สำนักงานการบินพลเรือนแห่งประเทศไทย
The Civil Aviation Authority of Thailand

Guidance Material for Maintenance of the Movement Area

CAAT-AGA-GM-MOTMA

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Approved By

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Abbreviations

Abbreviations	Meaning
AMC	Acceptable Means of Compliance
CAAT	The Civil Aviation Authority of Thailand
FOD	Foreign Object Debris
GM	Guidance Material
PAPI	Precision Approach Path Indicators
RCAAT	Requirement of The Civil Aviation Authority of Thailand

0. Introduction

0.1 Overview

This manual consolidates in one document a review of the maintenance practices required at airport to maintain the safety, efficiency and regularity aircraft operations. It is only concerned with those facilities which are normally the responsibility of the airport authority. In other words, maintenance of such facilities as radio navigational aids and meteorological equipment is not discussed.

Proper maintenance of airport facilities is important both for the safe operation of aircraft and extending the life of the facilities. Nevertheless, maintenance is frequently overlooked or reduced when establishing budgets for airport. It is hoped that this guidance material will establish the proper position of maintenance in the over-all airport program.

Differences between the facilities provided at an airport, differences in the local environmental conditions and differences in use make it impossible to name specific maintenance requirements. This guidance material attempts to overcome this by identifying the various types of maintenance required for airport facilities. It remains for each airport authority to decide if a particular maintenance check is appropriate for its airport and to establish the appropriate maintenance schedule.

This Guidance Material (GM) is directed at authorities responsible for the operation of airports and/or individual facilities on airports other than meteorological or electronic navigation aids. It is compiled in a manner suitable for those who have responsibility for the operational safety of airport facilities and equipment, and for ensuring the undisturbed operation of air traffic on the ground. Reference is made to specifications and other relevant material in CAAT documents which require authorities to take care of special tasks in the interest of safety and regularity of air transport.

While this GM addresses maintenance of airport components regardless of the airport's size or role, the description of tasks has been restricted to the maintenance of those facilities which are unique to or typical for airports. As airports are comparable to other kinds of industrial plants, many other maintenance functions have to be carried out to ensure serviceability and function of buildings, facilities and equipment. This guidance does not deal with any of these normal industrial maintenance tasks except in areas where a functional failure would impair safety or regularity of aircraft operation and/or passenger handling.

This GM is intended to give guidance to authorities on planning and conducting maintenance work on airport. Since wear and sensitivity of any technical component depend on material, utilization, age, climate and other environmental conditions, none of the recommendations on the type and intervals of maintenance action described in this GM should be considered a specification. Local needs, local experience, recommendations of manufacturers of components and national of local rules should be govern the plan on what and when maintenance tasks are to be carried out.

0.2 Purpose

An airport, being an important part of the aeronautical infrastructure, has to meet high safety standards. The required level of safety can only be achieved by proper maintenance of all the elements composing an airport.

Maintenance includes measures to keep or restore the operational function as well as measures to check and to evaluate the present function of an element. The basic components of maintenance are:

a) inspection;
b) servicing and overhaul; and
c) repair.

Inspection comprises all measures to check and evaluate the operating condition including spontaneous and scheduled checks. Scheduled checks are carried out in accordance with a plan specifying the preparation of the check, the sort of check, the report on the result and the evaluation of the results. From the evaluations the operator decides whether or not extra servicing or even repair has to be undertaken.

Servicing and overhaul comprise all measures to maintain or return a facility or device to its required operating condition. These measures should be carried out according to a plan specifying the time for the service, the nature of the service and the report of compliance.

Whenever inspection or servicing discovers deficiencies, repair measures have to be planned and carried out as soon as practicable. Repair can comprise minor or major work as, for instance, runway surface treatment with consequential traffic interruption.

Efficiency and safety of operation can only be expected from facilities that are in good operational condition. The maintenance of facilities, i.e. the sum of all measures described above is the perquisite to such a condition. Furthermore, maintenance minimizes wear and tear, thus controlling and extending considerably the life span of technical components. In this respect maintenance becomes an economic requirement to keep investment and capital costs for the aeronautical infrastructure within acceptable limits.

0.3 Applicability

This GM applies to Thai aerodrome operators operating a public-use aerodrome.

0.4 Effective Date

25 December 2022

0.5 Reference

a) Requirement of The Civil Aviation Authority of Thailand No. 37 on Aerodrome Standards B.E. 2565

b) Rule of Department of Civil Aviation on Standards of Aerodrome Operating Procedures B.E. 2557

c) Rule of the Civil Aviation Authority of Thailand on Standards of Aerodrome Manual B.E. 2562

d) Guidance Material for Airport Safety Self-Inspection (CAAT-GM-AGA-ASSI)

e) Doc 9137 Aerodrome Service Manual Part 2 – Pavement Surface Conditions

f) Doc 9137 Aerodrome Service Manual Part 9 – Airport Maintenance Practices

1. Organization of Airport Maintenance

Complete assessment of all parts of airport is the basic requirement of the maintenance organization.

Buildings, pavements sections and unpaved areas in between have to be numbered, as well as all machinery, technical and mechanical inventory, including vehicles. The numbers define the objects, for which the maintenance requirements can be specified individually. These requirements should be recorded on cards or computer tapes.

Maintenance programmes will be developed from experience with the needs of the different objects or in accordance with the manufacturer's advice. For economic reasons and in order to split responsibility equitably, a precise breakdown of the total work by fields of maintenance is recommended (e.g. for a building roofs, walls, (including doors and windows), machinery and mechanical facilities and electric installations). Each team or expert responsible for one special task can then work in accordance with a systematic work programme that will achieve optimum efficiency.

A fundamental task of the maintenance organization is to translate the maintenance requirement into man/hours and monetary value. This evaluation is the basis of staffing budget planning. It is, furthermore, a tool for decision-making when contracting third parties for maintenance tasks instead of employing extra personnel.

All maintenance programmes should be "screened" once a year, preferably at the time of budget planning. It is useful not only to rely on recorded data but to inspect the condition of all major objects at that time. In contrast to machines, whose operating hours give a good measure of wear, the deterioration of buildings is more dependent on weathering, utilization under heavy load, concealed construction deficiencies or other unpredictable sources of damage.

Updated maintenance programmes will allow:

a) Appropriate staffing;
b) Compliance with the recorded maintenance needs; and
c) Flexibility as to the timing of action when unexpected circumstances have affected the planned work schedule.

When management checks the work carried out against schedule tasks, it gains thereby full control of the maintenance progress and budget. Compliance reports are the feedback and have to be recorded, as well as observations on any reported deficiencies.

Computer assistance can be helpful and economical if the volume of maintenance is high. The computer is particularly capable of controlling preventive maintenance tasks typical of electrical systems and machines. Furthermore, evaluation of the aging of inventory and of maintenance budget control can be facilitated by suitable computer programmes. The computer is less effective for maintenance control of buildings and pavements, where repair work upon notice will always prevail.

To maintain the operation of the technical facilities at an airport, a sufficient number of technicians must be available during airport operating hours so that deficiencies can be overcome immediately. The team available should comprise, as appropriate, engineers, automotive technicians, locksmiths, tinsmiths, air conditioning and heating technicians, electricians and HF-technicians. If control/monitoring centres for technical facilities exist, they should be manned permanently.

This standard team can be reduced outside the operating hours to such a degree that vital components necessary for the technical function of the airport (e.g. electrical circuits, heating or air conditioning, telephone system etc.) can be kept serviceable and additional technicians can be called upon to arrive promptly in cases of serious disturbance. In all other cases the reduced maintenance team has to take care of provisional repair work and will report on maintenance needs to the standard team at the beginning of their duty hours.

The standard team need not be capable of doing all of the airport’s maintenance tasks. The airport authority may use contractors to carry out those maintenance tasks which can be easily organized on a time schedule. However, apart from the normal maintenance tasks (which according to the experience of the airport authority the maintenance staff can fully take care of) special tasks may occur unexpectedly due to the very nature of air transport and its sensitivity to external impacts. Reasons for extra maintenance work can be:

a) snowfall or ice forming on operational area;
b) sandstorm;
c) rain, heavy thunderstorm with consequential damage;
d) aircraft accidents or incidents; and
e) technical or criminal emergencies.

To cope with these inevitable work requirements and especially in view of the airport emergency plan, the airport authority will have to have a certain reserve of skilled craftsmen employed. This requirement reduces the scope for contract maintenance by third party companies.

To ensure the whole airport’s smooth operation the provision of workshops at the airport is necessary from both an operational and economic standpoint. The selection of the kinds of workshops depends largely on the local situation, i.e. size of airport, traffic volume, ownership of facilities and equipment, share of work between airport users (airlines) and airport operator etc. Individual solutions for the provision of workshops have to take into account:

a) local maintenance requirements;
b) compliance with the airport emergency plan; and
c) economic aims.

The economic aims may involve performing other business in the airport's workshops, for example, aircraft maintenance for home base carriers and/or general aviation. Alternatively, economic needs can require that outside workshops or craftsmen be used for maintenance work and even emergency assistance, A sound balance between the capacity of the airport's basic maintenance workforce and their system to comply with peak and emergency workloads is important for an economic airport operation.

2. Maintenance of Visual Aids

2.1 Introduction

2.1.1 The basic purpose of visual aid system is to aid in the safe operation of aircraft. Therefore, the highest standards of maintenance are required. Once a system has been installed, its usefulness is dependent on its serviceability which in turn depends upon the effectiveness of the maintenance work carried out, RCAAT No. 37 on Aerodrome Standards defines a light to have failed when its light output falls below 50 per cent of that specified for a new light. The cause for the loss in light output can be contaminants outside and inside the light unit, and degradation of the lamp and optical system due to aging. The light can and should be restored to its original condition by cleaning or replacing the lamp and any parts which have apparently become degraded. For this purpose, it is essential to establish a comprehensive routine maintenance system for servicing lights and other equipment so that the installation complies with the specified requirements. Reference is made to RCAAT No. 37 on Aerodrome Standards.

2.2 Personnel

2.2.1 The task of maintenance lighting aids should be entrusted only to reliable and skilled electricians who have had experience with high voltage, series circuits and lighting. These individuals should be present or on call during the operating hours of the airport to correct any deficiencies that might develop. Training programmes should be established to maintain the competence of maintenance personnel and to keep them abreast of new developments.

2.3 Spare parts

2.3.1 An adequate stock of spare parts should be available. The level of stock will vary depending on the time required to re-supply a particular item and its shelf life.

2.4 As-built drawings

2.4.1 A set of as-built drawings should be kept readily available. These drawings must be kept up to date and any changes at site should be reflected immediately on these drawings. The completeness and the accuracy of all circuit diagrams, drawings and descriptions should be checked at least annually.

2.5 Light maintenance schedule

General

2.5.1 When servicing lights the instructions of the appropriate authority and recommendations of the equipment manufacturer should be followed to ensure the required service standard. Service records showing maintenance schedules recommended by the manufacturer or local standards should be prepared for each piece of equipment. These can be arranged in a dated reminder file to make sure all equipment is serviced regularly. This record should have space to enter observations, measurements and initials of the servicing individual. If local conditions indicate a change in time interval of servicing to be desirable then the schedule can be altered in consultation with the equipment manufacturer.

2.5.2 The frequency at which routine inspection, cleaning and servicing are to be performed will vary according to the type of equipment, its location and usage, A maintenance programme must be drawn up for each individual airport based on past experience and its aim should be to achieve the required service standard. The following schedules are presented as guidance material in establishing a preventive maintenance programme. More frequent check may be necessary for the lights serving precision approach category II and III runways. The time schedules shown should not take precedence over manufacturers' instructions or be applied to similar equipment not mentioned. Each check should be followed by appropriate corrective action.

Basic maintenance program for approach, runway and taxiway lighting systems

2.5.3 Maintenance for all types of approach, runway and taxiway lights should include checking and, if necessary, taking the indicated corrective action, as follow:

a) Daily:
   - system for burnt-out lamps; replacing burnt-out lamps
   - system for gross misalignment (if applicable); adjusting
   - control equipment for proper operation on each brightness step (if applicable); correcting or repairing malfunctions
   - glass for breakage; replacing broken parts.

b) Annually:
   - fasteners of each light unit; tightening
   - lights for corrosion; painting or replacing rusted parts
   - reflector of each light unit (if applicable); cleaning or replacing
   - glass of each light; cleaning or replacing
   - lamps of the whole system; replacing of the unserviceable lamps or entire system (see 2.6.18)
   - elevation setting (if applicable); adjusting
   - horizontal alignment; adjusting
   - plug connections for cleanness and faultless contact; cleaning or replacing of dirty parts
   - light fittings and their supporting structure (if existing) for adequacy of fastening and for corrosion and rust; tightening fasteners; painting or spraying
   - general condition of the whole system, and recording result.

c) Unscheduled:
   - elevation sitting and the horizontal alignment (if applicable) of the light units after severe storms and snowfalls; adjusting

- light units for obstruction by grass or tree. etc. (not applicable for Inset lights); removing any obstacles found.

Additional maintenance programme for special types of lights

2.5.4 In addition to the maintenance programme specified in 2.5.3, the following should be carried out for visual approach slope indicator, runway threshold and lights, and inset lights.

2.5.5 Visual approach slope indicator maintenance should include checking and, if necessary, taking the indicated corrective action, as follows:

a) Twice monthly:
   - elevation setting (vertical angle) of the light units; adjusting
   - spreader glasses, filters and lamps for cleanness; cleaning
b) Annually:
   - system from the air, and recording results; adjusting and replacing lamps
   - supporting structure and the foundation of each unit; repairing.

2.5.6 Runway threshold and runway end light maintenance should include checking and, if necessary, taking the indicated corrective action as follows:

a) Twice weekly:
   - fasteners of lights; tightening
   - glass of each light for wear and tear; replacing.

2.5.7 Inset lights (runway center line lights, touchdown zone lights, taxiway centre line lights, stop bar lights) maintenance should include checking and, if necessary, taking the indicated corrective action, as follows:

a) Daily:
   - lenses for cleanness; cleaning
b) Twice weekly (not applicable to taxiway and stop bar lights):
   - light output of lights within 900 m from each threshold including measuring and recording the results; cleaning of the lenses
   - top parts of lights within 900 m from each threshold; replacing
c) Quarterly (not applicable to taxiway and stop bar lights):
   - light output of all lights within the system including measuring and recording the results; cleaning of the lenses
   - top parts of the lights; replacing
d) Semi-annually (not applicable to taxiway and stop bar lights):
   - lights for cleanness inside and out; cleaning
   - lights for moisture; drying
   - electrical connections of the lights; tightening; spraying with contact agent
   - alignment of lights; adjusting
e) Annually:

- prism and filters; cleaning or replacing
- sealing compound; resealing

f) Unscheduled:
- top parts of the lights two to four weeks after replacement; tightening.

Maintenance programme for other airport lights

2.5.8 Other airport lights include, for example, airport beacons, obstacle lights and wind direction indicators. These normally need less maintenance than approach, runway or taxiway lighting system. Their maintenance should include checking and, if necessary, taking the indicated corrective action, as follows:

a) Daily:
- lamps; replacing if necessary
- control equipment for proper operation (not applicable in the case of obstacle lights); correcting or repairing
- fabric of the wind cone; repairing or replacing

b) Semi-annually (only for airport beacon):
- power supply (brush and slip-rings); cleaning or replacing
- electrical connection; tightening

Rotating parts; fastening

c) Annually:
- optical system of the airport beacon
- glasses and the gaskets of obstacle lights; cleaning or replacing
- function of the flashing relays and of the twilight switches of the obstacle lights; cleaning; repairing of replacing
- power supply and the lighting of the wind direction indicators; repairing or replacing
- electrical connections; tightening; spraying with contact agent
- fasteners of obstacle lights
- structure and the fasteners of the wind direction indicator; tightening or repairing the structure
- lights for corrosion; painting
- colour of the fabric cone of the wind direction indicator; replacing
- location of obstacle lights for easy access for maintenance; arranging of change of location if required and possible

d) Unscheduled:
- wind direction indicator after severe storms; repairing.

Docking guidance systems

2.5.9 Maintenance programmes for various types of aircraft docking guidance systems are provided at airports and it is very difficult to describe a generally applicable maintenance programme for these very different systems. Principal requirements to be checked and maintenance action to be taken, if necessary, include:

a) Daily:
   - system for over-all operation: repairing
   - lamps; replacing burnt-out lamps
b) Semi-annually:
   - alignment of the system; adjusting
c) Annually:
   - electrical connections (if provided) for corrosion, wear and tear; cleaning, tightening and replacing
   - function of relays (if provided); cleaning or replacing
   - structure of the system and the function of all mechanical parts; repairing
   - system fir cleanness and moisture; cleaning and drying.

2.6 Light maintenance procedures

General hints for maintenance of lights

2.6.1 For reasons of efficiency the maintenance of lights should, as far as practicable, be carried out indoors. Inconveniences of working out of doors, such as heat, cold, precipitation and aircraft noise can be avoided and traffic restrictions or interruptions will be reduced to a minimum. The quality of service will also be higher in workshops than out of doors. This is particularly applicable when, in the interest of unrestricted traffic flow during day hours, the work has to be carried out during the night.

2.6.2 The maintenance procedure commonly used comprises two steps:

a) removal of defective lights and immediate replacement by new or repaired ones
b) servicing and overhaul of deficient lights in the workshop where all required tools, measuring and adjusting equipment are available.

2.6.3 This procedure has proven to be practical, particularly for the maintenance of inset lights. Provision of a sufficient number of stored spare lights is a prerequisite. The number of spare parts depends on the over-all requirement of the airport and the experience with the sensitivity to damage of the various types of lights on the airport. It is useful to select lights which are designed to permit removal and installation within a short time, without the use of very sophisticated technical equipment. Furthermore, all mechanical and optical parts of the light should be incorporated in the removable part.

Cleaning procedures for lights

2.6.4 The type and degree of contamination of the various lights on an airport will be different. While elevated approach and edge lights are normally contaminated by weather effects only (dust carried by wind and rain), more severe contamination can be observed on inset lights, particularly on runways. Rubber deposits from tires on touchdown and exhaust from engine reverse thrust procedures create firmly sticking deposits on the exterior glassware of lights. The very different degree of contamination must be reflected in the maintenance schedule of different categories of lights or sections in the runway/taxiway system.

2.6.5 When cleaning the glassware of lights, the manufacturer's recommendations should be observed. Normally, cleaning is accomplished by washing the glassware with a cleansing mixture of water and a special solvent that will neither affect the sealing material nor produce a residual film on the glass. The solvent must be given sufficient time to dissolve the deposits. If necessary, rubber spots may be scraped off by using plastic tools or powder before using the solvent. Other mechanical aids for cleaning may be sponges, cloths, hand brushes or electric rotating brushes. The cleaning technique and the materials used should not scratch or groove the glass surface or damage the sealing material.

2.6.6 Dry cleaning of glassware should be avoided. However, if cleaning becomes necessary for some reason, no sand or other abrasive material should be used. In such cases cleaning can be done by using clean ground-up walnut or pecan shells and dry compressed air. Special treatment can normally be avoided by following a maintenance schedule with wet cleaning at suitable intervals.

2.6.7 For cleaning light fittings on site special maintenance vehicles equipped with air compressors, vacuum cleaners and solvent tanks should be used. A low working seat at the rear or front, or an opening in the bottom of the maintenance vehicle facilitates the work considerably. In some cases, these vehicles can carry the required tools for all types of maintenance work, including the removal of old lights and the installation of new ones.

2.6.8 Thorough cleaning of the interior of the light to remove mud, moisture or rust should be carried out in workshops. Only minor contaminants, such as dust, should be removed on site.

Light measurement

2.6.9 The light output will diminish with the lapse of time due to lamp aging. Contamination of reflector and lens will result in a further degradation of light output. According to RCAAT No. 37 on Aerodrome Standards a light is considered to have failed when its output is less than 50 per cent of the required intensity. For practical reasons replacement of a light is recommended when its output fall below 70 per cent of that specified for a new light.

2.6.10 Light measurements should be carried out regularly to detect early light output reduction. Appropriate equipment for both field and bench measurement of light output is available. The equipment produced by light manufacturers does not, however, indicate the absolute intensity values but provide ratios between measured and original light intensities of each individual type.

2.6.11 Field measurements are particularly necessary for inset lights. Wheel loads on inset lights may frequently cause damage. One type of measuring equipment offered by the light manufacturers for field use consists of a photocell and a microammeter. Such measuring devices are placed over the light fitting and the meter reading observed is compared with the calibration value. Before measuring, the lights should be cleaned and switched to the highest available intensity setting.

2.6.12 Light measurements can also be made by using a photographic 1° spotmeter, which is not placed on the light casing directly, but moved vertically and horizontally through the light beam at a fixed distance. The intensity is checked by comparison with the results of a calibration test with a new light.

2.6.13 The measuring procedures described above are quite time-consuming. With the special device each measurement will take about 2 minutes. Often a much faster visual observation carried out by experienced personnel will achieve comparable results for discovering and reporting single lights with unacceptable light output. For visual checks the level of brightness must be switched to "low" (3 to 10 per cent of maximum).

2.6.14 For adjustment of the correct angle of the beam, lights are normally furnished with alignment markings. Furthermore, light manufacturers offer suitable adjustment equipment for their product. Beam misalignment caused by displacement of the optical system inside, however, cannot be corrected by adjusting the casting. When such misalignment is observed visually, the light should be adjusted in the workshop.

2.6.15 For measuring light output in the workshop the measuring equipment produced by the light manufacturer concerned should be used. The equipment consists of a bench to fix the light and a photocell sensor element. Microammeter readings should be compared with the calibration value, Directional adjustments can be made using the alignment screws.

2.6.16 Where light measurements have to be accomplished without the manufacturer's special equipment, a useful technique is to check the isocandela curve on a vertical surface located approximately 3 m in front of the light unit. With photocells at the vertical and horizontal limit lines of the isocandela curve, comparison with the light output of a new light will be possible. Lights should be switched to the maximum brightness level before testing.

Lamp replacement

2.6.17 The life span of lamps varies from 100 to some 1000 hours of operation. The life time depends on the percentage of operation at high brightness levels and on the number of switching. Also, dynamic stresses imposed by aircraft wheel loads (inset lights) and temperature-induced stresses inside the casing affect the lamp life. Lamps which have failed should be replaced as soon as possible since the lighting system of an airport has to meet specified serviceability requirements. Reference is made to RCAAT No. 37 on Aerodrome Standards.

2.6.18 Lamp replacement can be organized in two different ways;

a) only lamps which have failed or lamps showing major output reduction are replaced upon checking; this method requires check to be carried out at short intervals;
b) bulk changing of lamps in certain sections of the entire lighting system, in accordance with a fixed time schedule. The intervals between replacements have to be derived from local experience with the average life of lamps in use. Lamps should be changed when they have been operated for 80 percent of their average life. For this maintenance method a reliable record of operating hours for the individual sections of the airport’s lighting system is a prerequisite. This method requires less frequent checks.

2.6.19 Lamp replacement in the workshop is preferable, particularly with inset lights. The unserviceable light should be removed from its position and replaced by a serviceable light. Lamp replacement of elevated lights may be carried out on site provided that the casing can be opened easily and quickly, and the socket of the lamp needs no realignment afterwards.

Removal of water

2.6.20 Inset lights may sometimes collect water. Water inside the light increases corrosion, causes damage to electrical parts and deposits on lens and lamp and, furthermore, reduces the life of the lamp. Before insetting a light into the pavement good drainage of the opening must be ensured. Nevertheless, penetration of moisture and accumulation of water cannot be precluded completely. Regular inspection is necessary to check lights for the presence of water. Lights found to be wet inside should be removed and replaced, if such a procedure is possible with the type of light. Otherwise, drying must be carried out on spot. After drying, the sealings should be checked carefully and replaced when necessary. Before closing a dried light, the lamp should be switched on for some time to permit any residual moisture to evaporate due to the temperature increase inside.

2.6.21 Attention should be paid to the presence of water on and in front of the glass of inset lights. Water may bend the light beam, thus misaligning the light direction. If such a situation is observed, the drainage has to be improved.

2.7 Signs

2.7.1 Signs give pilots directional information for taxiing and holding. Maintenance should ensure integrity and perfect legibility of the information provided by the signs. The design and construction of signs varies considerably but the following general checks and, if necessary, maintenance action, are recommended for each sign:

a) Daily:
  - lighting; replacing burnt-out lamps;
  - inscriptions for legibility and absence of obstructions; repairing the signs and removing obstructions

b) Annually:
   - repairing mounting of both the sign and its lighting if provided;
   - cleaning, repairing or replacing structure and its paint

c) Unscheduled:
   - after storms for legibility; removing obstructions
   - after severe storms; re-positioning tumbled signs and repairing damaged signs.

2.8 Markings

2.8.1 All markings on paved areas should be inspected at least semi-annually. Local conditions will determine when to inspect. In general, a spring and fall inspection will suffice to detect deterioration due to the winter and summer weather extremes.

2.8.2 Markings which are faded or discoloured by soil should be repainted. When rubber deposits have been removed from the pavement all defaced markings should be restored as soon as possible.

3. Maintenance of Airport Electrical Systems

3.1 General

3.1.1 The serviceability and operational reliability of air navigation equipment and installations are requirements for the safe operation of aircraft in the airport area. Apart from visual aids, the air navigation equipment and installations include electronic landing aids, navigation equipment, radar and equipment oof the meteorological services. Guidance on the maintenance of visual aids is given in Chapter 2 of the guidance material, maintenance programmes for other equipment and installations are to be established by the appropriate authorities (ATC, Meteorological Services).

3.1.2 The required serviceability of installations and equipment will only be achieved as long as a constant power supply is maintained. To this end, regular maintenance work is required for airport equipment and installations distributing primary power and equipment supplying the secondary power when there is a circuit breakdown. The following paragraphs contain guidance on establishing maintenance programme for the individual elements of the power supply systems, such as power cables, control cables, transformers, transformer stations, regulators, relay and switch cabins and secondary power supply equipment. Furthermore, guidance is given on the regular maintenance of the floodlighting systems for aprons. Chapter 9 of this guidance material includes guidance on the maintenance of lighting systems in and around passenger terminal buildings.

3.2 Personnel

3.2.1 Maintenance work on airport electrical systems should be assigned to skilled electricians, fully acquainted with the work to be done. As work is often required in high voltage areas, they should be well informed and kept up to date on safety measures. To protect personnel the required safety devices should always be kept in good condition.

3.2.2 The maintenance personnel should be present or on call during the operating hours of the airport. It may be advisable to have the same persons take care of maintenance of both electrical systems and visual aids.

3.3 Schedule of maintenance

3.3.1 Schedules of routine maintenance of the individual elements of the airport electrical system should be based on manufacturers' recommendations adjusted to the operator's own experience regarding the frequency of malfunctions. Therefore, a record of maintenance work carried out will need to be maintained.

3.3.2 As the frequency of servicing depends on the type of equipment, it is not possible to set up generally applicable maintenance programmes. Therefore, the following schedules provide only general guidance on the setting up of a programme of preventive maintenance.

Power cables and distributors in field

3.3.3 Cables and distributors outside of buildings can only be checked where installed in channels. Preventive maintenance is not possible where power cables are buried in the soil. In such cases, work is restricted to repair when malfunctions have been notices. Their maintenance should include semi-annual checking and, if necessary, taking the indicated corrective action, as follows:

a) distributors located in manholes for cleanness and moisture; cleaning and drying
b) plug-in and clamp connections in the distributors for good contact; tightening and spraying
c) manholes for condition of the interior; pumping-out, drying up or cleaning
d) insulation resistance by measuring the earthing resistance of each circuit; recording readings and taking necessary corrective action.

Transformers and regulators (including standby units)

3.3.4 Maintenance of transformers and regulators should include checking and, if necessary, taking the indicated corrective action, as follow;

a) Monthly:
    - power supply transformers and regulators for cleanness and oil losses; cleaning and replacing oil
    - switches at all light intensity positions for malfunctions; restoring
    - switch over to standby units for serviceability; restoring
b) Annually:
    - transformers for noise; investigating reason for any unusual sound and repairing
    - over-all condition; repairing
    - insulators; repairing or replacing
    - collector bar system; cleaning
    - voltage and amperage at all intensity levels, measuring and recording; adjustment of voltage to nominal level.

Transformers stations for electric power supply

3.3.5 Maintenance of transformer stations for electric power supply should include checking and, if necessary, taking the indicated corrective action, as follow;

a) Weekly:
    - over-all condition visually; restoring
    - fuse boxes for completeness of contents; adding missing fuses

b) Semi-annually:
- insulators and electrical connections; cleaning and restoring
- station for dirt and moisture; cleaning and drying
- locks to stations for serviceability; repairing and locking

c) Annually:
- protection relay; adjusting
- high voltage cable insulation; recording condition of each cable; taking preventive measures
- earthing and its resistance; cleaning
- electrical supply system for noise and damage; repairing
- for rust, corrosion or defective coating; cleaning and painting
- warning sign and safety devices are present and in correct positions; cleaning or replacing
- safety grids for completeness, rust or coating deficiencies; completing, cleaning and painting
- safety grids for stability and earthing; tightening and restoring proper earthing.

Relay and switch cabinets (including switch cabinets in sub-stations)

3.3.6 Maintenance of relay and switch cabinets should include checking and, if necessary, taking the indicated corrective action as follow:

a) Semi-annually:
- turn and plug-in connections for cleanness and good electrical contact
- relays for positive closing of contacts; cleaning or replacing
- electrical contacts for corrosion and wear; cleaning and replacing
- cabinet condition including proper weather seal, cleanness and mechanical damage; cleaning and repairing
- monitoring relay of series circuits for proper feedback; repairing
- voltage switch-over, if available, of two circuits for serviceability; repairing

b) Annually:
- cabinet outer condition for dirt, moisture, easy access; cleaning and drying
- fuses (if provided) and fuse sockets; cleaning and spraying sockets and replacing fuses
- voltage output for all series circuits; recording results; taking corrective action.

Control cables, monitoring units, control desk

3.3.7 Maintenance of control cables. Monitoring units and control desk should include checking and, if necessary, taking the indicated corrective action, as follow;

a) Daily:
- optical and acoustical signal for feedback; restoring

b) Weekly:
   - nominal control voltage; charging battery
   - voltage and ammeter readings; adjusting
   - acid level in batteries; adding distilled water
c) Monthly:
   - functions of the monitoring units
   - parts for cleanness and condition; cleaning and repairing or replacing
d) Quarterly:
   - system components for loose connections; tightening, repairing or replacing
   - control desk for over-all operation; investigating any malfunctions; repairing or replacing parts
   - mimic panel indications for conformation to field conditions; correcting or adjusting
   - mechanical structure of the desk for stability, repairing
e) Semi-annually:
   - replacing lamps in monitoring units
f) Annually:
   - cables and distributors; cleaning and repairing
   - relays for cleanness; cleaning
   - control and monitoring units; replacing
   - connections; tightening and spraying
g) Unscheduled:
   - insulation of cables after each lightning strike, i.e. insulation between wire and wire, and insulation between wire and ground; improving insulation
   - relays for cleanness; cleaning

Secondary power supplies (generators)

3.3.8 Maintenance of secondary power supplies should include a monthly test run and checking and, if necessary, taking the indicated corrective action, as follow;

a) switch-over time from primary to secondary power supply for conformation to the requirement
b) voltmeter readings to ensure that the voltage remains within acceptable tolerances
c) transfer equipment for excessive heating and malfunctions
d) generator for vibrations and excessive heating
e) diesel engine for any irregularities and oil leakage
f) fuel level in the tank after the test run; refilling with fuel if necessary
g) abnormal or undesirable performance; taking corrective action and repairing
h) recording the meter readings of the test run and comparing with former records to detect potential deficiencies.

Fixed 400 Hz ground power supplies

3.3.9 Maintenance of ground power supplies should include checking and, if necessary, taking the indicated corrective action, as follow;

a) Daily:
   - plug, cables and cable holdings; repairing
b) Weekly:
   - proper functioning
   - tightness (oil spillage) and loose connections; repairing
c) Monthly:
   - serviceability of control lamps; replacement
   - screw connections at the contact rail for potential temperature rise; improvement of contact
   - cleanness of cables; cleaning
   - ventilator flaps and orifices for cleanness; cleaning
   - cone belts, driving the ventilator system; adjustment of belt stress
d) Quarterly:
   - current-input cables for potential deformation; removal of deficiencies
   - connector boxes for:
     i) mechanical damage
     ii) proper mounting of plug sockets
     iii) condition of contact clips in the plug sockets
   - bearings for lubrication
e) Semi-annually:
   - cables (wires and insulation) for serviceability; repairing or replacing
   - main conductor cables for temperature rise under nominal electric power; removal of discovered deficiencies
   - connectors, plugs and cable holdings; adjusting and tightening
   - switches for proper operation; removing of dust and dirt from switch elements
   - fixings holding the regulator and switch cabinet housings; tightening of mounting screws or bolts

Apron floodlighting

3.3.10 Maintenance of the apron floodlighting should include checking and, if necessary, taking the indicated corrective action, as follow;

a) Daily:
   - lamp outage; replacing lamps
   - switching operation from remote control; repairing

b) Annually:
   - turn and plug-in connection for cleanness and good electrical contact
   - relays for serviceability; cleaning or replacement
   - contacts for corrosion and wear; cleaning or replacement
   - relay cabinet condition including proper weather seal, moisture, cleanness, mechanical damage; cleaning, drying and repairing
   - fuses and fuse sockets; cleaning and spraying sockets and replacing fuses
   - relay cabinet outside condition including free access thereto.

4. Runway Friction-Measuring Devices

4.1 Possibility for standardization

4.1.1 Currently there are several types of friction-measuring equipment in operation at airports in various States. They incorporate diverse principles and differ in their basic technical and operational characteristics. The results of several research programmes for correlating the various friction-measuring equipment have shown that the correlation between the friction values obtained from the devices has been satisfactorily achieved on artificially wetted surfaces. However, consistent and reliable correlation between these devices and aeroplane stopping performance has not been achieved on wet surfaces. On compacted snow- and/or ice-covered surfaces, the correlation between the various friction-measuring devices, although not perfect, is substantially better than that acquired on wet surfaces. Measurements obtained by friction-measuring devices on artificially wetted surfaces can be used only as advisory information for maintenance purposes and should not be relied upon to predict aeroplane stopping performance.

4.2 Criteria for new friction-measuring devices

4.2.1 The Eighth Air Navigation Conference (1974) recommended that ICAO develop criteria for the basic technical and operational characteristics of equipment used to measure runway friction. In response to this recommendation, some relevant criteria were developed and transmitted to States. It was thought that the material would assist those States which might be planning to develop new friction-measuring devices. States, however, were informed of the uncertainty of obtaining, on wet runway surfaces, a more acceptable correlation between friction-measuring devices and aeroplane braking performance using any new measuring equipment developed in accordance with the proposed criteria. These criteria, which were reviewed and updated in 1991, are summarized below. The criteria are aimed at standardization of design parameters for new friction-measuring devices; they are intended to provide flexibility and allowance for future devices without precluding technical advancements in this field.

Basic technical specifications for friction-measuring devices

a) *Mode of measurement.* Continuous measurement in motion should be taken along the part of the pavement to be tested.
b) *Ability to maintain calibration.* The equipment should be designed to withstand rough use and still maintain calibration, thereby ensuring reliable and consistent results.
c) *Mode of braking.* During friction measurement operations using:
   - a fixed slip device, the friction-measuring wheel should be continuously braked at a constant slip ratio within a range of 10 to 20 per cent; and
   - a side force device, the included angle (single wheel) should be within a range of 5° to 10°.

d) *Excessive vibrations.* The design of the equipment should exclude any possibility of sustained vertical vibrations of the cushioned and uncushioned mass occurring in all travel speed ranges during the measuring operations, particularly in respect of the measuring wheel.

e) *Stability.* The equipment should possess positive directional stability during all phases of operation, including high-speed turns which are sometimes necessary to clear a runway.

f) *Friction coefficient range*. The recording range of the friction coefficient should be from 0 to at least 1.0.

g) *Presentation of the results of measurements*. The equipment should be able to provide a permanent record of the continuous graphic trace of the friction values for the runway, as well as allowing the person conducting the survey to record any observations and the date and time of the recording (see Figure 4-1. Test Report Form).

h) *Acceptable error.* The equipment should be capable of consistently repeating friction averages throughout the friction range at a confidence level of 95.5 per cent, ±6 μ (or two standard deviations).

i) *Measured and recorded parameter.*
   - For a fixed slip device, the recorded friction value should be proportional to the ratio of the longitudinal friction force to the vertical wheel loading.
   - For a side force device, the recorded friction value should be proportional to the ratio of the side force to wheel loading.

j) *Speed range.* When conducting friction measurements, the speed range for friction-measuring devices should be from 40 to at least 130 km/h.

k) *Averaged μ increments.* The equipment should be capable of automatically providing μ averages for at least the following conditions:
   - the first 100 m of the runway;
   - each 150 m increment; and
   - each one-third segment of the runway.

l) *Horizontal scale.* To minimize substantial variations in scale between the various friction devices, the manufacturer may provide, as one option, a scale of 25 mm equals 100 m. This may simplify data comparisons when two or more friction-measuring devices are used at an airport.

Type of equipment	Time	Location	Programme No.
Date of test	Wind	Direction	
Weather	Condition prior to test		
Runway			
Surface description			

Surface texture tests	Grease (mm)	Water (seconds)
Position 1 Position 2 Position 3		

Tire wear test Left Right	Rubber loss (grams)
Total	

Test conducted by	Towing vehicle (if applicable)
Method of wetting	Depth of water (mm)
Length covered by trace	Test speeds
Starting at	Ending at
Friction results	

Speed (km/h)	32	65	95	130	145	160
1st third Middle third 3rd third						

Recorder chart reference number and means of identification of individual run and speed:

Speed (km/h)	32	65	95	130	145	160
Section of runway 45 m from centre line giving lowest coefficient of friction (excluding paint markings)						

Note. – The original recorder chart or a print of it must be attached to this form

Figure 4-1. Test report form

m) *Standard tire specifications.* For testing on rain-wet or artificially wetted surfaces, the tread should be smooth with a pressure of 70 kPa for yaw-type friction-measuring devices; the tire must meet the specification contained in American Society for Testing Materials (ASTM) E670, Annex A2. With the exception of the Grip Tester, braking slip friction-measuring devices must use smooth tread tires made to ASTM E1551 specification and inflated to 210 kPa. The Grip Tester uses a tire made to ASTM E1844 specification. For loose, wet or dry snow or compacted snow- and/or ice-covered surfaces, a tread pattern tire meeting ASTM E1551 specification, with a pressure of 700 kPa, should be used for all fixed braking slip devices, except the Grip Tester, which should use either the manufacturer’s D-series (Slushcutter) or S-series (Disctyre).

n) *Allowable tire variations*. To minimize variations in the physical dimensions of the friction-measuring tire and the physical properties of tread compounds, the tire manufacturer should follow the requirements listed in the appropriate ASTM tire specification. The tire is a very critical component of the friction-measuring device; it is important to ensure that it will always be dependable and provide consistent and reliable results. The procedures for evaluating the performance and reliability of friction-measuring equipment and tires are given in 4.3.

o) *All-weather operation.* The design of the friction-measuring device should be such as to ensure its normal operation at any time and in all weather conditions.

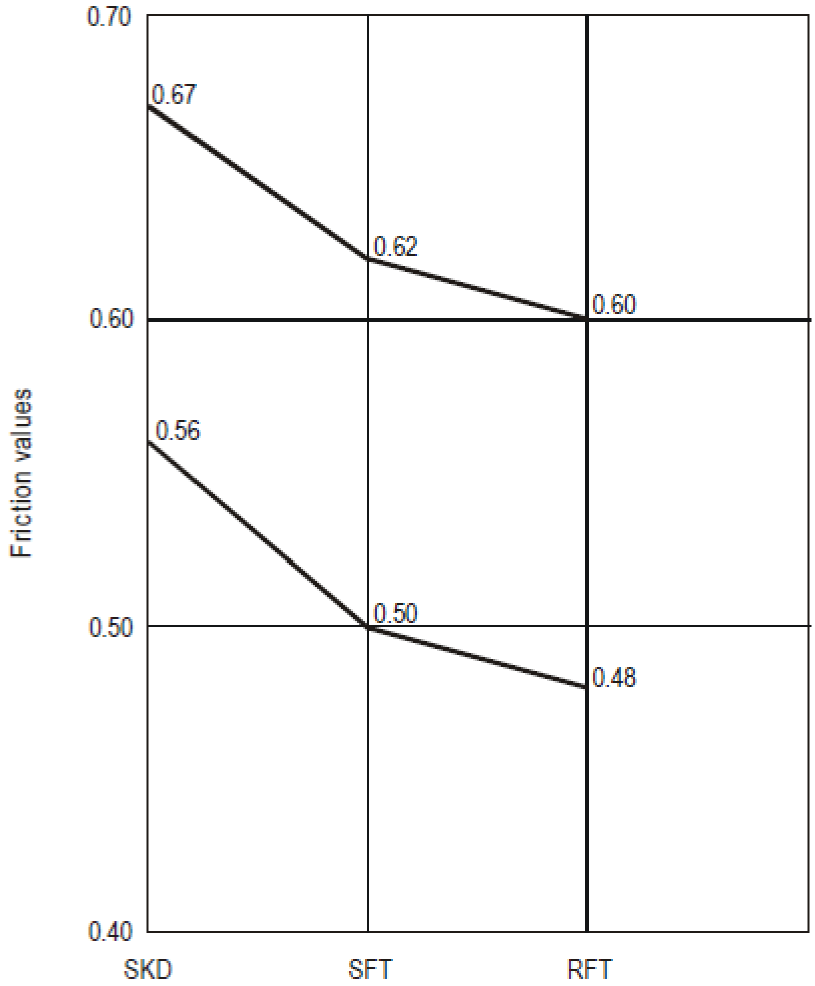
p) *Equipment maintenance.* The technical maintenance of the friction-measuring device should be such as to ensure the safe execution of the work during both measurement operations and transportation.

q) *Artificial wetting.* Friction-measuring devices should have the capability of using self-wetting features to enable measurements of the friction characteristics of the surface to be made at a controlled water depth of at least 1 mm.

Note. —A certification test procedure, developed by NASA, for continuous friction-measuring equipment used at airports.

4.3 Correlation between friction-measuring devices

4.3.1 The possibility of obtaining a useful degree of correlation between friction-measuring devices has been the subject of many trials in several States for many years. In 1989, the United States undertook a programme to develop standards that would ensure tire performance and reliability on artificially wetted runway surfaces. Subsequently, correlation trials were conducted using several continuous friction-measuring devices (see Figure 4-2).



Notes:
1. Test speed 65 km/h; water depth 1 mm.
2. Mu-meter value of 0.50 used as base in the correlation. The range quoted is ± two standard deviations.

Figure 4-2. Correlation chart for friction-measuring devices on artificially wetted dry surfaces

4.3.2 Originally, four friction-measuring devices were included in the trials. Three fixed slip devices (the Runway Friction Tester, Surface Friction Tester and Skiddometer) and one side force friction tester (the Mu-meter) were evaluated. Since that time, three additional fixed slip devices (the Grip Tester, the Tatra Friction Tester and the RUNAR Runway Analyzer and Recorder) have also undergone the same trials. The correlation among the seven devices used in the programme is set out in RCAAT No. 37 on Aerodrome Standards.

4.3.3 A programme for establishing tire performance and friction equipment correlation on compacted snow- and/or ice-covered surfaces was conducted at Brunswick Naval Air Station, Maine, in the winter months of 1985-1986 during the Joint FAA/NASA Runway Friction Programme. In addition to an instrumented NASA B-737 and FAA B-727 aeroplanes, the following types of ground test devices were included in the programme: Mu-meter, Runway Friction Tester, BV-11 Skiddometer, Tapley Meter, Bowmonk Brakemeter and Surface Friction Tester. Insufficient ground vehicle friction data were collected for slush and loose snow conditions to determine a reasonable correlation. Figure 4-3 shows the correlation between ground friction-measuring devices for compacted snow- and/or ice-covered surfaces only. The ambient temperature range for these winter runway conditions varied from –15° to 0°C. Additional friction measurements at lower temperatures are desirable to confirm the current data correlation.

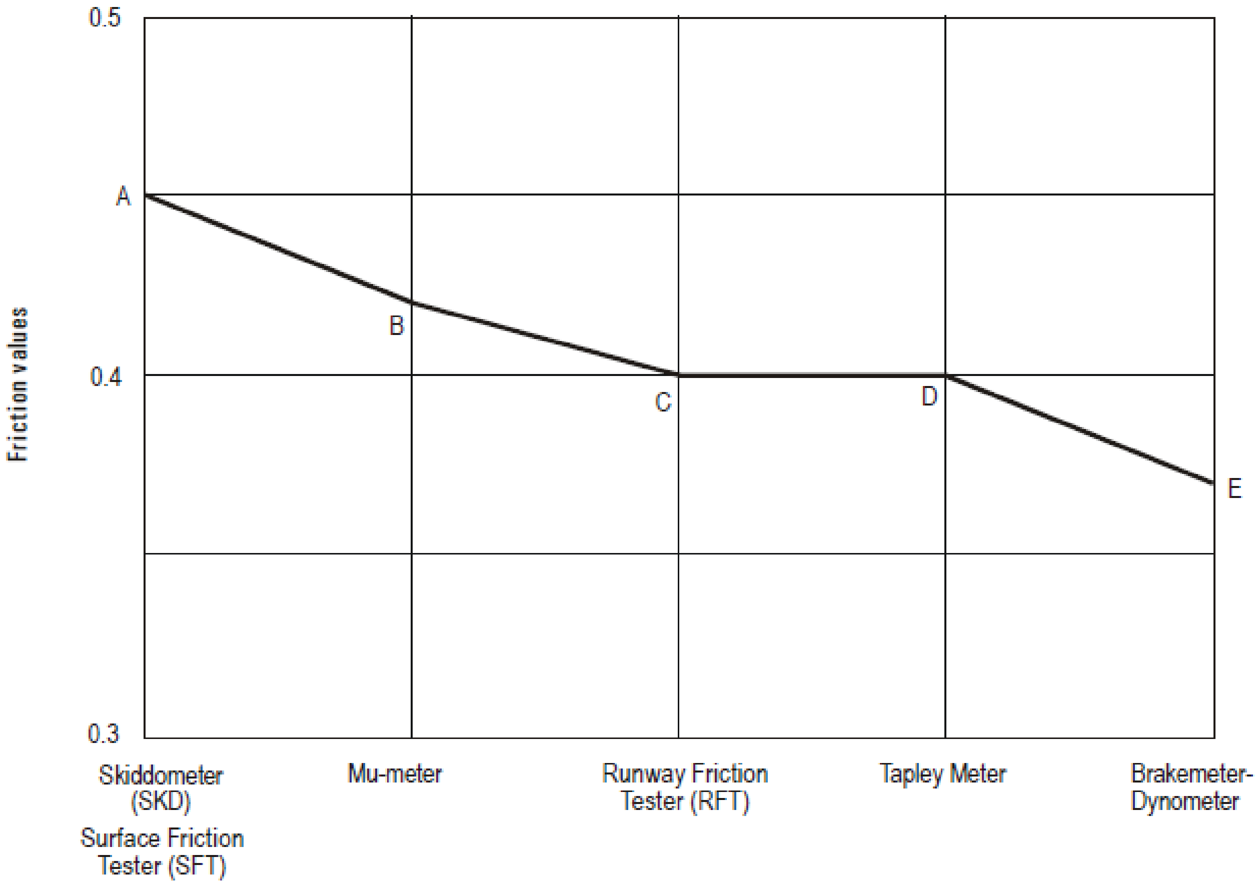


Figure 4-3. Correlation chart for friction-measuring devices
on compacted snow- and/or ice-covered surfaced

4.3.4 The data suggest that for compacted snow- and/or ice-covered runway conditions, the temperature of the runway surface and the air, as well as the type of surface contaminant accumulation, affect the friction readings. At temperatures below freezing, runway friction depends on the shear strength of compacted snow and ice which tends to increase as temperatures decrease. Consequently, the lower the snow or ice temperature, the higher the runway friction level. When temperatures are near the melting point for compacted snow and ice, a thin water film is produced which can greatly reduce runway friction levels through lubrication or viscous hydroplaning effects. Although friction measurements were collected using ground vehicle devices operating at a speed between 32 and 95 km/h, the data indicate an approximately constant friction value over this speed range (speed effect is negligible).

4.3.5 Although some continuous friction-measuring devices use different tires or operate at a fixed braking slip or in yawed rolling test mode, tests have shown that their readings are reliable and correlate with each other when using self-water systems that apply a controlled water discharge in front of the friction-measuring tire(s), either at a constant speed or over a speed range. However, when these same devices are used on runway surfaces that are wet due to rainfall, correlation can be less reliable. This is attributed to differential changes in water depths caused by variations in the pavement surface. For this reason, it is very important to control water depth when classifying pavements for maintenance purposes. For compacted snow- and/or ice-covered surfaces, fewer interacting variables affect the friction values because the braking action on these surfaces is not speed-dependent.

4.3.6 The correlation between the various friction-measuring devices when pavement surfaces are covered with compacted snow and/or ice is presented in Figure 4-3. The following practices for tests should be employed:

A) *Continuous friction-measuring devices* (e.g. Mu-meter, Grip Tester, Surface Friction Tester, Runway Friction Tester or Skiddometer)
   Test speeds: 65 km/h, except under icy conditions when a lower speed may be used.
B) *Decelerometer* (e.g. Tapley Meter, Breakemeter-Dynometer)
   a) Vehicle specifications
      - The vehicle should have a mass in the order of 1 to 2 tonnes.
      - It should be equipped with winter tires without studs, with the tire pressure set at manufacturer's recommendation. Tire wear should not exceed 75 per cent.
      - It must have 4 brakes properly adjusted to ensure a balanced action.
      - The vehicle should have minimum pitching tendency and maintain satisfactory directional stability under braking.
   b) The decelerometer should be installed in the vehicle according to the manufacturer's instructions. It should also be located and placed in the vehicle so it cannot be disturbed or displaced by either airport personnel or vehicle movement. The decelerometer should be maintained and calibrated according to the manufacturer's recommendations.
   c) Speed at brake application should be approximately 40 km/h.
   d) Friction survey techniques
      - Brakes should be applied sufficiently hard to lock all four wheels of the vehicle and then should be released immediately. The time during which the wheels are locked should not exceed one second.
      - The decelerometer used should record or retain the maximum retardation braking force occurring during the test.
      - Random very high or very low readings may be ignored when calculating the average values.

4.3.7 Since decelerometers require the test vehicle to be accelerated to given test speeds, which takes a finite distance, the intervals at which the test readings can be taken are necessarily greater than those taken by the continuous friction-measuring devices. These devices, therefore, can be considered only as spot reading friction-measuring devices.

4.3.8 The following example shows how the chart in Figure 4-3 is applied:

A reading of 0.45 (point A) with a BV-11 Skiddometer or Surface Friction Tester is equivalent to a reading of:
0.42 with a Mu-meter (point B)
0.40 with a Runway Friction Tester (point C)
0.40 with a Tapley Meter (point D)
0.37 with a Breakmeter-Dynometer (point E)

4.4 Correlation with aeroplane stopping performance

4.4.1 In order to be operationally meaningful, it is necessary to first determine the correlation between the friction data produced by the friction-measuring devices and the effective braking friction performance of different aeroplane types. Once this relationship is defined for the ground operational speed range of a given aeroplane, the aeroplane flight crew should be able to determine aeroplane stopping performance for a particular runway landing operation by considering the other factors including touchdown speed, wind, pressure/altitude and aeroplane mass, all of which significantly influence the stopping performance. At present, there is general agreement that success in this respect is greater for the compacted snow- and/or ice-covered surface conditions since fewer parameters affecting tire frictional behaviour are involved compared to the more complex and variable wet runway case.

4.4.2 In 1984, the United States undertook a five-year programme to study the relationship between aeroplane tire braking performance and ground vehicle friction measurements. Several types of surface conditions were evaluated: dry, truck-wet, rain-wet and snow-, slush- and ice-covered. The ground friction-measuring devices used in this study were the diagonal-braked vehicle, Runway Friction Tester, Mu-meter, BV-11 Skiddometer, Surface Friction Tester and two decelerometers (Tapley and Brakemeter-Dynometer). The results of this investigation showed that the ground vehicle friction measurements did not directly correlate with the aeroplane tire effective braking friction on wet surfaces. However, agreement was achieved using the combined viscous/dynamic aquaplaning theory.

4.5 General discussion on friction-measuring devices

4.5.1 There are several friction-measuring devices in use today throughout the world. Two decelerometers, the Tapley Meter and Brakemeter-Dynometer, provide a spot check on compacted snow- and/or ice-covered runway surface friction conditions. The seven devices described in this chapter (4.6 to 4.12) provide a permanent and continuous trace of friction values produced on a strip chart for the entire runway length surveyed.

4.5.2 Although the operational modes of the continuous friction-measuring devices are different, certain components operate in a similar manner. When conducting a friction survey for the maintenance programme, they all use the same smooth tread friction-measuring tire, size 4.00 - 8 (16 × 4.0, 6 ply, RL2) made to ASTM E1551 specification, with the exception of the Grip Tester which uses a smooth tread tire, size 10 × 4.5-5 made to ASTM E1844 specification. The friction-measuring tires mounted on the Mu-meter are made to ASTM E670, Annex A2, specification and operate at an inflation pressure of 70 kPa, whereas the Grip Tester tire uses 140 kPa inflation pressure. The five remaining devices use an inflation pressure of 210 kPa in the test tires. They all use the same friction scale, which ranges from 0.00 to 1.00, and they all provide friction averages for each 150 m of the runway length surveyed. It is required to provide information on the friction average for each one-third segment of the runway length (4.5.5 refers). With the exception of the Mu-meter and Grip Tester, the other five continuous friction-measuring devices provide, as an option, a high-pressure friction-measuring tire with an inflation pressure of 700 kPa, size 4.00 - 8 (16 × 4.0, 6 ply, RL2) that has either a patterned tread or circumferential grooves. This tire is used for operational purposes when pavement surfaces are covered with ice and/or compacted snow only. Another option available to the Mu-meter, Runway Friction Tester and Surface Friction Tester is a keyboard that allows the equipment operator the flexibility to record commands, messages and notes on observations taken during the time of the friction survey. All of these continuous friction-measuring devices are equipped with a self-watering system that provides a specified water depth in front of the friction-measuring tire(s). Friction surveys can be conducted at speeds up to 130 km/h.

4.5.3 The success of friction measurements depends heavily on the personnel responsible for operating the device. Adequate professional training in the operation and maintenance of the device and procedures for conducting friction measurements is essential to ensure reliable friction data. Periodic instruction is also necessary to review, update and certify that the operator maintains a high proficiency level. If this is not done, then personnel fail to maintain their experience level over time and lose touch with the new developments in calibration, maintenance and operating techniques. All friction-measuring devices should periodically have their calibration checked to ensure that it is maintained within the tolerances given by the manufacturer. Friction-measuring devices furnished with self-watering systems should be calibrated periodically to ensure that the water flow rate is maintained within the manufacturer's tolerances, and that the amount of water produced for the required water depth is always consistent and applied evenly in front of the friction-measuring tire(s) throughout the speed range of the vehicle.

4.6 Mu-meter

4.6.1 The Mu-meter is a 245 kg trailer designed to measure side force friction generated between the friction-measuring tires passing over the runway pavement surface at an included angle of 15 degrees. The friction-measuring tires on the Mu-meter are made to ASTM E670, Annex A2, specification. The trailer is constructed with a triangular frame on which are mounted two friction-measuring wheels and a rear wheel. The rear wheel provides stability to the trailer during its operation. Figure 4-4 shows the over-all configuration of the trailer. A vertical load of 78 kg is generated by ballast via a shock absorber on each of the friction-measuring wheels. The friction-measuring wheels operate at an apparent slip ratio of 13.5 per cent. The Mu-meter also has a rear wheel which has a patterned tread tire, size 4.00 - 8 (16 × 4.0, 6 ply, RL2). The tire operates with an inflation pressure of 70 kPa. The Mu-meter, being a trailer device, requires a tow vehicle; if the self-water system is required, a water tank must be mounted on the tow vehicle to supply water to the nozzles.

4.6.2 The distance sensor is a sealed photo-electric shaft encoder mounted on the rear wheel of the trailer. The distance sensor reads digital pulses in increments of a thousand-per-wheel revolution, transmitting them to the signal conditioner for calculation each time the trailer travels one metre. The load cell is an electronic transducer mounted between the fixed and movable members of the triangular frame. The load cell reads minute tension changes from the friction-measuring wheels. The signal conditioner is mounted on the frame and amplifies analog μ data received from the load cell and digital data from the distance sensor. The signals from the rear wheel distance sensor provide both distance measurement and, combined with increments of real time, speed measurement. The computer located in the tow vehicle is called a processor and it uses two microprocessors to display, calculate, store and process μ data received from the load cell and distance sensor (see Figure 4-5). Also shown in the figure is the keyboard which has command and function keys for selecting menus. The processor provides a continuous chart of friction values for the entire length surveyed. Five chart scales are available to the operator: 25 mm equals approximately 20 m, 40 m, 85 m, 170 m and 340 m. The expanded scales can be used to conduct a micro-investigation of areas where potential problems are suspected.

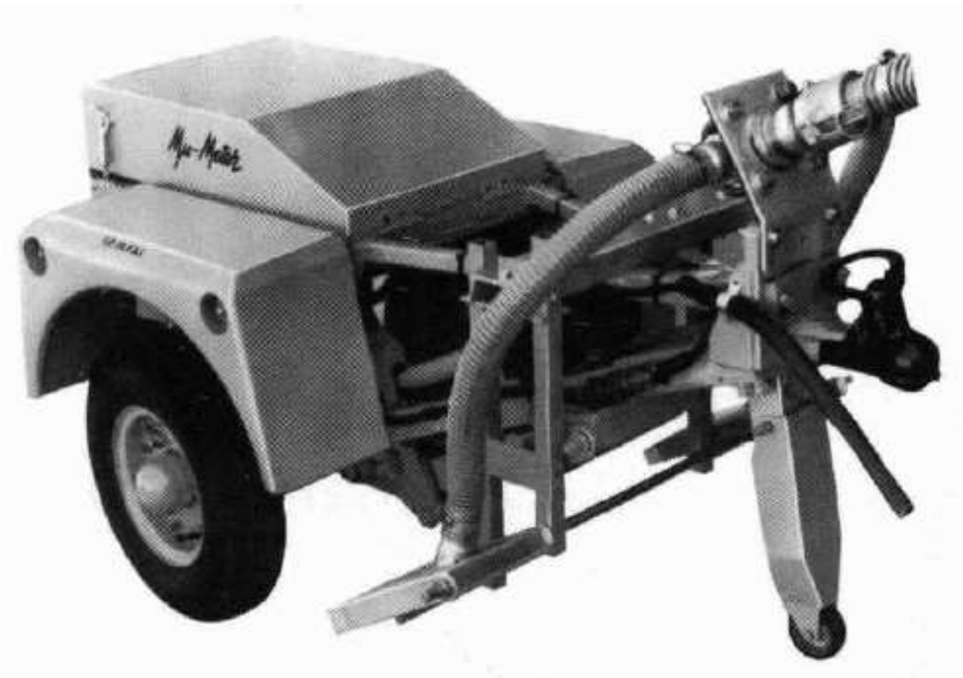


Figure 4-4. Mu-meter trailer

Figure 5-5. Processor unit and keyboard for Mu-meter trailer

4.7 Runway friction tester

4.7.1 The Runway Friction Tester is a van which has a tire, made to ASTM E1551 specification, mounted on a fifth wheel connected to the rear axle by a gear chain drive. Figure 4-6 shows the configuration of the van. The van is equipped with front-wheel drive and a powerful engine. The friction-measuring wheel is designed to operate at a fixed slip ratio of 13 per cent. The test mode utilizes a two-axis force transducer which measures both the drag force and the vertical load on the friction-measuring wheel. This method eliminates the need to filter the vehicle's deflections and the effects of tire wear, thus giving instantaneous measurement of dynamic friction. A vertical load of 136 kg is generated on the friction wheel by weights mounted on a double shock absorber spring assembly. The Runway Friction Tester is supplied with a self-water system and tank.

4.7.2 Vehicle speed and distance travelled are computed in a digital computer from pulses supplied by an optical encoder. The drag force and vertical load forces on the test wheel are sensed by a strain-gauged, two-axis force transducer and amplified for input into the digital computer. The digital computer samples these values approximately five times for each metre of travel and computes the dynamic friction coefficient. The friction coefficient, along with vehicle velocity (and, optionally, water flow rate), is stored in the memory of the digital computer. Figure 4-7 shows the vacuum fluorescent display unit which presents all programme menus and keyboard entries. All the menu selections and functions are entered into the digital computer from the keyboard.

4.7.3 When conducting a friction survey, the data are processed and sent to a printer which provides a continuous strip chart recording of μ and velocity. Average μ values are printed alongside the chart. Transmission continues throughout the survey at appropriate intervals until the entire length has been surveyed. Three chart scales are available to the operator: 25 mm equals approximately 30 m, 90 m and 300 m.

4.8 Skiddometer

4.8.1 The BV-11 Skiddometer is a trailer equipped with a friction-measuring wheel with a tire, made to ASTM E1551 specification, designed to operate at a fixed slip ratio between 15 and 17 per cent, depending on test tire configuration. Figure 4-8 shows the overall configuration of the 360 kg trailer. It consists of a four-sided welded frame supported by two independently sprung wheels. The three wheels are connected together by roller chains and sprocket wheels, with a gear ratio to force the centre frictionmeasuring wheel to rotate with a motion relative to the surface at the desired slip ratio. A vertical load of 105 kg is applied on the friction-measuring wheel by a weight via a spring and shock absorber. Since the Skiddometer is a trailer, it requires a tow vehicle. If a self-water system is required, a water tank must be mounted on the tow vehicle, along with a water supply line to the nozzle which is mounted ahead of the test wheel on the BV-11 Skiddometer.

Figure 4-6. Runway Friction Tester (T6810) van

Figure 4-7. The vacuum fluorescent display unit and keyboard for the Runway Friction Tester

5.8.2 The torque applied to the friction-measuring wheel is measured by a special torque transducer. The speed of the trailer is measured by a tachometer generator, driven by one of the roller chains. A cable between the trailer and the towing vehicle converts the analog signals to a strip chart recorder located inside the tow vehicle. Figure 4-9 shows the Skiddometer MI-90 computer. The data taken on a friction survey are processed by a digital computer and recorded on a strip chart as a continuous trace of friction values for the entire length surveyed. Four scales are available to the operator for measuring distance on the strip chart: 25 mm equals approximately 112 m, 225 m, 450 m and 900 m.

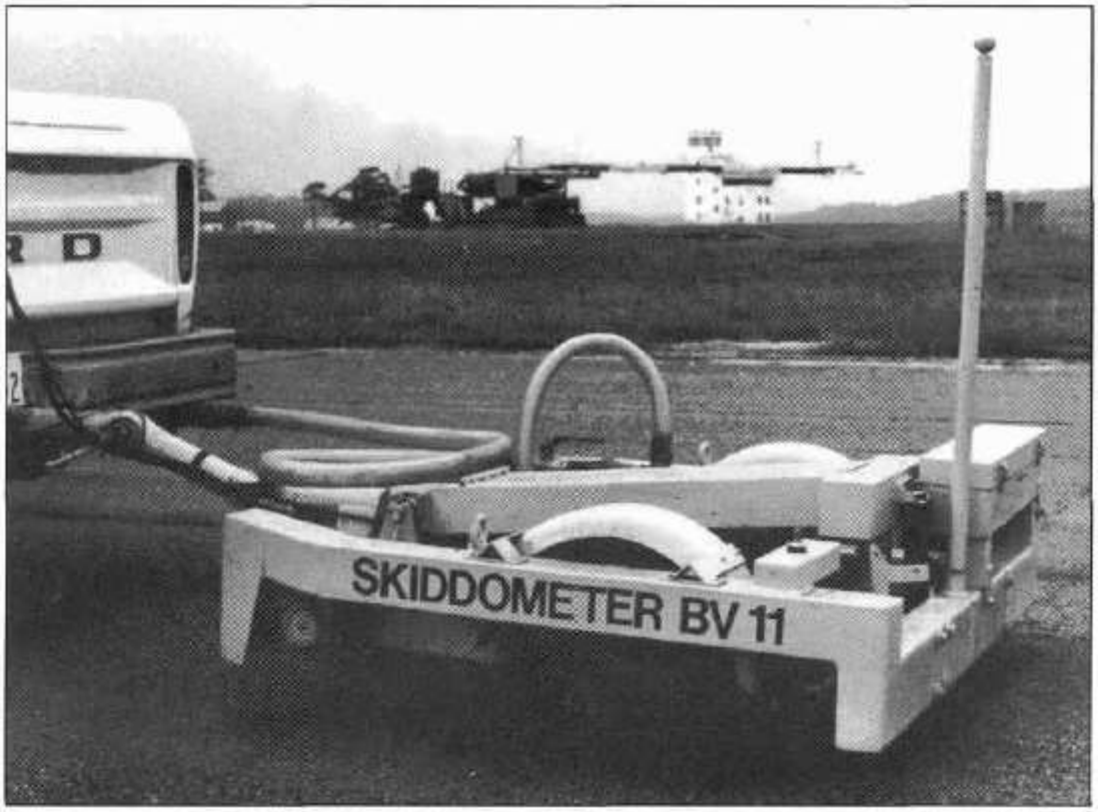


Figure 4-8. Skiddometer BV-11 trailer

Figure 4-9. MI-90 computer for Skiddometer BV-11 trailer

4.9 Surface friction tester

4.9.1 The Surface Friction Tester is an automobile which uses a fifth wheel with a tire, made to ASTM E1551 specification, located in the trunk to measure the coefficient of friction. Figure 4-10 shows the configuration of the Surface Friction Tester. The automobile is equipped with front-wheel drive; an optional turbo-charged engine is also available. The friction-measuring wheel is designed to operate at a fixed slip ratio of between 10 and 12 per cent, depending on the type of friction-measuring tire used in the survey. It is connected to the rear axle of the free rolling rear wheels by a chain transmission that is hydraulically retractable. A vertical load of 140 kg is generated by a weight via a spring and shock absorber on the friction-measuring wheel. The Surface Friction Tester is supplied with a self-water system and tank mounted in the rear seat area of the vehicle.

4.9.2 The torque acting on the friction-measuring wheel and the distance travelled are fed into a digital computer where the information is converted into coefficient form. The electric current flowing through the strain gauges within the torque sensor located on the friction-measuring wheel is affected by any minute changes in the tension of the chain transmission. Therefore, any variations in the frictional forces are monitored by the digital computer which measures these variations of the electric current and converts the analog signals into coefficient of friction data. The p values are continuously stored in the digital computer; upon completion of the survey, they are recorded on a strip chart as a continuous trace of p values for the entire length surveyed. Speeds during the test, as well as data to identify the test, are also recorded on the strip chart. The scale for measuring distance on the strip chart is 25 mm equals 100 m. A keyboard is available to the operator as an option

Figure 4-10. Surface Friction Tester automobile

4.10 Grip tester

4.10.1 The Grip Tester is a lightweight, three-wheel trailer which measures friction using the braked wheel, fixed slip principle. It has a single measuring wheel fitted with a smooth tread tire made to ASTM El844 specification. The wheel is mounted on an instrumented axle which measures both drag force and vertical load. From these measurements, the dynamic friction reading is calculated and transmitted to a data collection computer normally carried in the cab of the towing vehicle. The computer calculates and stores the survey speed for each 10 m of friction reading.

4.10.2 The average friction reading for each third of the runway is displayed by the computer on a schematic runway "map". When the survey has been completed, averages over the width and length of the runway are displayed. The results may be printed immediately or stored in a database.

4.10.3 For maintenance testing, storing the data in a database facilitates comparison between different surveys and the early detection of any trend towards poorer friction. For operational testing, the computer is able to generate a complete SNOWTAM of NOTAM. The Grip Tester is illustrated in Figure 4-11.

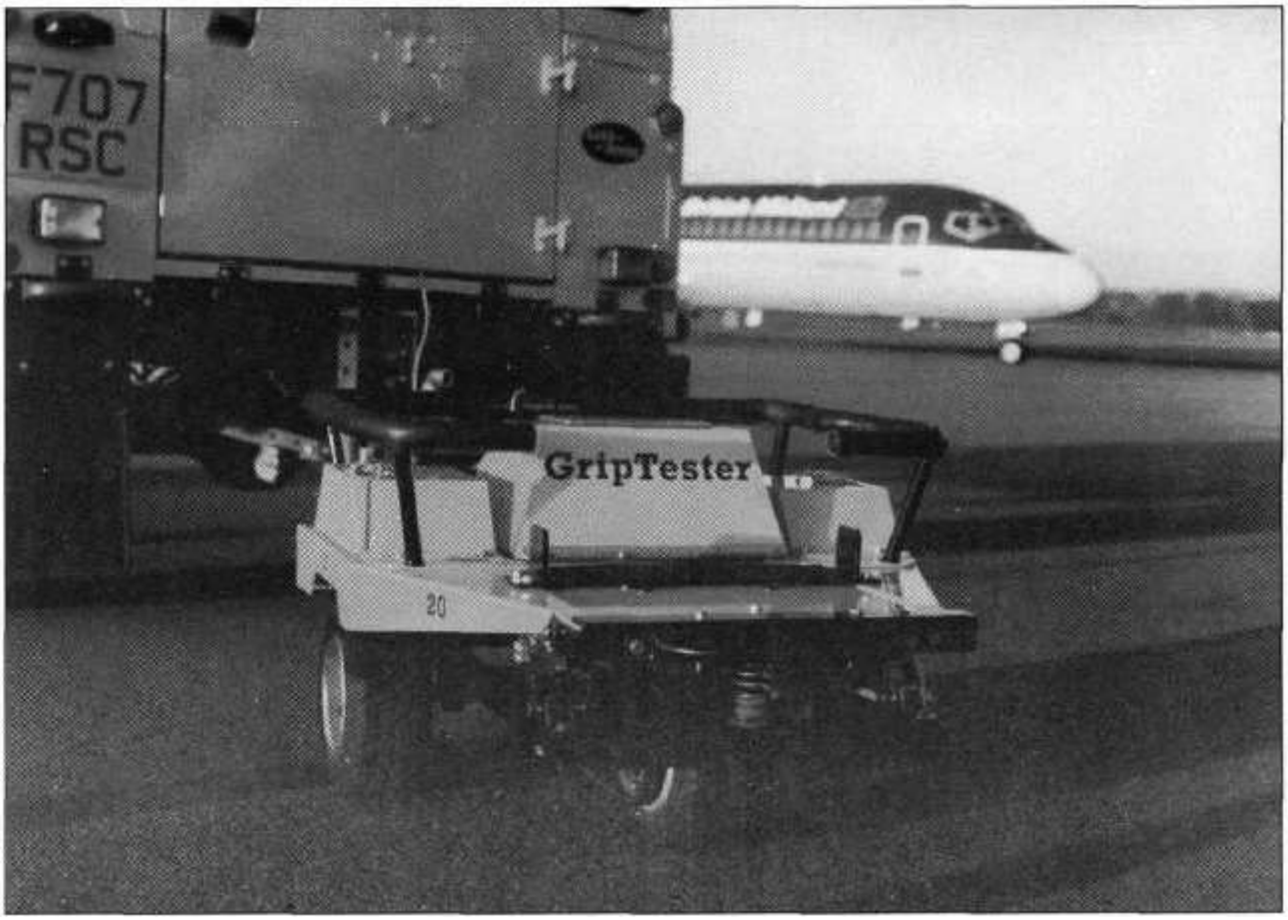


Figure 4-11. Grip Tester

4.11 Tatra friction tester

5.11.1 The Tatra Friction Tester, shown in Figure 4-12, is an automobile which has a hydraulically operated fifth wheel using an ASTM El551 specification test tire, located in the rear seat area, to measure the coefficient of friction. The automobile is powered by an air-cooled, V-8 engine which is located above the rear-driven axle and produces 220 HP or, optionally, 300 HP. The vehicle is equipped with two internal water tanks and a water dispersal system. Vertical loading of the measuring wheel is adjustable from 25 kg to 145 kg.

5.11.2 The system can be programmed to perform in continuous friction-measuring equipment (CFME) mode or variable slip-measuring mode, either automatically or manually. In the CFME mode, the test tire can be slipped at between 0 and 60 per cent of the forward speed. Aircraft wheel braking is simulated by using the variable slip-measuring mode which has an adjustable increase of the slip per time (distance) and the value (steepness) from 0 per cent to the maximum required, up to 99 per cent. The coefficient of friction of the surface to be tested is evaluated using the forward speed of the device, the distance measured, the surface characteristics and wheel slip. These data are measured and collected by the engine speed sensor, hydro generator speed induction sensor and a sensor on the left front wheel which measures the vehicle's forward speed and distance.

5.11.3 Monitoring equipment comprises a computer, three microprocessors, a display screen and a printer, as well as automatic calibration and diagnostic systems.

Figure 4-12. Tatra Friction Tester

4.12 Runway analyzer and recorder (RUNAR)

4.12.1 The standard RUNAR is a trailer equipped with the RUNAR basic friction-measuring unit. It is a hydraulically braked machine using an ASTM El551 specification test tire. The basic unit measures 90 cm H x 45 cm W x 80 cm L and weighs approximately 100 kg. The trailer-mounted configuration has a total weight of 400 kg. A version for side mounting on a maintenance truck has a total weight of approximately 150 kg. The standard trailer-mounted configuration is shown in Figure 4-13. The measuring sensors are mounted on the hydraulic brake providing continuous data which are collected, processed, stored and displayed to the operator by the data-processing computer. The instrumentation in the vehicle consists of a touch-screen operation panel and a 10-cm graphic roll or A4 colour graphic printer. The RUNAR can be operated at speeds up to 130 kmh. Measuring can take place above 20 km/h.

4.12.2 The RUNAR device can perform in the continuous friction-measuring equipment mode (CFME) and the variable slip-measuring mode. In the CFME mode, the constant slip ratio of the measuring wheel may be set to any percentage between 5% and 100%. In the variable slip-measuring mode, the test is conducted by applying wheel braking from free rolling to fully locked on the runway surface and measuring the braking friction force which the runway surface exerts against the braking wheel.

4.12.3 The RUNAR computer can be configured to provide average measurements for any length of pavement measured. It can also output averages for each third or for the whole length of the runway. The computer acquires and stores the following information:

a) brake friction force
b) rotational speed of the measuring wheel, and host vehicle speed
c) ambient air temperature at approximately 20 cm above the runway surface

All measured data are stored in a file for each measuring mission. As a backup, data are also saved on a computer diskette.

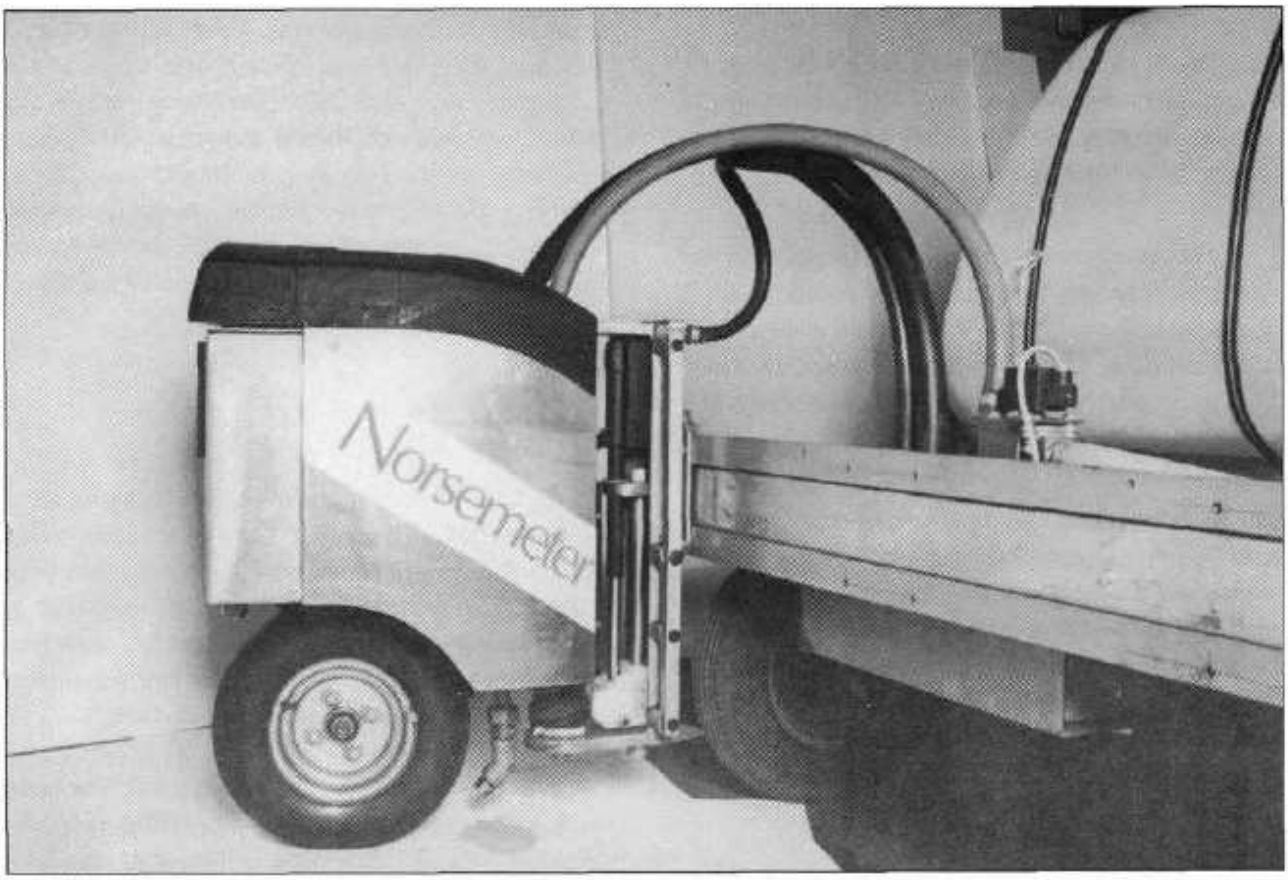


Figure 4-13. RUNAR Runway Analyzer and Recorder

4.13 Runway analyzer and recorder (RUNAR)

General

4.13.1 Decelerometers provide the most reliable information when pavement surfaces are covered with compacted snow and/or ice. Decelerometers should not be used on wet pavement surfaces, and tests should not be conducted when pavement surfaces are covered with loose or dry snow exceeding 51 mm depth or with slush exceeding 13 mm depth.

4.13.2 Since decelerometers have to be mounted inside a vehicle, certain requirements for the vehicle have to be met to ensure that reliable and consistent measurements are obtained. Acceptable vehicles are large sedans, station wagons, intermediate or full-size automobiles, utility and passenger-cargo trucks, vehicles that have front-wheel or four-wheel drive, and vehicles that have an anti-locking braking system (ABS) on the rear axle.

4.13.3 Tires on the vehicle can significantly influence friction measurements. Therefore, they should all have tread patterns that do not exceed 50 per cent wear, and tire pressure should always be maintained at all times according to the manufacturer's specifications.

4.13.4 The vehicle brakes should always be properly adjusted to ensure a balanced action. The vehicle should have minimum pitching tendency and satisfactory directional stability when the brakes are applied.

4.13.5 The decelerometer should be installed in the vehicle according to the manufacturer's instructions. It should be placed in the vehicle so that it is not displaced by any vehicle movement. The decelerometer should be maintained and calibrated according to the manufacturer's recommendations.

4.13.6 It is necessary to take a certain number of readings to obtain a reasonable appraisal of the runway surface condition. The total runway length is divided into three equal portions — the touchdown, mid-point and roll-out zones. A minimum of three tests at the speed of 35 km/h should be conducted in each zone. An averaged μ number should be determined for each zone. The averaged μ numbers are always recorded in the same direction the aeroplane lands.

4.13.7 The following procedures should be used in conducting friction surveys.

a) Brakes should be applied sufficiently hard to lock all four wheels and then should be released immediately. The time during which the wheels are locked should not exceed one second.
b) The decelerometer used should record or retain the maximum retardation braking force occurring during the test.
c) Random figures that are very high or very low may be ignored when calculating the average values.

4.13.8 Since decelerometers require the test vehicle to be accelerated to given test speeds, which takes a finite distance, the intervals at which the test readings can be taken are necessarily greater than those taken by the continuous friction-measuring devices. These devices, therefore, can be considered only as spot-reading friction-measuring devices.

Brakemeter-Dynometer

4.13.9 The Brakemeter-Dynometer consists of a finely balanced pendulum free to respond to any changes in speed and angle, working through a quadrant gear train to rotate a needle around a dial (see Figure 4-14). The dial is calibrated in percentage of "g", the accepted standard for measuring acceleration and deceleration. To stop all vibration, the instrument is filled with a fluid not sensitive to changes in temperature. The meter, which requires a vehicle for transport, should always be used with a floor-mounting stand. This device should only be used on runway surfaces covered with ice and/or compacted snow. It is not recommended for operation on wet runway pavement surfaces. The procedures for conducting friction tests are given in 4.13.7.

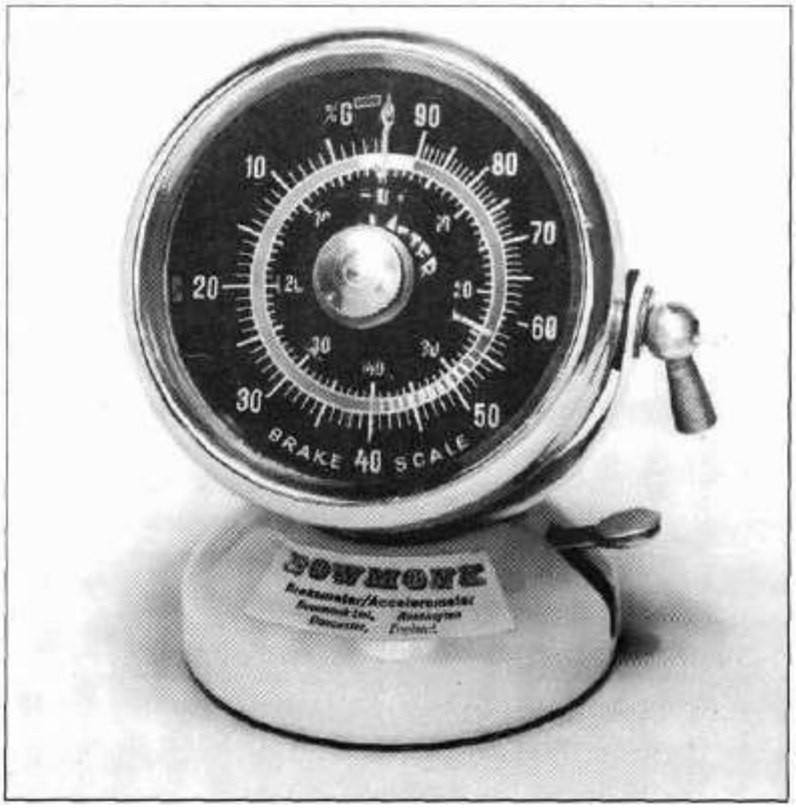


Figure 4-14. Brakemeter-Dynometer

Tapley Meter

4.13.10 Two versions of the Tapley Meter are available on the market: the original Tapley (a standard mechanical decelerometer) and the Tapley Electronic Airfield Friction Meter. Both require a vehicle for transport and are recommended for use only on compacted snow- and/or ice-covered runway surfaces. They are not recommended for operation on wet runway pavement surfaces.

4.13.11 Mechanical decelerometer. The mechanical version is a small pendulum-based decelerometer, consisting of a dynamically calibrated, oil-damped pendulum in a sealed housing (see Figure 5-15). The pendulum is magnetically linked to a lightweight gear mechanism to which is attached a circumferential scale which shows values in percentage of "g". A lightweight ratchet retains the maximum scale deflection reached upon completion of a test. The Mechanism is enclosed in an aluminium case and the scale is covered with a glass face. The whole assembly is mounted in a cast base plate by means of a fork assembly. Each meter is statically tested and dynamically calibrated before being issued a calibration certificate. When the meter is used in a friction survey, it is placed on the floor of the vehicle. The data have to be visually read and recorded by operator, and the averages of each one-third segment of the runway mentally calculated and recorded. The procedures for conducting friction tests are given in 4.13.7.

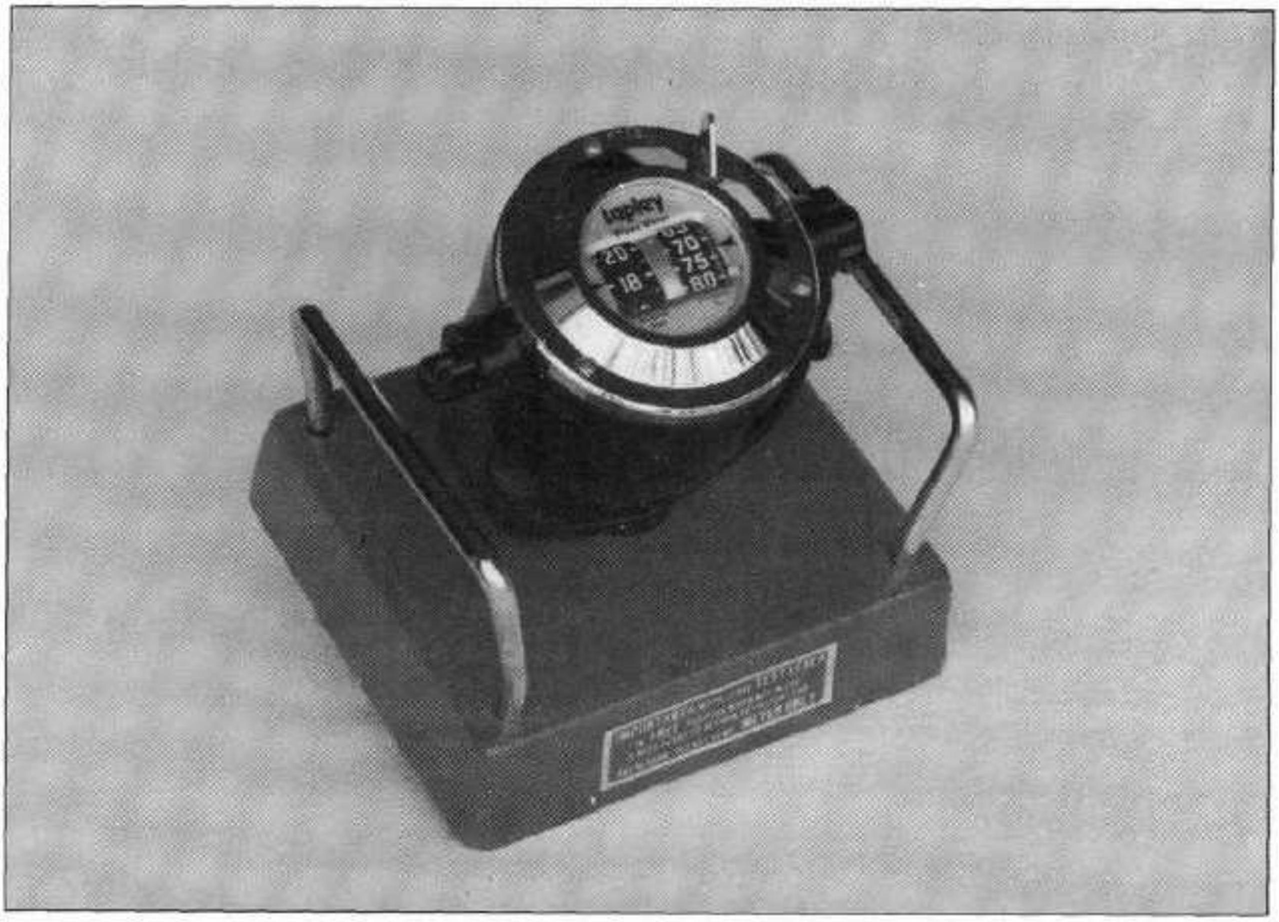


Figure 4-15. Tapley Standard Mechanical Meter

4.13.12 *Electronic decelerometer*. The Electronic Airfield Friction Meter provides a recording of the data taken during a friction survey. Including averages for each one-third segment of the runway. Figure 4-16 shows the configuration of the meter. The meter is a pendulum-activated, semi-automatic, recording decelerometer, which operates on the same principles as the original Tapley Mechanical Decelerometer. When preparing for a friction survey, the operator places the meter on the floor of the test vehicle. The actuating pad is filled to the brake pedal, and the command module is attached to the vehicle's window by a suction pad in front of the driver's side or in any location that is readily visible to the operator. The power leads are connected either to the vehicle's battery or to a separate battery. The electronic meter is tested at the factory against the standard Tapley Meter. These devices should be use only on runway surfaces covered with ice and/or compacted snow. The procedures for conducting friction tests are given in 4.13.7

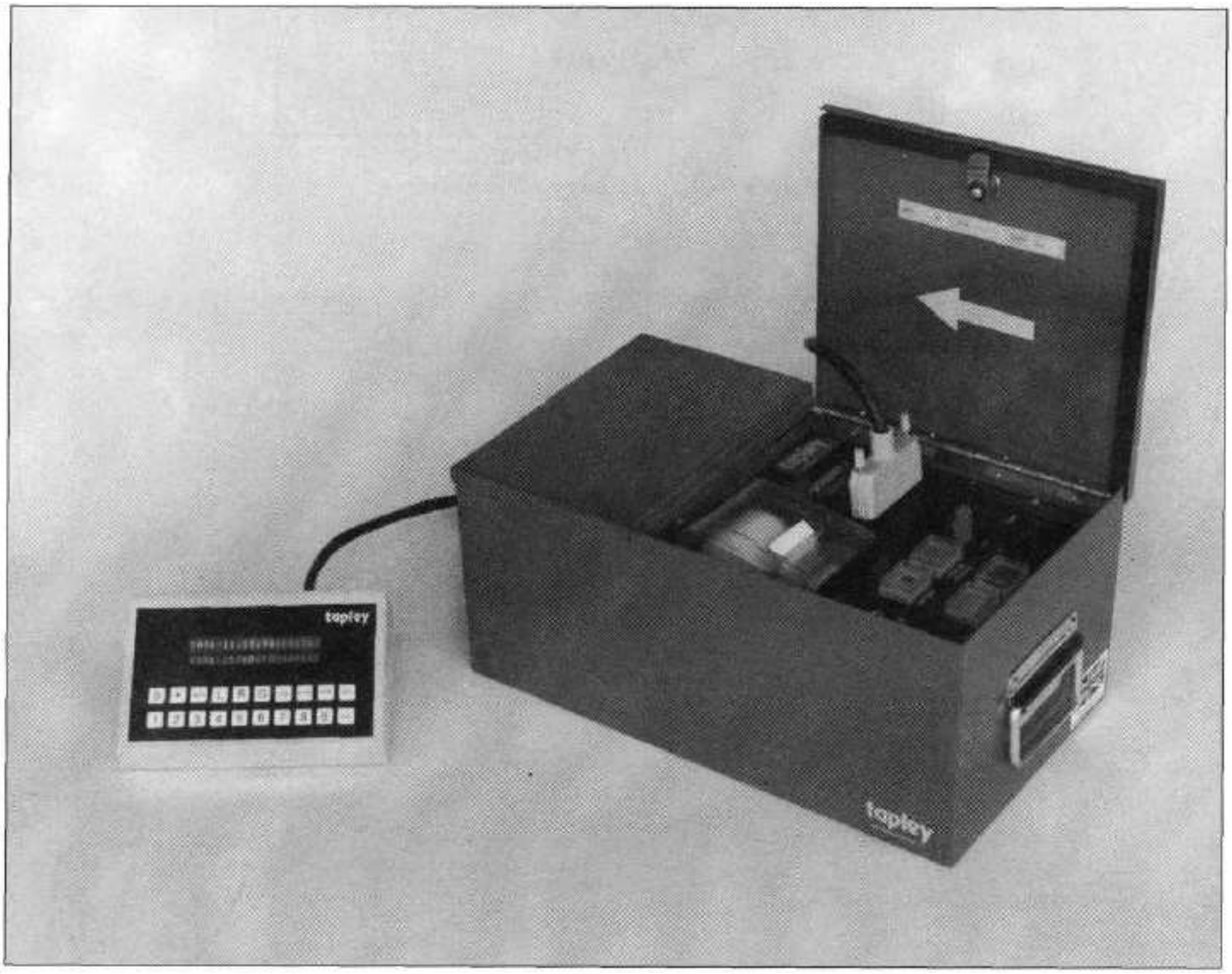


Figure 4-16. Tapley Electronic Airfield Friction Meter

5. Maintenance of Pavements

5.1 Surface repair

General

5.1.1 The surface of a runway should be maintained in a condition that precludes harmful irregularities or breaking off of pieces that would be a hazard to aircraft operation. Reference is made to RCAAT No. 37 on Aerodrome Standards. This specification requires continuous monitoring of pavements is costly and often imposes restrictions on the airport traffic even when damaged areas are small. Preventive maintenance is therefore of high importance for airport pavement management.

Portland cement concrete pavements

5.1.2 Surface damage on Portland cement concrete pavement normally stems from design or construction failures, such as insufficient cement, too high water content in the mixture, improper treatment during hardening, frost reaction on unsuitable aggregates or penetration of chemical de-icing fluids into micro cracks or pores. Typical forms of surface damage are:

a) porous or disintegrated surface
b) separation of thin top surface layer
c) extreme smoothing of the surface creates by polishing under traffic
d) breaking up of pavement where cracks extend into the inner layers.

5.1.3 Where the damaged layer of pavement is very thin and damage is identified as being the result of improper surface treatment during construction, surface scoring or grinding is often sufficient to correct the condition, no other treatment is required to restore the concrete pavement section. It should be checked that this kind of repair does not lead to unevenness or formation of puddle areas.

5.1.4 Where the surface has been found to be too porous, but no other pavement quality deficiencies have been observed, pores can be filed by sealing or coating. Epoxy resin solutions have proven to be suitable. The liquid penetrates into the surface material down to a depth of 5 mm. When applying epoxy resin sealing, the forming of closed surface films must be avoided. Such film would hamper moisture evaporation from within the concrete causing early destruction of the repaired surface. Furthermore, the surface will become too smooth and slippery when wet.

5.1.5 Where concrete surface material is more severely damaged with deep cracks, the damaged material has to be ground off until sound concrete material is reached. After grinding, the surface must be fully dry and free of dust before being refilled. The new surface has to be pretreated with a diluted solution of synthetic resin to create good adhesion. Where reinforcement steel is exposed, all rust has to be eliminated and wires must be covered by a new coating of epoxy resin or equivalent. A layer of epoxy grout is put on top of the pretreated area and levelled at the required thickness. A lean mixture of grout is recommended to permit the patch material to conform to the physical characteristics of the pavement. Similar shrinkage characteristics are most important for the grout to avoid chipping off after hardening. The grout can be made of special quartz sands or ceramic material. To prevent the surface from becoming too smooth, coarse quartz sand can be strewn on the still wet grout. Joints between concrete slabs should not be filled with grout in the course of repair.

5.1.6 For urgent provision pavement surface repair special quick-hardening cement products are available which gain high strength within one hour or less, Experience has shown, however, that the durability of such material is rather short.

Bituminous pavements

5.1.7 Surface damage on asphalt normally stems from wrong composition of the bituminous mixture, impact of fuel, grease or solvents, extreme spot loading, mechanical wear or destruction by chemicals. Also, frequent freezing and thawing may cause damage when de-icing fluid penetrates into the deeper layers. Other forms of damage are decay by weathering of the surface structure, softening of the surface and deformation.

5.1.8 When damage is minor and concerns the surface only, the repair can be carried out by spraying a bituminous seal onto which quartz sand or crushed basalt material is spread and rolled.

5.1.9 Where damage affects more than just the surface, the whole affected layer should be removed by grinding. The minimum grinding depth is 3 cm to allow reconstruction of an asphalt layer consistent with sound engineering. The bed for the new layer must be sharply edged to receive a clean seam. After grinding, the strips have to be carefully cleaned from contamination and grinding material (e.g. by road type suction sweepers) before they are sprayed with a bituminous binder. Then the new layer will be brough in, in accordance with road engineering design practice. Compaction (rolling) must be carried out very thoroughly at the edges of the old asphalt in order to close the joints. Covering the joints by spraying with a bituminous seal is recommended.

5.1.10 In cases where damage goes deeper, repair must include the sub-base material. In the course of such maintenance work sub-grade material may have to be replaced and compacted to restore its bearing capacity under the repaired pavement area. The bituminous layer or layers would then be laid according to good engineering practice.

5.2 Repair of joints and cracks

Joints in concrete pavements

5.2.1 Joints are provided in concrete pavements to eliminate stress induced by length variations of the concrete material due to temperature changes. Joints must be closed with a fuel resistant elastic material (bituminous sealant or hose-type plastic sealant) to prevent surface water from penetrating into the sub-base or sub grade and hard debris or stones from being pressed between adjacent concrete slabs. Once a joint becomes permeable the sub grade may be washed out and voids below the slabs may weaken the supporting capability of the base material. Where there is not a frost-resistant, well-drained sub grade under the pavement, it will suffer from frost impact. Both effects will result in destruction of the concrete. Basically, it is the sensitivity of the sub grade to water that determines the joint maintenance requirements.

5.2.2 The first sealant of a concrete joint will remain serviceable for a period of four to six years, depending on the mechanical and thermal impact of the pavement. Later on, the sealing material will lose part of its original elasticity and - due to shrinking - it will fail to adhere to the side flanks. Mechanical forces applied to such aged sealant will start the sealant breaking off, and rotary brooms of sweeping or snow clearing machines will accelerate the process. To protect concrete pavements from severe damage, a renewal of all joint sealants is necessary when the material in the joints is observed to fail and break off.

Concrete joint maintenance

5.2.3 For concrete joint maintenance all old sealing material has to be removed. A so-called "joint plough" may be used to carry out this task. Then the bare slab flanks should be cleaned thoroughly of soil, grease and dust. Where edges are damaged, they should be repaired with a suitable synthetic resin grout. After inserting a new inlay to limit the depth of the sealing material, the joint may be refilled with the liquid sealing material. Attention should be paid not to fill the joint up to the top. A surplus of sealing material in the joint will swell above the top when the pavement expands under thermal stress. This may lead to surface contamination later on. The selected material must be fuel-resistant, particularly in pavement sections where fuel spillage may occur occasionally.

5.2.4 Where joints are to be closed by plastics material, such as hollow Neoprene profiles, the same method for joint cleaning and preparation is applicable. To improve the sealing capacity of plastic material, the concrete flanks should be covered with an adhesive before placing the sealing profile into the joint. At joint intersections and ends the plastic material must be welded together to prevent water entering at the insert and it acting as a hose distributing water to the entire joint system.

Joints in bituminous pavements

5.2.5 Recent experience indicates that it is useful to provide for joints in bituminous pavements. For airport asphalt construction hard types of bituminous material are required. Reaction to temperature changes in such pavements is quite comparable with that in concrete. Unpredictable crack formation is very likely to occur in bituminous pavements, due to thermal stress. Stress reliever joints not wider than 8 mm and not deeper than two thirds of the thickness of the wearing course may be cut into the pavement to control the crack formation. When the pavement shrinks at low temperatures, cracks will only appear under the joints and these can be sealed to prevent water penetration.

5.2.6 Joints in bituminous pavements should be filled with a hot bituminous sealing material without any synthetic components. The chemical relationship between the pavement and the sealing material, and the almost identical thermoplastic reaction of both, provides a reliable closure of the joint.

5.2.7 Where joints in bituminous pavements are damaged, they normally can be repaired by filling with a hot sealing material, if the opening is not wider than about 3 cm. The same type of repair should be carried out where the sealing material is observed to have sunk into the joint.

Cracks in concrete pavements

5.2.8 Reasons for cracks in concrete slabs can be:

a) incorrect forming of expansion joints which has resulted in a transfer of force between concrete slabs
b) delayed cutting of hinged joints (dummy joints) in the construction phase so that shrinkage due to hardening was able to generate random strain cracks
c) improper treatment during the initial hardening phase as, for instance, due to strong sun radiation on fresh concrete
d) incorrect compacting of sub-base and therefore uneven settlement of sub grade so that slabs are not supported equally
e) insufficient dimensioning of concrete slabs in view of the load applied on them.

5.2.9 "Wild" cracks in concrete always go through the full depth of the slab. On the surface the crack will appear in the form of a hair crack or a break, the latter giving the separated parts the freedom to move one against the other. Repair of cracks in concrete can never restore its capability of load transfer. The purpose is only to avoid water penetration from the surface into the sub grade.

5.2.10 Cracks in concrete slabs should be repaired by transforming the breaks into expansion joints. The crack has to be widened by cutting a slot along its length about 1.5 cm wide and 1 cm deep. The widened crack must be filled with a fuel resistant thermoplastic sealing material.

5.2.11 When the subgrade is particularly affected by water, and optimum water tightness is required, a channel about 20 cm wide and 2 cm deep should first be cut along the track of the crack and then the crack widened to a slot as described in the preceding paragraph. The cleaned slot is filled with a flexible dummy insert. Then, after appropriate cleaning and priming the channel is filled with an epoxy resin grout. When the resin has hardened the insert is removed from the widened crack and the resulting void filled with a fuel resistant thermoplastic sealing material.

5.2.12 Hair crack repair can be accomplished by sealing the crack zones with epoxy resin solvents. Since the solvent will not penetrate very deeply into the crack, damaged slabs should be inspected regularly and sealing repeated when necessary. A hair crack slab has not lost much of its bearing capacity and thus does not represent a severe deficiency to the operational serviceability of the pavement.

Cracks in bituminous pavements

5.2.13 Cracks in bituminous pavements result from thermal stress building up in vast pavement areas when there are no expansion joints. Other reasons can be an insufficient adhesion of construction joints between adjacent lanes or deficiencies of subgrade bearing strength at isolated points due to construction mistakes. Repair of such cracks is essential to avoid penetration of water or deicing agent into the sub-base or subgrade. It is, however, not possible to stick the cracked parts firmly together and to retain the original stability of the pavement.

5.2.14 Cracks in bituminous pavements can be filled with a sealing emulsion without prior grinding. Special emulsions of high fluidity are available that will penetrate deeper into the crack than hot bituminous sealings. The filling can be carried out manually by using cans, or mechanically by using special pouring equipment. With a first run the crack's interior flanks will be covered, with a second run the crack can be filled up. The procedure should be repeated yearly or at longer intervals, depending on local climatic conditions.

5.3 Repair of pavement edge damage

General

5.3.1 Broken edges occur most frequently at pavement joints. The reason for this type of damage is the undesirable transfer of force across the joint mostly produced by incorrect joint design or stones pressed into the joint. The pavement material above the point of contact is split off due to the induced compressive stress. Another reason can be the application of extreme point loads near to a slab joint or slab edge as is sometimes caused by snow removal equipment. Comers are particularly sensitive to overload when for some reasons the slabs are insufficiently supported by the sub-base.

5.3.2 Broken edges produce loose parts of various size which create a substantial risk to aircraft. Furthermore, surface irregularities on pavement are undesirable for aircraft and ground vehicles. Therefore, broken edges should be repaired as soon as possible. At least, imminent danger to aircraft should be minimized by removing all loose material from the pavement surface and closing provisionally deeper openings in the pavement surface.

Edge repair

5.3.3 Part of the maintenance should be to carry out careful investigation of the damaged section to find out bile reason for the failure. When making the repair, the treated area should be made big enough to cover all damage. The boundary should be cut to a depth of at least 2 ern and all inside pavement material removed down to such a depth that all loose material is eliminated. Cutting can be done manually or by means of an electric hammer. When the damage is at a joint, the joint sealant must be removed to a length and depth of 5 cm beyond the cut-out section. The joint's flanks have to be cleaned and dust and debris removed from the opening, preferably by compressed air. After preparing the cut surface with a primer and after putting a form into tile emptied Joint, the opening can be refilled with a suitable synthetic resin mixture. it is most important that in the course of filling the cut area no bridge is built up between the two neighboring slabs, since sooner or later it would become the source of a new break In the repaired edge. Compacting should be done byer by layer and when smoothing the surface, a chamfer should be provided at the edge. After hardening, the form in the joint call be removed, flanks in tile joint cleaned, and the joint filled with a hot sealing material.

5.3.4 A filler material that meets the requirements of the climatic impact can the airport's. pavement should be chosen. it is essential to add sufficient aggregate (quartz, glass pearls or other ceramic) to achieve lean mixture with a small shrinkage ratio, Filler material which obtains its nominal strength no sooner than 24 hours after mixing has proven to be more suitable than quick hardening material.

5.3.5 For provisional repair some special cold asphalt materials have been developed which gain sufficient strength by compacting or hammering. Such material can be used for quick repair of both concrete and bituminous pavement. The costs are comparatively high and duration is limited, particularly on concrete pavement.

Corner repair

5.3.6 Broken comer repair will be carried out in the same way as described for edge repair. Attention should be paid to the slab's need to expand in two directions. Furthermore, the surface of the repaired slab must be level with both neighboring slab surfaces.

5.4 Repair of other pavement surface deficiencies

5.4.1 High quality requirements have been specified for runway pavement surfaces. The surface texture shall provide good friction characteristics and the runway surface shall be constructed without irregularities that could adversely affect the landing or take-off of an aeroplane.

5.4.2 Where the friction characteristics of the runway surface have been found to be below the level specified by the RCAAT No. 37 on Aerodrome Standards, remedial action will have to be taken. Repair measures may range from cleaning the surface of contaminations to major repair. According to experience the following three techniques are in use:

a) surface dressing
b) grooving of surface
c) scoring of surface.

5.4.3 With time a surface may become uneven without generating cracks. Where the unevenness occurs in spots and is, moderate, scoring or milking the surface can help to restore the required surface quality. Where the deficiencies are found to be more severe, corrective action, such as the construction of an overlay, may become necessary. Such work is generally not considered a matter of maintenance but rather a matter of airport design practice.

5.5 Sweeping

Purpose of sweeping

5.5.1 For safety reasons the surfaces of runways, taxiways and aprons have to be clean of sand, debris, stones or other loose objects. Aircraft engines can easily ingest loose material, and suffer severe compressor blade or propeller damage. There is also the risk that propeller or jet engine blast may cause loose objects to be ""shot" like bullets against adjacent aircraft, vehicles, buildings or people. Also, the tread on tires of taxiing aircraft or any other moving vehicle may throw up objects and cause damage. Maintenance of movement areas requires constant monitoring and regular sweeping of surfaces.

Surface monitoring

5.5.2 Runway and taxiway contamination. Objects to be found on runways and taxiways stem from the following sources:

a) debris from damaged pavement
b) debris from joint sealings
c) rubber debris from aircraft tires
d) stones from grass mowing
e) metal or plastic parts from aircraft
f) sand and soil from heavy storms or engine blast of aircraft
g) dead birds or other small animals hit by aircraft

5.5.3 Visual checks on runways and taxiways. Visual checks should be carried out regularly and at least every six hours during operating periods. Immediate checking is necessary upon advice of pilots on the existence of objects or debris. Special attention should be paid to the cleanness of runways and taxiways, when construction work on or near operational surfaces is going on. When construction machines or trucks use surfaces used also by aircraft, more frequent checking than normal is recommended.

Cleaning of surface

5.5.4 Frequency of sweeping. Surfaces intended to be used by aircraft and ground vehicles have to be swept regularly. The interval between sweepings depends on local needs and experience. Certain areas such as aircraft stands or freight handling zones at busy airports may require sweeping at least once a day.

5.5.5 Sweeping equipment. To accomplish the task of regularly sweeping all paved portions of the movement area, the use of truck-type cleaning equipment is practicable. The efficiency of the sweeper required depends on the size and traffic volume of the airport.

5.5.6 Integral sweeper-blowers as used for snow removal have the highest efficiency. They are useful for sweeping runways, taxiways and wide-open areas such as the outer portions of aprons, but because of their greater turn radii and the tendency to blow up dust clouds, they are not suitable for aircraft populated apron areas on positions close to buildings.

5.5.7 Truck-type street sweepers are the right equipment for sweeping populated apron areas, service roads, access roads, walkways, parking lots and even hangar or shed floors. They are available in many different sizes. They work like vacuum cleaners, suppressing dust generation. To enable them to pick up heavy iron metal parts a magnetic beam can be mounted close to the sucking orifice or to a trailer pulled by the sweeper truck.

5.5.8 Personnel discipline. Even with regular sweeping the airport authority cannot fully guarantee the absence of contamination in the areas where work is continually being carried out. Regular training courses for the apron personnel on accident risks and the benefit of discipline are useful to minimize careless attitudes on the movement areas. Sweeping can only keep the foreign object damage low when the whole staff takes notice of the problem and keeps the movement area as clean as possible.

5.5.9 Apron contamination. Aprons are more likely to become contaminated than other aircraft movement areas on the airport due to the greater number of users of this area, traffic concentration and the loading process going on there. Objects found on aprons include stones, bottles, cans, stoppers, bottle caps, lost hand tools, personal belongings, nails, screws, bolts, paper, rubber, wire, plastic material, wooden, textile, synthetic and metal parts of all sizes from boxes, cases, pallets, containers and other packing devices. Contamination is worst in freight handling areas and, of course, near construction areas. Another kind of contamination to the pavement surface is by hydraulic oils, fuel and lubricants. Special cleaning measures to be taken are described in 4.6.

5.5.10 Visual checks on aprons. Through training programs and regular reminding, personnel working on the apron can be taught to watch and visually check the condition of the apron and report on cleaning needs. Apron management service or the unit/service responsible for traffic on the apron should take immediate action to clear the apron of any dangerous contamination or debris observed or reported. Furthermore, inspection tours or walks should be carried out – when traffic activities justify – several times a day to ensure that the need to remove objects or any contamination on the apron is recognized in time.

5.6 Cleaning of contaminations

Purpose of cleaning pavements

5.6.1 Paved surfaces on airports can be contaminated by fuel, lubricants, hydraulic oils, marking paint or rubber. Contaminants may cause slipperiness and cover surface markings. Oil and rubber deposits on runways adversely affect the braking action of aircraft particularly when pavements are wet. A clean runway surface therefore is a safety requirement.

Removal of rubber deposits

5.6.2 Aircraft wheels contact the runway surface at high speed on touchdown resulting in a build-up of rubber deposits. Due to the friction-induced high temperature in the wheel contact area the rubber melts and is smeared into the surface texture. The rubber film is sticky and with the passage of time increases in depth. Layers of up to 3 mm thick may build up within 12 months in the touchdown zone of a busy runway. The aim of rubber removal is to restore the original macro roughness of the pavement surface. Such restoration is important to provide good drainage under the wheel in wet conditions.

5.6.3 Three methods are described below for removing rubber:

a) chemically
b) by mechanical grinding
c) by high pressure waterblast

The three methods are all effective; however; they are different in terms of speed, cost and erosion of surface material.

5.6.4 Rubber should he removed from runways when friction measurements under wet conditions indicate significant loss of braking quality in critical runway sections. Reference is made to RCAAT No. 37 on Aerodrome Standards.

5.6.5 Chemical method. The area of pavement to be treated is sprayed with a liquid chemical from a tank vehicle having a spray bar, or by hand with hose and nozzle. The chemical's reaction time ranges from 8 to 15 minutes, depending on the depth of the rubber film. During this time the rubber (and paint) swell tip and can be flushed away with high pressure water jets. Sweeper trucks or other equipment must clean the water- flooded area sucking up the loose rubber from the surface. Special equipment has been developed combining flushing and sucking in one vehicle. The chemicals dissolve not only rubber but also paint markings and bituminous material. When applied to asphalt pavements, sufficient water flushing is important to protect the pavement. The treatment must not be interrupted before treated patches have been flushed thoroughly with water.

5.6.6 Mechanical grinding method. There are various methods of grinding pavement surfaces. As runway maintenance should preserve the integrity of the original surface, a milling method has proven to be satisfactory. Milling rollers composed of metal discs on a rotating shaft are passed over the surface. The distance between the shaft and the pavement is controlled so that the discs just hit the pavement, but without much pressure. With three rollers fixed to the vehicle's chassis, a strip of about 1.8 m can be cleaned at one run. Working speed goes up to 400 m^2 per hour if rubber deposits are not too thick. The milling not only removes the rubber layer but, depending on the height control of the roller shaft, also roughens the pavement surface. While this can effectively improve the surface texture, the milled depth should be kept as small as possible. All mechanical methods must be applied very carefully to avoid severely damaging inset lights and joints between slabs. Sweepers must follow the milling vehicle to clean the strip of dust and rubber debris.

5.6.7 High pressure water blast method. Rubber removal is accomplished by high pressure water jets directed at oblique angles to the pavement surface. The equipment normally consists of a tank vehicle with motors pumping water at high pressure, e.g. 40 MPa through a nozzle bar guided closely above the pavement surface. Water consumption is high, about 1000 L per minute. The angle of attack of the water jets can be varied, e.g. by rotation of the nozzle bar. Working speed will range from 250 m^2 to 800 m2 per hour. Gleaning has to be done by sweepers following the removal truck at some distance. Where at water supply is not a problem, the high-pressure waterblast method is most efficient. As opposed to the chemical method, there are no special measures required for environmental protection.

Fuel and oil removal

5.6.8 Contamination by fuels, lubricants and oils can be found on many apron areas, such as aircraft stands and areas used regularly by loading vehicles. Contaminants can be removed by spraying grease solvents followed by water flushing. If necessary water jet cleaning may follow to achieve optimum results. Where fuel or oils are spilled accidently the spillage must immediately be covered by oil absorbing material, as developed by the oil industry. This material is a powder or granulate which, scattered on the spillage, absorbs the liquid and can be easily removed later by sweeping. However, it does not absorb oils already soaked into the pavement material. Repeated oil soaking of concrete and/or bituminous asphalt may deteriorate the surface material and require surface repair instead of cleaning. Since surface drainage from apron and workshop areas normally runs into the sewage system, national rules on environmental protection have to be borne in mind when cleaning pavements by means of chemicals.

6. Drainage

6.1 General

6.1.1 Drainage of the airport area is necessary:

a) to maintain sufficient bearing strength of the soil for the operation of vehicles and/or aircraft at any time during the year
b) to minimize the attraction of birds and other animals representing a potential hazard to aircraft.

6.1.2 Surface drainage is required to clear all parts of the movement area of standing water and prevent the formation of ponds or puddles. The quick run-off of water is particularly important on runways to minimize the hazard of aquaplaning.

Layout

6.1.3 For practical reasons an airport should have two drainage systems, one system which drains "'clean" areas such as runways, taxiways, aprons, service roads, public roads and parking lots, and another system which drains areas more likely to be polluted by oil, grease or chemicals such as hangars, aircraft maintenance areas, workshops and tank farms.

6.1.4 The drainage system intended to serve the "clean" area may be built in a way to sink the drain water (from precipitation) into the adjacent ground. Where the natural ground is not suitable to drain the surface water it must be collected in slot drains or other artificial sinks which are connected with a drain pipe, culvert or canal ducting the water to nearby creeks, rivers, lakes, etc. To protect these natural water courses from pollution, collector basins with oil separators should be installed.

6.1.5 The drainage system intended to serve hangars, workshops, tank farms and other pollutant generating areas should be connected to a regular sewage system which ducts the water to sewage treatment plants. For pretreatment the collected drain water should pass through fuel separators before entering the sewage culvert.

6.1.6 Generally, the airport operator will have to comply with rules on water treatment issued by the national or local authorities responsible for water conservation, water supply and environmental protection. The layout of airport drainage systems depends on local conditions and so does the maintenance programme.

6.2 Cleaning of slot drains

6.2.1 To facilitate the cleaning of slot drains, openings should be provided at 60 m intervals along the whole line. They must give good access to the bottom of the slot drain and serve as sand traps at the same time. Cleaning of a slot drain can be carried out most effectively by flushing all sections with water at high pressure, forced into the duct at 18 MPa or more. Where necessary, mud and sand deposits must be vacuumed off by special mobile cleaning equipment.

6.2.2 The time intervals for cleaning depend on local experience with drain lines. One cleaning action per year has proved to be the minimum. When sand has been used for winter services a second cleaning right at the end of the winter is recommended. Regular inspections should be carried out to detect the need for additional cleaning. After sandstorms or heavy rain showers which flood unpaved areas near the slot drain, immediate checking of the drain capacity is highly recommended.

6.3 Drain pipes or culverts between surfaces and collector basins

6.3.1 Drain pipes should have manholes at intervals to allow cleaning the pipe of deposits. Sections between consecutive manholes should not exceed 75 m and manholes should have a cross section of at least 1 m^2. The cleaning can be accomplished by means of flushing with water at high pressure.

6.3.2 Time intervals for cleaning depend on local experience. Cleaning once a year seems to be the operational minimum to ensure good drainage capacity of pipes and culverts collecting surface water from precipitation, Where the cross section of the pipes are less than 30 cm, cleaning twice a year may be necessary.

6.4 Oil and fuel separators

6.4.1 Oil separators are integral parts of water collectors. The number and size of collectors depend on the drained area and quantity of precipitation. The capacity of a separator shall be such that the flow speed will at any time be slow enough to prevent oil passing by the separator wall into the collector basin. The oil layer depth at the surface of the separator must be checked weekly and oil pumped off when necessary.

6.4.2 The bottom and the banks of the drain water collector basins should be kept clear of plants. Embankments should be mowed regularly. Once a year the bottom should be cleaned.

6.4.3 Fuel separators are components of the drainage system of hangars, workshops and other technical working areas which must be provided with separator installations. Their capacity will be determined by the expected maximum drain water through-put. The amount of trapped oil and/or fuel should be checked in accordance with a maintenance plan for the facility, describing the time intervals of pumping off oils. The intervals must be derived from local experience. They can vary widely. To avoid accidental overflow of the fuel collector, automatic monitoring can be provided. Oil and fuel separated from the drain water must be pumped or carried to a demulsification plant.

6.4.4 For removal of oil and fuel from separators the employment of specialists (under contract) can be practical since special tank vehicles are required and the deposits have to be removed in accordance with environmental rules on the treatment of waste oil.

6.5 Water hydrants

6.5.1 The capacity of the airport's water supply system should comply with the requirements of firefighting. All valves and flaps in the pipeline network should undergo functional testing once a year. Additional monitoring by checking the water consumption weekly can be useful to detect undiscovered leakages at an early date.

6.5.2 All fire hydrants including those at buildings must be checked regularly (see 9.12.1). Any subsurface hydrants should be kept clean of soil or mud so that they can be found without delay in cases of emergency.

7. Maintenance of Unpaved Areas

7.1 General

7.1.1 The maintenance of unpaved areas on an airport is essential for following major reasons:

a) safety of aircraft on operating areas (this concerns runways, taxiways, strips and runway end safety areas)
b) safety of airborne aircraft (this concerns areas on the airport and in its nearby vicinity within the defined flight pattern where trees and bushes may grow)
c) reducing bird hazards to aircraft (this concerns grass land within the airport's boundaries).

7.1.2 Work performed by contractors must be monitored by authorized personnel to safeguard air traffic safety requirements.

7.2 Maintenance of green areas within strips

7.2.1 Requirements as to the quality of surface grading and bearing capacity of strips and shoulders are specified in RCAAT No. 37 on Aerodrome Standards.

7.2.2 After construction work in strip areas, attention should be paid to retain the specified surface conditions. Where the bearing capacity has been reduced it must be improved by soil compaction. Humps and depressions should be eliminated. To protect the surface against blast erosion a sound matting of grass should be provided. On normal soil this condition can be achieved by seeding with grass. Poor soils will need fertilizing. Sometimes this can be accomplished by adding arable soil or humus from composted hay.

7.2.3 The use if urea on runways and taxiways will often kill the grass along the edges of treated pavement areas. In many cases soil replacement will become necessary. A biologically acceptable sealing material may have to be used for fixing the loose soil containing the fresh seed until the grown grass is capable of protecting the soil against blast erosion. Where poor drainage along the edges of pavement increases erosion effects, hard surface shoulders may have to be built to overcome the problem.

7.2.4 Grass in the strips should not exceed 10 cm in height. Regular mowing will be necessary to keep the grass low, the frequency depending on the climate. The cut material should be picked up since otherwise it might be sucked into jet engines, thus creating a potential hazard to aircraft operation. Where applicable, growth retardant can be used to control growth rate. Its application, however, is often limited by national or municipal rules for ground water protection, since some growth retardant chemicals can detrimentally affect the quality of drinking water. As these chemicals may also be expensive, it is useful to consider their cost effectiveness in comparison to more frequent mowing

7.2.5 Mowing attracts birds as the freshly mowed areas are rich in bird food. To minimize the ever-present risk of bird strikes, mowing should take place preferably before periods of lowest air traffic. In other cases, bird protection measures may have to be increased after mowing to keep the collision risk low.

7.3 Maintenance of grass on unpaved runways and taxiways

7.3.1 Grass height should be kept as low as practicable on unpaved runways and taxiways a rolling drag increases markedly with grass height. Take-off distances can increase by some 20 per cent when grass on runways is too high. For treatment refer to 6.2.4 and 6.2.5.

7.4 Maintenance of green areas outside strips

7.4.1 The major reason for maintenance of green areas of an airport outside the strips is to control animal life within the airport boundary. While generally it is not too difficult to keep wild animals that might create collision risks out of the area, for instance by means of fencing or hunting, the bird population is very difficult to control. The aim of measures concerning grass surface cultivation is to minimize bird population in order to keep the bird strike hazard as low as possible.

Note. —Sheep pasturing cannot be recommended as a suitable means for maintaining grass surfaces on an airport. It does not replace mowing since sheep do not eat all types of grass, thus leaving numerous clusters on their way. Furthermore, sheep unduly compact grass mats with their hooves and leave excrement which attracts insects and thereby birds

7.4.2 Maintenance of grass surfaces should be determined by the individual needs of the site, i.e. the local species of birds and their habits. Most species prefer low grass areas for food searching; conditions for finding food are better and watching out for enemies is facilitated by good visibility in all directions. For keeping large numbers of birds from settling, the optimum grass height has been observed to be around 20 cm. Only the smallest birds of body mass less than 20 g will prefer such meadows for residence. They are, however, less dangerous for aircraft than heavier birds.

7.4.3 Recent research indicates that dry grass land offers more food to birds than wet land. Draining should therefore be restricted to areas such as unpaved runways, taxiways and strips where good bearing capacity of the soil is necessary in the interest of air safety. In other parts of the airport swampy patches can be tolerated as long as ponds are precluded that would attract aquatic birds.

7.4.4 When the grass height is kept to not less than 20 crn, as protection against birds the mowing frequency will be low. One or two cuttings per year will suffice in many climatic areas to meet this grass height requirement. The grass should be mowed down to a height of about 10 cm and the cut grass should be picked up to prevent detrimental "choking" effects to the grass mats under a probably heavy hay coverage. Consequential compo sting effects on the mat also produce great numbers of microscopic organisms, insects, worms etc., and again, attract birds to the area. Since immediately after mowing the area attracts birds searching for food, the most favorable period for mowing with regard to local birds' habits should be chosen.

7.4.5 Maintenance work on grass lands should include special methods to diminish the number of mice. Where mice population exceeds a "normal" rate, birds of prey may be attracted which, due to their flight techniques and body mass, create the most severe bird strike hazard. Mice populations will then have to be controlled by using suitable chemicals.

7.4.6 Trees and bushes need no special maintenance except for controlling their height. When trees penetrate an obstacle limitation surface they should be shortened. One technique is to cut the trees or bushes but leave their roots in the ground so that they may sprout again. To discourage birds from settling, all bushes carrying berries should be eliminated from the airport.

Note. —The height of trees in the approach and departure areas outside the airport boundary must be controlled for air traffic safety reasons. To minimize the extent of cutting or shortening of trees, cutting can be done more frequently.

7.5 Equipment for maintenance of grass

7.5.1 As there are different types of mowers available the choice should be determined by local conditions, i.e. the size of the area to be maintained and the types of grass and plants on it. The following types are being used on airports:

a) spindle mowers
b) cutter bar mowers
c) rotary mowers
d) flail mowers.

7.5.2 Normally spindle mowers are trailing equipment. They are efficient on areas of low grass height, such as unpaved runways, taxiways etc. With the mowers arranged in groups (so-called mounted gangs), strips up to 8 m wide can be mowed in one run. Under favorable conditions the capacity can be 7 hectares per hour. Separate loaders are required to pick up the cut grass.

7.5.3 Cutter bar mowers are appropriate for both high and low grass. The cutter bar is generally a separate piece of equipment attachable to various tractor types, often in combination with a trailed self-picking hay loader. The cutting width is less than 2 m, thus resulting in a low mowing capacity of about 1/2 hectare per hour. A special type of bar mower, the so-called chaff-cutters, cut strips up to 4 m wide and, in combination with hay loaders, achieve a mowing capacity of almost 2 hectares per hour.

7.5.4 Rotary mowers are specialized on extremely high grass. They are produced in trailer form and mow a strip up to 5 m wide, thus achieving a mowing capacity of 4 hectares per hour.

7.5.5 The flail mowers are most effective for meadows with harder types of grass and plants, including low bushes. They are attachable to various types of towing equipment, have a maximum mowing width of 5 m and achieve a capacity of some 2 hectares per hour.

7.5.6 Capital and operating costs of the different types of mowing equipment vary widely, trailed equipment being cheaper. Operating costs for automotive equipment including automatic hay loading equipment will be three to four times higher. However costly the equipment and procedures are, the reduced bird strike hazard at the airport is a benefit.

7.6 Treatment of cut grass

7.6.1 Since grass should be removed immediately after mowing as a protection against birds and for other safety reasons, considerable quantities of cut grass will be collected on larger airports. If grass cannot be given away to nearby fanners or ranchers, two options exist:

a) composting at a suitable site and recycling as fertilizer for the airport, or for sale to gardeners or fanners, cut grass needs approximately three months for composting before it is usable
b) disposal in a dump. The dump should be far away from the airport since cut grass will, without proper treatment, decay producing a wet and very polluting waste.

8. Removal of Disabled Aircraft

8.1 Removal plan

8.1.1 If a disabled aircraft is on a part of the airport where it interferes with the movement of other aircraft, it has to be removed as quickly as possible. Aircraft removal is a rather complex procedure touching quite a number of responsibilities of different parties, such as aircraft registered owner, national authority for air safety and accident investigation, airport operator, owner of removal equipment and maybe others.

8.2 Personnel training

8.2.1 Regardless of how removal responsibility and removal performance is agreed, special equipment should be available and staff should be trained thoroughly to handle the equipment in the event of an aircraft removal. Training of the personnel assigned to this task should take place at least once a year, following a detailed and specified training program. The program has to include instruction on theoretical measures and methods to be applied and practical training in handling the equipment. It should be continuously updated according to the most recent knowledge and experience available on aircraft removal techniques.

8.3 Storage of equipment

8.3.1 Equipment should be stored in a manner to ensure quick access at any time. Consolidating equipment into transportable units is useful. This not only facilitates access in cases of a removal action but also for equipment inspection and maintenance procedures. Equipment packed in boxes or on pallets should be protected from the effect of weather such as wetness, moisture, heat, sunshine (ultraviolet radiation) which may rapidly destroy wooden, textile, plastic or rubber material. Protection must also be taken against vermin (mice, rats, termites, etc.). Only by careful storage and regular inspection will it be ensured that the equipment is in good condition and that any aircraft removal operation will be successful and expeditious. Furthermore, careful storage will extend the life of the equipment: important to the owner from an economical aspect.

8.3.2 All removal equipment should be stored at one location, if possible. The units should be designed for easy transport and loading, and should be stored in such a manner as to minimize the risk of damage by equipment and vehicle movements. Clear marking of each unit is necessary to allow quick identification of the contents.

8.3.3 In addition to the need to protect equipment from detrimental climatic conditions, no material should be stored close to the equipment which would cause damage to it. Wrapping will help to protect the equipment from contamination.

8.3.4 Wooden material, e.g. plywood sheets and cribbing timber, has to be stored flat to avoid warping. All steel material needs an oil or paint finish to protect against rust.

8.3.5 All pieces of the stored equipment should be listed. The list should identify their location within the store and show the maintenance needs.

8.3.6 A plan should be prepared that shows which vehicles are to be used for the transport of removal equipment and how the vehicles are to be available in the event of an aircraft removal action.

8.4 Maintenance of removal equipment

8.4.1 Regular inspection of all equipment is recommended to ensure that the equipment sets are complete and serviceable at all times. Some pieces of equipment may need maintenance work at periodic intervals.

8.4.2 Pneumatic lifting bags should be checked at yearly intervals where the climate is dry, moderate or cold, and at half-yearly intervals where the climate is tropical. More frequent inspections are recommended when the bag material has suffered from detrimental storage conditions such as high heat, direct sun radiation or wide temperature variations. The maintenance program for lifting bags should include:

a) cleaning of contamination, if necessary
b) inflation up to the checking pressure as indicated by the bag manufacturer repair of all deficiencies or damage
c) correct preparation for storage, i.e. dry surfaces, air valves protected by caps, surface powdered with French chalk
d) wrapping of folded bags to transportable packs.

Packed bags which have been stored below freezing temperature should not be unrolled before allowing a slow warming up over a period of some four hours or more. Sudden temperature changes are to be avoided in order to protect the bag material.

8.4.3 Protection pads (foam rubber pads) which are used to protect the lifting bags should be kept in good condition. To ensure this they should be inspected at half yearly intervals. When damaged, they should be repaired or replaced.

8.4.4 Air hoses should be stored wound up on hose reels. They should be kept clean inside and out to protect the rubber material. Ends should to be closed by caps and reels should be covered. Once a year, hoses must be unwound from their reels and stretched out on clean ground. A functional test can be accomplished by connecting them to the console module and applying air pressure. This procedure allows a check for any damage and the serviceability of all connections, any deficiencies discovered should be made good by repair or replacement.

Note. —A six-month check for integrity and cleanness of hoses is recommended in addition to the inspection.

8.4.5 Console module maintenance work should be carried out at least once a year. The maintenance program should include checking for:

a) integrity
b) damage to any components
c) serviceability of valves and stopcocks (function test under pressurized air according to manufacturer’s devices)
d) function of pressure gauges.

8.4.6 Air compressors should be subjected to a test run of at least five minutes once a month. In conjunction with this test the following should be checked:

a) tire pressure
b) oil content (compressor unit and engine)
c) diesel content of tank
d) battery capacity and acid content
e) cooling water content
f) any other technical details in accordance with the manufacturer’s advice.

In addition, a rolling test should be carried out every six months to check wheel brakes and lamps of the vehicle.

8.4.7 Hydraulic jacks should be inspected every six months in conjunction with a test run at which time the equipment can be checked for corrosion, oil leakage or any damage in accordance with the manufacturer's advice. Immediate repair is necessary when the jacks' function is affected by a deficiency.

8.4.8 Winches, cables and ropes should be inspected every six months for mechanical damage. Special attention should be given to bends and corrosion of steel cables and other load bearing lifting equipment. Stress tests have to be carried out in accordance with relevant national safety and/or manufacturer's advice.

8.4.9 Drainage pumps, flood lights and diesel generators should be inspected monthly for mechanical damage, oil and fuel leakage, battery capacity and acid content, fuel and oil content. All regular maintenance work should be carried out in accordance with the manufacturer's advice. Discovery of damage or deficiency should lead to immediate repair. A rest run should be part of the maintenance program.

8.4.10 Additional equipment consisting of:

a) plywood sheets
b) steel and aluminum plates
c) cribbing timber
d) steel spikes for crib assembly
e) ground reinforcement mats (trackways or other)
f) earth anchors

g) copperloy coated steel grounding rods, cables and clips
h) fencing material and warning signs
i) tools such as bolt cutters, sheet metal shears, picks, shovels, crow-bars, hammers, and saws should be inspected half-yearly for completeness and proper condition. Where damage such as corrosion, cracks, distortion or wetness is discovered, repair or replacement of the damaged equipment should be undertaken.

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9. Maintenance of Equipment and Vehicles

9.1 General

9.1.1 By preventive maintenance, facilities on an airport can be kept in such a condition as to maintain safety, regularity and expeditious operation of air traffic. This specification covers the following equipment and vehicles:

a) rescue and fire fighting vehicles
b) devices for snow and ice removal
c) devices for applying sand and de-icing agents
d) pavement surface friction measuring devices
e) sweepers for removal of contaminants from aircraft operating areas
f) mowers and other vehicles for control of grass height on unpaved areas

9.1.2 There also may be many other vehicles in operation for aircraft ground handling (fuel, water, electric energy, high- and low-pressure air), passenger handling, freight handling and transport. All these vehicles require preventive maintenance work in accordance with the manufacturer's advice. Operators of the vehicles have to make appropriate arrangements for keeping their equipment serviceable at any time as part of the airport maintenance task.

9.2 Organization of vehicle maintenance

9.2.1 Airport vehicle maintenance can be organized according to three different principles:

a) maintenance is carried out by the airport in its own workshops
b) maintenance is carried out by contractors in workshops located on the airport
c) maintenance is carried out by contractors outside the airport

9.2.2 The main reasons for providing workshops at the airport are:

a) the difficulty of moving specialized and very big vehicles, which are not licensed for use on public roads, outside the airport area
b) the time and manpower needed to move vehicles from the airport to remote workshops and vice versa

9.2.3 Reasons for providing airport-owned workshops are:

a) personnel can be supervised by the airport management and their schedule or work adjusted to fit the airport's needs
b) personnel can be trained to specialize in maintenance tasks for all airport equipment and will gain much experience
c) personnel can be organized in such a way as to carry out stand-by tasks outside the normal duty hours
d) personnel can carry out maintenance tasks on installed equipment

e) other duties like snow removal, aircraft removal, assistance in emergencies, etc. can be assigned to workshop personnel upon short notice.

9.2.4 Reasons for contracting with maintenance companies outside the airport are:

a) availability of expert knowledge, plants and tools for standard equipment overhaul and repair (e.g. motors, gear boxes, generators, drive axles of standard automotive design)
b) lack of own personnel or specialists for economic reasons (e.g. number of vehicles too low to warrant workshop installations and manning)
c) need to overcome peak or bottleneck situations

9.3 Schedule of vehicle maintenance

9.3.1 The basis for vehicle maintenance is a schedule of the services required and the intervals between servicing. The schedule can be developed by the maintenance workshop or by the vehicle operating branch. For maintenance of standard vehicles, the manufacturer's advice should be considered. In the absence of such recommendations the schedule should be based on experience with maintenance needs.

9.3.2 Inspection schedules for self-driven vehicles can be related to the kilometres driven or operating hours recorded. For other equipment, fixed time intervals are practical. Special procedures are applied for winter equipment, which should undergo inspection and overhaul twice a year, i.e. once before the winter season and then again shortly after it.

9.3.3 Fixed time intervals offer the advantage of a well-balanced workshop utilization. Equipment with a low number of operating hours per year should be inspected regularly. Maintenance to protect from true wear, however, cannot be met by the fixed interval method, since the individual use of equipment is not considered.

9.3.4 Where the hours driven are the basis of the schedule, the user must maintain a record of the hours operated. The equipment user should take care to rotate the use of equipment and check the operating hours record. An easy way of controlling the operating hours can be Achieved by marking the limit of the vehicle on a label attached to the driver's panel or screen. Monitoring can also be carried out by fuelling personnel.

9.3.5 The user (or proprietor) of the vehicles will define the maintenance intervals in accordance with experience, manufacturer's recommendation and workshop capacity. No standards can be given. Numbers given in Table 8-1 result from airport experience and may serve as guidance.

9.3.6 The maintenance program is individual for each type of vehicle or equipment and depends on its function, wear and tear characteristics and manufacturer's recommendation. Inspection must be carried out by specialists.

9.3.7 In the interest of safety, operating personnel must be advised to check the functioning of all essential components, e.g. brakes, control, tires, lights every day before using any vehicle or piece of equipment. Whenever deficiencies or failures are discovered, the unserviceable equipment should be taken out of service and repair should be carried out as soon as practicable.

9.3.8 An important element of the maintenance of airport vehicles is the servicing of installed radio telecommunication equipment, since, by the very nature of traffic control on an airport, the radiotelephone has to be serviceable at any time.

Table 8-1 Equipment Maintenance Interval

Equipment	Maintenance Intervals	
	km driven	Operating hours
Firefighting and rescue vehicles, ambulances	3,000 – 5,000	100 – 200
Standard cars, station wagons and buses	Up to 5,000	–
Special passenger buses	–	100 – 200 (At least twice a year)
Standard trucks, tractors (aircraft tractors)	–	100 – 200
Self-driven aircraft handling equipment (lifters, electric power trucks, water trucks, etc.)	–	100 – 200
Other aircraft handling equipment (dollies, stairs, etc.)	–	Once or twice a year

9.4 Workshops

9.4.1 Workshops on airports should be concentrated, if possible, to form a workshop centre. The capacity and equipment to be provided depends on the workload which is a function of the size of the airport's equipment fleet. The availability of the following workshops is most useful:

a) automotive engine with test bed
b) chassis (garage) with paint section
c) automotive electric workshop
d) mounting platform and car hoist
e) break test bed
f) hydraulics
g) tinsmith
h) washing.

9.4.2 Workshops should be manned by specialists. At intervals the personnel should be sent to equipment manufacturers for training.

10. Buildings

10.1 General

10.1.1 Many airports are sites for various industrial activities generated by aviation or related business. The built-up area of an airport therefore can be covered by great number of buildings, only part of which house the primary aviation functions. Typical buildings to be found on airports are:

a) passenger buildings
b) freight handling sheds and cargo stores
c) air traffic control buildings
d) aircraft hangars
e) fire stations
f) workshops and aircraft/engine maintenance plants
g) vehicle and equipment sheds
h) fuel farms and fuel tanks
i) depots and silos
j) aircraft catering buildings
k) administration and office blocks
l) hotel/restaurant buildings
m) convention centres
n) parking garages.

10.1.2 All these buildings require maintenance; however, little of this work is airport0specific. In the context of airport maintenance practices dealt with in this guidance material, normal building and technical facilities maintenance is not described. Descriptions will be limited to elements, the proper function of which is a prerequisite to efficient passenger or baggage handling, or passenger safety.

10.1.3 The building on an airport that directly affects passenger and baggage handling is the passenger or terminal building. Its purpose is the interchange between ground and air transportation, and transfers between flights. While the safety requirement is the same as for any other public facility, the outstanding requirement is for a speedy flow of passengers and baggage through the facility.

10.1.4 In order to meet this efficiency requirement the following components of the terminal building should not suffer from operational deficiencies during the operating hours:

a) lighting system for the passenger terminal buildings and associated landside forecourt and car parking area
b) passenger flight information system
c) air conditioning system

d) heating system
e) mechanical (automatic) doors
f) baggage conveyor belts
g) baggage delivery equipment in claim areas
h) fixed passenger loading devices (nose loaders or loading bridges)
i) lifts (elevators)
j) escalators
k) people movers
l) fixed fire protection installations
m) emergency exits.

10.1.5 A great deal of the maintenance work described in the following section is particularly appropriate to contract work. Maintenance contracts on servicing and overhaul of such facilities as automatic doors, conveyor belt systems, passenger loading bridges, lifts, escalators and moving walkways have proven to be useful and economical.

10.2 Lighting and electric equipment

10.2.1 The complete lighting system of the passenger building and forecourt has to be checked daily. Visual monitoring should cover all lamps, illuminated signs and information boards. Any deficiencies that would adversely affect passenger orientation or handling should be corrected quickly. Other reported deficiencies should be noted for repair within the schedule of the maintenance plan.

a) Daily:
   - visual inspection of all lamps for proper operation
b) Weekly:
   - replacement of fluorescent tubes and their ignition starters in accordance with the replacement schedule that the terminal operator has laid down in the maintenance plan
c) Monthly:
   - repairs which have been found necessary by inspections according to the maintenance plan for electric installations
   - checking of accumulator (battery capacities)
   - replacement of light bulbs according to plan
d) Quarterly:
   - checking of lighting control units
   - adjustment of dimmers
e) Semi-annually:
   - checking of supply lines and cables, switches and distributors
   - cleaning of plugs, contacts and terminals in the electric wiring
f) Annually (or less frequently):

- cleaning of lamps
- checking of insulation capacity by overload voltage.

10.2.2 Lighting system for roads and parking lots. Basically, the maintenance program is the same as for apron lighting systems, described in 3.3.10. A functional check during daylight, however, is not required, since the serviceability of the total system is maintained in spite of single lamp failures. The unserviceable lights can be identified more easily during regular night inspections. Other possible failures will be noticed by the operator of control desks, particularly where the lighting system is connected to a control center equipped with appropriate electric monitoring meters.

10.3 Communication facilities

10.3.1 Means of communication in passenger terminals can be flight information boards, television monitors, loudspeakers and electric clocks. Normally such installations are self-monitoring, i.e. deficiencies are identified electronically and indicated at the technical control center. Maintenance should include checking of:

a) Daily:
   - control unit for flight information board
   - readability of television monitors
   - electric clock's control unit
   - electric circuit of the loudspeaker system.

   Whenever possible, adjustments should be carried out immediately.
b) Semi-annually: Servicing of all components of:
   - flight information boards and television monitors
   - electric clock system
   - amplifiers for the loudspeaker system
c) Annually:
   - cleaning of information boards, e.g. all drives and flaps of electro-mechanical systems, screens or lights used for giving information visually to passengers.

10.4 Air conditioning system

10.4.1 The operational condition of the system has to be monitored constantly from the control centre so that any failures can be detected early and corrective action take in time. Maintenance should include checking the following:

a) Daily: Inspection of all machinery and air ducts concerning temperature, pressure and leakage including:
   - moisture controls
   - energy consumption of electric motors
   - freezers

- cooling water flow meters
- timer control.

Finding should be recorded and, in case of deficiencies, remedial action taken.

b) Weekly:
- activated carbon filters; changing when necessary
- other air filters; changing when necessary
- energy consumption of freezers (refrigerators), air supplies, fans, electric motors, flaps, valves, regulators and pumps
- insulation for damage
- cone belts

c) Monthly:
- servicing of all air ducts, fans, electric motors, flaps, valves, regulators and pumps
- cleaning of all dirt traps in the pipe network
- energy consumption record
- air ducts

d) Semi-annually:
- servicing of refrigerators and switching units
- cleaning of heat exchanges and fans
- output data and adjustment of performance of all components to desired standards
- servicing of hot air curtain including air filters
- cleaning of fire protection gates and other closing devices in the system.

e) Annually:
- chemical and mechanical cleaning of condensers and evaporators
- servicing of fore protection gates

f) Unscheduled:
- activated carbon has to be replaced at intervals of between two and three years according to experience with air conditioning system in use.

10.5 Heating facilities

10.5.1 Maintenance of heating facilities should include checking of:

a) Daily:
- temperatures, pump and regulator performance
- water heaters, pumps and valves for leakage
- serviceability of safety installations

b) Weekly:
- servicing of packing at pumps and valves
- limiter gauges at heating ovens
- switching units

- monitoring of the indicators for energy consumption and data comparison with expected; theoretical quantities

c) Monthly:
- cleanliness in burner chambers and cleaning if necessary
- regulators by comparison of true with theoretical performance data
- repair or replacement of deficient pumps, if necessary, according to the record of daily checks
- lubrication of taps and valves
- inspection of stand-by boilers for potential corrosion

d) Semi-annually: The following task must be carried out before or after the heating period, i.e. when burners are turned off:
- checking of heating elements (radiators) and their valves
- repair of faulty valves and packings
- removal of air from pipes and heating elements
- decalcifying (deliming) of heater coil in boilers
- repair of heater coils in water boilers
- cleaning of dirt traps and non-return flaps

e) Unscheduled:
- indicators and consumption meters should be checked and calibrated at intervals of two or more years to ensure reliable and precise system monitoring during the heating period.

10.6 Automatic doors

10.6.1 Automatic doors may be operated electrically, hydraulically or pneumatically. Any observed deficiencies of such doors should be reason for immediate repair or closure of the unserviceable entrance/exit to avoid damage to the door and – even more important – to avoid the risk of injuries to people. Unserviceable automatic doors should be marked by warning signs that at the same time give guidance to people on where to walk. Maintenance should include:

a) Weekly:
- checking of control mechanism at all automatic doors
- adjustment of the level of sensitivity of necessary
- at pressured air operated doors: checking of compressed air tanks and pipes for tightness.

b) Annually:
- full overhaul including cleaning of the door drives and at compressed air operated doors also the overhaul of compressors
- checking on wear at activator rods, chains and guide rails of the driving mechanism
- replacement of worn parts
- checking of serviceability and if necessary, adjustment of all safety installations.

10.7 Baggage conveyor belts (fixed installations)

10.7.1 Baggage conveyor belts are normally installed between baggage check-in areas and sorting or baggage make-up areas as well as between unloading stations for incoming bags and luggage reclaim areas. To ensure uninterrupted operation the condition of all belts has to be monitored continuously. Short cracks at the edges can be eliminated by cutting off the damaged edge material. Maintenance should include:

a) Weekly:
   - visual checking of belts for damage such as cuts and cracks
   - checking on smooth movement and low noise; whenever necessary, replacement of noisy or squeaking rollers
   - adjustment of loose spring rollers
   - adjustment of belt movement and stress

b) Monthly:
   - cleaning of joints and dirt trapping boxes
   - removing of paper and other waste from underneath the belt by vacuuming

c) Annually:
   - checking and overhaul of drives
   - cleaning of driving motors, oil change or refilling of gear boxes
   - cleaning and lubrication of driving chains.

10.8 Baggage claim units

10.8.1 Weekly maintenance should include checking for:

a) damage and cracks
b) smooth movement and low noise, and, when necessary, replacement of noisy rollers.

10.9 Passenger boarding bridges

10.9.1 Passenger boarding bridges (fixed and apron drive) are exposed to weather impact. Major maintenance work should follow immediately after rain or winter seasons to counteract corrosion.

Bridge gear and lift device maintenance should include:

a) weekly check of tires for surface damage and wear and replacing if necessary
b) inspection of wheel brakes
c) inspection of electric driving motor and cleaning of drive chains
d) inspection of lifting jacks for wear
e) checking of lubrication of lifting jacks
f) inspection of hydraulic system

Intervals of regular maintenance work depend on experience and/or manufacturer's advice.

Bridge body maintenance should include:

a) Weekly:
   - checking of all bridge movement, i.e. extension, retraction, lowering, raising and steering
b) Semi-annually:
   - checking of bearings and their lubrication
   - replacement of worn or corrosive rollers
   - checking of drive chains and adjustment of chain stress
   - checking of floor covers for damage and fixing or replacement of loose parts
   - warm water cleaning of outer skin of bridge tunnel
   - renewal of paint, if necessary

10.10 People lifts (elevators)

10.10.1 Maintenance responsibility of the building owner or operator is limited to observation of the lift's function and to cleaning. All other maintenance work, i.e. regular inspection, replacement of parts and repair, remains with the manufacturer. A complete overhaul of ropes, drives and other moving elements has to be carried out at least once a year. National safety regulations for lift manufacturers, however, should be consulted for the extent of maintenance and intervals between inspections.

10.11 People movers (escalators, etc.)

10.11.1 Maintenance responsibility of the building owner or operator is limited to observation of the people movers' or escalators' proper function and to cleaning. All other maintenance works, i.e. regular inspection, replacement of parts and repair, remains mostly with the manufacturer. The operator can check movement and wear of guide rails, rollers, steps or lamellae, hand rails and refill lubrication pots. Complete overhaul of moving elements has to be carried out (by the manufacturer) at specified intervals. National safety regulations for manufacturers of such facilities should be consulted for the extent of maintenance and intervals between inspections.

10.11.2 No general guidance can be given on the maintenance of train-type people movers since they are complex systems which have to be operated in compliance with national safety standard regulations or technical requirements. The operator must, however, make provision for the daily checking of the emergency escape capability from the cabins.

10.12 Fixed fire protection installations

10.12.1 Maintenance of fixed fire protection installations should include checking of:

a) Weekly:
   - fire extinguishers within the whole building for integrity
   - emergency exits for access clearance and removal of obstacles
b) Quarterly:

- serviceability of all components of the fire warning and fire alarm system in the building

c) Semi-annually:
   - serviceability of fire doors designed to close automatically in case of fire or smoke
   - serviceability of all fire extinguishers in the building

d) Annually:
   - functioning of smoke doors and flaps
   - serviceability of emergency exit locks
   - serviceability of pumps and fire hydrants
   - hose condition

Note. —National rules for the provision and maintenance of fire protection installation have to be observed carefully.