are using gives you a tear strength of sixteen by fourteen. The two ply, you can probably say it's twenty five by twenty five by laboratory testing. So don't go saying it's forty five or fifty. Yes, we can give you one hundred pounds but your not going to do it at the seven or eight pound weight that the present slides are being made from.

Jack Fleisher

Well the TSO requirements of thirteen pounds, if you had such a tear, on the slide path going down, nobody would get out of that aircraft safely. Even the one that was illustrated there on the other side.

Jim Summer

Now, Jack, your talking about the sliding surface, we're talking about the air holding surfaces.

Jack Fleisher

Yes, we are, right.

Jim Summer

Alright, now if you are talking about sliding surfaces that tear strength is a lot higher than the air holding.

Jack Fleischer

Not the requirement.

Jim Summer

The requirement isn't but everybody does use a higher air strength material for the sliding surface.

Jack Fleischer

But the point I'm making again is on the Kevlar you're, I would like to know what kind of tear strength you would get trapazoidal tear strength after you subjected it to forty flexes. I doubt you would want to be very much over that mimumum requirement for tear and if you had a situation where you made a tube fabric out of material like that and something happened to that aircraft, I would not want to be in a product liability situation for something just maybe borderline regarding one of the requirements.

Jim Summer

Jack, forty tests sounds real good, but unless you have the slide going through some kind of a training program, you name one slide that's out on an aircrft that probably during its whole life has more than five inflations on it, and at five inflations you can hardly find any degradation so although we are always talking forty, we are not anywhere near that on production aircraft.

Jack Fleisher

Well everything you say is probably absolutely true but you still cannot bypass the fact that your sitting with requirements that have to be met.

Jim Summer

But again those requirements don't say anything about what the values should be after you have run service life on it, the equivalent of maybe fifteen years?

Jack Fleischer

I presume they still want thirteen pounds.

Jim Summer

That is on initial requirement.

Mel Blahnik, TWA

I'd like to turn our attention back again to the aluminized coating question and the reference to the retrofit and NPRM amendment and put the problem with retrofit in perspective, we had a comment yesterday on how many slides are actually out inservice right now and just quickly putting some numbers together something like ten thousand or fifteen thousand slides that are in-service right now and before the NPRM comes out that would propose such a thing as retrofit I'd only like to suggest that some the problems be explored such as weight addition which is critical on the overhead rising door on an airplane such as the DC-10 or L-1011 plus the impact on the airlines of having to work on so many slides to make a change that would require several number of hours. Some airlines would choose to probably replace their slides. I'm not sure if the industry could provide enough slides to replace so many, if enough operators decide this to replace rather than to put the cost into a retrofit change. It is just something to keep in mind when you talk about an NPRM.

Henri Branting

Alright, you make a good point there and before we go out with the NPRM we probably would like to get together with the airlines and the manufacturers possibly through ATA or some other means and get this information because we do want to know what slides are up against, what the slides are made of, what schedules the operators have to work with, the lead times of the manufacturers; these are a lot of partical questions that will have to be answered before the NPRM goes out at least as much as possible, possibly some of them could be answered after the NPRM goes out but surely before the final rule goes into effect because we don't really want to put anybody into a bind. We do have preliminary cost figures and weight figures on this.

Mel Blahnik

There is a degree of bind that I think should be investigated.

Henri Branting

Well this is the purpose of the NPRM, we will try to find out what the big problems are and then address, at least ask the questions in the NPRM, but we would like to at least pin these problems down before it goes out and what you mentioned are exactly the problems that we are concerned with. We don't have the answers now, we have the results of the R&D. We have what we think are going to be the big problems but must as Ed mentioned awhile ago there are a lot of these things, the information is going to have to come from the operators and the manufacturers and we haven't made that contact yet. We haven't gotten that information yet.

Wayne Howell

Like Henri says we have some preliminary information in our contract with Goodrich we did come up with some of this and maybe it would be worthwile for Stan to relay this to the group right now.

Stan Sims

I don't have that with me but I can find out whoever needs that information and give it to them later.

Wayne Howell

Okay, fine.

Ed Thomas

Henri, you have heard some of the questions that have been brought up here and if you have any questions where you need some information from the airlines, if you will get in touch with me, I will provide that information to you and will also provide some additional questions we think you ought to be looking at but I suggest that this be done before you get to the NPRM's stage because once you get involved in the rule making then you have all the protocol and the legal requirements and all that sort of stuff and we would like to, if you're going to issue an NPRM, it ought to be based on as much advanced information as you can get which we have to provide.

Henri Branting

Okay Ed, we appreciate the cooperation and we'll be in touch.

Ian Goodyear, Douglas Aircraft

I just wanted to make a point, if I may, concerning the recommendations from the SAFER Committee, we didn't believe that there was really enough information available to address the retrofit situation on the aluminized coating logistics and the possibility of, like Mel mentioned, where an airline would probably choose to install new slides.

Henri Branting

I don't follow what you mean in installing the new slides, if the airline chooses to install new slides.

Ian Goodyear

In lieu of removing slides from service probably sending them back to the manufacturer to be sprayed is quite a financial burden on that kind of an exercise.

Henri Branting

I guess that what you're saying is that for retrofit of a slide, then the airline would more or less be forced to send the slide back to the manufacturer for treatment.

Ian Goodyear

I think so in most cases, yes!

Henri Branting

I don't know whether this is true or not. This is one of the problems we are going to have to resolve.

Ian Goodyear

Also, I don't believe it might be a real safe condition to have untrained personnel, lets say, near a slide, the aspirators and valves and inflation systems with a spray gun with aluminum paint in it.

Henri Branting

Well one of the things we will have to do is take a look to see what facilities and the personnel, equipment, the airlines have and can they treat a slide and can the results pass this test. We have got to have possibly a real closely defined process spec or something, something in that order. I wouldn't say right now that you would have to sent it back to the factory, I don't think...

Ian Goodyear

I'm just putting that out for consideration and I think there will be cases where...

Henri Branting

It won't be a simple problem but I don't see anything that can't be solved.

Ian Goodyear

No, I guess that what I'm trying to do is to add to the point that was made that I don't think that we really would like to see an NPRM until there is a lot more data available which tells exactly what's involved with that particular task.

Henri Branting

Okay, you make a good point.

Ian Goodyear

And the other point is, I think, I'm not sure there is information available on the temperature cycling aspects of the long-time folded, packed up of slide sitting on a airplane for maybe three years that's been coated with some of these aluminized paints.

Henri Branting

Incidentally, if anyone has any comments on this and there are an awful lot of good comments coming up right here this morning, you don't have to wait until an NPRM comes out to put these in writing and send these to the FAA. We'd sure would like to hear what these are. We will try to answer as many of these questions as possible before the NPRM goes out. And if we have to do a little more work, well then we can sure do it.

Bob Livesey, Lockheed

I think the tests that Lou ran early this summer indicated that there wasn't a very great improvement with this spray-on type paint on a retrofit basis and I think there was a hesitation on the part of the SAFER Committee to recommend a retrofit program at this time. The big gain was on the mill run materials and the treatment at the mills.

Lou Brown

We have seen on new materials a bigger gain with the aluminum coating, however, we did realize a two-fold improvement over your yellow slide materials which is a hundred percent gain in time and we feel as though each second is crucial in an evacuation. And if you're taking a couple people per slide more, it might be a couple of more lives saved in double the time. We still feel as though it is worthwhile.

Sam Oroshnik, Eastern Aero Marine

In general, the problem with the misdeployment because of strong winds seems secondary in view of the problem of the fires but I'm wondering if some research or some attention is being applied to that particular problem. From the pictures it appears to be one of the more serious ones and I don't know who to address that question to.

Henri Branting

I don't know of any research funded by the government to address that the rules were changed recently to say that in effect you had to have deployment in twenty five knots wind you could use the assistance of one person, which is just the weight of one person, on the slide and I don't know of any plans of the FAA to conduct any more research on that. It's a standing requirement for airplanes now, twenty five knots wind and leaves the burden of compliance up to the manufacturer or the slide producer or both who must meet that requirement.

Ben Werner, Boeing

I think I might comment, the picture we saw of the Pan Am in San Franscisco, I'm not positive but my recollection is that the engines were running when some of those slides were deployed and that's the problem and it was that they did it too quickly and they didn't have the engines shut down so I think the comment from Henri here that the twenty five know requirement for winds at site you can not have the slide deployed in an airplane rolling with the engines running but you should be able to have them deployed in normal winds and any direction.

Bill Bishop, B. F. Goodrich

Could someone tell me more details about how the rule is intended to be written covering the assistance of one person in this wind condition and also whether there is any feeling about how these wind tests are conducted because when you talk about big slides and little slides your talking about needing an anemometer twenty five feet high. The wind around the door and the center of the slide is where the action is. so taking a reading from an airport weather station is not an appropriate way to run a wind test. I would like to know exactly how the rule is intended for a person to assist the slide.

Dick Johnson

The idea of the person assisting and making a slide useable under a wind condition was brought about by the fact in very large slides the slide has a tendency to sail slightly above the ground in many cases and there are those that consider this unuseable. We allow the use of one person to bottom the slide on the ground, the first man out and that is the reference and definition of assistance by one person.

Bill Bishop

So in other words, if I understand it as right, the slide has to deploy into a useable position then to keep it touching the ground, then another person is allowed into the system. Is that correct?

Dick Johnson

That is correct.

Bill Schultz, United Airlines

I guess I have to agree with the other airlines here on the coating of the slides say existing slides, first of all, United has over two thousand of them, and we had taken a look at whether we could do it in house and whether we would have to send them back to the manufacturer. We definitely feel that we have the capability to do it in house, however, because of the size of some of the slides it might require building a new facility. What concerns me some is what I have heard regarding the paint itself and the drying time, curing time of the paint, would hurt us tremendously. It would set the slides away for a day or so until they are cured properly and the other thing that we are concerned about is this serviceability and maintainability of the painted slide. Is there any testing planned or done that would tell us how long a given slide is going to hold up or are we going to have to plan on painting it each time we see it, every six months? I think these things surely ought to be looked at before any NPRM is put out which puts us then in a more defensive position at that time.

Stan Sims

Everything we have done has been accelerated in weatherometer tests and hot air oven aging and we haven't seen change in reflectivity or I can relate it back to the TSO requirement of aging at 158 degrees farenheight in a hot air oven fourteen days, seven days minimum. And when run through about one hundred hours in an Atlas weatherometer we haven't seen any change in reflectivity or radiant heat resistance. Of course, we don't have any actual inservice data that we could relay to you as far as how long the finish is going to last. To say thirty six months...

Bill Schultz

How about on the creasings and the foldings of the pack in the full environment that the pack sees in an airplane?

Stan Sims

We have run tests where the slides have been packed and folded, we have not seen any cracking or deterioration of the coating where it flaked off. Of course, this will depend on the kind of material that's going to be coated, too. If your talking about a ten year old neoprene slide that has a lot of oxidation on the surface that itself is sort of boney and brittle it may be borderline of flammability, We are not going to improve, for example, the flammability properties or the cracking that may occur in a ten or twelve year old neoprene slide. All we have is a coating that we can spray over it right now and I can't tell you how long it will last inservice.

Lou Brown

In relation to the other part of your question about a special facility requirement when we coated our own slides here, we just waited until a calm day and sprayed our slides outside.

Bill Schultz

We can't even paint with polyeurthane paints in the hangar with other people so it has got to be in a paint shop.

Bob Fraebel, Air Cruisers

We do not have any open space, it would have to be in the Lakehurst Blimp

Hangar. We do not have the capability that you do.

Henri Branting

This is an interesting point here, I don't suppose anybody pictures forcing anyone to build a new hangar. On the other hand there is an awful lot of repair work, modification work that is done on the airlines that isn't necessarily done on the premises there. There are other buildings within the radius of your maiatenance base that these could be shipped to, or subcontracted, or somebody like that. There must be somebody that specializes in painting that could handle this job.

Bill Schultz

But then again, that adds so much time to cycling. The only way we could look at this practically is to do it in overhaul cycles.

Henri Branting

Right, that's what we sort of had in mind. Now,if this is running into problems, then we sure would like to know what these problems are, they have to be ironed out somehow.

Bob Freabel

Is there a rule that says that they have to be sprayed? Did you look into a brush coat, overcoat? You'd need a spray booth forty feet long for a DC 10 off-wing (slide). It isn't feasible.

Stan Sims

Well, we didn't spray them in a spraying booth either, we were outside.

Bob Freabel

Did OSHA look into your test set up?

Stan Sims

We didn't spray then in that spray booth, we were outside. It can be brushed on. The only problem is when you...

Bcb Fraebel

My question was can it be brushed on or rolled on?

Stan Sims

Yes, I said. We have brushed it on. The only problem we saw was that you cannot control the thickness as easily with the brush on coating. It picked up a lot more weight. And you turn somebody loose with a four inch paint brush you start to slop it on.

Henri Branting

Do you think this is one of the points we would have have to work on? How you put this on, or that processing you go through to put this on the slide has not been established. Now, there can be any number of processes as long as the end result ends up in a slide material that passes the flame test, and this is, we are going to have to eventually tie it back to the flame test. Take a sample of the material somehow or a similar material and convince ourselves that however you put that on the slide it is going to pass the flame test and you can buy the slide off. Maybe its a roller, maybe its a brush or a spray, I don't know. This is what we are looking for.

Sam Hayden, FAA

Once you get a slide and coat it in the process, I would like to ask the airlines how frequently do they take it out and what do they do from the maintenance stand point? Right now my only thoughts are that the only reason they take them out and deploy them is the replace the survival equipment; they have some kind of a limit on it. If you didn't have to do that would you ever take the slide out?

Bill Schultz, United

Every slide and slide/raft is taken out every three years

Sam Hayden

How about Pan Am?

Pan Am

Forty eight months.

Jack Grant

We're the same, two years.

Sam Hayden

Is that the life of the survival equipment? Two years? Can you replace certain survival equipment without taking the slide apart?

Jack Grant

We can unpack the slides without inflating them.

Sam Hayden

Unpacking them like this, is that where the folding forty times comes in?

Jim Summer

Thats what I said, "our testing might have gone on at forty but if you look at the actual amount of inflations that a slide gets over its life it's probably in the order of four or five.".

Sam Hayden

I have another question, sir, on the turbine type aspirator, who is the manufacturer on that?

Phil Burrough, RFD Inflatables

It is proposed to overspray only the tube part or is the sliding surface also going to be sprayed? In relation to the seam failure of aluminized slides, has any consideration been given to a highly reflective tape to protect seams?

Lou Brown

Okay in answer to your first question, we are not including the sliding surface itself; the actual means of egress for the people. There would, I feel as though there probably would be problems there with changing the sliding characteristics of the slide fabric itself. So we are proposing only the inflatable portion and the option I would say the back side of the sliding surface. It would probably be easier in spraying or brushing the slide to just go right on over the underside of the sliding fabric. It wouldn't change anything. In answer to your second question, we are planning on conducting a feasibility study either on somehow improving radiant heat resistant of the seams or maybe redesigning slides and overtaping of the seams with a highly reflective cover is being considered.

Sam Zinn

In answer to that question on the inflation device, that was Tech Development in Dayton, Ohio.

Sam Hayden

My question was, I think the turbine is running around 34,000 RPM. What I wanted to know was have they determined the tests concerning containment of that so it doesn't fly apart? Looks like its lined up so if it burst it might go towards the airplane where all the people are ready to go out the chute.

Jim Broscoe, B. F. Goodrich Company

The overspeed tests we ran have been at 45 thousand RPM's and what happens is the entire turbine ring expands and binds so that no fragmentation takes place at all.

Fred Jenkins, FAA

Historically our containment tests have been where we cut it down so it doesn't bind up in that manner. We have only weakened the blade so that it would fail anyway. We have not accepted in the past for air conditioning systems expansion of the blades. Apparently this was not tested.

Wayne Howell

Are there any other questions?

G. McKenzie, TWA

I would just like to suggest that before you require retrofitting of slides you should run some tests on actual, typical examples of what we have in operation today. Looking at the production way of doing the recoating process. All the things the airlines would have to do... blocking out certain things we wouldn't want to paint over, creasing and/or pealing, and reflective tests. And secondly, I think Jack touched on it earlier, one of the important things is repacking the slide and determining the slide will repack into the same envelope. We have a very particular requirement for packing the slides to fit the bustles in door installations.

Lou Brown

Yes, we have repacked slides, however, we have not had a slide raft coated and repacked. From the feelings that I get from the industry I think the problem is probably with the slide/rafts; we have a larger volume of material to be packed into the door case. We have sent an aluminized slide up to Air Cruiser and Bob Fraeble could elaborate a little more on that. I don't think they had any difficulty with the slide.

Bob Fraebel

We tried an L-1011 slide and there didn't seem to be any problems.

Jack Grant

I believe its pretty tight on the 747 but I doubt that it'll go in that pack.

M. Blanik

I believe Boeing ran some tests on the 727 slide containers and found space problems.

Wayne Howell

Any other questions?

Simmons, Boeing

I'd like to ask Stan, are there any problems with repairability?

Stan Sims

You can wash the coating off with something like MEK for patching.

Simmons

For John Morton, do I understand from your pitch yesterday, that one of the limiting factors in the type of weaves you would use is the denier of the yarn?

John Morton

Well, in terms of making lighter weight fabrics I'm limited. 200 denier is the lightest denier I have. Well the problem is if I had something like 100 denier or smaller diameter yarns, I could make lighter weight fabrics, but with the size of the yarn I have and the problem of trying to create something that does not distort so that we can give the coater something that is not distorted, the 2.2 ounce in the plain weave is the lightest fabric that we dare work with. If I take "ends" and "picks" out of that to save weight, its going to be very difficult to handle it and it would distort easily.

Simmons

What does it take to get 100 denier yarn?

John Morton

Well, I would like very much to go back and tell my management that there is a potential need for 100 denier yarn in this application because there are several applications that could use the 100 denier and I think I could build a pretty strong case for producing such an item and we are definitely interested in doing it. Now the only problem, I got to warn you this in advance, I have no idea what the cost per pound of the 100 denier would be because the 200 denier is approaching $30 per pound. I don't know if the 100 denier is going to be twice that or not, I just don't know. But it is likely to be certainly a premium. Paul Langston Do you have any comments on that?

Paul Langston

It would be a premium definitely and I'm not sure that the lighter weight fabric is that desirable. I mean we are assuming that it is, but we have no data that says that it is that would make a case for that. But we haven't proved it.

Wayne Howell

We seem to be running out of questions here, I'd like to throw out to the public maybe someone has had experience already. I've been fairly impressed.I'm not trying to sell a material here, but the silicone coated fiberglass and I wonder if anybody in the audience, I know the representative from the company who manufacturers this is not here, if anybody has had any experience with this would like to comment at this time because it shows a significant increase in resistance to heat by using this material as Lou Brown pointed out in his presentation. Has anyone had any experience with this or sees the impracticality of using this type of material?

Hal Hoder

I think you would have a great deal of difficulty with the fiberglass. If your concerned with the loss of tensile strength with Kevlar you are going to magnify that condition many times with the use of fiberglass as far as the tight packing that goes on when you pack a slide. I've taken fiberglass, folded it, and just tapped it and it looses tensile strength. So I think you have some doubts with Kevlar I think you're taking a real risk with the fiberglass in addition to and of course as you said the gentleman who made the silicone glass is not here, you may also run into some flame problems using a silicone on another substrate but again he may know more about that than I do but I think we would be taking a real good chance with fiberglass.

Jack Fleischer, Viking Technical Rubber

I agree with Mr. Hoder because my experience in the past with fiberglass is that you have to be extremely careful in the curing operation. You could fracture the yarn in doing that I think, I don't doubt it probably is the most superior fiber to use in terms of fire. I don't know that you necessarily need silicone; that or neoprene or polyurethane wouldn't do as well as long as the basic fiber is fiberglass but I think you bring into vogue many other problems concerning the packing, pliability of the yarns, and other things, it would have to be studied. It may have great merit but I think it would have to be studied very carefully.

Phil Burrough, RFD Inflatables

I'll go along with Mr. Hoder on the likelihood of problems of fiberglass.

We examined this and found this to be so, though there are certain variants on the forms of fiberglass which have improved this matter. Also, silicone rubber is very good against high temperatures but it can actually burn quite effectively, you get coating, burning off leaving you the fiberglass behind for what its worth. The last point I'd make very stongly is the extreme difficulty fabricating slide inflatables or any other items; say, sticking techniques using silicone rubber. It's a real difficult one to get good adhesion. You have to use special adhesives quite frequently temperature cures or the new techniques used. It's a real difficult problem to get at.

Wayne Howell

Okay. Thank you very much. Are there any other questions? If there aren't any other questions I would like to thank all of you for attending and I would particularly like to thank the panel members here for excellent presentations and I think this is a good example of a good technical exchange between industry and government and I hope all this information will lead to better research for us and better regulatory requirements, so I thank you all for coming.

Evacuation Slide Seminar
Federal Aviation Administration Technical Center
Atlantic City Airport, New Jersey 08405
October 28, 1980

Name	Affiliation
Roger Young	FAA, ANW-212
Steven Nemeth	Boeing
James M. Peterson	Boeing
Everett A. Tustin	Boeing
Peter H. LeVan	BFG
Jim Briscoe	BFG
G. Stan Sims	BFG
Samuel Hayden	FAA, AEA-219
Ted Edison	Bell Helicopter
Jack Grant	Quantas Airways
Brian Stark	DME Corporation
Willian Schultz	United AL
Ian Goodyear	Douglas
Dave Walkinshaw	United Airlines
E. L. Thomas	Air Transport Assoc.
M. W. Eastburn	American Airlines
Samuel Oroshnik	Eastern Aero Marine
James R. Summer	Eastern Aero Marine
R. S. Schultz	Pan AM
R. L. Braster	Pan AM
David Bentley	SAE
Jane Searle	Association of Flight Attendants
Mel Blahnik	TWA
Lou Tournoy	TWA
Gordon W. McKenzie	TWA
Ben F. Werner	Boeing
Burt Chesterfield	FAA
Phil Burrough	RFD Inflatables
John Holt	Sargent Ind., Pico Division
Jack Fleischer	Viking Tech. Rubber Inc.
Clarence Melander	Sargent Ind., Pico Division
Tom Olsen	Otto Fab. Inc.
Bob Livesey	Lockheed
Robert Graham	Tech Development Inc.
E. C. Schmidt	Talley Ind.
Gale Braden	NTSB
H. J. Morton	DuPont Co.
J. C. Simmons	Boeing
W. M. Bishop	B. F. Goodrich
D. S. Harris	Boeing
Ed Paige	Boeing
Frank Traeger	Boeing
Skip Wallawine	Boeing
Kathy Reirre	FAA/AAM-510, Washington, DC

A. F. Torne	FAA/AAM-510
R. Berg	FAA/ACDO-31
G. Rugulo	FAA/ADCO-31
Robert Fraebel	Air Cruisers
Ralph Miller	Air Cruisers
Earl Day	Air Cruisers
Fred Jenkins	FAA/AWE-130
Joe Starkel	FAA/ANW-212
Lou Brown	FAA/ACT-350
Hal Hoder	Chem Tech Rubber
John Andrews	Uretek Inc.
Nelson Miller	FAA/ACT-4A
Steve Van Note	FAA/ACT-4A
Sam Zinn	FAA/ACT-350
Wayne Howell	FAA/ACT-350
Paul Langston	DuPont
Dr. Roy Reichenbach	FAA/ACT-300
Tom Edwards	FAA/ACT-301
Sharon Barthelmess	FAA/ASF-300