U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: MEASUREMENT, CONSTRUCTION, AND MAINTENANCE OF SKID-RESISTANT AIRPORT PAVEMENT SURFACES

Date: 3/18/97
Initiated by: AAS-100

AC No: 150/5320-12C
Change:

1. PURPOSE. This advisory circular (AC) contains guidelines and procedures for the design and construction of skid-resistant pavement, pavement evaluation with friction measuring equipment, and maintenance of high skid-resistant pavements.

2. CANCELLATION. AC 150/5320-12B, *Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces,* dated November 12, 1991, is canceled.

3. RELATED READING MATERIAL. Appendix 2 contains a listing of documents containing supplemental material relating to the subject. Information on ordering these documents is also provided.

4. APPLICATION. The guidelines and standards contained herein are recommended by the Federal Aviation Administration (FAA) for applications involving runway friction measurement, construction, and maintenance. For airport projects funded under Federal grant assistance programs, the standards identified by **BOLDFACE CAPITALS** in chapter 2, section 4, paragraphs 2-21 and 2-22 and those in appendix 3 are mandatory.

5. BACKGROUND. With the introduction of turbojet aircraft, braking performance on pavement surfaces has become more critical. Under certain conditions, hydroplaning or unacceptable loss of traction can occur, resulting in poor braking performance and possible loss of directional control. To address this concern, a number of research projects were conducted by the National Aeronautics and Space Administration (NASA), FAA, United States Air Force (USAF), and various foreign governments. These efforts concentrated in two major areas: (a) high skid-resistant pavement surface design and evaluation and (b) application of proper maintenance techniques and procedures. In this circular, guidelines are provided to airport operators on how to locate and restore areas on the pavement surface where friction has deteriorated below acceptable levels for aircraft braking performance. The material contained in this circular summarizes the findings of these research efforts.

6. METRIC UNITS. To promote an orderly transition to metric (SI) units, this circular contains both English and metric dimensions. The metric conversions may not be exact equivalents and, until there is an official changeover to the metric system, the English dimensions will govern.

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CHAPTER 1. OVERVIEW

1-1. PURPOSE. This AC provides guidelines for designing, constructing, and maintaining skid-resistant airport pavement surfaces and for conducting evaluations and surveys of runway friction for pavement maintenance purposes. It also contains performance specifications for friction measuring equipment. Guidance on pavement friction measurement for aircraft operational purposes during winter weather and performance standards for decelerometers are found in AC 150/5200-30, *Airport Winter Safety and Operations*.

1-2. BACKGROUND. Since the advent of turbojet aircraft with their greater weight and high landing speeds, braking performance on runway surfaces, particularly when wet, has become a significant safety consideration. A number of research programs by FAA, NASA, and USAF, as well as those performed by foreign governments, have been directed in two major areas: original pavement surface design to maximize skid-resistance with proper materials and construction techniques and effective evaluation and maintenance techniques to detect deterioration of skid-resistance and to restore it to acceptable levels.

1-3. PAVEMENT DESIGN RESEARCH. Pavement grooving was the first major step in achieving safer pavement surfaces for aircraft operations in wet weather conditions. These studies were completed by NASA at the Langley Research Center, Langley, Virginia, in 1968. The FAA, through its Technical Center in Atlantic City, New Jersey, directed a test program on pavement surface treatments at the Naval Air Engineering Center, Lakehurst, New Jersey. The study was completed in 1983. Both the NASA Langley and the FAA Technical Center studies showed that a high level of friction could be achieved on wet pavement by forming or cutting closely spaced transverse grooves on the runway surface, which would allow rain water to escape from beneath tires of landing aircraft. Other research conducted both in the United Kingdom and the United States determined that an open graded, thin hot-mix asphalt (HMA) surface course called "porous friction course" (PFC) also could achieve good results. This permits rain water to permeate through the course and drain off transversely to the side of the runway, preventing water buildup on the surface and creating a relatively dry pavement condition during rainfall. The FAA Technical Center study demonstrated that a high level of friction was maintained on PFC overlays for the entire runway length.

In addition, a number of studies were carried out, and are continuing, on basic skid-resistant behaviors of pavement surfaces, both HMA and Portland cement concrete (PCC). These have led to other noteworthy surface treatments that improve pavement surface texture such as asphaltic chip and aggregate slurry seals. For concrete pavements, wire combing the surface, while the concrete is still in the plastic condition, notably improves pavement surface texture.

1-4. PAVEMENT MAINTENANCE AND EVALUATION RESEARCH. Regardless of pavement type or surface treatment, runway friction characteristics will change over time depending on type and frequency of aircraft activity, weather, environmental issues, and other factors. In addition to ordinary mechanical wear and tear from aircraft tires, contaminants can collect on runway pavement surfaces to decrease their friction properties. Contaminants such as rubber deposits, dust particles, jet fuel, oil spillage, water, snow, ice, and slush all cause friction loss on runway pavement surfaces. Rubber deposits occur in the touchdown areas on runways and can be quite extensive. Heavy rubber deposits can completely cover the pavement surface texture thereby causing loss of aircraft braking capability and directional control when runways are wet.

In October 1978, the FAA embarked on a 2-year program to conduct friction and pavement evaluation surveys at 268 airports (491 runways) within the contiguous United States. The information obtained represented a very broad collection of data on the friction characteristics of runways at airports that have turbojet aircraft operations. Field observations of the runway pavement surface conditions and analysis of the friction test data identified those areas on the runway pavement which were below the minimum acceptable friction level. Test data and surface condition information obtained during this program were given to airport owners so that they could take proper corrective measures to eliminate runway pavement deficiencies.

1-5. FRICTION MEASURING EQUIPMENT RESEARCH. Beginning in the early 1970's, NASA, FAA, and USAF conducted runway traction studies to determine the correlation between various types of aircraft and friction measuring equipment. These studies showed a fair correlation between some of the friction measuring devices, but the tests on correlation between the friction devices and aircraft were inconclusive. The tests did show, however, that friction measuring devices were effective when used to evaluate pavement surface friction properties for engineering and maintenance purposes.

In March of 1990, FAA concluded a test program to evaluate the performance of different tires on approved friction measuring devices and to develop correlation data in order to ensure that devices of different manufacture and design would give comparable results in field use. Appendix 1 summarizes research on qualification and correlation of friction measuring equipment.

1-6. ADDITIONAL BACKGROUND AND INFORMATION. Appendix 2 contains a list of pertinent reading material on design and evaluation of skid-resistant pavements.

CHAPTER 2. DESIGN AND CONSTRUCTION OF SKID-RESISTANT PAVEMENT

Section 1. Basic Design Considerations

2-1. GENERAL. In building new runways, major reconstruction, or adding overlays, the design engineer must choose either HMA or PCC as the basic paving component. The selection is usually based on economics, local preference, and other design factors. These considerations, as well as basic pavement structural design, are covered in AC 150/5320-6, *Airport Pavement Design and Evaluation*. This chapter is limited to discussion only of the surface of the airport pavement, literally "where the rubber meets the runway." All of the techniques discussed in this chapter may be applied during original construction (or reconstruction), and some may be applied to existing pavement to restore or create good friction characteristics.

2-2. SURFACE TEXTURE AND DRAINAGE. In discussing the effects of pavement texture on friction and hydroplaning, two terms commonly used to describe the pavement surface are microtexture and macrotexture. Microtexture refers to the fine scale roughness contributed by small individual aggregate particles on pavement surfaces which are not readily discernible to the eye but are apparent to the touch, i.e., the feel of fine sandpaper. Macrotexture refers to visible roughness of the pavement surface as a whole. Microtexture provides frictional properties for aircraft operating at low speeds and macrotexture provides frictional properties for aircraft operating at high speeds. Together they provide adequate frictional properties for aircraft throughout their landing/takeoff speed range.

The primary function of macrotexture is to provide paths for water to escape from beneath the aircraft tires. This drainage property becomes more important as the aircraft speed increases, tire tread depth decreases, and water depth increases. All three of these factors contribute to hydroplaning. Good microtexture provides a degree of "sharpness" necessary for the tire to break through the residual water film that remains after the bulk water has run off. Both properties are essential in providing skid-resistant pavement surfaces.

Textural appearances, however, can be deceiving. A rough looking surface could provide adequate drainage channels for the water to escape, but the fine aggregate in the pavement may consist of rounded or uncrushed mineral grains that are subject to polishing by traffic, thereby causing the pavement surface to become slippery when wet. Likewise, a less rough looking surface, that may even have a shiny appearance when wet, will not necessarily be slippery if it has good microtextural properties.

All paving should, of course, be constructed with appropriate transverse slope for basic drainage and must have adequate provision for prompt removal of storm runoff. AC 150/5300-13, *Airport Design*, provides guidance in this area.

2-3. PAINTED AREAS ON PAVEMENT SURFACES. Painted areas of wet runway pavement surfaces can be very slippery. In addition, an aircraft with one main gear on a painted surface, and the other on an unpainted surface, may experience differential braking. It is important to keep the skid-resistance properties of painted surfaces as close to that of unpainted surfaces as possible. Usually this means adding a small amount of silica sand to the paint mix to increase the friction properties of the painted surface. Glass beads, while used primarily to increase conspicuity of markings, have been shown to increase friction levels, also.

Section 2. Hot-Mix Asphalt (HMA) Pavement

2-4. CONSTRUCTION TECHNIQUES FOR HMA PAVEMENT. The surface texture of newly constructed HMA pavements is usually quite smooth. This is due to the rolling done during construction to achieve the required compaction and density. Nevertheless, several methods are available to improve surface texture and friction in HMA pavements. These include proper mix design and the use of PFCs, chip seals, and aggregate slurry seals. Saw cut grooves made after final compaction are highly effective. This chapter gives guidance for providing these surface treatments. The construction specification for HMA pavement is contained in AC 150/5370-10, *Standards for Specifying Construction of Airports*.

2-5. HMA PAVEMENT MIXTURES. Several factors concern the pavement designer in selecting the appropriate design mix. These factors include the blending of aggregate sources, aggregate size and gradation, the relationship between aggregates and binder, and the construction methods to obtain the required surface properties which meet all other requirements.

a. Blending Aggregates. When superior quality aggregates are in limited supply or processing costs are prohibitive, natural aggregates can be combined with synthetic aggregates.

b. Aggregate Size and Gradation. The maximum size aggregate, as well as the mix gradation, may be varied by the pavement designer to produce the desired surface texture and strength. For HMA pavement, the size and properties of the coarse aggregate are critical for good macrotexture. Generally, the larger size aggregates in HMA pavement mixtures provide greater skid-resistance than the smaller ones.

c. Aggregate Characteristics. After size and gradation, the most frequently considered characteristics for skid-resistant aggregates are resistance to polish and wear, texture, and shape of particles.

(1) Resistance to Polish and Wear. The ability of an aggregate to resist the polish and wear action of aircraft traffic has long been recognized as the most important characteristic. Certain aggregates in pavements are more susceptible to wear and polish effects than others, becoming extremely slippery when wet. The presence of coarse grain sizes and gross differences in grain hardness appear to combine and lead to differential wear and breaking off of grains resulting in a constantly renewed abrasive surface. Rocks high in silica content are the most satisfactory performers. Generally, high carbonate rocks are poor performers. Rocks that are generally acceptable are unweathered crushed quartzite, quartz diorite, granodiorite, and granite.

(**2) Texture.** The surface textures of individual aggregates are governed by the size of the individual mineral grains and the matrix in which they are cemented. For an aggregate to exhibit satisfactory skid-resistant properties, it should contain at least two mineral constituents of different hardness cemented in a matrix that will wear differentially, thus continually exposing new surfaces.

(**3) Shape.** The shape of an aggregate particle, which is determined by crushing, significantly affects its skid-resistant properties. Aggregate shape depends on many of the same factors that influence texture. The angularity of an aggregate contributes to its skid-resistant quality. Flat, elongated particles are poor performers.

d. Asphalt Cement. The characteristics and percentages of the asphalt cement used should be in accordance with standard HMA pavement design practice.

2-6. PFC. One method used to improve runway pavement skid-resistance and mitigate hydroplaning is a thin HMA surface course overlay that ranges from 3/4 inch to 1-1/2 inches (25 mm to 40 mm) thick, characterized by its open graded matrix.

a. Pavement Suitability for PFC. Prior to constructing this type of surface course, the existing pavement surface should be evaluated to determine its structural integrity. Strengthening of the existing pavement, if needed, should be accomplished before laying the PFC. Also, the pavement should be in good condition; that is, it should have proper longitudinal and transverse grades and a watertight surface that is free of major cracks, significant depressions, or any other surface irregularities. For minor cracks, normal maintenance procedures should be followed as given in AC 150/5380-6, *Guidelines and Procedures for Maintenance of Airport Pavements*. If there are rubber deposits on the runway pavement surface, these areas should be cleaned prior to constructing the PFC overlay. The PFC should be constructed only on HMA pavements. It has been shown that a longer life, as well as better adhesion and bond, can be achieved by adding rubber particles during the preparation of the mix. The specification for the PFC is given in AC 150/5370-10. Figure 2-1 shows an edge view of a typical PFC overlay.

b. Restrictions to PFC Construction. On PFC constructed runway surfaces that have high aircraft traffic operations, rubber accumulation can become a serious problem if not closely monitored. If the rubber deposits are not removed before they completely cover the pavement surface and plug up the void spaces in the matrix of the overlay, water can no longer drain internally through the structure of the overlay. When this condition occurs, it is impossible to remove the rubber deposits without causing serious damage to the structural integrity of the overlay. Therefore, the FAA recommends that PFC overlays not be constructed on airport runways that have high aircraft traffic operations (over 91 turbojet arrivals per day per runway end).

2-7. CHIP SEAL. Temporary improvement of surface friction can be achieved by constructing a chip seal. Latex added to the chip seal extends its life and provides better bond and adhesion to the existing pavement surface. A fog seal added on top of the chip seal will help minimize loose chips and prevent aircraft damage.

2-8. AGGREGATE SLURRY SEAL. Temporary improvement of skid-resistance for pavement surfaces can be gained by constructing an aggregate slurry seal, either gradation type II or type III, as given in the specification in AC 150/5370-10. Aggregate slurry seats are recommended only as an interim measure until an overlay is constructed. This type of construction is usually adequate for 2 to 5 years. Figure 2-2 shows a typical type II aggregate slurry seal. Experience has shown that slurry seals do not hold up well in cold climates where snow removal occurs. A life cycle cost analysis should be conducted to determine the long term benefits.

Section 3. Portland Cement Concrete (PCC) Pavement

2-9. CONSTRUCTION TECHNIQUES FOR PCC PAVEMENT. Several methods are available to the paving contractor for constructing skid-resistant PCC pavement surfaces. When PCC pavement is still in the plastic condition, it is strongly recommended that some type of textural finish be constructed in the pavement surface prior to grooving. Such texturing can be accomplished by using either a brush or broom finish or a heavy burlap drag finish. Wire combed or wire tined construction provides an excellent textural finish to the surface. Also, plastic grooves can be constructed in the pavement before it has hardened. For PCC pavements that have hardened, grooves can be saw cut in the pavement. The textural and grooving construction techniques are briefly described in the following paragraphs. The basic construction specifications for PCC pavement are given in AC 150/5370-10. Quality concrete is a prerequisite to the retention of pavement skid-resistance. The physical properties of the fine aggregates and effectiveness of curing are important factors in improving wear resistance.

2-10. TIMING AND CURING. Timing in applying the curing compound is as important as timing the final finishing operations to assure long lasting, nonskid pavement surface texture. The timing of the texturing operation is critical because PCC pavements rarely lose surface moisture evenly or set at a uniform rate, especially during warm weather paving operations. The best time to texture a PCC pavement during construction is when the water spots have dried enough to reasonably hold the texture but before the drier spots have dried too much to texture at all. This is one of the toughest decisions for the paving contractor. After texturing of the pavement surface has been completed, immediate application of the curing compound assures that the pavement surface will not lose water and cure too rapidly. If the pavement cures too quickly, the ridges of mortar left by the finishing technique will not set properly and their durability will be greatly reduced, resulting in a faster rate of diminishing skid-resistance. Therefore, extreme care must be taken in this process to assure an effective cure.

2-11. BRUSH OR BROOM FINISH. If the pavement surface texture is to be a type of brush or broom finish, it should be applied when the water sheen has practically disappeared. The equipment should operate transversely across the pavement surface, providing corrugations that are uniform in appearance and approximately 1/16 inch (1-1/2 mm) deep. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. Any imperfections resulting from the texturing operation should be corrected immediately after application before the concrete becomes too stiff to work. Figure 2-3 shows the texture formed by the broom finish.

2-12. BURLAP DRAG FINISH. Burlap used to texture the pavement surface should be at least 15 ounces/square yard (355 gm/square m). To produce a rough textured surface, the transverse threads of the burlap should be removed from approximately 1 foot (0.3 m) of the trailing edge and grout should be allowed to accumulate and harden on the trailing burlap threads. A heavy buildup of grout on the burlap threads produces the desired wide sweeping longitudinal striations on the pavement surface. The aggregate particles form the corrugations which should be uniform in appearance and approximately 1/16 inch

(1-1/2 mm) deep. A runway pavement constructed with a burlap drag finish is shown in Figure 2-4.

2-13. WIRE COMBING. The wire comb technique uses rigid steel wires to form a deep texture in the plastic concrete pavement. An excellent example of this method is the runway constructed at Patrick Henry Airport in Virginia, where the spacing of the ridges is approximately 1/2 inch (13 mm) center to center (see Figure 2-5). The spring steel wires which were used had an exposed length of 4 inches (100 mm), thickness of 0.03 inch (0.7 mm), and width of 0.08 inch (2 mm). The wire comb equipment should provide grooves that are approximately 1/8 inch x 1/8 inch (3 mm x 3 mm) spaced 1/2 inch (13 mm) center to center. It is not necessary to provide preliminary texturing before constructing the wire comb texture. Because of the closeness of the spaced grooves, the preliminary texturing of the remaining land areas would not be effective. The wire comb technique should be constructed over the full pavement width. **This technique is not to be confused with saw cut or plastic grooved runway pavements**. Wire combing is a texturing technique and cannot be substituted for saw cut or plastic grooves because it does not prevent aircraft from hydroplaning.

2-14. WIRE TINING. Flexible steel wires are used to form deep texture in the plastic concrete pavement. The flexible steel bands are 5 inches (125 mm) long, approximately 1/4 inch (6 mm) wide, and spaced 1/2 inch (13 mm) apart. The appearance of this technique is quite similar to the wire comb method. **This technique is not to be confused with saw cut or plastic grooved runway pavements.** Wire tining is a texturing technique and cannot be substituted for saw cut or plastic grooved because it does not prevent aircraft from hydroplaning.

Section 4. Runway Grooving

2-15. GENERAL GROOVING TECHNIQUES. Cutting or forming grooves in existing or new pavement is a proven and effective technique for providing skid-resistance and prevention of hydroplaning during wet weather. In existing pavement (both HMA and PCC), grooves must be saw cut; in new PCC pavement, grooves may be formed while the concrete is still plastic. Grooves in HMA pavement must be saw cut whether new or existing pavement is to be treated.

2-16. DETERMINING NEED FOR GROOVING. Grooving of all runways, serving or expected to serve turbojet aircraft, is considered high priority safety work and should be accomplished during initial construction. Such existing runways without grooving should be programmed as soon as practicable. For other runways, the following factors should be considered:

a. Historical review of aircraft accidents and incidents related to hydroplaning at the airport.

b. Wetness frequency (review of annual rainfall rates and intensity).

c. Transverse and longitudinal grades, flat areas, depressions, mounds, or any other surface abnormalities that may impede water runoff.

d. Surface texture quality as to slipperiness under dry or wet conditions. Polishing of aggregate, improper seat coating, inadequate micro-macrotexture, and contaminant buildup are some examples of conditions that may cause the loss of surface friction.

e. Terrain limitations such as dropoffs at the ends of the runway safety areas.

f. Adequacy of number and length of available runways.

g. Crosswind effects, particularly when low friction factors prevail at the airport.

h. The strength and condition of the runway pavements at the facility.

2-17. SUITABILITY OF EXISTING PAVEMENTS FOR GROOVING. Existing pavements may have surfaces that are not suitable for sawing grooves. A survey should be conducted to determine if an overlay or rehabilitation of the pavement surface is required before grooving.

a. Reconnaissance. A thorough survey should be made of the entire width and length of the runway. Bumps, depressed areas, bad or faulted joints, and badly cracked and/or spalled areas in the pavement should not be grooved until such areas are adequately repaired or replaced. To verify the structural condition of the pavement, tests should be taken in support of the visual observations.

b. Tests. The strength and condition of the runway pavement should be evaluated and tested according to the procedures specified in ACs 150/5320-6 and 150/5370-10. Future aircraft loads and activity levels should be considered when making the evaluation. Core samples should be taken in HMA pavement to determine stability. The American Society for Testing and Materials (ASTM) Standard D 1559, *Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus*, provides methods for testing the resistance to plastic flow of HMA pavements. Engineering judgment should be exercised when employing these methods in determining the stability readings. These tests are recommended to be used for guidance only. Other factors should be considered in determining how long grooves will remain effective in HMA pavements, such as maximum operational pavement surface temperature, effective tire pressure, frequency of braking action in given areas, mix composition, and aggregate properties. If, in the judgment of the person evaluating the existing pavement, any of the above conditions are not met, the pavement should not be grooved.

2-18. OVERLAYS. If the evaluation shows that the existing pavement is not suitable either because of surface defects or from a strength standpoint, an overlay, flexible or rigid, will be required. The new overlay may then be grooved according to the instructions given in the following paragraphs:

2-19. HMA PAVEMENT GROOVING. Construction specifications for grooving are given in paragraph 2-21. Grooving should not commence until the HMA pavement has sufficiently cured to prevent displacement of the aggregate (usually 30 days). Figure 2-6 shows a saw-grooved HMA pavement surface.

2-20. PCC Pavement Grooving. There are two acceptable methods for grooving PCC pavements: plastic grooving and saw cut grooving.

a. Plastic Grooving.

(1) Vibrating Ribbed Plate. One method to form grooves in the concrete while in the plastic state uses a vibrating ribbed plate attached to the bridge that spans across the pavement slab. The plate is vibrated to help redistribute the aggregate in the concrete. This prevents tearing and shearing as the plate proceeds transversely across the pavement slab. The grooves formed in the pavement are approximately 1/4 inch x 1/4 inch (6 mm x 6 mm) width and depth, spaced 1-1/2 inch (40 mm) center to center. Figure 2-8 shows the grooving operations.

(2) Ribbed Roller. Another method uses a roller with protrusions or ribs which form the grooves in the plastic concrete. This method does not give the same finish as the method using the vibrating ribbed plate. The roller is not vibrated and, therefore, does not consistently penetrate to the required depth of 1/4 inch (6 mm). Figure 2-9 shows the results of this technique.

b. Saw Grooving. For existing or new PCC pavements that have hardened, transverse grooves can be saw cut in the pavement. The timing should be as directed by the engineer. Construction specifications for providing saw grooves in PCC pavements are given in paragraph 2-21. Figure 2-7 shows a saw-grooved PCC pavement surface.

2-21. FAA SPECIFICATIONS FOR RUNWAY GROOVING.

a. THE FAA STANDARD GROOVE CONFIGURATION IS 1/4 INCH (±1/16 INCH) IN DEPTH BY 1/4 INCH (+1/16 INCH, -0 INCH) IN WIDTH BY 1 1/2 INCH (- 1/8 INCH, + 0 INCH) CENTER TO CENTER SPACING).

THE FAA STANDARD GROOVE CONFIGURATION IN METRICS IS 6 MM (±1.6 MM) IN DEPTH BY 6 MM (+1.6 MM, -0 MM) IN WIDTH BY 38 MM (- 3 MM, + 0 MM) CENTER TO CENTER SPACING).

b. THE DEPTH OF 60 PERCENT OR MORE OF THE GROOVES SHALL NOT BE LESS THAN 1/4 INCH (6 MM).

c. THE GROOVES SHALL BE CONTINUOUS FOR THE ENTIRE RUNWAY LENGTH AND TRANSVERSE (PERPENDICULAR) TO THE DIRECTION OF AIRCRAFT LANDING AND TAKEOFF OPERATIONS.

d. THE GROOVES SHALL BE TERMINATED WITHIN 10 FEET (3 M) OF THE

RUNWAY PAVEMENT EDGE TO ALLOW ADEQUATE SPACE FOR OPERATION OF THE GROOVING EQUIPMENT.

e. THE GROOVES SHALL NOT VARY MORE THAN 3 INCHES (8 CM) IN ALIGNMENT FOR 75 FEET (23 M) ALONG THE RUNWAY LENGTH, ALLOWING FOR REALIGNMENT EVERY 500 FEET (150 M) ALONG THE RUNWAY LENGTH.

f. GROOVES SHALL NOT BE CLOSER THAN 3 INCHES (8 CM) OR MORE THAN 9 INCHES (23 CM) FROM TRANSVERSE JOINTS IN CONCRETE PAVEMENTS.

g. WHERE LIGHTING CABLES ARE INSTALLED, GROOVING THROUGH LONGITUDINAL OR DIAGONAL SAW KERFS SHALL BE AVOIDED. Grooves may be continued through longitudinal construction joints.

h. Extreme care must be exercised when grooving near in-pavement light fixtures and subsurface wiring. **GROOVES SHALL BE SAWED NO LESS THAN 6 INCHES (15 CM) AND NO MORE THAN 18 INCHES (46 CM) FROM IN-PAVEMENT LIGHT FIXTURES.**

i. Bidding should be based on the square yard of the grooved area, using the two-dimensional method of measure with no deduction for areas skipped next to joints and fixtures as specified.

j. Clean-up is extremely important and should be continuous throughout the grooving operations. The waste material collected during the grooving operation must be disposed of by flushing with water, by sweeping, or by vacuuming. If waste material is flushed, the specifications should stipulate the following:

(1) Whether or not the airport owner or contractor is responsible for furnishing water for clean-up operations.

(2) That the waste material should not be flushed into the storm or sanitary sewer system.

(3) That the waste material should not be allowed to drain onto the grass shoulders adjacent to the runway or left on the runway surface. Failure to remove the material from all paved and shoulder areas can create conditions hazardous to aircraft operations.

2-22. GROOVING RUNWAY INTER-SECTIONS AND ANGLED EXIT TAXIWAYS.

a. IN ALL CASES, THE ENTIRE LENGTH OF THE PRIMARY RUNWAY WILL BE GROOVED. THE SECONDARY RUNWAY INTERSECTING THE PRIMARY RUNWAY SHALL BE SAW CUT IN A STEP PATTERN AS SHOWN IN FIGURE 2-10.

b. HIGH SPEED OR ANGLED EXIT TAXIWAYS SHALL BE SAW CUT IN A STEP PATTERN AS SHOWN IN FIGURE 2-11. Since grooving machines vary in cutting width, it is suggested that the step pattern width start at the projecting pavement edge, not exceeding 40 inches (102 cm) in width.

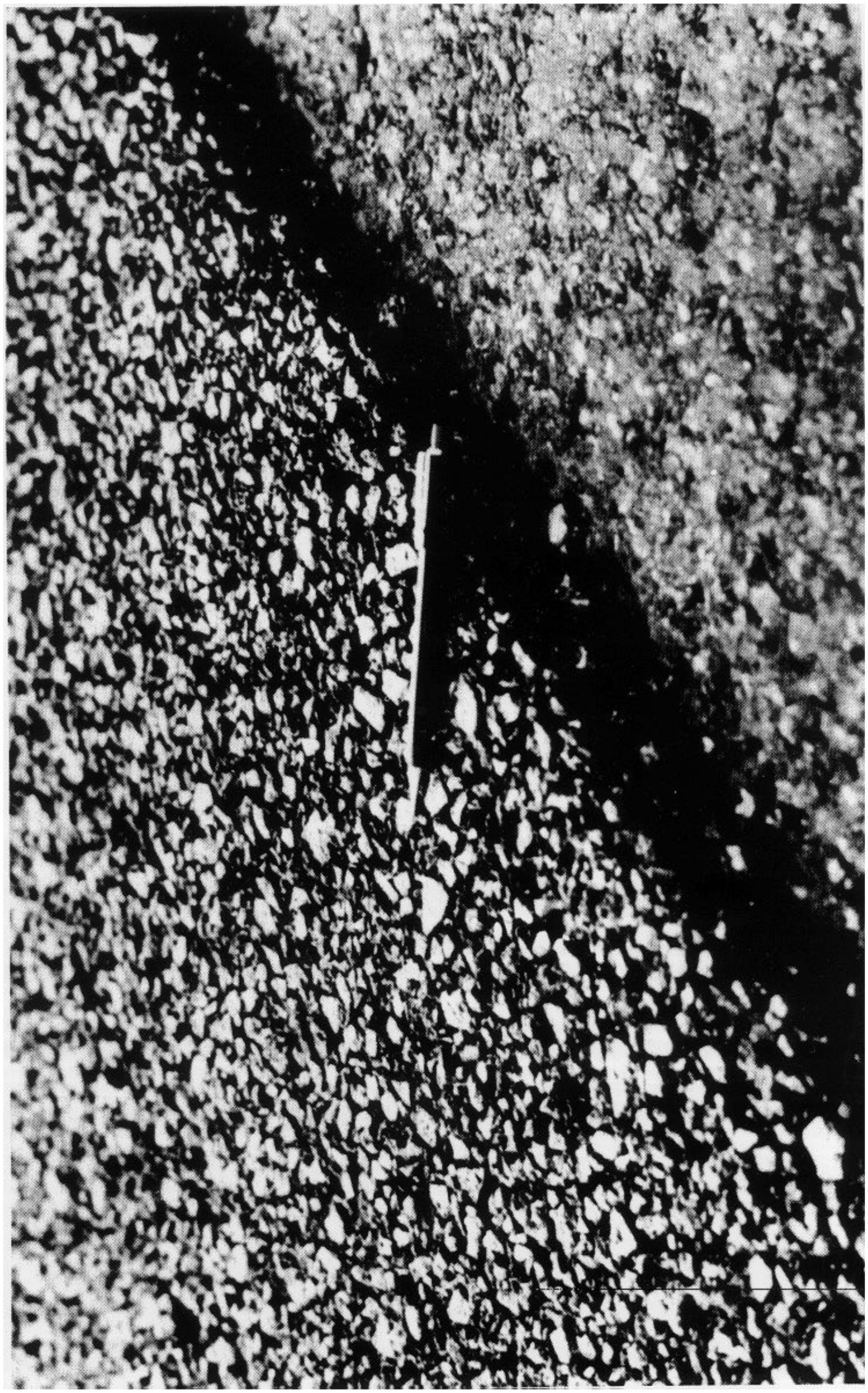

FIGURE 2-1. EDGE VIEW OF PFC OVERLAY

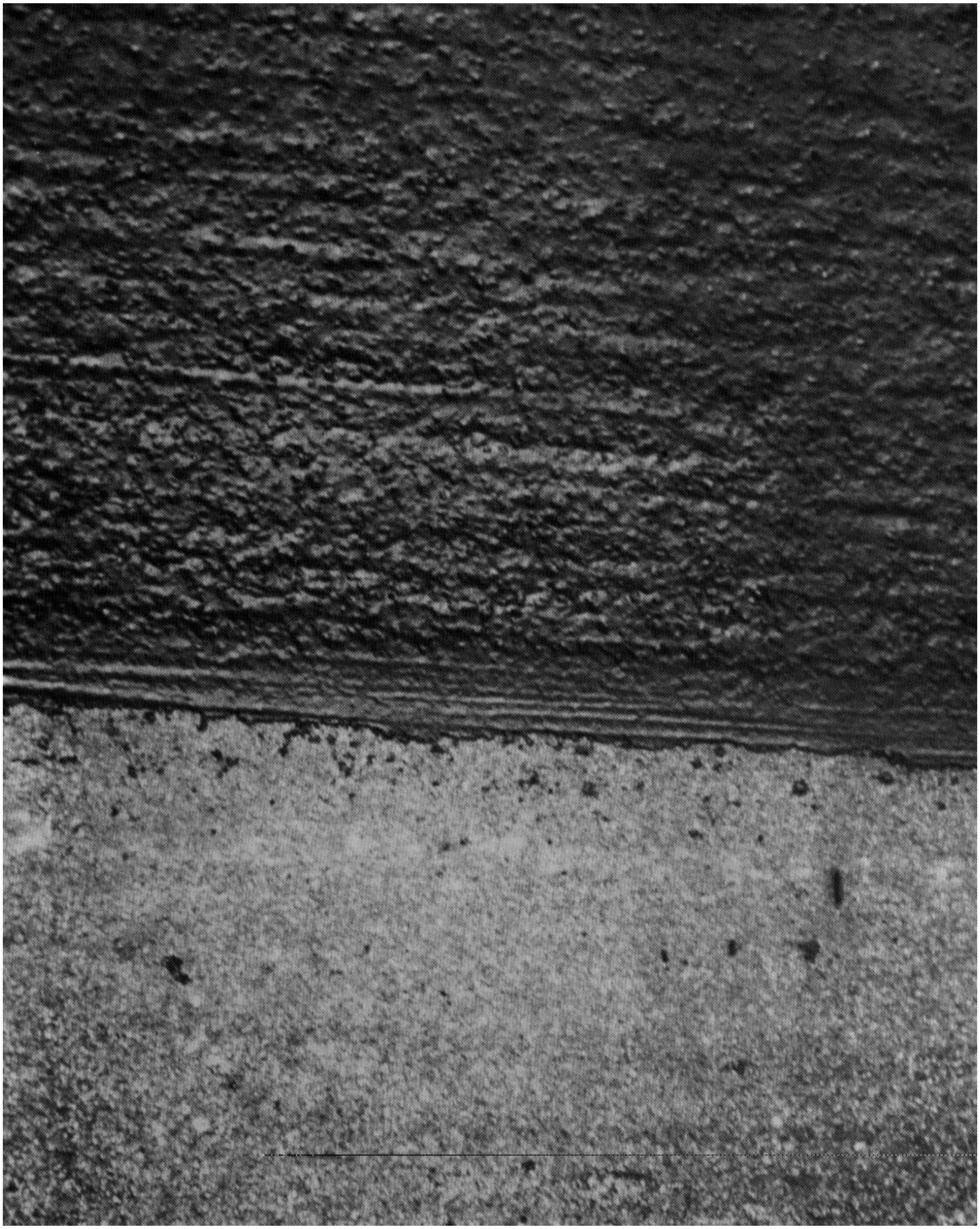

FIGURE 2-2. AGGREGATE SLURRY SEAL

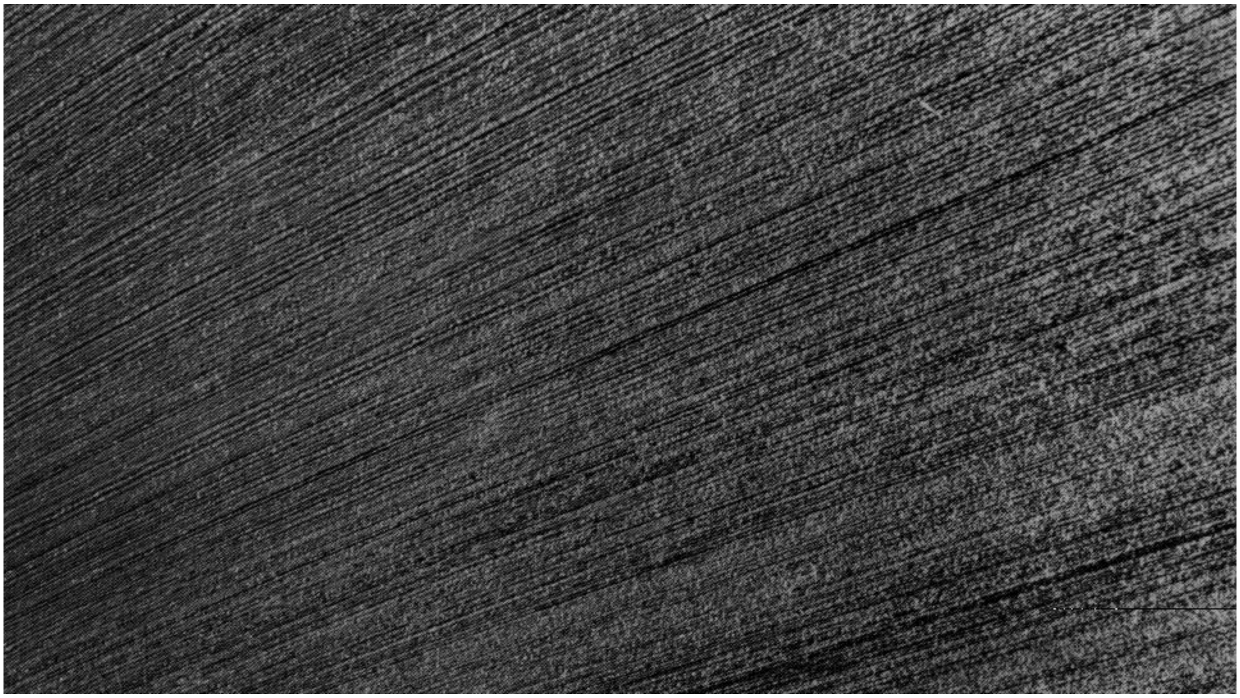

FIGURE 2-3. HEAVY PAVING BROOM FINISH

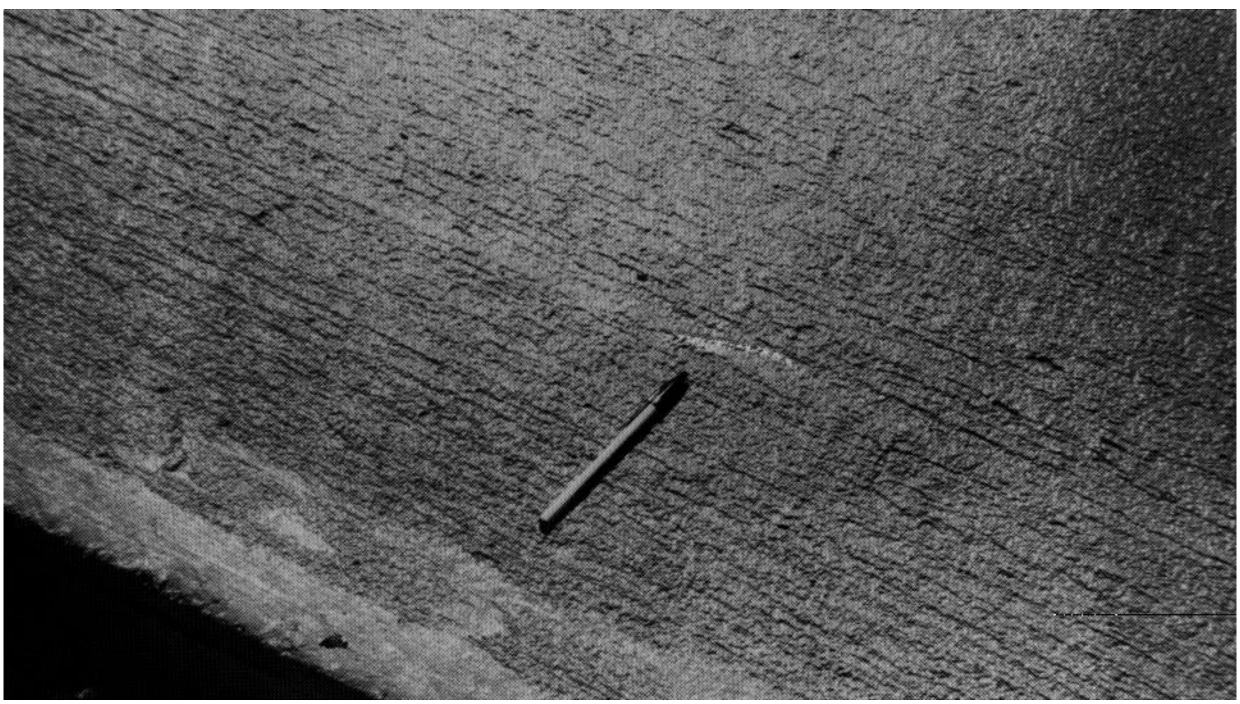

FIGURE 2-4. HEAVY BURLAP DRAG FINISH

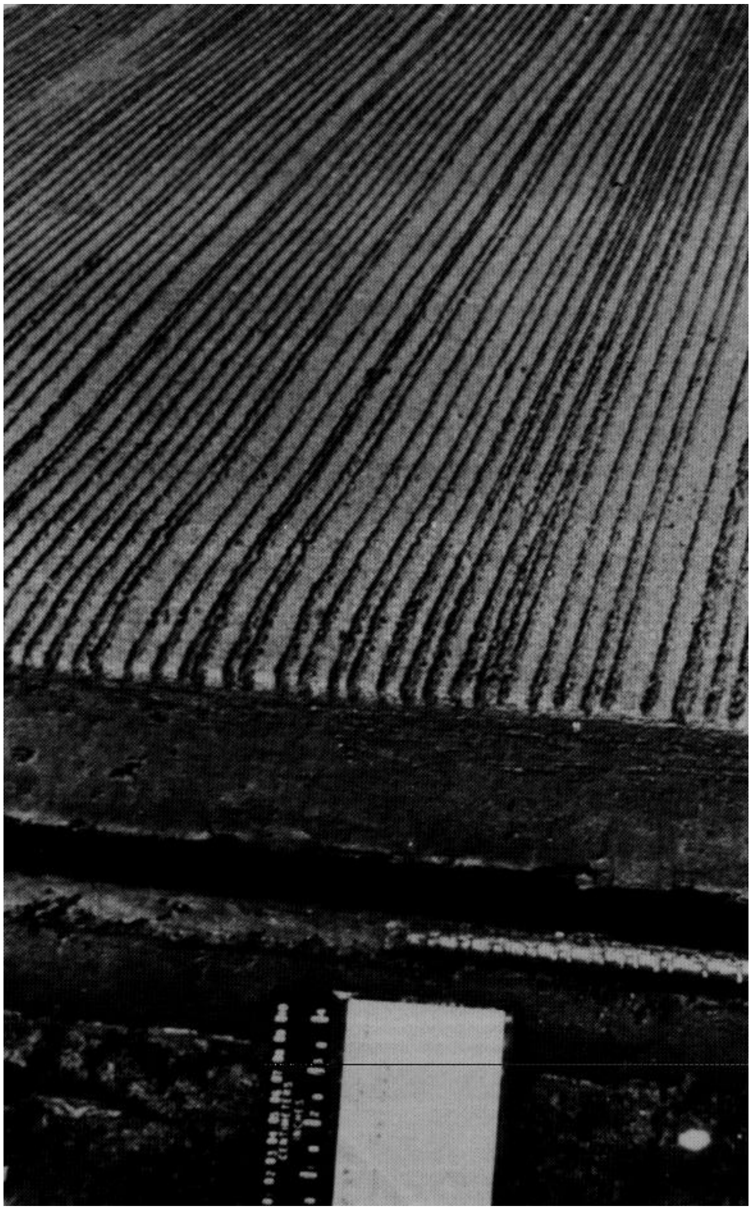

FIGURE 2-5. WIRE COMB TECHNIQUE CONSTRUCTED AT PATRICK HENRY AIRPORT, VIRGINIA, USING A 1/8 INCH X 1/8 INCH X 1/2 INCH CONFIGURATION

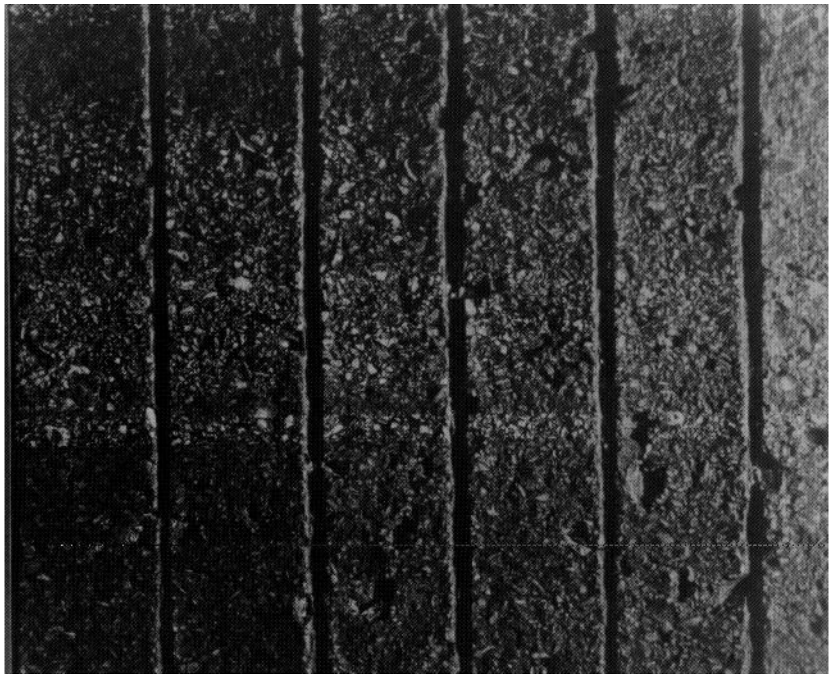

FIGURE 2-6. SAWED GROOVES IN HMA PAVEMENT

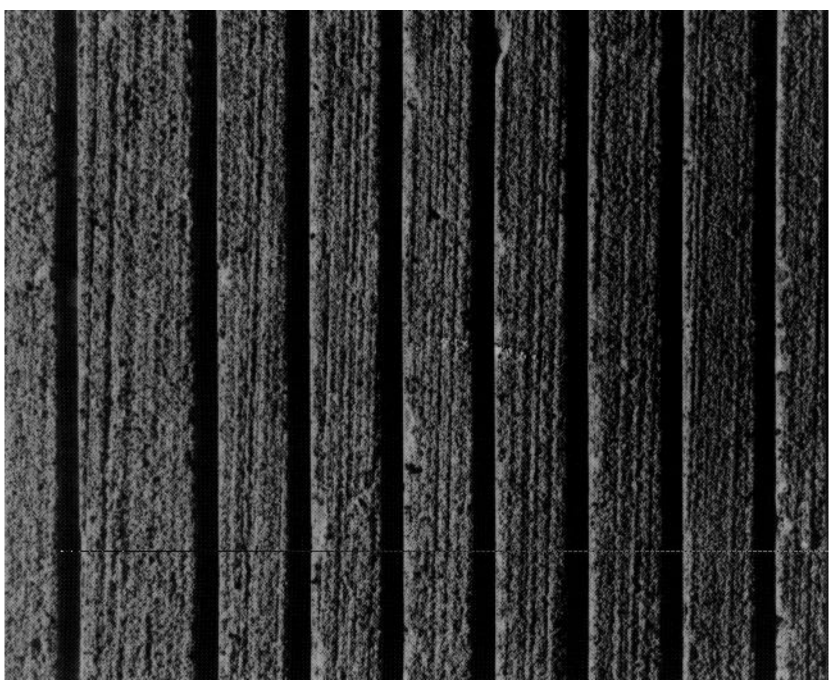

FIGURE 2-7. SAWED GROOVES IN PCC PAVEMENT

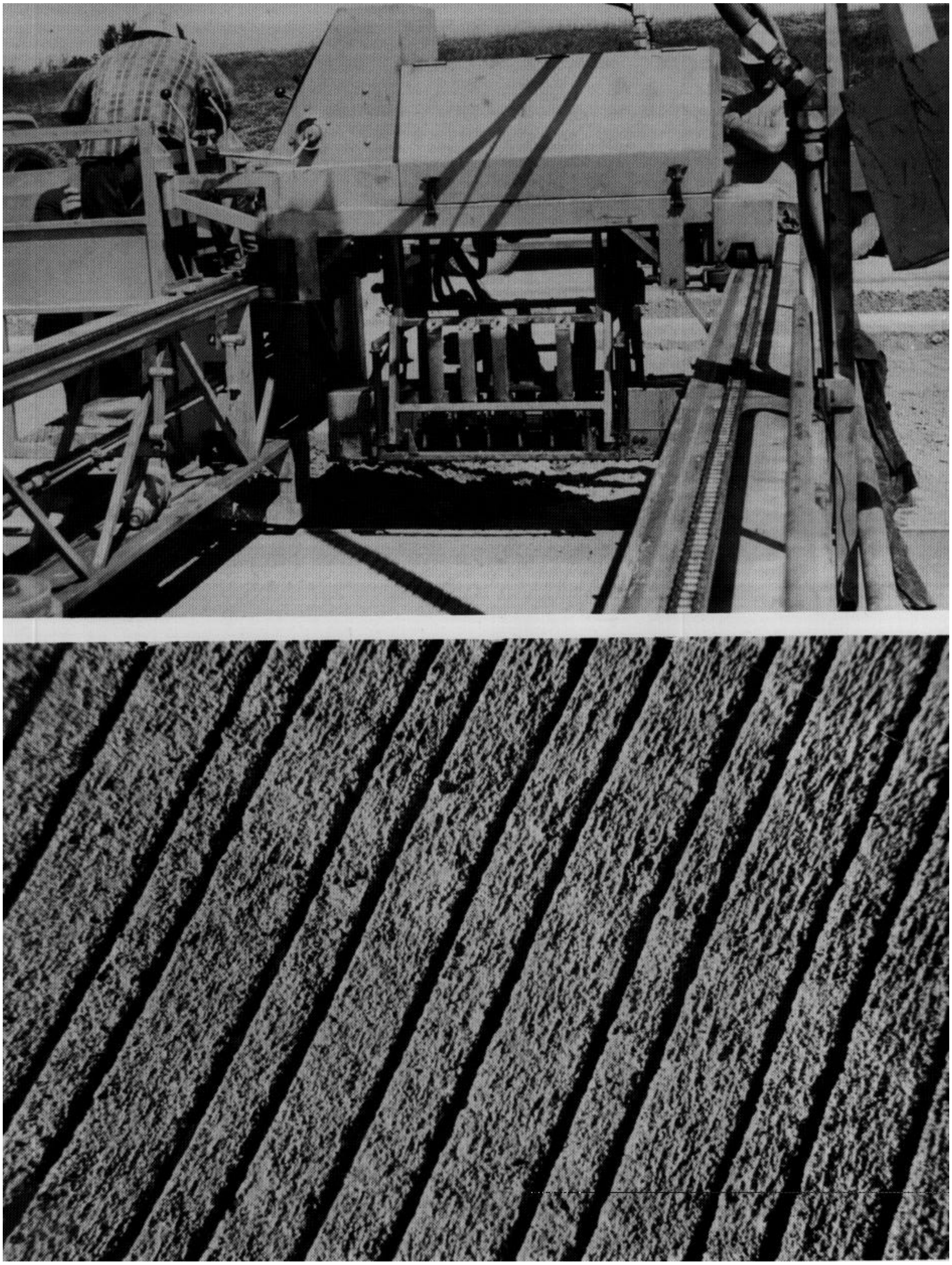

FIGURE 2-8. PLASTIC GROOVING TECHNIQUE USING A VIBRATING RIBBED PLATE

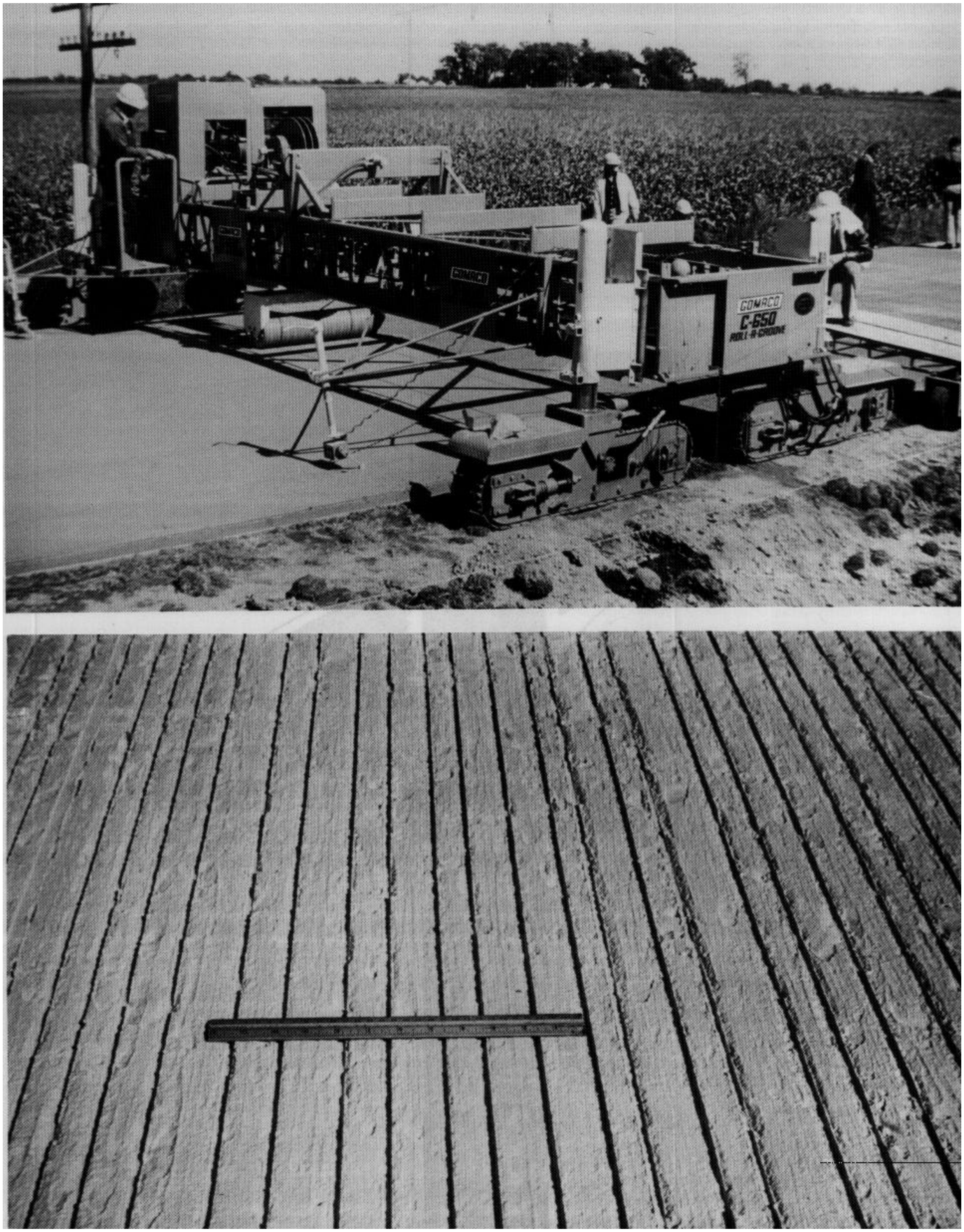

FIGURE 2-9. PLASTIC GROOVING TECHNIQUE USING A RIBBED ROLLER TUBE

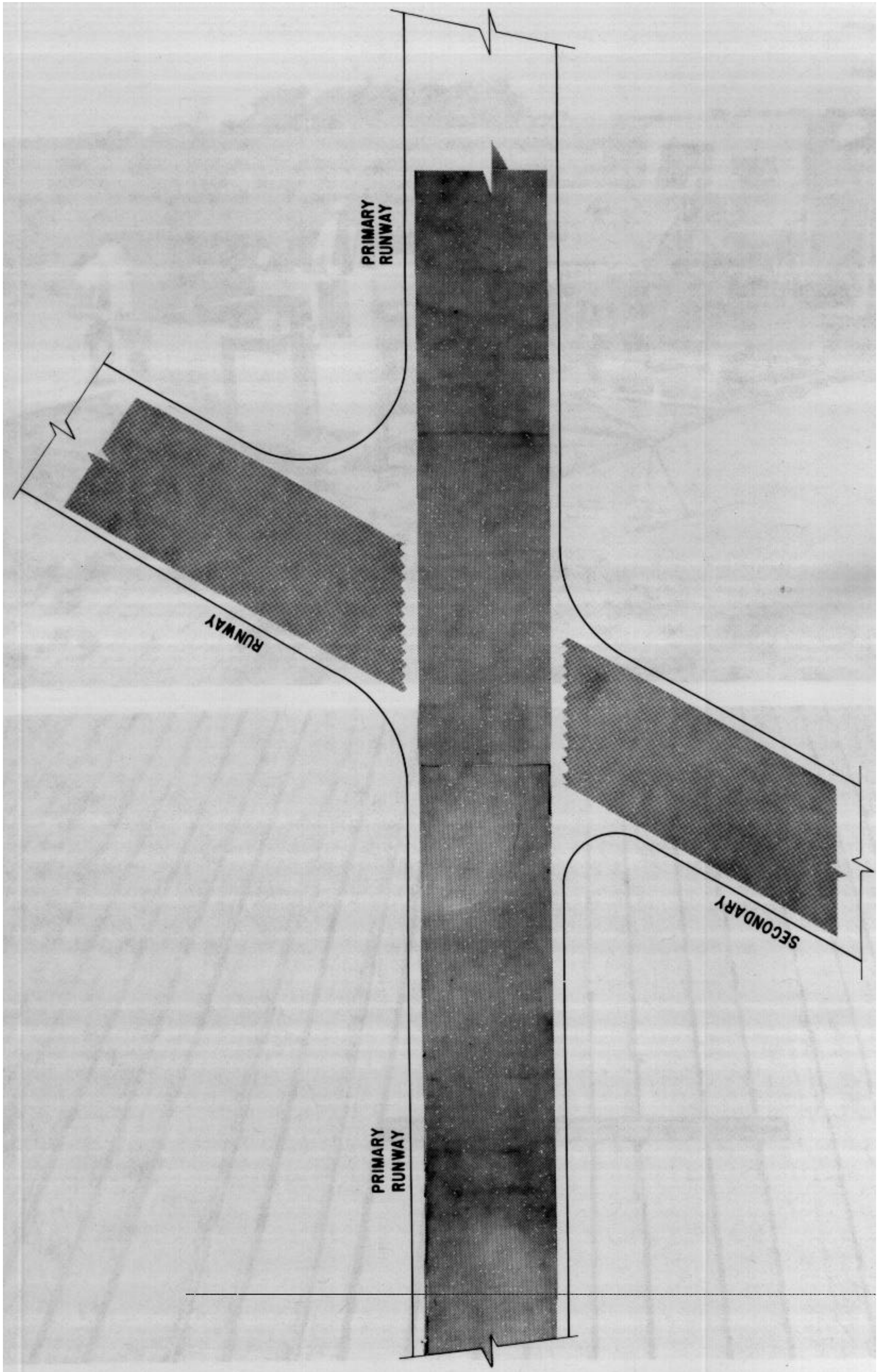

FIGURE 2-10. GROOVING INTERSECTIONS OF PRIMARY AND SECONDARY RUNWAYS

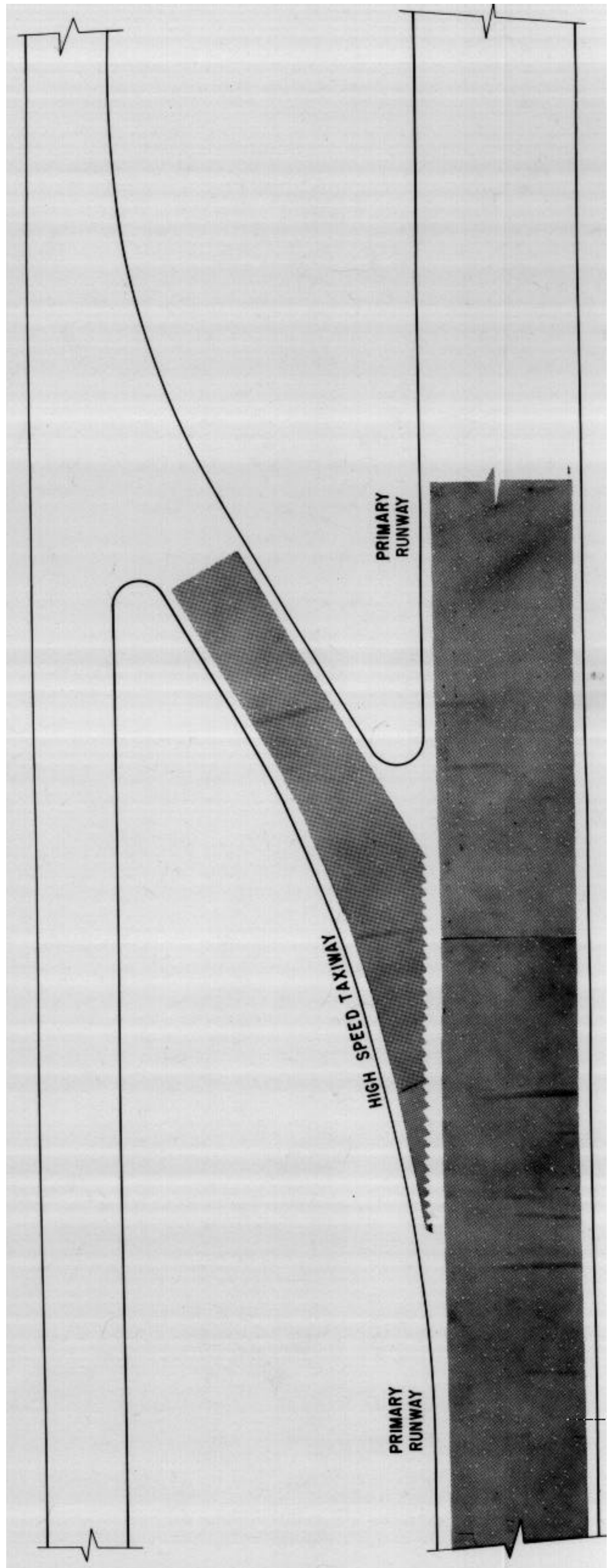

FIGURE 2-11. GROOVING OF HIGH SPEED OR ANGLED EXIT TAXIWAYS

CHAPTER 3. PAVEMENT EVALUATION

Section 1. Need for and Frequency of Evaluation

3-1. FRICTION DETERIORATION. Over time, the skid-resistance of runway pavement deteriorates due to a number of factors, the primary ones being mechanical wear and polishing action from aircraft tires rolling or braking on the pavement and the accumulation of contaminants, chiefly rubber, on the pavement surface. The effect of these two factors is directly dependent upon the volume and type of aircraft traffic. Other influences on the rate of deterioration are local weather conditions, the type of pavement (HMA or PCC), the materials used in original construction, any subsequent surface treatment, and airport maintenance practices.

Structural pavement failure such as rutting, raveling, cracking, joint failure, settling, or other indicators of distressed pavement can also contribute to runway friction losses. Prompt repair of these problems should be undertaken as appropriate. Guidance on corrective action may be found in chapter 2 and AC 150/5380-6.

Contaminants, such as rubber deposits, dust particles, jet fuel, oil spillage, water, snow, ice, and slush, all cause friction loss on runway pavement surfaces. Removal and runway treatment for snow, ice, and slush are covered in AC 150/5200-30. The most persistent contaminant problem is deposit of rubber from tires of landing jet aircraft. Rubber deposits occur at the touchdown areas on runways and can be quite extensive. Heavy rubber deposits can completely cover the pavement surface texture causing loss of aircraft braking capability and directional control, particularly when runways are wet.

3-2. SCHEDULING PAVEMENT EVALUATIONS. The operator of any airport with significant jet aircraft traffic should schedule periodic friction evaluations of each runway that accommodates jet aircraft. These evaluations should be carried out in accordance with the procedures outlined in either Section 2 or 3 of this chapter, depending upon the availability to the airport operator of continuous friction measuring equipment (CFME). Every runway for jet aircraft should be evaluated at least once each year. Depending on the volume and type (weight) of traffic on the runways, evaluations will be needed more frequently, with the most heavily used runways needing evaluation as often as weekly, as rubber deposits build up. Runway friction measurements take time, and while tests are being conducted, the runway will be unusable by aircraft. Since this testing is not time critical, a period should be selected which minimizes disruption of air traffic. Airport operations management should work closely with air traffic control, fixed base operations, and/or airlines.

3-3. MINIMUM FRICTION SURVEY FREQUENCY. Table 3-1 should be used as guidance for scheduling runway friction surveys. This table is based on an average mix of turbojet aircraft operating on any particular runway. Most aircraft landing on the runway are narrow body, such as the DC-9, BAC-111, B-727, B-737, etc. A few wide body aircraft were included in the mix. When any runway end has 20 percent or more wide body aircraft (L-1011, B-747, DC- 10, MD-11, C-5, etc.) of the total aircraft mix, it is recommended that the airport operator should select the next higher level of aircraft operations in Table 3-1 to determine the minimum survey frequency. As airport operators accumulate data on the rate of change of runway friction under various traffic conditions, the scheduling of friction surveys may be adjusted to ensure that evaluators will detect and predict marginal friction conditions in time to take corrective actions.

TABLE 3-1. FRICTION SURVEY FREQUENCY

NUMBER OF DAILY MINIMUM TURBOJET AIRCRAFT LANDINGS PER RUNWAY END	MINIMUM FRICTION SURVEY FREQUENCY
LESS THAN 15	1 YEAR
16 TO 30	6 MONTHS
31 TO 90	3 MONTHS
91 TO 150	1 MONTH
151 TO 210	2 WEEKS
GREATER THAN 210	1 WEEK

NOTE: Each runway end should be evaluated separately, e.g., Runway 18 and Runway 36.

3-4. SURVEYS WITHOUT CFME. Research has shown that visual evaluations of pavement friction are not reliable. An operator of an airport that does not support turbojet operations who suspects that a runway may have inadequate friction characteristics should arrange for testing by CFME. Visual inspections are essential, however, to note other surface condition inadequacies such as drainage problems, including ponding and groove deterioration, and structural deficiencies.

3-5. GROOVE DETERIORATION. Periodically, the airport operator should measure the depth and width of a runway's grooves to check for wear and damage. When 40 percent of the grooves in the runway are equal to or less than 1/8 inch (3 mm) in depth and/or width for a distance of 1,500 feet (457 m), the grooves' effectiveness for preventing hydroplaning has been considerably reduced. The airport operator should take immediate corrective action to reinstate the 1/4 inch (6 mm) groove depth and/or width.

3-6. MEASUREMENT OF PAVEMENT SURFACE TEXTURE. When a friction test identifies a pavement surface with inadequate friction characteristics, the cause, such as rubber accumulation, is often obvious. When the cause is not obvious, the following guidance may be helpful in determining if the deficiency is a result of a deterioration in surface texture depth. Such deterioration may be caused by weather influences, wear/polishing effects of aircraft traffic, and contaminants including but not limited to rubber deposits. Visual inspections cannot be relied upon to identify pavement surfaces with poor texture. Pavement texture depths can only be determined by direct measurements. Even direct measurements may be affected by the operator of the equipment, so they should be used as only part of an overall pavement friction evaluation.

Section 2. CFME - General

3-7. GENERAL REQUIREMENTS FOR CFME. All airports with turbojet traffic should own or have access to use of CFME. Not only is it an effective tool for scheduling runway maintenance, it can also be used in winter weather to enhance operational safety (see AC 150/5200-30). Airports that have few turbojet traffic operations may be able to borrow the CFME from nearby airports for maintenance use, share ownership with a pool of neighboring airports, or hire a qualified contractor.

3-8. FAA PERFORMANCE STANDARDS FOR CFME. Appendix 3 contains the performance specifications for CFME. These standards should be used by airport operators in procuring CFME and replacement tires for the equipment.

3-9. FAA QUALIFIED PRODUCT LIST. The equipment listed in Appendix 4 has been tested and meets the FAA standards for CFME for use in conducting maintenance friction tests.

3-10. USE OF DECELEROMETER. Since decelerometers are not capable of providing continuous friction measurements and do not give reliable results on wet pavement surfaces, they are not approved for conducting runway maintenance surveys as discussed in this AC. However, the devices are approved for conducting friction surveys on runways during winter operations (reference AC 150/5200-30).

3-11. FEDERAL FUNDING OF CFME. The Airport and Airway Improvement Act of 1982 (AAIA) includes friction measuring equipment as an eligible item for airport development. However, before programming or procuring this equipment, airport operators should contact their FAA Regional or Airports District Office for guidance.

3-12. TRAINING OF PERSONNEL. The success of friction measurement in delivering reliable friction data depends heavily on the personnel who are responsible for operating the equipment. Adequate professional training on the operation, maintenance, and procedures for conducting friction measurement should be provided either as part of the procurement package or as a separate contract with the manufacturer. Also, recurrent training is necessary for review and update to ensure that the operator maintains a high level of proficiency. Experience has shown that unless this is done, personnel lose touch with new developments on equipment calibration, maintenance, and operating techniques. A suggested training outline for the manufacturers is given in Appendix 5. Airport personnel should be trained not only in the operation and maintenance of the CFME but also on the procedures for conducting friction surveys. These procedures are provided in Section 4 below. At airports where friction tests are performed less frequently than quarterly, and CFME is not used for winter operations, consideration should be given to hiring a qualified contractor to perform tests.

3-13. CALIBRATION. All CFME should be checked for calibration within tolerances given by the manufacturer before conducting friction surveys.

CFME furnished with self-wetting systems should be calibrated periodically to assure that the water flow rate is correct and that the amount of water produced for the required water depth is consistent and applied evenly in front of the friction measuring wheel(s) for all test speeds.

Section 3. Conducting Friction Evaluations with CFME

3-14. PRELIMINARY STEPS. Friction measurement operations should be preceded by a thorough visual inspection of the pavement to identify deficiencies as outlined in paragraph 3-4. Careful and complete notes should be taken not only of the CFME data but of the visual inspection as well. The airport operator should assure that appropriate communications equipment and frequencies are provided on all vehicles used in conducting friction surveys and that all personnel are fully cognizant of airport safety procedures. Personnel operating the equipment should be fully trained and current in all procedures. The CFME should be checked for accurate calibration and the vehicle checked for adequate braking ability.

3-15. LOCATION OF FRICTION SURVEYS ON THE RUNWAY. The airport operator, when conducting friction surveys on runways at 40 mph (65 km/h), should begin recording the data 500 feet (152 m) from the threshold end to allow for adequate acceleration distance. The friction survey should be terminated approximately 500 feet (152 m) from the opposite end of the runway to allow for adequate distance to safely decelerate the vehicle. When conducting friction surveys at 60 mph (95 km/h), the airport operator should start recording the survey 1,000 feet (305 km) from the threshold end and terminate the survey approximately 1,000 feet from the opposite end of the runway. Where travel beyond the end of the runway could result in equipment damage or personal injury, additional runway length should be allowed for stopping. The lateral location on the runway for performing the test is based on the type of aircraft operating on the runway. Unless surface conditions are noticeably different on either side of the runway centerline, a test on one side of the centerline in the same direction the aircraft lands should be sufficient. However, when both runway ends are to be evaluated, vehicle runs can be made to record data on the return trip (both ways).

The lateral location on the runway for performing friction surveys is based on the type and/or mix of aircraft operating on the runway:

a. Runways Serving Only Narrow Body Aircraft. Friction surveys should be conducted 10 feet (3 m) to the right of the runway centerline

b. Runways Serving Narrow Body and Wide Body Aircraft. Friction surveys should be conducted 10 and 20 feet (3 and 6 m) to the right of the runway centerline to determine the worst case condition. If the worst case condition is found to be consistently limited to one track, future surveys may be limited to this track. Care should be exercised, however, to account for any future and/or seasonal changes in aircraft mix.

3-16. VEHICLE SPEED FOR CONDUCTING SURVEYS. All of the approved CFME in Appendix 4 can be used at either 40 mph (65 km/h) or 60 mph (95 km/h). The lower speed determines the overall macrotexture/contaminant/drainage condition of the pavement surface. The higher speed provides an indication of the condition of the surface's microtexture. A complete survey should include tests at both speeds.

3-17. USE OF CFME SELF-WETTING SYSTEM. Since wet pavement always yields the lowest friction measurements, CFME should routinely be used on wet pavement which gives the "worst case" condition. CFME is equipped with a self-wetting system to simulate rain wet pavement surface conditions and provide the operator with a continuous record of friction values along the length of the runway. The attached nozzle(s) are designed to provide a uniform water depth of 1 mm (0.04 inch) in front of the friction measuring tire(s). This wetted surface produces friction values that are most meaningful in determining whether or not corrective action is required.

3-18. FRICTION SURVEYS DURING RAINFALL. One limitation in using the self-wetting system on a friction measuring device is that it cannot by itself indicate the potential for hydroplaning. Some runways have depressed areas which pond during periods of moderate to heavy rainfall. These areas may exceed considerably the water depth used by the self-wetting system of the friction measuring device. Therefore, it is recommended that the airport owner periodically conduct visual checks of the runway surface during rainfall, noting the location, average water depth, and approximate dimensions of the ponded areas. If the average water depth exceeds 1/8 inch (3 mm) over a longitudinal distance of 500 feet (152 m), the depressed area should be corrected to the standard transverse slope. If possible, the airport owner should conduct periodic friction surveys during rainfall through the ponded areas.

3-19. FRICTION LEVEL CLASSIFICATION. Mu numbers (friction values) measured by CFME can be used as guidelines for evaluating the surface friction deterioration of runway pavements and for identifying appropriate corrective actions required for safe aircraft operations. Table 3-2 depicts the friction values for three classification levels for FAA qualified CFME operated at 40 and 60 mph (65 and 95 km/h) test speeds. This table was developed from qualification and correlation tests conducted at NASA's Wallops Flight Facility in 1989.

TABLE 3-2. FRICTION LEVEL CLASSIFICATION FOR RUNWAY PAVEMENT SURFACES

	40 mph			60 mph		
	Minimum	Maintenance Planning	New Design/ Construction	Minimum	Maintenance Planning	New Design/ Construction
Mu Meter	.42	.52	.72	.26	.38	.66
Dynatest Consulting, Inc. Runway Friction Tester	.50	.60	.82	.41	.54	.72
Airport Equipment Co. Skiddometer	.50	.60	.82	.34	.47	.74
Airport Surface Friction Tester	.50	.60	.82	.34	.47	.74
Airport Technology USA Safegate Friction Tester	.50	.60	.82	.34	.47	.74
Findlay, Irvine, Ltd. Griptester Friction Meter	.43	.53	.74	.24	.36	.64
Tatra Friction Tester	.48	.57	.76	.42	.52	.67
Norsemeter RUNAR (operated at fixed 16% slip)	.45	.52	.69	.32	.42	.63

3-20. EVALUATION AND MAINTENANCE GUIDELINES. The following evaluation and maintenance guidelines are recommended based on the friction levels classified in Table 3-2. These guidelines take into account that poor friction conditions for short distances on the runway do not pose a safety problem to aircraft, but long stretches of slippery pavement are of serious concern and require prompt remedial action.

a. Friction Deterioration Below the Maintenance Planning Friction Level (500 ft). When the average Mu value on the wet runway pavement surface is less than the Maintenance Planning Friction Level but above the Minimum Friction Level in Table 3-2 for a distance of 500 feet (152 m), and the adjacent 500 foot (152 m) segments are at or above the Maintenance Planning Friction Level, no corrective action is required. These readings indicate that the pavement friction is deteriorating but the situation is still within an acceptable overall condition. The airport operator should monitor the situation closely by conducting periodic friction surveys to establish the rate and extent of the friction deterioration.

b. Friction Deterioration Below the Maintenance Planning Friction Level (1000 ft). When the averaged Mu value on the wet runway pavement surface is less than the Maintenance Planning Friction Level in Table 3-2 for a distance of 1000 feet (305 m) or more, the airport operator should conduct extensive evaluation into the cause(s) and extent of the friction deterioration and take appropriate corrective action.

c. Friction Deterioration Below the Minimum Friction Level. When the averaged Mu value on the wet pavement surface is below the Minimum Friction Level in Table 3-2 for a distance of 500 feet (152 m), and the adjacent 500 foot (152 m) segments are below the Maintenance Planning Friction Level, corrective action should be taken immediately after determining the cause(s) of the friction deterioration. Before undertaking corrective measures, the airport operator should investigate the overall condition of the entire runway pavement surface to determine if other deficiencies exist that may require additional corrective action.

d. New Design/Construction Friction Level for Runways. For newly constructed runway pavement surfaces (that are either saw cut grooved or have a PFC overlay) serving turbojet aircraft operations, the averaged Mu value on the wet runway pavement surface for each 500 foot (152 m) segment should be no less than the New Design/Construction Friction Level in Table 3-2.

3-21. COMPUTER EVALUATION OF FRICTION TEST DATA. A manual evaluation of friction test data as required by the criteria above can be tedious and prone to human error. An IBM PC-compatible computer program which performs this evaluation is available free of charge. The computer program may be downloaded from the FAA Airports Internet web site at http://www.faa.gov/arp/software.htm.

Section 4. Conducting Texture Depth Measurements

3-22. RECOMMENDED TESTING. When friction values meet the criteria in paragraphs 3-20.(a), 3-20.(b), and 3-20.(c), no texture depth measurements are necessary. When friction values do not meet the criteria in paragraphs 3-20.(a), 3-20.(b), or 3-20.(c), and the cause is not obvious (e.g. rubber deposits), the airport operator should perform texture depth measurements.

3-23 RECOMMENDED TEXTURE DEPTHS.

a. Newly Constructed Pavements. The recommended average texture depth to provide good skid-resistance for newly constructed concrete and asphalt pavements is 0.045 inch (1.14 mm). A lower value indicates a deficiency in macrotexture that will require correction as the surface deteriorates.

b. Existing Pavements.

(1) When the average texture depth measurement in a runway zone (i.e., touchdown, midpoint, and rollout) falls below 0.045 inch (1.14 mm), the airport operator should conduct texture depth measurements each time a runway friction survey is conducted.

(2) When the average texture depth measurement in a runway zone is below 0.030 inch (0.76 mm) but above 0.016 inch (0.40 mm), the airport operator should initiate plans to correct the pavement texture deficiency within a year.

(3) When the average texture depth measurement in a runway zone (i.e., touchdown, midpoint, and rollout) falls below 0.010 inch (0.25 mm), the airport operator should correct the pavement texture deficiency within 2 months.

c. Retexturing. Retexturing of the pavement surface should improve the average texture depth to a minimum of 0.030 inch (0.76 mm).

3-24. LOCATION OF MEASUREMENTS. Groove depths are never included in texture depth measurements. For grooved runway pavements, texture depth measurements should always be located in nongrooved areas, such as near transverse joints or light fixtures, but as close as possible to heavily trafficked areas.

3-25. TEST METHODS. A minimum of three texture depth measurements should be taken in any area noted as deficient. More measurements should be taken when obvious textural changes in the pavement surface are observed. An average texture depth should be computed for each area. Descriptions of the equipment and methods used and the computations involved in determining texture depths are as follows:

a. Equipment. The NASA Grease Smear Method is used to determine the macrotexture of the pavement surface by measuring the average distance between the peaks and valleys in the pavement texture. This method cannot be used to evaluate the pavement microtexture. On the left in Figure 3-1 is shown the tube which is used to measure the 1 cubic inch (15 cc) volume of grease. On the right is shown the tight-fitting plunger which is used to expel the grease from the tube, and in the center is shown the rubber squeegee which is used to work the grease into the voids in the runway surface.

The sheet rubber on the squeegee is cemented to a piece of aluminum for ease in use. Any general purpose grease can be used. As a convenience in the selection of the length of the measuring tube, Figure 3-2 gives the relation between the tube inside diameter and tube length for an internal tube volume of one cubic inch (15 cu cm). The plunger can be made of cork or other resilient material to achieve a tight fit in the measuring tube.

b. Measurement. The tube for measuring the known volume of grease is packed full with a simple tool, such as a putty knife, with care to avoid entrapped air, and the ends are squared off as shown in Figure 3-3. A general view of the texture measurement procedure is shown in Figure 3-4. The lines of masking tape are placed on the pavement surface about 4 inches (10 cm) apart. The grease is then expelled from the measuring tube with the plunger and deposited between the previously placed lines of masking tape. It is then worked into the voids of the runway pavement surface with the rubber squeegee, with care that no grease is left on the masking tape or the squeegee. The distance along the lines of masking tape is then measured and the area that is covered by the grease is computed.

3-26. COMPUTATION. After the area is completed, the following equations are used to calculate the average texture depth of the pavement surface:

$$\text{Texture depth (inches)} = \frac{\text{Volume of Grease (cu. in.)}}{\text{Area Covered by Grease (sq. in.)}}$$

$$\text{Average Texture Depth} = \frac{\text{Sum of individual Tests}}{\text{Total Number of Tests}}$$

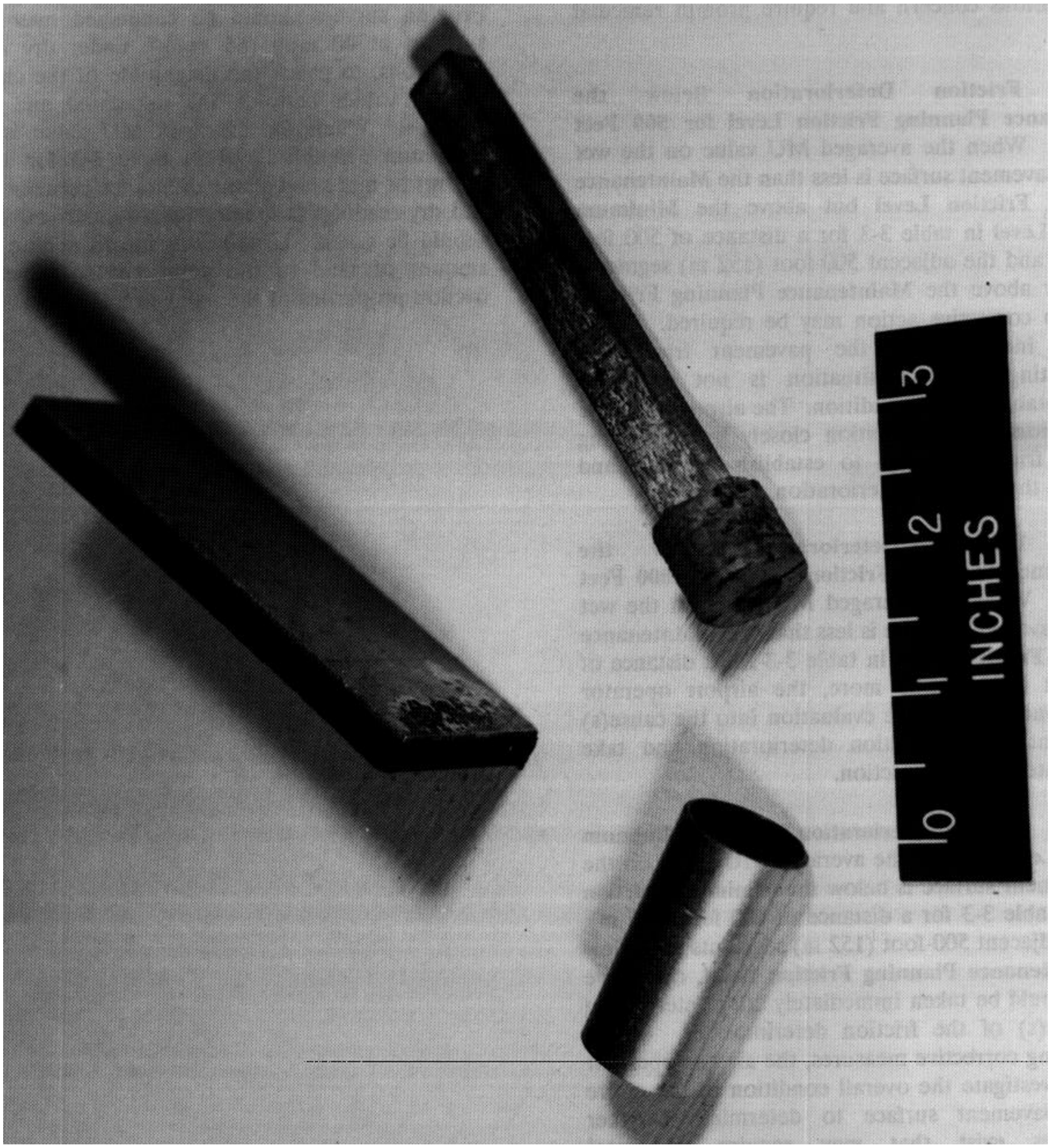

FIGURE 3-1. GREASE-VOLUME MEASURING TUBE, PLUNGER, AND RUBBER SQUEEGEE

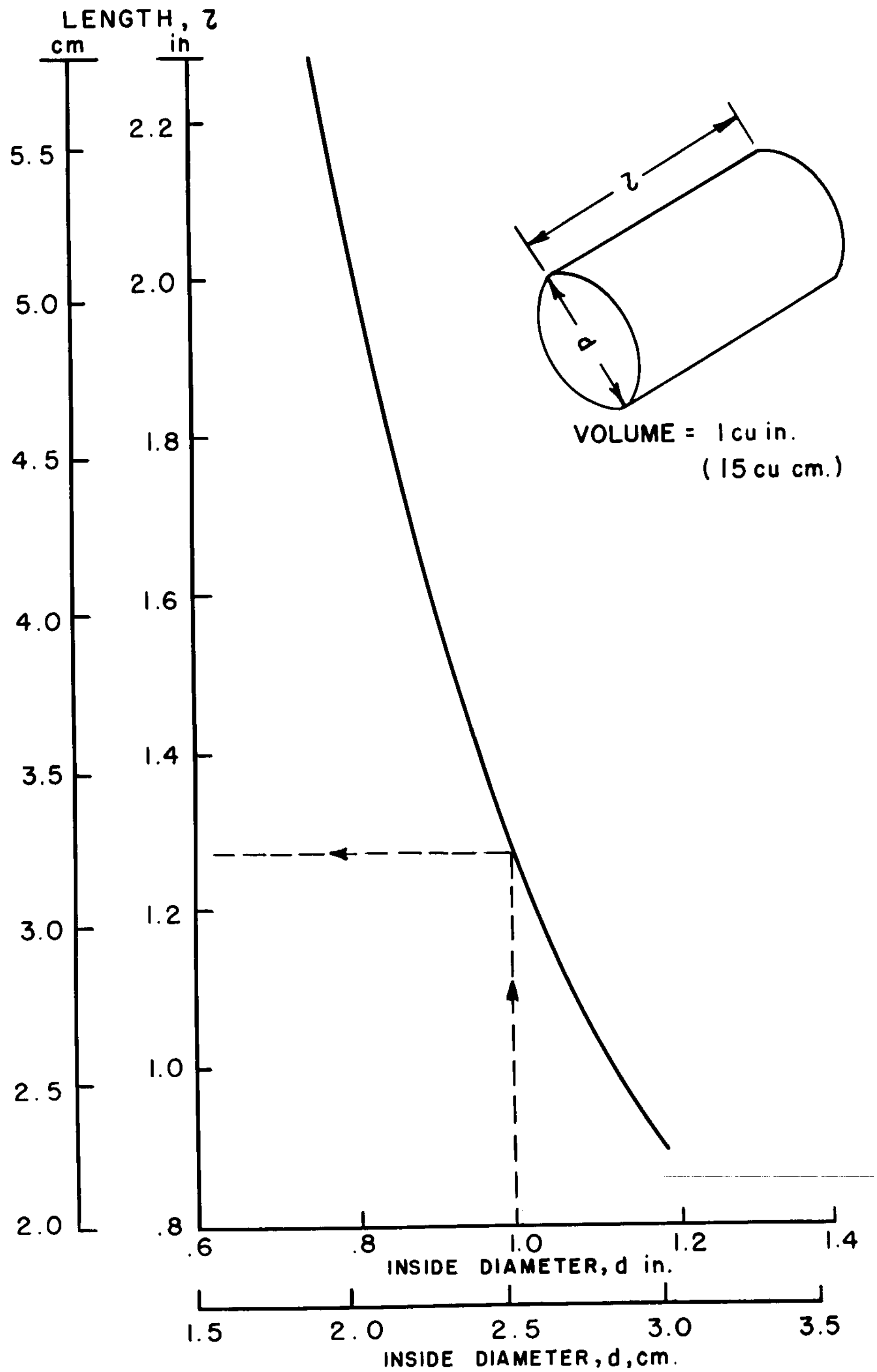

FIGURE 3-2. MEASURING TUBE DIMENSIONS TO MEASURE

ONE CUBIC INCH OR FIFTEEN CUBIC CENTIMETERS

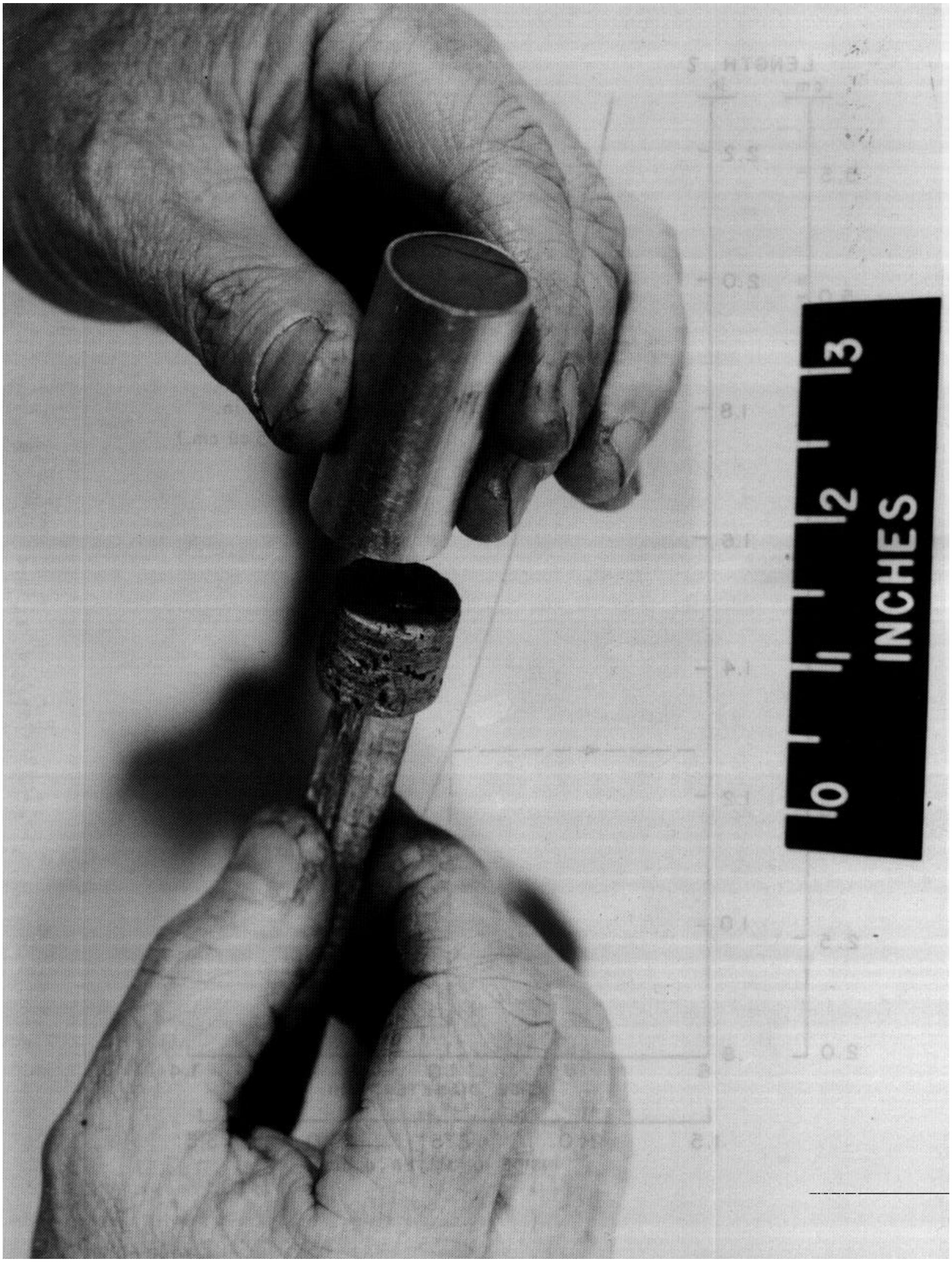

FIGURE 3-3. MEASURING TUBE FILLED WITH GREASE

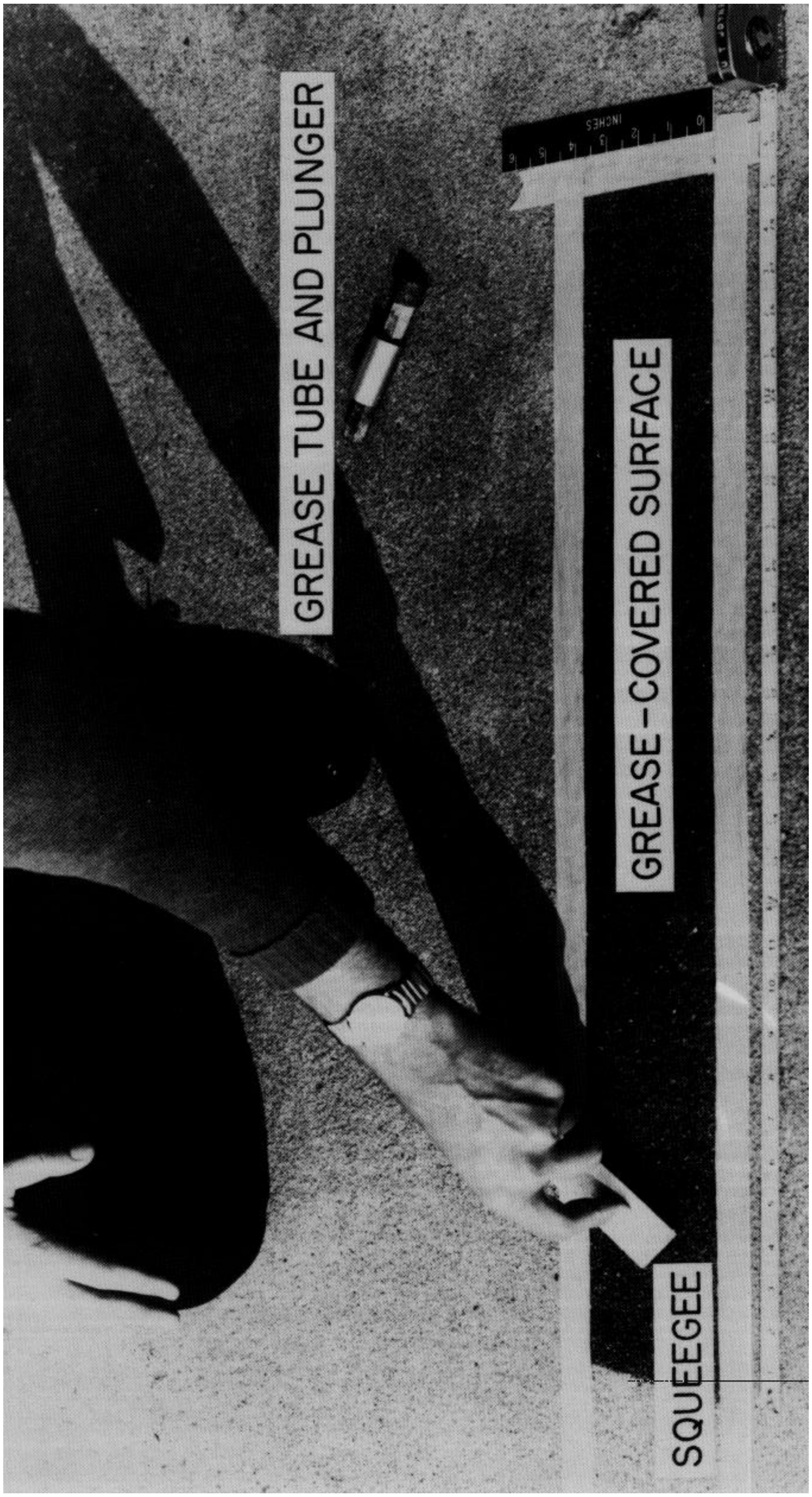

FIGURE 3-4. ILLUSTRATION OF APPARATUS USED IN GREASE APPLICATION TECHNIQUE FOR MEASURING PAVEMENT SURFACE TEXTURE DEPTH

CHAPTER 4. MAINTAINING HIGH SKID-RESISTANCE

Section 1. Maintenance Considerations

4-1. NEED FOR MAINTENANCE. As traffic mechanically wears down microtexture and macrotexture and as contaminants build up on runway pavements, friction will decrease to a point where safety may be diminished. At joint use airports, where high numbers of military aircraft operations occur, the venting of excess fuel can lead to serious loss of friction by either causing contaminant buildup or an oil film on the pavement surface. Also, fog seal treatment of HMA surfaces can substantially reduce the pavement's coefficient of friction during the first year after application. Surfaces which already have marginally acceptable friction can become unacceptable when given this type of surface treatment.

When the measured coefficient of friction values approach or drop below the Maintenance Planning Level as shown in Table 3-2 in chapter 3. Table 4-1 may be used as a tool for budgeting for and scheduling appropriate and timely maintenance for removal of contaminants and restoration of good friction characteristics. As stated in chapter 3, the average aircraft mix was based on mostly narrow body aircraft with a few wide body aircraft operations included. Rubber accumulation is dependent on the type and frequency of aircraft landing operations; e.g., weight of aircraft, the number of wheels that touchdown on the surface, climate, runway length, and runway composition. When more than 20 percent of the total aircraft mix landing on any one runway end are wide body aircraft, it is recommended that the airport operator select the next higher level of aircraft operations in Table 4-1 to determine the rubber removal frequency. Experience and the use of CFME will allow the airport operator to develop a schedule specific to each runway.

TABLE 4-1. RUBBER DEPOSIT REMOVAL FREQUENCY

NUMBER OR DAILY TURBOJET AIRCRAFT LANDING PER RUNWAY END	SUGGESTED RUBBER DEPOSIT REMOVAL FREQUENCY
LESS THAN 15	2 YEARS
16 TO 30	1 YEAR
31 TO 90	6 MONTHS
91 TO 150	4 MONTHS
151 TO 210	3 MONTHS
GREATER THAN 210	2 MONTHS

Note: Each runway end should be evaluated separately, e.g. Runway 18 and Runway 36.

Section 2. Methods for Removing Contaminants

4-2. RECOMMENDED CONTAMINANT REMOVAL TECHNIQUES. Several methods are available for cleaning rubber deposits, other contaminants, and paint markings from runway surfaces. They include high pressure water, chemical, high velocity impact, and mechanical grinding. After the contaminants have been removed from the runway surface by any of these methods, the airport operator should conduct friction measurements to assure that the Mu values have been restored to within 10 percent of those on the uncontaminated center portion of the runway and that both measurements are well within the acceptable friction levels for safe aircraft operations. The effectiveness of rubber deposit removal procedures cannot be evaluated by visual inspection. It is highly recommended that rubber deposit removal contracts base payments on final tests by CFME. A brief description follows for each of the contaminant removal techniques. None of the techniques should be used unless the runway is free of standing water, snow, slush, and/or ice. Also, chemical or water impact removal methods should not be used if there is a danger of the fluids freezing.

The ultimate success of any method will depend on the expertise of the equipment operator. Results can vary from completely ineffective to a situation where all rubber deposits are removed, but the underlying pavement is significantly damaged. It is recommended that airport operators require that a test section be cleaned by the contractor to demonstrate that rubber deposits will be removed without damage to the underlying pavement.

a. Removal by High Pressure Water. A series of high pressure water jets is aimed at the pavement to blast the contaminants from the surface, allowing the water to transport the rubber particles to the edge of the runway. The technique is economical, environmentally clean, and effectively removes deposits from the pavement surface with minimal downtime to the airport operator. High-pressure water blasting also may be used to improve the surface texture of smooth pavements. Water pressures used vary significantly. There are so many other parameters that vary from one contractor's equipment to another, however, that the pressure of the water used is not a good indication of the potential for either effectiveness or pavement damage. The airport operator should rely on the contractor's experience, demonstrated expertise, and references.

b. Removal by Chemicals. Chemical solvents have been used successfully for removal of contaminants on both PCC and HMA runways. Any chemicals used on runways must meet Federal, state, and local environmental requirements. For removal of rubber deposits on PCC runways, chemicals are used which have a base of cresylic acid and a blend of benzene, with a synthetic detergent for a wetting agent. For removal of rubber deposits on HMA runways, alkaline chemicals are generally used. Because of the volatile and toxic nature of such chemicals, extreme care must be exercised during and after application. If the chemicals remain on the pavement too long, the painted areas on the runway and possibly the surface itself could be damaged. It is also very important to dilute the chemical solvent that is washed off the pavement surface so that the effluent will not harm surrounding vegetation or drainage systems or pollute nearby streams and wildlife habitats. Detergents made of metasilicate and resin soap can be used effectively to remove oil and grease from PCC runway surfaces. For HMA pavements, an absorbent or blotting material such as sawdust or sand combined with a rubber alkaline degreaser may be used.

c. High Velocity Impact Removal. This method employs the principle of throwing abrasive particles at a very high velocity at the runway pavement surface, thus blasting the contaminants from the surface. Additionally, the machine that performs this operation can be adjusted to produce the desired surface texture, if so required. The abrasive is propelled mechanically from the peripheral tips of radial blades in a high speed, fan like wheel. The entire operation is environmentally clean in that it is self-contained; it collects the abrasive particles, loose contaminants, and dust from the runway surface; it separates and removes the contaminants and dust from the abrasive; and it recycles the abrasive particles for repetitive use. The machine is very mobile and can be removed rapidly from the runway if required by aircraft operations.

d. Mechanical Removal. Mechanical grinding that employs the corrugating technique has been successfully used to remove heavy rubber deposits from both PCC and HMA runways. It has also been used to remove high areas such as bumps on pavement surfaces or at joints where slabs have shifted or faulted. This method greatly improves the pavement surface friction characteristics. Pavement surfaces that are either contaminated (rubber buildup or bleeding) or worn can have their surface friction coefficient greatly increased by a thin milling operation. This technique removes a surface layer between 1/8 and 3/16 inch (3.2 and 4.8 mm) in depth.

APPENDIX 1. QUALIFICATION PROCESS FOR CFME

1. FRICTION EQUIPMENT CORRELATION PROGRAM. From 1982 through 1985, the FAA conducted a series of tests to determine the correlation of the Mu Meter with the Saab Friction Tester, Skiddometer, and the Runway Friction Tester, using the equipments' self-wetting systems on dry pavement surfaces at NASA's Wallops Right Facility. Correlation values were established for the Saab Friction Tester, the Runway Friction Tester, the Skiddometer, and the Mu Meter. Reference Appendix 2, Report No. DOT/FAA/AS-90-1, which shows the results of the correlation trials conducted at NASA's Wallops Flight Facility in August 1989. Additional devices have since been found to meet FAA specifications. All devices found to meet FAA specifications are listed in appendix 4.

2. FRICTION/SPEED RELATIONSHIPS FOR PAVEMENT SURFACES. The relationship of speed to friction has a profound influence on aircraft braking performance when pavements have little or no microtextural properties. According to the Unified Mechanism of Rubber/Pavement Friction, the adhesion component of friction, which is governed mainly by the shear force between the tire and the pavement surface, is high at lower speeds of up to about 100 mph. The rubber couples well with a good microtextured surface to provide high friction at the lower speeds. At speeds over 100 mph, the hysteresis component of friction governs. This component is the effect of damping or reacting elastic pressure of rubber when deformed around aggregate particles. The deformation is produced best by good macrotextured surfaces. In essence, the Unified Mechanism simply states that a good macro/microtexture surface will provide relatively high friction and flat friction speed gradient on wet pavement surfaces. As speed increases, macrotextured surfaces will provide good drainage to keep the hydrodynamic pressure low and the tire in contact with the pavement surface for a low friction/speed gradient. However, a poor macrotextured pavement surface cannot provide sufficient drainage for good tire/pavement contact. Thus, the friction speed gradient decreases rapidly.

The relationship of the friction/speed gradient was determined at NASA's Wallops Flight Facility by conducting friction surveys on several types of pavement surfaces that represented a wide range of friction values at speeds of 20, 40, 60, and 80 mph. Testing operational runways at 20 mph is not practicable, since a test of a 10.000' runway would take approximately 6 minutes. Likewise, the distance required to accelerate to and decelerate from 80 mph would preclude testing most of a typical touchdown zone. Therefore, a compromise is made and tests are conducted at only two speeds, 40 and 60 mph. These two speeds will provide an adequate representation of the friction/speed gradient for the various textured pavement surfaces encountered.

3. DEVELOPMENT OF PERFORMANCE SPECIFICATION FOR FRICTION EQUIPMENT. The following paragraphs discuss the qualification process used to develop the performance specification for the friction equipment and friction measuring tires.

a. Development of the Friction Equipment Performance Specification. To qualify for Federal funds, friction equipment performance standards had to be developed. Friction tests were conducted at NASA's Wallops Flight Facility to develop the performance specification for friction measuring equipment. The specification was developed to assure the airport operator that the friction measuring equipment would perform with reliability and consistency on all types of pavement surface conditions.

b. Development of the Tire Performance Specification. Prior to 1989, only one friction measuring tire was available for friction measuring devices. During 1988, the E-17 committee of ASTM requested the FAA to conduct tire performance tests on two tires manufactured according to ASTM specifications E-524, *Specification for Standard Smooth Tire for Pavement Skid-resistance Tests*, and E-670, *Standard Test Method for Side Force Friction on Paved Surfaces Using the Mu-Meter*, and compare these tires with the performance of the then FAA standard tire. A tire performance specification was developed for the test program. The tests were conducted at NASA's Wallops Flight Facility in August 1989. The tires are manufactured in the United States by the McCreary Tire & Rubber Company of Indiana, Pennsylvania and Dico Tire, Inc. of Clinton, Tennessee.

APPENDIX 2. RELATED READING MATERIAL

1. The latest issues of the following free publications may be obtained from the U.S. Department of Transportation, Warehousing and Subsequent Distribution Section, SVC-121.23, Washington, DC 20590. AC 00-2, *Advisory Circular Checklist*, current edition, contains the listing of all current issues of circulars and changes thereto.

a. AC 150/5200-28, *Notices to Airman (NOTAMS) for Airport Operators*.

b. AC 150/5200-30, *Airport Winter Safety and Operation*.

c. AC 150/5320-6, *Airport Pavement Design and Evaluation*.

2. Copies of the following publications may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Send check or money order with your request made payable to the Superintendent of Documents in the amount stated. No C.O.D. orders are accepted.

a. AC 150/5300-13, *Airport Design* ($15.00).

b. AC 150/5370-10, *Standards for Specifying Construction of Airports*, current edition ($18.00).

c. AC 150/5380-6, *Guidelines and Procedures for Maintenance of Airport Pavements* ($7.00).

3. Copies of Part 15, *Road, Paving, Bituminous Materials, Skid-resistance, and Skid-resistance of Highway Pavements, STP 530*, may be obtained from the American Society For Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

4. Copies of the following publications may be obtained from the National Technical Information Service, Springfield, Virginia 22151.

a. *Pavement Grooving and Traction Studies*, Report No. NASA SP-5073, 1969.

b. *A Comparison of Aircraft and Ground Vehicle Stopping Performance on Dry, Wet, Flooded, Slush, and Ice-covered Runways*, Report No. NASA TN D-6098, November 1970.

c. *Runway Friction Data for 10 Civil Airports as Measured with a Mu Meter and Diagonal Braked Vehicle*, Report No. FAA-RD-72-61, July 1972.

d. *Effects of Pavement Texture on Wet Runway Braking Performance*, Report No. NASA TN D-4323, January 1969.

e. *Porous Friction Surface Courses*, Report No. FAA-RD-73-197, February 1975.

f. *Laboratory Method for Evaluating Effect of Runway Grooving on Aircraft Tires*, Report No. FAA-RD-74-12, March 1974.

g. *Investigation of the Effects of Runway Grooves on Wheel Spin-up and Tire Degradation*, Report No. FAA-RD-71-2, April 1971.

h. *Environmental Effects on Airport Pavement Groove Patterns*, Report No. FAA-RD-69-37, June 1969.

i. *The Braking Performance of an Aircraft Tire on Grooved Portland Cement Concrete Surfaces*, Report No. FAA-RD-80-78, January 1981.

j. *Braking of an Aircraft Tire on Grooved and Porous Asphaltic Concrete*, Report No. DOT-FAA-RD-82-77, January 1983.

k. *Analytical and Experimental Study of Grooved Pavement Runoff*, Report No. DOT-FAA-PM-83/84, August 1983.

l. *Surveys of Grooves in Nineteen Bituminous Runways*, Report No. FAA-RD-79-28, February 1979.

m. *Modified Reflex-Percussive Grooves for Runways*, Report No. DOT-FAA-PM-82-8, March 1984.

n. *Reliability and Performance of Friction Measuring Tires and Friction Equipment Correlation*, Report No. DOT/FAA/AS-90-1, March 1990.

5. Copies of *MS-16, Asphalt in Pavement Maintenance*, may be obtained from the Asphalt Institute Building, College Park, Maryland 20740.

6. Copies of *Maintenance Practices for Concrete Pavements*, may be obtained from the Portland Cement Association, Old Orchard Road, Skokie, Illinois 60076.

7. Copies of the following publications may be obtained from the Highway Research Board, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418.

a. *Skid-resistance, National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 14*, 1972.

b. *Pavement Rehabilitation - Materials and Techniques, National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 9*, 1972.

c. *Factors Affecting Skid-resistance and Safety of Concrete Pavements*, Special Report No. 101, 1969.

d. *Road Surface Texture and the Slipperiness of Wet Roads*, Record No. 214, 1968.

e. *Pilot Field Study of Concrete Pavement Texturing Methods*, Record No. 389, 1972.

f. *Prediction of Skid-resistance Gradient and Drainage Characteristics of Pavements*, Record No. 131, 1966.

g. *Standard Nomenclature and Definitions for Pavement Components and Deficiencies*, Special Report No. 113, 1970.

h. *Development of Specifications for Skid-Resistant Asphalt Concrete*, Record No. 396, 1972.

i. *Skid-resistance of Screenings for Seal Coats*, Record No. 296, 1968.

8. Copies of the following technical bulletins may be purchased from the American Concrete Paving Association, Suite 490, 3800 N. Wilke Rd., Arlington Heights, Illinois, 60004-1268.

a. *Texturing of Concrete Pavements*, Bulletin No. 1.

b. *Interim Recommendations for the Construction of Skid-Resistant Concrete Pavement*, Bulletin No. 6.

c. *Guideline for Texturing of Portland Cement Concrete Highway Pavements*, Bulletin No. 19.

9. Copies of *Evaluation of Two Transport Aircraft and Several Ground Test Vehicle Friction Measurements Obtained for Various Runway Surface Types and Conditions*, NASA Technical Paper 2917, February 1990, may be obtained from NASA, under the Code NTT-4, Washington, DC 20546-0001.

10. Copies of ASTM Specifications can be obtained from ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.

APPENDIX 3. PERFORMANCE SPECIFICATIONS FOR CFME

1. FRICTION EQUIPMENT PERFORMANCE STANDARD. The friction measuring equipment may be self-contained or towed. If towed, the tow vehicle will be considered an integral part of the device. The vehicles and/or trailers shall meet all applicable Federal and state laws and/or regulations for vehicles and/or trailers for use on public highways. The side force friction measuring device, the Mu Meter, shall meet the Standard Test Method given in ASTM E 670. The Standard Test Method for the fixed brake slip devices is under preparation by the ASTM Committee.

a. The Friction Measuring Equipment shall do the following:

(1) provide fast, continuous, accurate, and reliable friction measurements for the entire length of the runway, less the differences required for accelerating and decelerating the vehicle at the runway ends.

(2) be designed to sustain rough usage and still function properly and provide efficient and reliable methods of equipment calibration.

(3) be capable of automatically providing the operator with a selection of average friction values for both a 500 foot (150 m) and one-third segment of runway length. In addition, it shall be capable of providing data, whereby, the average friction value for any length of runway can be manually calculated.

(4) be capable of producing a permanent trace of friction measurements versus pavement length at a scale of at least one inch (25 mm) equals 300 feet (90 m).

(5) be capable of consistently repeating friction averages throughout the friction range on all types of pavement surfaces. Friction averages for each 500 foot (150 m) segment located on the pavement surface must be within a confidence level of 95.5 percent, or two standard deviations of ±.06 Mu numbers.

(6) contain a self-wetting system that distributes water in front of the friction measuring wheel(s) at a uniform depth of 0.04 inch (1 mm). The manufacturer shall provide documentation to show that the flow rate is within a tolerance of ±10 percent for both test speeds.

(7) be able to conduct friction surveys at speeds of 40 and 60 mph (65 and 95 km/hr), within a tolerance of ±3 mph (±5 km/hr).

(8) include a complete set of the latest operation and maintenance manuals including guidelines for training airport personnel. The training manuals shall include the current copy of this AC.

(9) have electronic instrumentation (solid-state electronics), including a keyboard for data entry, that will enhance the information gathering and analysis capability of the equipment, and provide the operator more convenience in equipment operation and performance. The information gathered during a friction survey should be stored in an internal microprocessor memory and be readily visible to the operator of the vehicle. This will allow for the examination of data, printouts, and calculation of average friction values over all or any portion of the test run. Each printout of the chart produced by the microprocessor unit shall include the following recorded information: runway designation and date; time of friction survey; a continuous trace of the friction values obtained for the entire runway length minus the acceleration/deceleration distances; printed marks depicting each 100 foot (30 m) increment of the runway length so easy reference can be made by the operator in identifying specific areas on the runway pavement surface; average friction value for 500 foot (150 m) and one-third segments of the runway length as preselected by the operator; and average vehicle speed for that segment.

b. The vehicle shall:

(1) be able to conduct friction surveys at speeds of 40 and 60 mph (65 and 95 km/hr), within a tolerance of ±3 mph (±5 km/hr). The vehicle, when fully loaded with water, shall be capable of accelerating to these speeds within 500 and 1000 feet (150 and 300 m) from the starting position, respectively.

(2) be equipped with electronic speed control.

(3) conform to the requirements of AC 150/5210-5, *Painting, Marking, and Lighting of Vehicles Used on an Airport*, for airfield service vehicles.

(4) be equipped with transceiver(s) necessary for communication with airport operations and air traffic control.

(5) be equipped with a water tank constructed of strong lightweight material, of sufficient capacity to complete a friction survey on a 14,000 foot (4,267 m) runway in one direction and all necessary appurtenances to deliver the required water flow rate to the friction measuring wheel(s).

(6) be equipped with appropriate heavy duty shock absorbers and heavy duty suspension to adequately handle imposed loads.

(7) be equipped with a device that will regulate the water flow within the confines of the vehicle near the driver's position. Where flow regulation is automatic, no device is required in the vehicle.

(8) be equipped with internally controlled spot lights on each side of the vehicle. For trailer mounted equipment, the tow vehicle shall also be equipped with at least two floodlights mounted such that the friction measuring device and rear portion of the tow vehicle is illuminated to a level of at least 20 foot-candles within an area bounded by lines 5 feet (2 m) on either side of the friction measuring device and 5 feet (2 m) in front of and behind the friction measuring device.

(9) be equipped with an air conditioner when specified by the purchaser.

2. TIRE PERFORMANCE STANDARD. The friction measuring equipment shall be furnished with measuring tires which are designed for use in conducting friction surveys and which meet ASTM standard E670, E-5551, or E-1844, as appropriate. Nonribbed (blank) tire(s) shall be used to eliminate the effect of tire tread wear and provide greater sensitivity to variations in pavement surface texture. The tires shall be furnished with split rims and the tubes shall have curved valve stems. The manufacturer of the friction equipment shall provide the airport user with a calibrated pressure dial gauge.

APPENDIX 4. FAA-APPROVED CFME

AIRPORT SURFACE FRICTION TESTER AB PL 2217 S-761 92 Norrtalje SWEDEN	**AIRPORT SURFACE FRICTION TESTER** +46 1 766 96 90 FAX +46 1 766 98 80
AIRPORT TECHNOLOGY USA Six Landmark Square - Fourth Floor Stamford, CT 06901-2792	**SAFEGATE FRICTION TESTER** (203) 359-5730 FAX (202) 378-0501
BISON INSTRUMENTS, INC. 5610 Rowland Road Minneapolis, MN 55343-8956	**MARK 4 MU METER** (612) 931-0051 FAX (612) 931-0997
INTERTECH ENGINEERING 726 South Mansfield Avenue Los Angeles, CA 90036	**TATRA FRICTION TESTER** (213) 939-4302 FAX (213) 939-7298
DYNATEST CONSULTING, INC. (FORMERLY K. J. LAW ENGINEERS, INC.) 13953 US Highway 301 South Starke, FL 32091	**RUNWAY FRICTION TESTER (M 6800)** (904) 964-3777 FAX (904) 964-3749
AEC, AIRPORT EQUIPMENT CO. P.O. Box 20079 S-161 02 BROMMA SWEDEN	**BV-11 SKIDDOMETER** +46 8 295070 FAX +46 8 6275527 E-mail aec@aec.se
FINDLAY, IRVINE, LTD. Bog Road, Penicuik Midlothian EH 26 9BU SCOTLAND	**GRIPTESTER FRICTION TESTER** +44 1968 672111 FAX +44 1968 672596
NORSEMETER P.O. Box 42 Olav Ingstads vei 3 1351 Rud NORWAY	**RUNAR RUNWAY ANALYSER AND RECORDER** +47 67 15 17 00 FAX +47 67 15 17 01

APPENDIX 5. TRAINING REQUIREMENTS OUTLINE FOR CFME

1. GENERAL DISCUSSION. The following paragraph lists the major items which should be considered in developing a training program for airport personnel responsible for operating and maintaining CFME. Whenever a major change in equipment design occurs, the training and instruction manuals should be revised. A document titled *Training and Instruction Manual* should always be provided to the airport personnel by the manufacturer and kept updated.

2. TRAINING REQUIREMENTS OUTLINE.

a. Classroom Instruction.

(1) Purpose of Training Program.

(2) General Discussion on Pertinent Federal Aviation Regulations.

(3) General Discussion on Pertinent ACs.

(4) General Discussion on Pertinent ASTM Standards.

(5) General Overview of Program.

(6) Review of Requirements in AC 150/5320-12.

(i) Coefficient of Friction Definition.

(ii) Factors Affecting Friction Conditions.

(iii) ASTM Standards for CFME.

(iv) ASTM Standards for Friction Measuring Tires.

(v) Operation of CFME.

(vi) Programming the Computer for FAA and ICAO Formats.

(vii) Maintenance of CFME.

(**viii)** Procedures for Reporting Friction Numbers.

(ix) Preparation and Dissemination of NOTAMS.

(7) Orientation to the Calibration, Operation, and Maintenance of CFME.

b. Field Experience. Operation and Maintenance of CFME.

c. Testing. Solo Test and Written Examination on All Items Covered in Course.

d. Award Of Training Certificate.