Aircraft Maintenance Engineer International Trade Training (NVET) Standards

Australia's aviation MRO businesses, to stay competitive in the domestic and global aviation market, need maintenance personnel with skills and qualifications that meet the minimum training standards that have been, for many decades, promulgated by the International Civil Aviation Organisation. Aircraft and aircraft component maintenance personnel globally are trained to meet these knowledge and practical skill standards. Australia, once again, needs to adopt and implement these training standards into our National Vocational Education Training System. This guide is based on those ICAO minimum training standards.

Part A – Trade Training Syllabi Based on ICAO AME Training Manual

Aviation Maintenance Repair & Overhaul Business Association, inc.

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PART A

GUIDE

TO

AIRCRAFT MAINTENANCE

ENGINEER

TRADE TRAINING

Based on ICAO's AME Training Manual

covering both

Avionics and Mechanical Trades

Ratified Treaty

'Convention on International Civil Aviation'

Article 37

Adoption of international standards and procedures

Each contracting State **undertakes to collaborate in securing the highest practicable degree of uniformity** in **regulations**, **standards**, procedures, and organization in relation to **aircraft**, **personnel**, airways and auxiliary services in all matters in which such uniformity will facilitate and improve air navigation.

Foreword

(Department of Civil Aviation 1956)

"*The International Civil Aviation Organisation (ICAO) decided at the Third Air Navigation Conference at Montreal in September, 1956, to amend International Standards and Recommended Practices to permit Member States [Australia] adopting either a system of personnel licencing or a system of approved organisations whereby the privileges of the licenced aircraft maintenance engineer are delegated to persons in the approved organisation who must fulfil the experience and knowledge requirements specified for the aircraft maintenance engineer.*

Australia has retained a system of personnel licencing as the most suitable means of determining a standard of experience and knowledge necessary for the supervision and certification of most aircraft maintenance activities other than overhaul, major repair or major modification of aircraft, and ensuring that it meets its obligation in the international sphere.

Under international standards it is a requirement that every aircraft be in an airworthy condition prior to flight and that a certification be issued as evidence of this airworthiness. This requirement is implemented by means of a licencing system whereby aircraft maintenance engineers are authorised by the Director-General of Civil Aviation [now CASA] to exercise stated privileges and accept responsibilities directly related to airworthiness. ***These engineers act on behalf of the Director General [CASA] in ensuring that established and approved airworthiness standards are continuously maintained during the operation of all aircraft.***

This phase of airworthiness control begins after an aircraft is manufactured or undergoes overhaul or other major work in an approved workshop and it continues at all times throughout the operating life of the aircraft."

Note: **The Department of Civil Aviation in 1956 also correctly specified the privileges and responsibilities of the licenced aircraft maintenance engineer as follows**:

"The privileges which may be exercised by a licenced aircraft maintenance engineer include (1) certification of safety of flight of an aircraft; (2) certification of documents for issue or renewal of a Certificate of Airworthiness; (3) approval of subsequent flight tests; (4) certification for issue of an aircraft maintenance release; (6) certification for work carried out under regular maintenance schedules; (7) certification after (a) replacement of components; (b) rectification of defects; and (c) maintenance inspections. i.e. certification for completion of.

***The exercise of these privileges involves the acceptance of responsibilities and briefly stated they are as follows**: -*

When certifying work and inspections the licenced aircraft maintenance engineer must ensure that he/she has (1) adequately supervised the work, that (2) established standards have been maintained and that (3) the resulting condition is satisfactorily in all respects. This means the he/she must satisfy himself/herself that all work or processes leading up to the end result and that which is the product of other approved persons or organisations, have been properly certified.

The crucial role that the licenced aircraft maintenance engineer plays in the on-going airworthiness of aircraft is ***fully dependent on the aircraft maintenance engineers' vocational education training system providing training courses that meet the minimum training standards promulgated by ICAO****. The following are reprints of these minimum training standards and syllabi for both the avionics and mechanical trades*."

The only change that has happened since 1996 is the Vocational Training System has been changed so much that the avionic and mechanical trade training levels no longer meet these international minimum training standards promulgated by ICAO.

AMROBA recommends these international aircraft maintenance engineers minimum training standards to the Education Department of Australia as the minimum training standards that should be included in the Aircraft Maintenance Engineer NVET AQF IV training packages.

Introduction

(ICAO AME Training Manual Chapter 4 Excerpts)

In addition to the subjects which are of direct day-to-day concern to the responsibilities of the Aircraft Maintenance (Technician / Engineer / Mechanic) (AME), the AME training should include a sound understanding of the academic aspects of aircraft and aviation operations. This background will provide the trainees with a more complete understanding of not only their working environment but also the wider scientific principles employed in aviation.

The academic level of background subjects such as mathematics and physics should be specified as a prerequisite to course entry. However, if this is not practical or possible, then mathematics and physics may be taught to the required level before the start of the aviation training course. Where the knowledge of mathematics and physics is only just below the required entry level, or it is felt that a refresher course in mathematics and physics would be advantageous to the students, then these subjects could be taught in parallel with the aviation subjects.

The selection of topics for the mathematics and physics syllabi as well as the type of course instruction must reflect the depth and breadth of knowledge required to fully complement the level required by the aviation subjects.

Even though it is covered in the Maintenance Practices and Materials sections of both the mechanical and avionics curricula, technical drawing has been incorporated into the area of natural science and general principles of aircraft for the benefit of those students who will be involved in major modification and/or repair work.

Understanding the subjects of mathematics, physics, technical drawing. etc. constitutes an important part of the AMEs training base. It will permit a more comprehensive operational understanding, develop general in-depth awareness of air transport operations, and improve communication with both flight crew members and other maintenance personnel, thereby improving the overall safety of the aircraft operation.

TRAINING OBJECTIVES

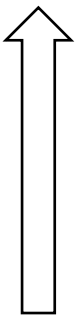
***Conditions**: The trainees will receive instructions on pertinent information on aviation-relevant situations or characteristics.*

***Performance**: The trainees will be able to identify and explain how the conditions relate to the scientific principles by using correct aviation nomenclature and mathematics.*

***Standard of accomplishment**: The trainees will display a good understanding of the principles, and make required calculations quickly and accurately, while also displaying some understanding of the context of practical applications*

1.1 REGULATORY REQUIREMENTS

1.1.1 The successful application of regulations concerning the safety and regularity of aircraft operation and the achievement of regulatory objectives depend greatly on the appreciation by all individuals concerned of the risks involved and on a full understanding of the regulations. This can only be achieved by well-planned and well-maintained initial and recurrent training programmes for all persons involved in aircraft operations. Aircraft maintenance personnel play a significant role in the safe operation of an aircraft, and the Annexes to the Convention on International Civil Aviation require that they be appropriately trained.



Knowledge/Practical Training Elements – Trade Skills

Training Code ***Level of capability/requirements***

1 *denotes a basic understanding of a subject. Trainees should have a basic understanding of the subject but are not expected to be able to apply it in practice.*

2 *denotes understanding of the subject and the ability, where applicable, to apply it in practice with the help of reference materials and instructions.*

3 *denotes a thorough understanding of the subject and the ability to apply it with speed, accuracy and judgement appropriate to the circumstances.*

Table A2-1 & 2. Recommended course duration and level of capability

Subject matter	*Recommended duration (hours)*	*Level of capability*
Chapter 4 Natural science and general principles of aircraft – knowledge	**445 total hrs**	
4.3 Mathematics	75	1
4.4 Physics	70	1
4.5 Technical drawing	70	1
4.6 Chemistry	30	1
4.7 Fixed wing aerodynamics and flight control	100	2
4.8 Rotary wing aerodynamics and flight control	100	2
Chapter 5 Aircraft engineering and maintenance: Airframe Knowledge	**800 total hrs**	
5.3 Maintenance practices and materials: Airframe/Powerplant	200	3
5.4 Aircraft systems and structures: Fixed wing	250	3
5.5 Aircraft systems and structures: Rotary wing	250	3
5.6 Airship systems and structures	100	3
Chapter 6 Aircraft engineering and maintenance: Engines/Powerplants - Knowledge	**750 total hrs**	
6.3 Piston engines	250	3
6.4 Propellers	100	3
6.5 Gas turbine engines	300	3
6.6 Fuel systems	100	3
Chapter 7 Aircraft engineering and maintenance: Avionics — Electrical and instrument Knowledge	**1350 total hrs**	
7.3 Maintenance practices and materials	200	3
7.4 Electrical and electronic fundamentals	450	2
7.5 Digital techniques, computers and associated devices	200	2
7.6 Aircraft electrical systems	250	3
7.7 Aircraft instrument systems	250	3
Chapter 8 Aircraft engineering and maintenance: Avionics — AFCS/Navigation/Radio Knowledge	**785 total hrs**	
8.3 Automatic flight control systems (AFCS): Fixed wing	200	3
8.4 Automatic flight control systems (AFCS): Rotary wing	75	3
8.5 Aircraft inertial navigation systems (INS)	60	3
8.6 Aircraft radio and radio navigation systems	450	3
Chapter 9 Human performance and limitations Knowledge	**30 total hrs**	
9.7 Required knowledge, skills and attitudes		
A. General programme overview	3	3
B. Human Factors knowledge	3	3
C. Communication skills	3	3
D. Teamwork skills	3	3

Subject matter	*Recommended duration (hours)*	*Level of capability*
E. Performance management	3	3
F. Situation awareness	3	3
G. Human error	3	3
H. Reporting and investigating errors	3	3
I. Monitoring and auditing	3	3
J. Document design	3	3
Chapter 10 Practical maintenance skills: Airframe	**1825bhrs**	
10.3 Basic workshop and maintenance practices: Airframe	725	3
10.4 Basic workshop and maintenance practices: Repair, maintenance and function testing of aircraft systems/component	1 000	3
10.5 Job/task documentation and control practices	100	3
Chapter 11 Practical maintenance skills: Engine and propeller	**1000 total hrs**	
11.3 Basic workshop and maintenance practices: Engine and Propeller	450	3
11.4 Basic workshop and maintenance practices: Engine/Propeller Systems/ Component and Function Testing	450	3
11.5 Job/task documentation and control practices	100	3
Chapter 12 Practical maintenance skills: Avionics — Electrical, instruments, autoflight and radio	**3075 total hrs**	
12.3 Basic workshop and maintenance practices: Avionics — Electrical	775	3
12.4 Basic workshop and maintenance practices: Avionics — Instrument	1 000	3
12.5 Basic workshop and maintenance practices: Avionics — Autoflight	225	3
12.6 Basic workshop and maintenance practices: Avionics — Radio	875	3
12.7 Repair, maintenance and function testing of aircraft systems/component: Avionics	100	3
12.8 Job/task documentation and control practices	100	3

NB: Some hours can be reduced when each Chapter training is combined within a course.

System is potentially very suitable for secondary technical school practical training or TAFE pre-employment training courses. Naturally, some theory knowledge is associated with the practical training elements.

Minimum Aircraft Maintenance Trade Training Standards

Minimum International AME Training Standards that must underpin NVET Avionic and Mechanical Trade Training Packages

Table of Content

CHAPTER 4 (ICAO Manual) 7
Mathematics, Physics, Chemistry & Technical Drawing 7
CHAPTER 5 (ICAO Manual) 12
Airframes and Airframe Systems: Knowledge. 12
CHAPTER 10 (ICAO Manual) 24
Practical Training Skills: Airframe Trade 24
CHAPTER 6 (ICAO Manual) 30
Mechanical Engines/Powerplants: Knowledge 30
CHAPTER 11 (ICAO Manual) 39
Practical Training Skills: Engine and Propeller Trade 39
CHAPTER 7 (ICAO Manual) 44
Basic Avionics and Avionic Systems: Knowledge 44
CHAPTER 8 (ICAO Manual) 64
Advanced Avionics and Avionics Systems: Knowledge 64
CHAPTER 12 (ICAO Manual) 77
Practical Training Avionics — Electrical, Instrument, Autoflight and Radio Trade 77
CHAPTER 9 (ICAO Manual) 83
Human Factors 83

Licenced Aircraft Maintenance Engineer Training Package should be a post trade course covering Chapter 3 of the ICAO Aircraft Maintenance Engineer Training Manual.

AMROBA has produced Part B to this Guide to address AME licencing training subjects and standards that licence holders should possess.

Implementing these international trade training standards will improve safety in aviation.

CHAPTER 4 (ICAO Manual)

Mathematics, Physics, Chemistry & Technical Drawing

Natural Science and General Principles of Aircraft: Knowledge

4.1 INTRODUCTION 7
4.2 TRAINING OBJECTIVES 7
4.3 MATHEMATICS 7
4.4 PHYSICS 8
4.5 TECHNICAL DRAWING: 10
4.6 CHEMISTRY: 11

4.1 INTRODUCTION

4.1.1 *In addition to the subjects which are of direct day-to-day concern to the responsibilities of the Aircraft Maintenance (Technician / Engineer / Mechanic) (AME), the AME training should include a sound understanding of the academic aspects of aircraft and aviation operations. This background will provide the trainees with a more complete understanding of not only their working environment but also the wider scientific principles employed in aviation.*

4.1.2 *The academic level of background subjects such as mathematics and physics should be specified as a prerequisite to course entry. However, if this is not practical or possible, then mathematics and physics may be taught to the required level before the start of the aviation training course. Where the knowledge of mathematics and physics is only just below the required entry level, or it is felt that a refresher course in mathematics and physics would be advantageous to the students, then these subjects could be taught in parallel with the aviation subjects.*

4.1.3 *The selection of topics for the mathematics and physics syllabi as well as the type of course instruction must reflect the depth and breadth of knowledge required to fully complement the level required by the aviation subjects.*

4.1.4 *Even though it is covered in the Maintenance Practices and Materials sections of both the mechanical and avionics curricula, technical drawing has been incorporated into the area of natural science and general principles of aircraft for the benefit of those students who will be involved in major modification and/or repair work.*

4.1.5 *Understanding the subjects of mathematics, physics, technical drawing. etc. constitutes an important part of the AMEs training base. It will permit a more comprehensive operational understanding, develop general in-depth awareness of air transport operations, and improve communication with both flight crew members and other maintenance personnel, thereby improving the overall safety of the aircraft operation.*

4.2 TRAINING OBJECTIVES

Conditions: The trainees will receive instructions on pertinent information on aviation-relevant situations or characteristics.

Performance: The trainees will be able to identify and explain how the conditions relate to the scientific principles by using correct aviation nomenclature and mathematics.

Standard of accomplishment: The trainees will display a good understanding of the principles, and make required calculations quickly and accurately, while also displaying some understanding of the context of practical applications.

4.3 MATHEMATICS

4.3.1 Arithmetic

- Arithmetical terms and signs; methods of multiplication and division; fractions and decimals; factors and multiples; weights, measures and conversion factors; ratio and proportion; averages and percentages; areas and volumes; squares, cubes, square and cube roots

4.3.2 Algebra

- Evaluation of simple algebraic expressions; addition, subtraction, multiplication and division; use of brackets; simple algebraic fractions, linear equations and their solutions; and introduction to simultaneous equations
- Polynomials and binomial theorem, solution of second-degree equations with one unknown, solution of simultaneous linear equations, and use of complex numbers

4.3.3 Geometry

- Simple geometrical constructions
- Graphical representation: nature and uses of graphs, rectangular and polar coordinates; graphs of equations
- Solution of plane triangles; solution of spherical triangles; application of some hyperbolic functions

4.3.4 Trigonometry

- Simple trigonometry: trigonometrical relationships and use of tables

4.3.5 Logarithms

- *Indices and powers: negative and fractional indices; square root; reciprocal and exponential tables*
- *Logarithms: use of log tables, and logarithms of produces, quotients, powers and root*

4.3.6 Calculators

- *Use of electronic calculators for logarithmic and trigonometric applications*

4.3.7 Differential and integral calculus

- *Derivatives and differentials; maxima and minima; expansion in series; indeterminate forms; curvatures; table of indefinite integrals, definite integrals; differential equations encountered in physics*

4.3.8 Graphical representation of functions

- *Equations involving two variables;*
- *equations for empirical curves; use of logarithmic paper; equations involving three variables; alignment charts*

4.4 PHYSICS

4.4.1 Mechanics

- *Forces as vectors: scalars, vectors, resultants, triangle of vectors, polygon of vectors, and resolution of a vector*
- *Forces and moments, composition and resolution*
- *Centre of gravity*
- *Uniform motion in a straight line; acceleration; motion under gravity; Newton's Laws; momentum; force; mass and weight; work, energy, rate of doing work, potential energy, relative velocity, angular velocity, physical units of mass, force, speed, work and power*
- *Friction: nature and effects, and coefficient of friction*
- *Specific gravity and density*
- *Viscosity, fluid resistance and rolling resistance*
- *Pressure and buoyancy in liquids (barometers)*
- *Elements of fluid dynamics: streamlines, Bernoulli's Theorem, venturi, Pitot tube and speed of sound*
- *Elements of vibration theory: harmonic motion, pendulum, damped harmonic motion, forced harmonic motion, and resonance*
- *Velocity ratio, mechanical advantage and efficiency*

- *Elements of theory on stress, strain and elasticity; tension, compression, shear and torsion stress; Hooke's Law and Young's Modulus*
- *Dynamics: kinematics of pure rotation, work, power, torque, kinetic energy, moment of inertia, radius of gyration, rotational equilibrium, centre of mass, couples, momentum and impulse, conservation of momentum, elastic and inelastic collisions, two-dimensional motion, and rolling bodies*
- *Elasticity: internal forces in solids, stress, strain, Hooke's Law, Poisson's ratio, shear, torsion, and bulk modulus*
- *Periodic motion: motion in a circle at constant speed, energy relations in simple harmonic motion, angular harmonic motion**, and equilibrium of a dynamical system***

4.4.2 Heat

- *Temperature: thermometers and temperature scales (Celsius/Centigrade, Fahrenheit, Rankine and Kelvin); conversion from one scale to another*
- *Expansion: linear expansion, surface and volume expansion*
- *Quantity of heat: units of heat (calories, BTU, CHU), heat capacity and specific heat*
- *Heat transfer: convection, radiation and conduction*
- *Mechanical equivalent of heat, first and second laws of thermodynamics*
- *Properties of fluids: solid, liquid and gaseous states, melting, boiling, evaporation and reverse processes, vapour pressure, absolute and relative humidity*
- *Gases: ideal gas; Charles' and Boyle's Laws; internal energy of a gas; specific heat of a gas; relationship between internal energy and heat*
- *Latent heats of fusion and evaporation, thermal energy, and heat of combustion*
- *Gases: specific heat at constant volume and constant pressure; work done by expanding gas; kinetic theory of gases*
- *Avogadro's number*
- *Thermodynamics: isothermal expansion and compression; adiabatic expansion and compression; the Carnot cycle; engine cycles; constant volume and constant pressure; refrigerators and heat pumps*

4.4.3 Light

- *Introduction to nature of light; speed of light*
- *Laws of reflection and refraction: reflection at plane surfaces; reflection by spherical mirrors, refraction, lenses, cameras and projectors, microscopes and telescopes*
- *Propagation of light, illumination, and photometry*
- *Wave optics: interference, interferometers, Huygens' model, diffraction, diffraction gradings, and polarization*
- *Spectra: dispersion by refraction, spectrometers, emission and absorption spectra, and quanta*

4.4.4 Electricity and magnetism

- *Fundamentals: atoms and electrons, conductors and insulators, electric currents, electromotive force, difference of potential, electrical units, power, work and energy, Ohm's Law, specific resistance, series, parallel and combined DC circuits, Kirchoff's Laws and the Wheatstone Bridge*
- *Batteries and thermal EMF: theory of electrolysis, primary cells, secondary cells; lead-acid and alkaline accumulators; and thermocouples*
- *Magnetism: permanent magnets, laws of magnetism, the earth's magnetism, magnetic fields, electro-magnetism, polarity rules, field strength and flux density, permeability, hysteresis, and reluctance*
- *Electrostatics: positive and negative charges, charges developed by friction, electrostatic induction, surface charges, electrostatic fields, static charges on aircraft and methods of dispersing them*
- *Electromagnetic induction: Faraday's Laws, Lenz's Law, magnitude and direction of induced EMF, generators, and induction coils*

- *Inductance and capacitance: mutual inductance; self- inductance; unit of capacitance; specific inductive capacity; dielectric strength; losses and efficiency*
- *Outline of AC theory: generation, principles, single-phase and three-phase generation, measurement of current and voltage, RMS, audio and radio frequencies.*
- *Resistance, inductance and capacitance in AC circuits: inductive reactance, resistance and inductance in series, impedance, power factor and true power, capacitive reactance, resistance and capacitance in series, resonance, Q factor, and voltage developed at resonance*
- *Resistance, inductance, capacity and parallel combinations*
- *Methods of coupling: mutual inductive coupling, resistive coupling, auto-inductive coupling, capacitive coupling, equivalent resistance, equivalent reactance, coupling factor, and resonance curves*
- *Transformers: primary and secondary EMF; load-on secondary, resistive, inductive and capacitive loads; transformer losses; tests of transformers; X-rays and natural radioactivity; photoelectric and inverse photo- electric effect; generation of X-rays; radioactive substances; radiography with X-rays and gamma-rays; Wave motion and sound*
- *Wave motion: mechanical waves, sinusoidal wave motion, interference phenomena, and standing waves*
- *Sound: speed of sound, production of sound, intensity, pitch and quality, and Doppler effect*

4.5 TECHNICAL DRAWING:

4.5.1 Introduction

- *Purpose of technical drawing*
- *Care and use of drawing instruments*
- *Standard paper sizes, blocks, conventions for lines, and dimensions*
- *Practice with drawing instruments*
- *Lettering*
- *Simple geometric constructions*
- *Layout of patterns with metric or inch dimensions*

4.5.2 Simple orthographic projections

- *Orthographic conventions*
- *Practice in first angle projections*
- *Practice in third angle projections*

4.5.3 Simple isometric projections

- *Isometric conventions*
- *Practice in making workshop sketches*

4.5.4 Geometric construction

- *Constructions involving lines and angles, circles and conic sections*
- *Geometric projections*

4.5.5 Practice in sketching

- *Proportioning*
- *Orthographic sketching*
- *Pictorial sketching*

4.5.6 Orthographic projection

- *Rules, determination of number of views, notation and representations, layout of three-view drawings, computation of weights*
- *Sectional views, standard symbols for sections and materials*
- *Dimensioning*
- *Representation of machine elements, threads, bolts, nuts, rivets, etc.*

- *Exercises incorporating standard conventions*

4.5.7 Shop terms and processes

- *Relationship between drawing and manufacturing processes*
- *Drawings for castings, forgings, machined parts, sheet metal parts, and welded constructions*
- *Practices as appropriate to particular course*

4.5.8 Assembly drawings

- *Layout drawing*
- *Assemblies, erection and installation drawings, inter-changeability, tolerances, fits and clearances, datum surfaces, tolerancing of form and position*
- *Surface finish, finish marks and specifications*
- *Checking drawings*

4.5.9 Auxiliary projections

- *Notation and relationship of auxiliary planes*
- *Layout of drawing with one auxiliary view*
- *Layout of drawing with two auxiliary views*
- *Axonometric projection*
- *Isometric projections, dimetric and trimetric projections*
- *Theory of axonometric projections*

4.5.10 Oblique projection

- *Theory*
- *Cavalier projection*
- *Cabinet projection*

4.5.11 Circuit layout

- *Convention for electrical and radio components*
- *Standard symbols for theoretical circuits and wiring diagrams*
- *Exercises in blueprint reading*
- *Interpretation of blueprint data*
- *Check for consistency*

4.5.12 Exercises in engineering design

- *To be selected by the instructor in accordance with the nature of the particular course and the type of work that the student will undertake in the future*

4.6 CHEMISTRY:

- *Nature of matter:*
    - *the chemical elements; structure of atoms, molecules, crystals, colloids, solutions and solvents; hardness and ductility.*

CHAPTER 5 (ICAO Manual)

Airframes and Airframe Systems: Knowledge.

Mechanical Trade Training Aircraft Airframes and Airframe Systems

5.1 INTRODUCTION 12

5.2 TRAINING OBJECTIVES 12

5.3 MAINTENANCE PRACTICES AND MATERIALS: AIRFRAME/POWERPLANT 12

5.4 AIRCRAFT SYSTEMS AND STRUCTURES: FIXED WING 16

5.5 AIRCRAFT SYSTEMS AND STRUCTURES: ROTARY WING 22

5.1 INTRODUCTION

5.1.1 *In order to be able to satisfactorily assimilate training on individual aircraft types, the Aircraft Maintenance (Technician/Engineer/Mechanic) (AME) must have a good fundamental understanding of the principles and functions of construction generally used in aircraft of all types.*

5.1.2 *In order to be able to satisfactorily assimilate training on individual aircraft types, the Aircraft Maintenance (Technician/Engineer/Mechanic) (AME) must have a good fundamental understanding of the principles and functions of construction generally used in aircraft of all types.*

5.1.3 *In order to be able to perform or supervise "hands-on" tasks of mechanic/technician on the aircraft or its components, the AME must have a very complete knowledge of all the associated maintenance practices that are likely to be used.*

5.2 TRAINING OBJECTIVES

Conditions: The trainees will receive training on aircraft engineering principles related to the aircraft structure, materials, components, construction, specifications and functional systems.

Performance: The trainees will describe the characteristics and applications of the materials used in aircraft construction, including the principles of construction and functions of aircraft structures; fastening techniques; powerplants and their associated systems; mechanical, fluid, and electrical power sources; basic aircraft instrument and display systems; aircraft flight control systems; basic airborne navigation and communication systems.

Standard of accomplishment: The trainees will describe the characteristics and applications of the materials, construction, system operating principles and maintenance practices in accordance with actual practice on existing aircraft.

*5.3 MAINTENANCE PRACTICES AND MATERIALS: AIRFRAME/POWERPLANT**Aircraft, hangar and workshop safety precautions***

- *A guide to the various aspects of safe working practices, including the precautions to be taken when working with electricity, gases, oils and chemicals*
- *Instruction in the remedial action to be taken in the event of an accident with one or more of the hazards*

5.3.2 Principles of workshop practice

- *Care of tools*
- *Use of workshop materials*
- *Dimensions and standards of workmanship*

5.3.3 General purpose tools

- *Review of types of tools: hammers and mallets, screwdrivers, wrenches (spanners), torque wrenches, punches, pliers, clamps/vices/presses, hacksaws, snips/ nibblers, chisels, files, taps and dies, reamers, drill bits, thread gauges and crimping tools, grease guns, oil cans and lubrication methods*

5.3.4 General purpose power tools

- *Electric and pneumatic powered saws, drills, grinders, sanders, routers, nibblers, rivet guns and heat guns*

5.3.5 Precision measuring tools

- *Micrometers: metric/inch, vernier gauge, vernier callipers, surface table and accessories, marking out, dial test indicators, go/no-go gauges, combination sets, bore and depth gauges, steel rule, inside and outside callipers, slip gauges and feeler gauges*

5.3.6 Screw threads

- *Screw nomenclature*
- *Thread forms, dimensions and tolerances for standard threads used in aircraft*
- *Measuring screw threads*

5.3.7 Bolts, studs, screws and fasteners

- *Bolt types: specification, identification and marking of aircraft bolts, Society of Automotive Engineers (SAE) and metric*
- *Nuts: self-locking, anchor, and standard types*
- *Machine screws: aircraft specifications*
- *Studs: types and uses, insertion and removal*
- *Woodscrews, cotter pins, dowels, self-tapping screws and nuts*
- *Locking devices: tab and spring washers, locking plates, split pins, pal-nuts, wire locking, quick release fasteners, keys and circlips*

5.3.8 Fits and clearances

- *Allowances and tolerances, drill sizes for bolt holes, and classes of fits*
- *Common system of fits and clearances*
- *Schedule of fits and clearances for aircraft and engines*
- *Limits for bow, twist and wear*
- *Standard methods for checking shafts, bearings and other parts*

5.3.9 Maintenance data, engineering drawings and diagrams

- *Understanding of the following drawing types and diagrams, their symbols, dimensions and tolerances:*
  - *orthographic*
  - *isometric*
  - *oblique*
  - *perspective*
  - *electrical*
  - *block*
  - *schematic*
  - *sectional*
  - *blueprint*
  - *logic flow chart*
- *Identification of the following information within the title block:*
  - *drawing and revision number*
  - *reference number*
  - *scale*
  - *weight*
- *Understanding of the use of maintenance data to Specifications 100 and 2100 of the Air Transport Association (ATA) of America*

5.3.10 Electrical cables and connectors (as applicable to a mechanical AME)

- *Electrical connector: identification, codes, shape, locking pins, removal, insertion, crimping and soldering*
- *Electric cables: types, sizes, gauges, insulation, properties application, temperature ranges, numbering and identification*
- *Coaxial cables, high and low-tension cables and precautions when attaching them*

- *Crimping, terminal ends, splices, wire grip, insulation grip, diamond grip, tools, colour codes, crimp insulation dimple codes tool testing, millivolt drop test, and go/no-go gauges*

5.3.11 Aircraft fasteners

- *Types of riveted joints, rivet spacing, and pitch*
- *Types of solid rivets: specifications and identification*
- *Types of hollow rivets: cherry, pop, chobert, avdel and semi-pierced*
- *Tools used for riveting and dimpling*
- *Inspection of rivets*

5.3.12 Pipes and unions

- *Identification of types of rigid and flexible pipes and their connectors that are used in aircraft*
- *Bending and belling/flaring aircraft pipes*
- *Standard unions for aircraft hydraulic, fuel, oil, pneumatic and air system pipes*
- *Inspection and testing of aircraft pipes and hoses*

5.3.13 Springs

- *Types of springs, materials, applications, limitations, inspection and testing*

5.3.14 Bearings

- *Purpose of bearings, loads, material, construction and application*
- *Types of bearing: plain, ball, roller, needle, self- aligning and air bearing*
- *Testing, cleaning and inspection of bearings*
- *Lubrication requirements of bearings*
- *Defects in bearings and their causes: brinelling, burnishing, galling, spalling, abrasion, burning, burring, chafing, chipping, corrosion, fretting, gouging, grooving, cutting, inclusions; nicks, peening, pitting and scoring*

5.3.15 Gears

- *Gear types: spur, helical, bevel, hypoid, worm, planetary, differential, sector, rack and pinion*
- *Gear ratios, reduction and multiplication gear systems, driven and driving gears, idler gears, and mesh patterns*
- *Inspection of gears, backlash and lubrication*

5.3.16 Transmission systems

- *Belts and pulleys, Bowden cables, and chains and sprockets*
- *Aircraft flexible control systems*
- *Screw jacks, lever devices, and push-pull rod systems*

5.3.17 Cables and wires used in aircraft

- *Standard wire gauges: British, American and metric*
- *Types of wire used on aircraft and specification for aircraft wire ropes*
- *Splicing and swaging of end fittings and types of end fittings*
- *Turnbuckles and standard tensioning devices, pulleys and cable system components*
- *Inspection and testing of flying control cables*

5.3.18 Sheet metal work

- *Marking out of sheet metal*
- *Calculation of bending allowance*
- *Folding, bending, forming, stretching, shrinking, shearing and riveting of sheet metal*

5.3.19 Machine tool operation

- *General understanding of operation of lathes, grinders, milling machines, shapers, scrapers, drills and saws (band)*

5.3.20 Forging, welding, brazing, soldering and bonding

- *Forging: hand forging of simple items, hardening and tempering of carbon steel using forge*
- *Welding: gas welding and brazing*
- *Electric arc welding: metallic arc welding, tungsten inert gas arc welding (TIG), atomic hydrogen arc welding, carbon arc welding, and metal inert gas arc welding (MIG)*
- *Resistance welding and spot welding*
- *Identification of welding defects, bad depth and width, penetration, undercut and spatter*
- *Soldering: soft soldering, hard soldering, silver soldering, flux, tinning, lead/tin content, melting points, and cold/dry joints*
- *Use of heat sinks*
- *Soldering iron types, temperature controlled and bits*
- *Bonding: resin bonding and adhesives*

5.3.21 Aircraft materials: Ferrous

- *Iron and steel production, strength, and melting points*
- *Characteristics of low, medium and high carbon steels*
- *Identification of common steels used in aircraft by SAE number*
- *Characteristics of various alloy steels*
- *Heat treatment, properties and application of carbon/ alloy steels*
- *Testing of ferrous materials for hardness, tensile strength, fatigue strength and impact resistance*
- *Electrical/magnetic properties of the material*

5.3.22 Aircraft materials: Non-ferrous

- *Aluminium, magnesium, brass, bronze, copper, lead, tin, zinc and titanium: production, weight, strength, melting points, heat treatment, anodic treatment, plating, applications and limitations*
- *Common alloying elements for magnesium and aluminium and the effect on the base metal*
- *Identification of heat treatment of aluminium alloys by code number*
- *Testing of non-ferrous metal for hardness, tensile strength, fatigue strength and impact resistance*
- *Electrical/magnetic properties of the material*

5.3.23 Aircraft materials: Composite/Non-metallic

- *Wood: types, specifications, plywoods, damage/failure mode, environmental contamination, disease, joining, cutting, grain, protection, sealing, application and uses*
- *Identification of composite materials commonly used in non-structural aircraft applications: glass, carbon, and Kevlar fibres*
- *Standard weaves used in fibre mats and properties of fibre elements*
- *Resin matrixes and their properties*
- *Core material used in sandwich-type construction*
- *Defects in non-structural composite material; its detection and rectification*
- *Repair of laminates and fibre reinforced plastics, tools, testing, and vacuum processes*
- *Plastics, transparent materials, acrylics, glass and wood*
- *Sealants, bonding agents, rubbers, synthetic rubbers, characteristics, handling precautions, vulcanizing and inspection*
- *Electrical properties of the material*

- *Fabric covering, dopes, thinners, paints, cements, stitching, nails, tapes, patches, zips, and inspection panels*

5.3.24 Corrosion

- *Formation by galvanic action process, microbial and stress*
- *Types of corrosion: surface, intergranular, pitting, filiform and exfoliation*
- *Causes of corrosion: dissimilar metals, heat treatment, welding, fretting and stress*
- *Material types susceptibility to corrosion*
- *Identification of corrosion types, forms and effect*

5.3.25 Aircraft corrosion control

- *Methods of corrosion removal from common aircraft metals*
- *Corrosion protection treatment methods: chemical, sacrificial and mechanical*
- *Mercury contamination of aircraft structure, removal, protection and precautions*

5.3.26 Non-destructive testing (NDT)/Non-destructive inspection (NDI)

- *Dye/chemical penetrant method: water washable, post emulsifiable and solvent removable*
- *Magnetic particle, eddy current, conductivity and ultrasonic*
- *Radiographic X-ray/gamma ray*
- *Use of ultraviolet light with fluorescent dyes*
- *Methods for testing, castings, forgings, extrusions, welds aircraft and engine components*
- *Visual probes and eyeglass equipment*

5.3.27 Basic electricity

- *Use of electricity in aircraft*
- *Elementary electrical physics: types of electricity*
- *Units: amps, ohms, volts, watts, and Ohm's Law*
- *Mechanical and chemical methods of producing electricity*

5.3.28 Aircraft handling

- *Aircraft towing: safety precautions, towing arms, weak links, locking devices, weight limits, turning angle limits, control of aircraft brakes, lookouts, tugs and tractors*
- *Aircraft jacking: principles of aircraft jacking, safety precautions, weight and balance limits, jack types, jacking points and jacking techniques*

5.4 AIRCRAFT SYSTEMS AND STRUCTURES: FIXED WING

5.4.1 Mechanical control components: Construction and function

- *Function and adjustment (where applicable) of bell cranks, quadrants, levers, torque arms, torque tubes, push-pull rods and their end fittings, universal joints, fire and vapour seals for control systems*
- *Function, inspection, maintenance and identification of cables, cable end fittings, pulleys, cable guards, and cable tensioning devices*
- *Chains and sprockets: types, construction, distortion, wear, elongation, and prevention against jamming*

5.4.2 Hydraulic system

- *Principles of hydraulics: its relation to Pascal's Law, understanding of the relationship between pressure, force and area relating to differential areas, pressures and mechanical advantage*
- *Hydraulic fluids: types, identification, military specifications, colour, properties, user precautions, and applications*
- *Hydraulic seals: types, seal/fluid correct compatibility, identification, applications, tools, storage life, and maintenance practices*

- *Fittings and flexible pipes: identification of pipes, inspection and maintenance of pipes, and hydraulic accumulators*
- *Pumps: manual and power operated; reservoirs; filters; regulating valves; hydraulic fuses; priority systems*
- *Pressure/contents/temperature indication*
- *Interface with electrical and emergency systems*
- *Typical hydraulic systems in aircraft*

5.4.3 Pneumatic and air systems

- *High-pressure air systems and components*
- *Bleed air pneumatic systems*
- *Safety precautions when working with high-pressure gas systems*
- *Pneumatic control systems features, components and function*
- *Inspection and maintenance of air/pneumatic systems*
- *Ducting, mass flow, pressure control/indication, leak detection, valves, alternate supply, Auxiliary Power Unit (APU), and ground cart supply*
- *Indications and system protection devices*

5.4.4 Airframe structures: General concepts

- *Airworthiness requirements for structural strength*
- *Understanding of the following terms:*
  - *strain*
  - *bending*
  - *compression*
  - *shear*
  - *torsion*
  - *tension*
  - *hoop stress*

5.4.5 Understanding of the principles of "fail safe" design, fatigue life, strength and rigidity

- *Construction methods: monocoque, semi-monocoque and truss (Pratt truss and Warren truss)*
- *Non-stressed skin fuselage construction and stressed skin fuselage construction*
- *Formers, stringers, longerons, bulkheads, frames, struts, ties, beams, floor structures, reinforcement methods of skinning, anti-corrosive protection skin, wing and empennage attachments, doors, windows, nacelles, engine mounts, pylons, vibration damping methods, and firewalls*
- *Wings, primary and auxiliary control surfaces*
- *Wing construction methods: monospar, multispar, and box beam*
- *Wood, metal and composite spars*
- *Constructional features: ribs, struts, wires, tie rods, braces, stringers, stressed skin, and biplanes*
- *Leading and trailing edges, and wing tips*
- *Fuel tanks: integral and detachable, internal and external, sealing of fuel tanks and inspection of tanks*
- *Load distribution on cantilever spar beams*
- *Special construction methods: spot welding, adhesive bonding, honeycomb structures, integral milling, and contour etching*
- *Constructional and general features of primary and auxiliary control surfaces*
- *Static and aerodynamic balancing of control surfaces*
- *Calculations for the balance of controls following repair or repainting*
- *Trim and balance tabs, and mass balance*

5.4.6 Inspection of structures

- *Understanding of the following terms:*

- *fuselage station*
- *wing station*
- *buttock lines*
- *water lines*
- *butt lines or*

- *ATA-100 zoning system used to identify aircraft component locations and access points*
- *Inspection of structures for wear, damage and deterioration*
- *Identification of visual indications of flight or ground overloads, structural failure of adjacent members and corrosion*
- *Classification of damage, repair or maintenance implications attributed to structures*

5.4.7 Airframe symmetry

- *Methods of alignment and symmetry checks: wings and horizontal stabilizers for dihedral and incidence; vertical stabilizers for alignment; fuselage for twist and bending, and complete airframe for symmetry*
- *Understanding of the following terms as they are applied to airframe symmetry requirements:*
  - *stress*
  - *rigging position*
  - *incidence angle*
  - *wash in*
  - *wash out*
  - *anhedral*
  - ***struts***
  - *dihedral*
  - *longitudinal dihedral*
  - *stagger*
  - *decolage*
  - *cabane struts*
  - *interplane*

5.4.8 Fastener installation

- *Identification of solid and blind rivets by head markings, physical characteristics and identification number*
- *Requirements for edge distance, pitch and gauge for rivet installation*
- *Identification of incorrectly installed rivets and rivet failure*
- *Understanding of the following terms in relation to rivet design, installation or layout:*
  - *pitch*
  - *gauge*
  - *clearance*
  - *dimpling*
  - *shaving*
  - *countersinking*

5.4.9 Sheet metal repair in aircraft

- *Understanding of the following processes used in the fabrication/repair of sheet metal parts: folding, bumping, dimpling, crimping, stretching, shrinking, joggling, coining operation and use of the hand and power tools such as shears, presses, brakes/folding machines, roll formers, cutters and guillotine*
- *Calculation of bend allowance and setback*
- *Calculation of geometric shapes: circumference of circles, length and angles of the sides of triangles, etc.*
- *Calculation of weight of completed repair and determination of its effect on surrounding structure*

5.4.10 Tubular structure repair

- *Design characteristics: angles and dimensions of tubular weld repairs patching, inner and outer sleeves, and splicing*
- *Typical non-welded repairs of tubular structural members*

5.4.11 Window and windshield repairs

- *Hot and cold methods of forming acrylic sheet*
- *Considerations and precautions to be taken when cutting acrylic sheet*
- *Cementing and curing of acrylic sheet*

- *Finishing methods for acrylic sheet, buffing, polishing and cleaning*
- *Glass windshields: construction, lamination, fitting, removal, handling, storage, inspection, heating, sealing, cleaning, and minor damage repair techniques*

5.4.12 Pressurized structures

- *Understanding of aircraft design related to load transfer, load path continuity and reduction of stress raisers in pressurized fuselages*
- *Methods by which doors and other large cutouts are restrained from opening under pressurization loads*
- *Methods used to seal structure and components to the structure of airframe pressure cells*
- *Methods used to ensure structural protection from rapid decompression*
- *Sealing methods at pressure bulkheads for control and electrical cables*
- *Sealing methods used in doors and cutouts in pressure cells*
- *Maintenance precautions in maintenance of blowout panels, airflow louvres, and decompression doors*
- *Methods used to achieve minimum drag and aero- dynamically clean structures*

5.4.13 Surface protection and paint systems

- *Methods for the removal of existing corrosion protection and surface corrosion*
- *Methods of preparation, cleaning and degreasing prior to surface treatment*
- *Methods of pre-treatment prior to application of finishes*
- *Various types of primers; advantages, disadvantages and uses*
- *Various types of topcoat finishes; advantages, disadvantages and uses*
- *Physical conditions necessary for correct application of particular finishes: temperature, humidity, dust free, etc.*
- *Application process and equipment including cleaning equipment after use, techniques of spraying, etc.*
- *Identification and understanding of possible causes of defects in applied coatings or finishes*

5.4.14 Landing gear and associated systems

- *Fixed landing gear: tail wheel assemblies, nose wheel types, shock struts, shock or bungee cords, bracing, spring steel struts, air-oil oleo struts, spring-oleo struts, floats and skids*
- *Retractable landing gear: geometry, construction, actuation, locking, position indication, torque links, drag braces and bogey beams*
- *Limit vertical inertia load factor and energy dissipation rate*
- *Tail wheel and nose wheel types, track-type gear, tandem and multi-contact gears, crosswind landing gear, anti-shimmy mechanisms, gear doors and mechanisms, and emergency extension*
- *Nose wheel steering: principles, control, actuation, maintenance and inspection*
- *Wheels and tyres: treads, size, construction, speed limits, identification/markings, pressures, valves, safety devices, inflation, inspection and maintenance*
- *Brakes: braking factors, actuation, heat dissipation, anti-skid devices, disc brakes, drum brakes and expanding tube brakes*
- *Auto-brakes, single and dual servo brakes, and master cylinders*

5.4.15 Ice and rain protection

- *Ice formation on aircraft, engines and propellers, its effects and classification*
- *Anti-icing systems: electric, thermal and chemical*

- *De-icing systems: electric, pneumatic and chemical sensors, and indicators for quantity or temperature cyclic systems*
- *Chemical rain repellent systems*
- *Pneumatic rain removal*
- *Ice detection systems*
- *Water and toilet drain heaters*
- *Windshield wipers: electric and hydraulic*
- *Demisting*
- *Ground removal of frost, ice and snow: temperatures, time limits, materials and application techniques*

5.4.16 Cabin systems and installation

- *Water systems and pressure control*
- *Safety installations: emergency exits, life jackets and dinghies, escape slides, harnesses and safety belts, seats and seat belts, freight stowage, and catering trolleys, and crash, rescue and first aid equipment*
- *Operation of safety devices and control of service power supply (such as refrigeration, galleys, heaters and other cabin equipment including lift mechanisms)*
- *Toilet and sanitary equipment including health precautions*
- *Waste collection and drainage*
- *Safety precautions related to emergency exits and escape slides*
- *Cabin entertainment (films, video, television and audio) and public address*
- *Furnishings, soundproofing, and role change equipment*
- *Operation of internal and external, normal and emergency lighting systems*

5.4.17 Environmental, air conditioning and oxygen systems

- *Gas composition of the atmosphere and the physical properties of oxygen*
- *Understanding of hypoxia, anoxia, hyperventilation and carbon monoxide poisoning, including related symptoms for each*
- *Elements and principles of cabin air conditioning: power, air supply, cabin structure, pressure control, pneumatic and electronic control devices and sensors, safety and warning devices*
- *Cooling and heating: air cycle machines, refrigeration equipment, vapour cycle systems and controls, electrical, exhaust and combustion heaters, temperature control equipment, and circulation systems*
- *Humidity control: humidification, water separation, and humidity control devices*
- *Oxygen systems: oxygen storage, distribution and production*
- *System components: regulators (continuous flow, demand, diluter-demand and pressure-demand types), oxygen bottles, identification of oxygen equipment, demand valves, charging valves, quantity and pressure indication, pipes and connectors, masks, safety and pressure relief devices, liquid oxygen systems, gaseous oxygen systems, chemical oxygen systems, on-board oxygen generation systems, and purging method for oxygen systems*
- *Safety precautions related to the handling and replenishment of oxygen systems*
- *Testing of oxygen systems, pressure cabins and test equipment*
- *Bleed air, turbo-charged bleed air, mass flow control, temperature control, differential pressure and maximum pressure*

5.4.18 Fire warning, protection and control systems

- *Aircraft and engine fire warning principles and control*
- *Principles of fire and smoke warning and detection systems*

- *Principles of fire extinguishers: extinguishing agents, types of extinguishers and their operation*
- *Installation layout of typical fire warning and detection systems in aircraft and their operation*
- *Awareness of life limitations of fire extinguisher components*
- *Testing of fire warning/detection/extinguisher systems*
- *Precautions to be taken during servicing and maintenance*
- *Centralized warning systems, principles of inputs- outputs and priority philosophy.*

5.4.19 Fuel supply systems

- *Layout of fuel supply system for piston- and turbine- powered aircraft*
- *Contents indication, instrument and electrical interface*
- *Identification and location of fuel system components*
- *Fuel-specific gravity, densitometer, and fuel properties*
- *Boost/scavenge systems*
- *Non-return valves: refuelling/de-fuelling/fuel dump*
- *Venting, tank sealing, and sealants*
- *Water drains and testing for water contamination of fuel*
- *Usable/unusable fuel*
- *Use of fuel for aircraft trim control*

5.4.20 Aircraft electrical systems

- *Lead acid batteries: plate material, electrolyte, specific gravity, capacity and capacity testing, determination of state of charge, charging constant voltage/constant current, gassing, sulphation, temperature, hydrometer, and insulation and resistance (I/R) checks*
- *Safety precautions when dealing with lead acid batteries*
- *Neutralization of acid spills, cleaning and maintenance*
- *Storage and shipping requirements*
- *Environmental hazards associated with lead acid batteries*
- *Separation of lead acid and nickel-cadmium battery: charging facilities, location, storage, components, chemicals and service equipment*
- *Nickel-cadmium batteries: plate material, electrolyte, capacity and capacity testing, determination of state of charge, gassing, charging constant current, cell imbalance/balance, cell voltage reversal, I/R checks deep cycle recovery, cell removal/replacement, and cell leak tests*
- *Thermal runaway: cause and prevention, temperature indication/warning and control*
- *Neutralization of electrolyte spills, cleaning and maintenance*
- *Storage and shipping requirements*
- *DC power supplies: generators construction, function and maintenance, and generator balancing*
- *Voltage regulators: carbon pile, mechanical, electronic, cut-outs, reverse current relays, and circuit protection*
- *Typical DC circuits, DC motors and actuators*
- *AC power supplies: alternators (single phase and three phase), inverters (static and rotary), transformers, rectifiers, transformer rectifier units, and protection devices*
- *Alternator drives, constant speed devices, integrated drive generator systems, and data bus systems*
- *Aircraft electrical wiring: cable specifications, looms, identification, fuses, circuit breakers, current limiters, bonding and discharge of static*
- *Logic gates, electrostatic devices handling and protection*

- *Engine starter motors*

5.4.21 Aircraft instrument systems

- *Pitot static system: function, layout, testing, airspeed indicators, pressure altimeters, and vertical speed indicators*
- *Gyroscopic components: principles, turn and slip indicators, directional gyros, artificial horizons, and turn coordinators*
- *Precautions when handling gyroscopic instruments*
- *Engine instruments: manifold pressure gauge, oil pressure gauge, electrical and mechanical tachometers*
- *Electrical resistance thermometers, thermocouples, radiometer and torque meters*
- *Flow measuring instruments: pressure/volume, fuel and mass airflow, sensing type, fuel quantity indicator capacitive and float types*
- *Compasses: principles and function of magnetic compasses, standby and remote reading*
- *Effect of faults in components of the aircraft/engine instrument system*

5.4.22 Float planes, amphibians and flying boats

- *Floats: design, construction, material, corrosion protection, draining and plugs*
- *Hull: shape, step, planing and strakes*
- *Water rudders: design, construction, and control*
- *Mooring, fittings and mooring points, tie down points, anchors and life jackets*
- *Taxiing, manoeuvre and control of aircraft on water*
- *Docking and slipping*

5.5 AIRCRAFT SYSTEMS AND STRUCTURES: ROTARY WING

5.5.1 Main rotor heads (MRH)

- *Main rotor head: various designs and features to accommodate flapping, feathering, leading and lagging actions of main rotor blades*
- *Operation of swash plate and its effect on tip path plane*
- *Construction and operation of rotor blade dampers*
- *Mounting, inspection and maintenance of main rotor heads*

5.5.2 Tail rotors and anti-torque control

- *Methods of achieving directional/anti-torque control through tail rotor, bleed air or aerodynamics*
- *Principles, construction, mounting and maintenance requirements of typical tail rotor drive systems (including shafts, bearings, couplings, universal joints, gearboxes and pitch change mechanisms)*

5.5.3 Clutches, freewheel units and rotor brakes

- *Operation, function, construction, and component location*

5.5.4 Cyclic control system

- *Operation and function of system*
- *Layout and location of components (cyclic stick to pitch-change rod inclusive)*

5.5.5 Collective control system

- *Operation and function of system*
- *Layout and location of components (collective lever to pitch-change rod inclusive)*
- *Pilot control for power and non-power assisted flying controls*
- *Methods of rotor revolutions per minute (RPM) compensation applicable to collective control*

5.5.6 Main rotor gearbox and main rotor mast

- *Operation, function and mounting methods of gear- boxes and masts*
- *Lubrication and loads*
- *Inspection and maintenance of gearboxes and masts*

5.5.7 Main/Tail rotor blades

- *Construction methods and materials used in wood, metal and composite main and tail rotor blades*
- *Blade attachment systems*
- *Inspection and maintenance of main and tail rotor blades*

5.5.8 Blade tracking and helicopter vibration analysis

- *Precautions to observe when moving and positioning helicopters (e.g. turning rotor blades)*
- *Methods of and requirements for tracking main and tail rotor blades*
- *Balancing, static and dynamics of main and tail rotor blades*
- *Hub and main rotor alignment; checks and adjustment on semi-rigid rotor heads*
- *Types of vibration experienced in helicopters: causes and effects*
- *Methods used to reduce vibration and dampers*
- *Auto-rotation: calculation of correct rotor speed and effects of too high or too low rotor RPM*

5.5.9 Fuselage, doors, engine mounts and landing: (Gear attachments)

- *Construction methods: truss (Pratt truss and Warren truss), monocoque and semi-monocoque (including the identification of load-carrying members)*
- *Construction of doors, nacelles and firewalls*
- *Engine mountings, pylons, and vibration damping*
- *Landing gear and skid mounting attachment points*
- *Winches, cables, supports, lifting hooks, and hard points*
- *Flotation devices: explosive and mechanical activation*

CHAPTER 10 (ICAO Manual)

Practical Training Skills: Airframe Trade

10.1 INTRODUCTION 24
10.2. TRAINING OBJECTIVES 24
10.3 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AIRFRAME 25
10.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: REPAIR, MAINTENANCE AND FUNCTION TESTING OF AIRCRAFT SYSTEMS/COMPONENT 27
10.5 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES 28

10.1 INTRODUCTION

10.1.1 *In order to be able to satisfactorily assimilate the training on individual aircraft and systems, the Aircraft Maintenance (Technicians/Engineers/Mechanics) (AMEs) must have good fundamental practical skills and understand the maintenance processes and principles generally used in aircraft hangars and workshops.*

10.1.2 *In order to be able to perform or supervise "hands-on" tasks of an AME on the aircraft, the aircraft engines and systems, the AME must have a very complete knowledge of all the tools and associated maintenance processes that are likely to be used in hangars and workshops.*

- *In order to be able to perform or supervise "hands-on" tasks of an AME on the engines, propellers and systems, the AME must have a very complete knowledge of all the tools and associated maintenance processes that are likely to be used in hangars and workshops.*

10.1.3 *For future aircraft hangar and workshop technicians, their basic workshop training should commence with Phase Two — Skills (Chapters 10-13 inclusive), and should be completed before the students begin working on airworthy aircraft, engines or equipment. For this purpose, the Performance parameters required to meet the Training Objectives outlined in 10.2 & 11.2 of this chapters are divided into two sections: Section a) requires basic manual skills and Section b) refers to the application of these skills to non-airworthy aircraft, components or specially-designed practice rigs. The level of manual skills to be developed also varies according to the category of AMEs being trained. For example, bench fitting is of importance to all categories of AMEs, while avionic component AMEs may require skills in soldering but they only need an introduction to welding.*

10.1.4 *The recommended facilities, tools and equipment are described in Appendix 1 to this chapter.*

10.2. TRAINING OBJECTIVES

Conditions: The trainees will be provided with appropriate facilities; tools (both hand and machine); materials; a selection of airframe assemblies, component or parts; specially- made repair, assembly and rigging test exercises. (See Appendix 1 to Chapter 10.)

Performance:

a) The trainees will practice repair schemes on airframe components as well as assemble and adjust test exercise pieces and/or assemblies by using simple engineering drawings and aircraft maintenance test (real or simulated).

b) The trainees will practice fault finding, dismantling, inspecting, repairing, decision-making regarding repair or replacement, reassembly and testing. They will also use engineering drawings as well as engine manufacturers' maintenance, overhaul and repair manuals.

Standard of accomplishment: During workshop training, the standard is a function of the variety of exercises completed and the time spent in workshop training. The trainees/students should work individually on airframe exercises so that they have "ownership" of the standard. If necessary, they should practice and repeat increasingly complex exercises to develop greater manual skills within their respective areas of competence. Finally, they should carry out tests or operate the system exercise rigs.

10.3 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AIRFRAME

10.3.1 Introduction

a) Training in workshop practice should begin with exercises in the use of hand tools to make a series of simple shapes to specified dimensions from various metals. Each shape should be progressively more complicated with more precise tolerances. From the start, instructors should ensure that students develop the habit of handling basic hand or machine tools in the correct manner, and action should be taken to correct any bad or potentially dangerous practices before they become habitual. At all times, and particularly during the early stages of training, the importance of producing accurate and careful work must be stressed. These exercises can be used to develop the trainees' inspection ability, i.e. the necessary judgement and sense of responsibility required to assess the accuracy of their own work and that of others.

b) It is desirable that licensed AME students should have the opportunity to remove and replace major components. Practice in inspection functions during simulated repair or maintenance activities is considered an important training element in this phase.

10.3.2 Bench fitting

- *Cutting and filing: exercises in cutting metal with hacksaws; filing; drilling; drill grinding; thread cutting with taps and dies; and scraping*
- *Measurements: use of steel rule, dividers, callipers, micrometers, vernier, combination set, surface place, and dial test indicator*

10.3.3 Forging, heat treatment, soldering and welding

- *Forging by hand simple specimens such as chisels, punches and others*
- *Hardening and tempering carbon steel by using forge*
- *Tin soldering, tin-plating, and use of proper flux*
- *Silver soldering and brazing*
- *Welding: oxyacetylene and metallic arc welding of different materials*
- *Inspection of welded joints for flaws*

10.3.4 Sheet metal work

- *Sheet aluminium alloy: cutting, marking out, drilling, forming, bending, bending allowances, shrinking and flashing*
- *Forming sheet metal by pressing and rolling*
- *Riveting: types of rivets, riveting with hand tools, rivet spacing, countersinking and dimpling*
- *Use of pneumatic riveting hammer*
- *Blind riveting*
- *Inspection of rivets, removal of rivets, use of oversized rivet and rivet jackets*
- *Tube work: use of taper pins and tubular rivets*
- *Exercises in sheet metal patching and repair work*
- *Heat treatment of aluminium alloy and alloy rivets: use of salt baths and furnaces; annealing and solution treatment*

10.3.5 Machine shop

- *Drilling: using machine drills to drill close tolerance holes in various materials; reaming holes to close tolerances; others*
- *Turning: exercises in turning steel, aluminium alloy and brass parts; use of lathe for thread cutting; others*
- *Grinding: use of grinding wheels for tool sharpening*

10.3.6 Woodwork

- *Cutting and smoothing of wood: marking out, sawing and planing wood, and exercises in woodwork involving tenon and scarf joints*

- *Selection of aircraft woods: defects of timber, timber, tests for moisture content, and straightness of grain*
- *Plywoods and laminated woods: bending, patching, and standard repairs to aircraft woodwork*
- *Gluing: approved glues (casein and synthetic resin); mixing; uses; drying times*
- *Varnishing and protection of aircraft woodwork*
- *Environmental aspects*

10.3.7 Wire and cable work

- *Inspection of aircraft cables for defects*
- *Splicing exercises*
- *Swaging exercise: attachment of standard end fittings to flying control cables*
- *Demonstration of proof test on flying control cable*

10.3.8 Tube Work

- *Tube bending, with or without heat treatment.*
- *Tube flaring*
- *Fitting of different kinds of unions used in fuel, oil and hydraulic systems*
- *Inspection and testing of tubes and flexible hoses*

10.3.9 Airframe familiarization

- *Airframe structures: detailed examination of various types of wing and fuselage construction, including primary and secondary structures*
- *Use of forged, extruded, cast and sheet material*
- *Main joints: methods of riveting, spot welding, and adhesive bonding*
- *Doors and cut-outs, positions of inspection panels, removal of fairings, and methods of gaining access to all parts of structure*
- *Landing gear: examination of control system; checking of control surface movements and cable tensions; interconnections of autopilot to control systems; examination (by visiting airline, if necessary) of power-operated control systems*

10.3.10 Ground handling of aircraft

- *Pre-flight inspection with aircraft on apron*
- *Starting and running of engines and auxiliary power unit (APU); observation of instrument readings; function check(s) of electrical components and radios; stopping of engines*
- *Compass swinging and automatic direction finder (ADF) loop swinging*
- *Use of ground equipment for moving, lifting or servicing aircraft*

10.3.11 Installation and testing of equipment

- *Removal, replacement, in situ inspection, and function testing*
- *Testing for leaks, errors and electrical faults of electrical equipment, instruments, autopilots, communication and navigation equipment as appropriate*

10.3.12 Small aircraft

- *Dismantling of aircraft: removal of engine, control surfaces, landing gear, wings, tail plane and fin, and seats*
- *Inspection: inspection of condition of fuselage alignment checks, freedom from distortion, and symmetry*
- *Checking of wings and other airframe components for condition, and freedom from distortion*
- *Reassembly of aircraft: replace wings, empennage, control surfaces, and engine; check rigging angles of wings and tail plane; adjust flying controls and check control surface movements; replace landing gear and check alignment track*

10.3.13 Fabric and dope

- *Exercises in covering frames with hand-sewn fabric; doping; stringing; repairing cuts in fabric; patching*

10.3.14 Wheels and tyres

- *Complete wheel assemblies: dismantling, inspection (including crack detection of wheels) and reassembly*
- *Inner tubes: puncture repairs*
- *Outer covers: inspection, identification of defects, and spot vulcanizing*
- *Brake units: inspection and salvage of brake pads and discs*
- *Inspection and testing of anti-skid devices*

10.3.15 Control surfaces

- *Overhaul and repair: repairs to typical fabric-covered and metal-skinned ailerons, and elevators*
- *Hinges and actuating mechanisms: inspection, and renewal of ball races*
- *Correction of mass balance after repair*
- *Adjustment of balance tabs, and servo-tabs on aircraft (to correct for hinge moments and flying faults)*

10.3.16 Multi-engined aircraft

- *Simulated airline check: familiarization with maintenance schedule*
- *Performance of sequence of major periodic inspection by the students, including signing of check sheets for each job done and recording of and, if possible, rectification of all defects*
- *Full functioning checks after replacement of components, including ground testing of hydraulic system with retraction of landing gear and function testing of electrical system; ground running of engines; weighing of the aircraft and calculation of centre of gravity*

10.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: REPAIR, MAINTENANCE AND FUNCTION TESTING OF AIRCRAFT SYSTEMS/COMPONENT

10.4.1 Hydraulic systems

- *Demonstration of hydraulic system rig*
- *Dismantling and reassembly of typical components such as hydraulic pumps, regulators, selectors, control valves, accumulators and actuators*
- *Dismantling and examination of control and actuating devices from powered flying control systems*
- *Dismantling, reassembly and recharging of selection of landing gear shock struts, nose-wheel steering mechanisms, anti-shimmy devices and other landing gear components*

10.4.2 Pneumatic systems

- *Demonstration of pneumatic system rig, examination of typical components such as compressors, regulators, selectors and actuators*
- *Dismantling, reassembly and testing of representative selection of pneumatic components: selectors, thrust reversal rams, and others*

10.4.3 Environmental control systems

- *Demonstration of pressurization system models or rigs*
- *Dismantling and reassembly of selected components such as cabin superchargers, mass flow controllers, cabin pressure controllers, discharge valves and safety valves*
- *Demonstration and partial dismantling of cabin heating, cooling and humidifying devices*
- *Dismantling, reassembly and testing of selected components*

- *Familiarization with the servicing and inspection of various types of pressure and mass flow control devices; heat exchangers, combustion heaters and electrical heaters; cold air units (air cycle machines), vapor cycle coolers, cabin temperature sensing and regulating devices; humidifying and dehumidifying equipment; crew and passenger emergency oxygen equipment*

10.4.4 Fire control systems

- *Inspection, weighing and recharging of fire extinguisher bottles*
- *Demonstration of fire detection and extinguishing system principles by using simulators, individual components, and operation*
- *Practice in controlling aircraft and shop fires*
- *Familiarization with different types of alarm systems, extinguishers and their uses*

10.4.5 De-icing systems

- *Demonstration of rigs and individual de-icing system components*
- *Dismantling, reassembly and testing of air control devices for mechanical de-icing systems; repairs to inflatable leading-edge overshoes/boots*
- *Hot air systems: overhaul procedures for combustion heaters, and hot air control valves*
- *Repair schemes for air-to-air heat exchangers, and mixing valves*
- *Repair schemes for electrically heated overshoes, and spray-mats*

10.4.6 Miscellaneous systems

- *Demonstrations and inspection of vacuum systems, water/methanol, drinking and washing water systems*
- *Inspection and tests, as necessary, of fuel system components: cocks, line booster pumps, filters, and refuelling valves*
- *Tests and repairs, as necessary, of safety equipment: inspection of dinghies, life jackets, survival kits, safety belts etc.*

10.5 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES

10.5.1 Aircraft heavy maintenance check

- *Preparation for Heavy Maintenance Check: documentation (task/job cards), logbooks, defect records, modification instructions; emptying and inserting fuel tanks, draining oil and other systems; selection and display of equipment; tools required*
- *Selected major operations: internal inspection of internal tanks; detailed examination of cabin structure followed by pressurization and leak rate test; change of main landing gear*
- *Adherence to aircraft maintenance manual and a typical airline major check schedule for each job*
- *Conclusion of Heavy Maintenance Check: replacement of components, function tests, restoration of internal and external finish, weighing and calculation of centre of gravity, preparation for flight test, and completion of documentation*

10.5.2 Aircraft or helicopter repair

- *Selection of repair scheme: damage to be studied and related to approved repair scheme as shown on manufacturers' drawings or structural repair manual (SRM)*
- *Selection of material to be checked for compliance with specification*
- *Embodiment of repairs according to prepared drawings or SRM*
- *Testing to destruction of selected repair specimens to demonstrate strength of repair*
- *Experience in workshop processes as applicable to repair and reconditioning of aircraft parts (e.g. enlargement or reduction of dimensions to accept oversized or undersized parts; chemical or electro- chemical treatments for the protection of metals;* ***metal***

depositing processes; special methods of heat treatment; special methods of welding; advanced metal processing techniques, surface texture measurement)

- *Acceptance tests and final inspection*
- *Completion of documentation*

CHAPTER 6 (ICAO Manual)

Mechanical Engines/Powerplants: Knowledge

6.1 INTRODUCTION 30
6.2 TRAINING OBJECTIVES 30
6.3 PISTON ENGINES: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 30
6.4 PROPELLERS: REQUIRED KNOWLEDGE, SKILLS, AND ATTITUDES 34
6.5 GAS TURBINE ENGINES: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES 34
6.6 FUEL SYSTEMS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 38

6.1 INTRODUCTION

6.1.1. In order to be able to satisfactorily assimilate training on individual engine types, the Aircraft Maintenance (Technician/Engineer/Mechanic) (AME) must have a good fundamental understanding of the principles and functions of construction generally used in engines of all types.

6.1.1. In order to be able to perform or supervise "hands-on" tasks of mechanic/technician on the engine or its components, the AME must have a very complete knowledge of all the associated maintenance practices likely to be used.

6.2 TRAINING OBJECTIVES

Conditions: The trainees will receive training in engineering principles related to the engine, propeller and powerplant structure, materials, components, construction, specifications and functional systems.

Performance: The trainees will describe the characteristics and applications of the materials used in engine and propeller construction, including the principles of their construction and function: fastening techniques; associated powerplant systems (mechanical, fluid, electrical and electronic); associated flight deck instruments and display systems; engine and propeller control systems; and ground running and maintenance adjustments.

Standard of accomplishment: The trainees will describe the characteristics and applications of the materials, construction and system operating principles and maintenance practices in accordance with actual practice on existing engines, propellers and powerplants.

6.3 PISTON ENGINES: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES

6.3.1 Principles of operation and terminology

- *Understanding of the following terms:*
  - *bore*
  - *stroke*
  - *top dead centre (TDC)*
  - *bottom dead centre (BDC)*
  - *swept volume*
  - *clearance volume*
- *Calculation of mechanical and thermal efficiency*
- *Four-stroke operating cycle: efficiency, volumetric efficiency, piston displacement and compression ratio*
- *Two-stroke operating cycle: piston displacement and compression ratio*
- *Valve operating cycle: valve lead, valve lag and valve overlap*
- *Layout and typical firing order of in-line, horizontally opposed, vee and radial piston engines.*

6.3.2 Engine construction: Top end

- *Constructional features, function, classification and material composition of: cylinders, pistons, piston rings, piston or dudgeon pins, connecting rods, inlet and exhaust manifolds*

6.3.3 Engine construction: Valves and valve operating mechanisms

- *Constructional features, function, classification and material composition of: rocker assemblies, push rods, cam followers, tappets, inlet and exhaust valves/seats/ guides/springs*
- *Valve types: poppet, sleeve, rotary, disc and reed*

6.3.4 Engine construction: Bottom end

- *Constructional features, function, classification and material composition of: crankshafts, cam shafts, cam rings, engine casings, sumps, and accessory/reduction gearboxes*
- *Typical ball, roller and plain bearings*

6.3.5 Engine power

- *Calculation of mechanical efficiency, thermal efficiency, volumetric efficiency, piston displacement and compression ratio from given information*
- *Effect of incorrect valve timing on the above parameters*
- *Measurement of piston displacement, compression ratio and manifold pressure*

6.3.6 Engine power measurement

- *Determination/calculation of horsepower (HP) and/or kilowatt (KW); indicated horsepower (IHP); friction horsepower (FHP); brake horsepower (BHP); indicated mean effective pressure (IMEP); brake mean effective pressure (BMEP); friction mean effective pressure (FMEP)*
- *Plot of fuel consumption and engine power charts from given information*

6.3.7 Factors affecting engine power

- *Rich and lean mixture burn rates and effect upon engine*
- *Symptoms and causes of: pre-ignition, detonation, after firing and backfiring*
- *Calculation of brake-specific fuel consumption (BSFC) from given engine data*
- *Definition of the following terms:*
  - *stoichiometric mixture*
  - *rich best power mixture*
  - *lean best power mixture*
  - *cruise power mixture*

6.3.8 Classification of engine lubricants and fuels

- *Properties and specific uses of mineral, ashless dispersant, detergent and hypoid oils*
- *Terms in relation to engine oil ratings: viscosity and viscosity index, flashpoint, pour point and cloud point*
- *Classification methods of piston engine fuels (aviation gasolines)*
- *Terms in relation to piston engine fuels: octane rating, anti-knock additive (tetraethyl lead), performance number, volatility, specific gravity, and Reid vapour pressure test values*
- *Grease: types, characteristics and uses*

6.3.9 Magneto ignition system principles

- *Magneto principles*
- *Terms: "E" gap, flux eddies, flux reversal, etc.*
- *Function of contact breaker and condenser/capacitor distributor*

- *Primary and secondary systems*

6.3.10 Ignition systems

- *Construction of polar inductor and rotating magnet magneto types*
- *Effect on timing of magneto points gapping*
- *Advanced and retarded ignition timing*
- *Magneto switches, harnesses, screening and bonding*
- *Construction and function of magneto compensating cam*
- *Battery ignition systems*
- *Auxiliary ignition systems, booster coil, induction vibrator and impulse coupling*
- *Low- and high-tension systems*
- *Safety precautions associated with ignition systems*

6.3.11 Spark plugs and ignition leads

- *Constructional features and materials, temperature classification, reach, gapping and effect on spark plug performance*
- *Diagnosis of engine condition by spark plug appearance*
- *Ignition lead/harness construction, features and screening*

6.3.12 Float chamber carburettors

- *Principles, features and construction*
- *Configurations, updraught and downdraught*
- *Operation of: throttle valves, main and idle jets, power enrichment systems, float chambers, discharge nozzles, accelerator pumps, mixture control systems, and altitude control*
- *Causes and effects of impact, throttle and fuel ice*
- *Carburettors heat*

6.3.13 Pressure injection carburettors

- *Principles, features and construction*
- *Operation of air/fuel metering forces, mixture control system, idle system, acceleration system and power enrichment system (manual/airflow)*

6.3.14 Fuel injection systems

- *Principles, features and construction*
- *Operation and function of air/fuel metering forces, impact tubes, venturis, flow dividers, throttle valves, altitude mixture controls, fuel injection nozzles, fuel injection pumps, fuel control units, and electronic control*

6.3.15 Lubrication systems

- *Principles, features, operation and construction of wet and dry sump lubrication systems*
- *Operation, features and construction of pressure pumps, scavenge pumps, oil coolers, oil cooler regulators, oil tank/hoppers, relief valves, check valves, oil filters, and oil dilution systems*
- *Oil pressure regulation and indication*
- *Induction, exhaust and cooling systems*
- *Construction and operation of typical engine induction/ intake and alternate air systems*
- *Construction, features, material and operation of typical engine exhaust systems*
- *Engine cooling: air and liquid, and cooling efficiency*
- *Radiators, liquid jackets, pipes and connections*
- *Coolant fluids: types, characteristics and hazards*
- *Heat exchangers, fins, baffles, cowls, cowl flaps, gills, panels, and air seals*

6.3.16 Supercharging/Turbocharging

- *Principles and purpose of supercharging and its effects on charge density and temperature; brake horsepower (BHP); manifold absolute pressure (MAP); detonation; revolutions per minute (RPM); fuel consumption*
- *Construction and operation of typical geared super - charger*
- *Construction and function of impeller; diffuser; engine gear drives; turbine; intercooler*
- *Understanding of the following terms:*
  - *rated altitude*
  - *critical altitude*
  - *overshoot*
  - *boot strapping*
  - *upper deck pressure*
  - *manifold pressure*
- *System configurations: internal (supercharger), external (turbo supercharger), multi-stage and multi-speed*
- *Differences between ground and altitude boosted engines*
- *Function and construction of system control components: absolute pressure controller; variable absolute pressure controller; ratio controller; manifold pressure relief valve; waste gate assembly*
- *Operation and function of system with ground adjusted waste gate valve and manifold pressure relief valve*
- *Function, requirements and operation of lubrication system*
- *Identification of supercharging faults involving low power, surging, low deck pressure, high deck pressure, low critical altitude, and low oil pressure*
- *Lubrication system and protective devices*
- *Control system adjustments*

6.3.17 Rotary (Wankel) engine theory

- *Analysis of Wankel (rotary) cycle*
- *Rotor design and shape: rotor tip seals*
- *Combustion chamber shape and sealing*
- *Rotor shaft and epitrochoidal gear drive to output shaft*
- *Unit construction, weight, power, and fuel consumption*
- *Lubrication system*
- *Carburation and control system adjustments*

6.3.18 Piston engine installation

- *Safety precautions associated with the installation and removal of engines*
- *Storage, preservation and inhibiting techniques required for piston engines*
- *Engine bearers, anti-vibration mounts, and bearer mounting points*
- *Hoses, pipes, feeders and connections from systems to engine*
- *Control lines and cable lifting points*
- *Inspection of engine bearers for serviceability and condition*
- *Cowls, drains, electrical wiring, exhaust and inlets associated with engine installations*

6.3.19 Piston engine operation, maintenance and ground running

- *Precautions and pre-start checks prior to ground running a piston engine*
- *General precautions for starting, running and stopping a piston engine*
- *Use of power charts and graphs to determine engine performance*

- *Determination of piston engine defects from data obtained during an engine run*
- *Maintenance procedures: removal, replacement and inspection of valve operating assemblies, cylinders, pistons, bearings and associated components*
- *Top-end overhauls*
- *Understanding of the use of maintenance data in Specification 100 or 2100 of the Air Transport Association (of America) (ATA)*

6.4 PROPELLERS: REQUIRED KNOWLEDGE, SKILLS, AND ATTITUDES

6.4.1 Propeller theory

- *Blade element theory*
- *Effects on propeller thrust by high/low blade angle and reverse angle, angle of attack, pitch, and rotational speed*
- *Understanding of propeller slip*
- *Forces affecting rotating propeller blade: aerodynamic force, centrifugal force, torque and thrust*
- *Effects in changes in the direction of relative airflow on blade angle of attack*

6.4.2 Propeller configuration and type

- *Propeller types: fixed pitch, ground adjustable, controllable pitch, and constant speeding*

6.4.3 Propeller construction, assembly and installation

- *Construction methods and specific materials used in composite, metal and wooden propellers*
- *Typical mounting requirements for tapered and splined propeller installations*
- *Understanding of the following terms:*
  - *blade station*
  - *blade face*
  - *blade shank*
  - *blade back*
  - *blade shank*
  - *hub assembly*

6.4.4 Pitch change mechanisms

- *Operation and function of the following pitch change mechanisms: mechanical, hydraulic, aerodynamic, aerodynamic and hydraulic combination, and electrical*
- *Function and operation of propeller feathering and synchronizer systems*

6.5 GAS TURBINE ENGINES: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES

6.5.1 Fundamental principles

- *Relationship between force, work, power, energy, velocity, and acceleration and their respective relationship to gas turbine operation*
- *Operation and function of the following pitch change mechanisms: mechanical, hydraulic, aerodynamic, aerodynamic and hydraulic combination, and electrical*
- *Function and operation of propeller feathering and synchronizer systems*

6.5.2 Governors: Principles of operation and construction

- *Operation of typical governors*
- *Effects of variation in spring pressure and engine RPM on governor operation*
- *Single and double acting governors*
- *Operation and function of speeder springs, pitch change stops, pilot valves, and fly weights*
- *Understanding of the following conditions on speed:*
  - *under speed*
  - *over speed*

- *alpha*
- *beta*
- *feathering*
- *unfeathering*
- *reverse pitch*

6.5.3 Damage and repair criteria

- *Assessment of propeller blade damage*
- *Erosion, corrosion, impact damage and delamination*
- *Treatment/repair schemes for metal, wooden and composite blades*
- *Definition and application to gas turbine operation of the following:*
  - *potential energy*
  - *kinetic energy*
  - *Newton's Laws of Motion*
  - *Brayton Cycle*
  - *Bernoulli's Theorem*
  - *thermodynamic laws*
- *Constant pressure gas turbine cycle, open cycle and closed cycle gas turbines*
- *Basic constructional arrangement and the relative merits of the following engine types: turbojet, turbofan, turboshaft, turboprop, prop fan and ducted fan*

6.5.4 Principles of propulsion

- *Understanding of the following conditions, their relationship to each other and their application to engine operation:*
  - *gross thrust*
  - *net thrust*
  - *chocked nozzle thrust*
  - *thrust distribution*
  - *resultant thrust*
  - *thrust horsepower*
  - *equivalent shaft horsepower*
  - *specific fuel consumption*
- *Adiabatic, thermal and propulsive engine efficiencies and ways to derive them*
- *Bypass ratio and engine pressure ratio*
- *Pressure, temperature and velocity of the gas flow as it passes through each section of the engine*

6.5.5 Inlet ducts

- *Principles of operation and construction of the following compressor inlet ducts: subsonic, supersonic and bell-mouth*
- *Effects on pressure, velocity and temperature of airflow through convergent, divergent and convergent- divergent ducts*
- *Effects of ram recovery and the causes of inlet duct losses*

6.5.6 Centrifugal compressors

- *Constructional features, materials, operating principles and applications of single stage and multi-stage centrifugal compressors*
- *Purpose and function of impellers, diffusers, and inlet guide vanes*
- *Pressure ratios, inspection and balancing*

6.5.7 Axial compressors

- *Constructional features, materials, operating principles and applications of the following axial flow compressors: single spool, dual/twin spool and triple spool*
- *Purpose and function of rotor blades, stator blades, fixed inlet guide vanes and variable inlet guide vanes*

6.5.8 Compressor operation

- *Purpose, constructional features, materials, operating principles, advantages and disadvantages of a combined axial and centrifugal compressor assembly*
- *Causes, effects and control of compressor stall and surge*

- *Principal methods of air flow control: bleed valves, variable inlet guide vanes, variable stator vanes and rotating stator blades*
- *Compressor ratio and ways to derive it*

6.5.9 Combustion section

- *Constructional features, materials and principles of operation of the following combustion chambers and their respective advantages and disadvantages: can type, can-annular type, annular type and reverse flow annular type*
- *Understanding of the following terms:*
  - *primary zone/airflow*
  - *secondary zone/airflow (dilution and cooling)*
  - *combustion fuel/air ratio*
  - *overall fuel/air ratio*
  - *flame temperatures*
  - *flame stabilization*
- *Construction, purpose and principles of simplex (single orifice) atomizing fuel nozzles, duplex (dual orifices) atomizing fuel nozzles, spill type atomizing fuel nozzles, and vaporizing type nozzles*
- *Construction, purpose and operation of swirl chambers, air shrouds and discharge orifices*

6.5.10 Turbine section

- *Principles of operation and characteristics of the following turbine blading: impulse, reaction and impulse-reaction*
- *Purpose and function of nozzle guide vanes and driving force for impulse and impulse reaction turbines*
- *Differences between turbine power extraction requirements for turbojet, turbofan and turboprop engines*
- *Various methods of turbine blade to disc attachment*
- *Causes and effects of turbine blade stress*
- *Factors which determine blade creep*
- *Constructional properties of typical materials used in the fabrication of turbine components*

6.5.11 Exhaust section

- *Constructional features, purpose, operating principles and materials of exhaust system: cone, tailpipe, propelling nozzle, cooling shroud, and gas flow straighteners*
- *Purposes of convergent, divergent and variable area nozzles*
- *Pressure, velocity and temperature changes that occur in various types of exhaust systems*
- *Principles of operation, constructional features and purpose of thrust reversers*
- *Effect of thrust reversers on engine efficiency, re-ingestion of exhaust gases, and magnitude of reverse thrust produced*
- *Constructional features, materials and principles of operation of engine noise suppressors*
- *Methods of reducing engine noise level*
- *Relationship between turbulence and energy in the exhaust gas stream to engine noise levels, typical noise patterns and methods of reducing noise levels*

6.5.12 Bearings and seals

- *Types, constructional features and principles of operation of bearings used in gas turbine engines*
- *Primary loads and causes acting on the engine main bearings*

- *Purpose, construction and principles of operation of typical gas turbine engine bearing seals*

6.5.13 Classification and properties of lubricants and fuels

- *Basic requirements of a gas turbine lubricant: viscosity and viscosity index*
- *Desirable characteristics of synthetic-based lubricants: low volatility, anti-foaming quality, low lacquers and coke deposit, high flashpoint, and low pour point*
- *Properties of gas turbine fuels: specific gravity, calorific value, vapour pressure, flashpoint, fire hazard, fuel icing, and corrosion characteristics*
- *Fuel additives: anti-icing and anti-microbiological*
- *Ground handling requirements and safety precautions to be observed in relation to gas turbine engine fuels, oils and additives*
- *Effects of the following on safety, handling and inspection procedures: exposure to skin or eyes, flammability, misting, evaporation rate, gum formation, corrosion, contamination (water and dirt), and sampling*

6.5.14 Lubrication systems

- *Arrangement, requirements and principles of operation of gas turbine engine lubrication system*
- *Function, relationship and typical location of oil tank; oil pumps (pressure/scavenge); oil filters/screens; oil jets; oil cooler; scavenge sub-system; vent sub-system (air/oil separators); valves (bypass/check/relief)*

6.5.15 Fuel control and metering systems

- *Requirements, arrangement and principles of operation of gas turbine fuel control and metering system including: starting control, acceleration scheduling, over-speed governing, power limiting, temperature limiting, air density/altitude/outside air temperature (OAT)/airspeed compensation, and shutdown control*
- *Operation and function of fuel system components: main fuel pumps, fuel filters (HP and LP), fuel heater, fuel control unit (hydro-pneumatic, hydro mechanical and electromechanical), governors and limiting devices, engine sensing variables, and valves (throttle/dump/ shut off)*

6.5.16 Engine air systems

- *Requirements, arrangements and principles of operation of gas turbine engine air distribution and anti-ice control systems (including internal cooling, sealing and external air services)*
- *Relationship, location and operation of engine internal cooling/sealing system components, air distribution/ external services components, and air starting system components*
- *Effects of faults in components on internal cooling/ sealing, anti-icing, anti-surge, bleed and air distribution systems*

6.5.17 Starting and ignition systems

- *Requirements, arrangements and principles of operation of gas turbine engine starter systems and their components: electric starters, starter generators, air turbine starters, turbo starter systems (cartridge and monofuel), and pressure regulating and shut-off valves*
- *Requirements, arrangements and principles of operation of the following engine ignition systems and their components: low voltage D.C. input, high voltage AC input, igniter and glow plug types, and harnesses*
- *Safety precautions during servicing and maintenance of engine ignition systems*
- *Effect of faults in components of engine ignition and starting systems*

6.5.18 Power augmentation systems

- *Principles of operation, requirements and typical location of components in water injection and water/ methanol injection systems*

- *Interrelationship between the augmentation system components and the fuel control system*
- *Principles of operation and typical location of components in a reheat/afterburner system: burner ring, variable propulsion nozzle/two-position propulsion nozzle, burner ignition (spark, hotshot and catalytic), jet pipe, cooling/airflow, and heat shield*
- *Effects of faults in engine power augmentation systems*

6.5.19 Engine controls

- *Principles of operation, requirements and typical location of components of the following engine controls: linkages and controls to and from propeller coordinator/interconnector and fuel control unit; units and components interconnected for emergency shut- down; mechanical control inputs and outputs for electrical fuel control systems; throttle/power/condition levers, cables and linkages*
- *Effects and rectification of faults in engine controls*
- *Electronic engine control (digital and analogue) including Full Authority Digital Engine Control (FADEC)*

6.5.20 Engine operation, maintenance, and ground running

- *Precautions and pre-start checks prior to ground running a gas turbine engine*
- *General procedures for starting, ground run-up and stopping a gas turbine engine*
- *Determination of engine and system malfunctions by using given typical manufacturers' data*
- *Interpretation of engine power output and parameters from limitation/performance charts*
- *Principles of trend monitoring pertaining to engine condition*
- *Determination of engine condition/defects from obtained data*
- *Inspection of engine and components according to criteria, tolerances and data specified by engine manufacturer*
- *Hot section inspections and manufacturer designated module split inspections*
- *Compressor washing/soft blasting*

6.5.21 Engine installation, storage and preservation

- *Function, construction and configuration of typical gas turbine engine firewalls; cowlings; acoustic panels; engine mountings; anti-vibration mounts; hoses; pipes; feeders; connectors; wiring looms; control cables and rods; lifting points and drains*
- *Blade containment areas/rings*
- *Basic requirements for the preservation and de-preservation of gas turbine engines, accessories and systems (both installed (on the wing) and during storage)*

6.5.22 Turboprop engines

- *Gas-coupled and gear-coupled turbines*
- *Reduction gears: construction, function and layout*
- *Over-speed safety devices*
- *Propellers for turboprops: design factor, starting requirements, constant speeding, feathering and braking control systems*

6.6 FUEL SYSTEMS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDESOperation, control, construction and indication

- *Fuel boost pumps, engine high-pressure pumps and fuel heaters*
- *Refuel/de-fuel, feed, jettison and cross-feed systems*
- *Fuel valve operation and control*

CHAPTER 11 (ICAO Manual)

Practical Training Skills: Engine and Propeller Trade

11.1 INTRODUCTION 39
11.2 TRAINING OBJECTIVES 39
11.3 BASIC WORKSHOP & MAINTENANCE PRACTICES: ENGINE AND PROPELLER 39
11.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: ENGINE/PROPELLER SYSTEMS/COMPONENTS & FUNCTION TESTING 42
11.5 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES 42

11.1 INTRODUCTION

Note: *— The basic practical training specified in this section is very similar to that described in Chapter 10 for airframe trainees.*

11.2 TRAINING OBJECTIVES

Note*: — The training objectives specified in this section is very similar to that described in Chapter 10 for airframe trainees.*

11.3 BASIC WORKSHOP & MAINTENANCE PRACTICES: ENGINE AND PROPELLER

11.3.1 Introduction

Note. — The basic practical training specified in this section is very similar to that described in Chapter 10 for airframe trainees.

11.3.2 Bench fitting

- *Cutting and filing: exercises in cutting metal with hacksaws, filing, drilling, drill grinding, thread cutting with taps and dies, and scraping*
- *Measurements: use of steel rule, dividers, callipers, micrometers, vernier, combination set, surface place, and dial test indicator*

11.3.3 Forging, heat treatment, soldering and welding

- *Forging by hand simple specimens such as chisels, punches and others*
- *Hardening and tempering carbon steel by using forge*
- *Tin soldering, tin-plating, and use of proper flux*
- *Silver soldering and brazing*
- *Welding: oxyacetylene and metallic arc welding of different materials*
- *Inspection of welded joints for flaws*

11.3.4 Sheet metalwork

- *Sheet aluminium alloy: cutting, marking out, drilling, forming, bending, bending allowances, shrinking and flashing*
- *Forming sheet metal by pressing and rolling*
- *Riveting: types of rivets, riveting with hand tools, rivet spacing, countersinking and dimpling*
- *Use of pneumatic riveting hammer*
- *Blind riveting*
- *Inspection of rivets, removal of rivets, use of oversized rivet and rivet jackets*
- *Tube work: use of taper pins and tubular rivets*
- *Exercises in sheet metal patching and repair work*

- *Heat treatment of aluminium alloy and alloy rivets: use of salt baths and furnaces; annealing and solution treatment*

11.3.5 Machine shop

- *Drilling: using machine drills to drill close tolerance holes in various materials; reaming holes to close tolerances; others*
- *Turning: exercises in turning steel, aluminium alloy and brass parts; use of lathe for thread cutting; others*
- *Grinding: use of grinding wheels for tool sharpening*

11.3.6 Wire and cable work

- *Inspection of aircraft cables for defects*
- *Splicing exercises*
- *Swagging exercise: attachment of standard end fittings to engine control cables*
- *Demonstration of proof test on engine control cable*

11.3.7 Tube work

- *Tube bending, with and without heat treatment*
- *Tube flaring*
- *Fitting of different kinds of unions used in fuel, oil and hydraulic systems*
- *Inspection and testing of tubes and flexible hoses*

11.3.8 Familiarization

- *Practical explanation of the mechanical arrangement of the engines available for work and practice (e.g. 2-stroke and 4-stroke spark ignition and compression ignition engines); air-cooled and water-cooled piston engines; piston aero engines of various types; turbojet, turboshaft, turbofan and turboprop aero engines; others*

11.3.9 Initial inspection

- *Examination of complete engine and propeller for identification to manufacturers' service publications*
- *Confirmation of external accessories and features*
- *Recognition of visible defects*
- *Ground run of engines (if possible) and recording of performance*
- *Ensured availability of manuals, workshop tools and equipment*
- *Identification of safety precautions to be observed*

11.3.10 Dismantling

- *Removal of accessories as appropriate (i.e. starters, generators and electrical equipment, pressure transmitters, transducers, thermocouples, magnetos, carburettors and spark plugs)*
- *Dismantling of core engine to a specified level according to manufacturer's service publications*
- *Complete dismantling of smaller engines: removal of all accessories, manifolds, cylinders, pistons, connecting rods, crankshaft and bearings; cleaning and laying out of these components for inspection*
- *Partial dismantling of larger engines: removal of accessories, reduction gear, cylinders, and pistons (without disturbing crankshaft or crankcase)*
- *Partial dismantling of gas turbines: removal of accessories, jet pipe assembly, and combustion chambers (without disturbing turbine/compressor assembly)*

11.3.11 Inspection of dismantled engine

- *Visual inspection in accordance to manufacturer's service publications*

- *Dimensional checks in accordance with procedures given in manufacturers' manuals for deterioration in accordance to manufacturer's service publications on blades, vanes, shafts, bearings, and connecting rods for wear, ovality, twist and distortion*
- *Checking of cylinder valves, pistons and piston rings as directed in overhaul manual: checking of fits and clearances; practise on repair schemes, as applicable*
- *Non-destructive crack detection: electromagnetic, dye penetrant, etc. on crankshafts and camshafts*
- *Checking for cracks and distortion on exhaust manifolds, jet pipes, and combustion chamber flame tubes*
- *Inspection of gas turbine and turbo-supercharger compressor and turbine assemblies; inspection of blades for deposits, damage and distortion*

11.3.12 Repair and reconditioning of engine parts

- *Repairs by machining and grinding; checks for fits and clearances; fitting of oversized or undersized parts*
- *Castings: checks and rectification of cracks, porosity and corrosion*
- *Rigid and flexible pipes and hoses: testing and reconditioning*
- *Inspection and repair of gears, accessory drives, and torque metre* ***components***
- ***Welding repairs to nickel alloy components (e.g. jet pipes)***

11.3.13 Reassembly

- *Rebuilding of totally or partially dismantled engines (with particular attention to be paid to cleanliness, correct torqueing and safety, correctness of working clearances, and accuracy of valve and ignition timing)*

11.3.14 Engine test bed running and fault finding

- *Installation of engine on test bed, checking of instrumentation, control runs, and fuel supplies*
- *Fan testing of piston engines: calibration of test fan for test site, and engine type*
- *Full "after overhaul" test programme as specified in the State's airworthiness requirements and in the manufacturer's approved test schedule, using a method appropriate to the type of engine: initial test, strip inspection, reassembly and final test*
- *Interpretation of engine performance based on test results*
- *Experience in starting, running and ground testing of aero engines*
- *Inspection of powerplant installed in aircraft*
- *Fault finding and rectification*

11.3.15 Aircraft installation

- *Preparation of powerplant for installation in aircraft: functional checks on controls and interconnections*
- *Flow tests of fuel system*
- *Checks on pyrometry and on fire warning system*
- *Checks on engine bearers and alignment*
- *Slinging and installation of powerplant*
- *Ground running tests after installation*

11.3.16 Storage and transit of engines

- *Protection against corrosion*
- *Engine stands, crating, lifting and tie-down points*
- *Storage bags/covers and use of desiccant*
- *Preparation of engines for running after long-term storage*

11.3.17 Propeller maintenance tasks

- *Practice in removal and replacement of propellers on engine propeller shaft*
- *Dismantling and inspection of typical variable pitch propeller*
- *Checking of blades and blade root bearings for damage and permissible repairs*
- *Reassembly, resetting of blade angles, blade torque loadings, static balance of propeller, and inspection*

11.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: ENGINE/PROPELLER SYSTEMS/COMPONENTS & FUNCTION TESTING

11.4.1 Components: Ignition

- *Dismantling, reassembly and testing of various kinds of magnetos and distributors*
- *Renewal of cables in an ignition harness*
- *Continuity and insulation tests*
- *Cleaning and testing of spark plugs*
- *Inspection and testing of igniter equipment for turbine engines*
- *Safety precautions associated with ignition equipment*

11.4.2 Components: Fuel and control

- *Float and injection carburettors: partial dismantling and inspection; reassembly and flow tests; others*
- *Propeller control devices, governors and feathering pumps: partial dismantling, reassembly and bench tests*
- *Fuel pumps, oil pumps, oil coolers, gearboxes, flow, pressure and other tests as specified in manufacturer's manuals*
- *Gas turbine fuel system components: pumps, pressure and flow control units, metering devices, automatic valves, and burners; partial dismantling to view and understand mechanism; reassembly testing; others*

11.5 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES

11.5.1 Heavy maintenance check or overhaul of engine/propeller

- ***Preparation for Heavy Maintenance Check: documentation (task/job cards), logbooks,** defect records, modification instructions; draining oil and other systems; selection and display of equipment; tools required*
- *Selected major operations (e.g. turbine blade inspection either by dismantling or by optical probe techniques)*
- *Adherence to the aircraft maintenance manual and to a typical airline check or overhaul schedule for each job*
- *Conclusion of Heavy Maintenance Check or overhaul: replacement of components, function tests, restoration of internal and external finish, preparation for engine run, and completion of documentation*

11.5.2 Engine/propeller repair

- *Selection of repair scheme: damage to be studied and related to approved repair scheme as shown on manufacturers' drawings or repair manual*
- *Selection of material to be checked for compliance with specification*
- *Embodiment of repairs according to prepared drawings or repair manual*
- *Testing to destruction of selected repair specimens to demonstrate strength of repair*
- *Experience in workshop processes as applicable to repair and reconditioning of aircraft parts (e.g. enlargement or reduction of dimensions to accept oversized or under- sized parts; chemical or electrochemical treatments for the protection of metals; **metal***

depositing processes; special methods of heat treatment; special methods of welding; advanced metal processing techniques; surface texture measurement)

- *Acceptance tests and final inspection engine run*
- *Completion of documentation*

CHAPTER 7 (ICAO Manual)

Basic Avionics and Avionic Systems: Knowledge

ELECTRICAL/INSTRUMENTS

7.1 INTRODUCTION 44
7.2 TRAINING OBJECTIVES 44
7.3 MAINTENANCE PRACTICES AND MATERIALS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 44
7.4 ELECTRICAL & ELECTRONIC FUNDAMENTALS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 46
7.5 DIGITAL TECHNIQUES, COMPUTERS & ASSOCIATED DEVICES: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 52
7.6 AIRCRAFT ELECTRICAL SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES 55
7.7 AIRCRAFT INSTRUMENT SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES 59

7.1 INTRODUCTION

7.1.1 In order to be able to satisfactorily assimilate training on individual aircraft avionics systems, the Aircraft Maintenance (Technician/Engineer/Mechanic) (AME) must have a good fundamental understanding of the principles and functions of the operation generally used in all types of aircraft avionics systems.

7.1.2 In order to be able to perform or supervise "hands-on" tasks of mechanic/technician on the aircraft avionics systems or its components, the AME must have a very complete knowledge of all the associated maintenance practices that are likely to be used.

7.2 TRAINING OBJECTIVES

Conditions: The trainees will receive training in aircraft, electrical and electronic engineering principles related to the electrical, avionics and instrument components, materials, installations, specifications and functional systems of the aircraft.

Performance: The trainees will describe the characteristics, applications, and materials of aircraft electrical, avionics and instrument systems, including the principles of installation and operation, connection techniques, interface with associated aircraft and powerplant systems, flight deck instruments and displays.

Standards of accomplishment: The trainees will describe the characteristics and applications of the materials, installation, construction, system operational principles and maintenance practices in accordance with actual practice on existing aircraft and systems.

7.3 MAINTENANCE PRACTICES AND MATERIALS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES

7.3.1 Aircraft and workshop safety precautions

- *A guide to the various aspects of safe working practices, including precautions to be taken when working with electricity, gases, oils and chemicals*
- *Instruction in the remedial action to be taken in the event of an accident with one or more of the hazards*

7.3.2 Principles of workshop practices

- *Care of tools*
- *Use of workshop materials*
- ***Dimensions and standards of workmanship***

7.3.3 General purpose tools

- *Review of types of tools: hammers, mallets,*

- *screwdrivers, wrenches (spanners), torque wrenches, punches, hacksaws, clamps, vices and presses, snips and nibblers, chisels, files, reamers, taps and dies, drill bits, thread gauges, strippers, crimping tools, grease guns, oil cans, and lubricating syringes*

7.3.4 General purpose power tools

- *Electric and pneumatic-powered saws, drills, grinders, sanders, routers, nibblers, riveting guns and heat guns*

7.3.5 Precision measuring tools

- *Micrometers: metric and inch, vernier gauge, vernier callipers, surface table and accessories, marking out, dial test indicators, go/no-go gauges, combination sets, bore and depth gauges, steel rule, inside and outside callipers, slip gauge and feeler gauge*

7.3.6 Screw threads

- *Screw nomenclature*
- *Thread forms, dimensions and tolerances for standard threads used in aircraft*
- *Measuring screw threads*

7.3.7 Bolts, studs, screws and fasteners

- *Bolt types: specification, identification and marking of aircraft bolts, Society of Automotive Engineers (SAE), and metric*
- *Nuts: self-locking, anchor and standard types*
- *Machine screws: aircraft specifications*
- *Studs: types and uses, insertion and removal*
- *Woodscrews, cotter pins, self-tapping screws and nuts, and dowels*
- *Locking devices: tab and spring washers, locking plates, split pins, pal-nuts, wire locking, quick release fasteners, keys, circlips and turnbuckles*

7.3.8 Fits and clearances

- *Allowances and tolerances, drill sizes for bolt holes, and classes of fits*
- *Common system of fits and clearances*
- *Schedule of fits for avionics systems installation*
- *Limits for bow, twist and wear*

7.3.9 Engineering drawings and diagrams

- *Understanding of the following drawing types and diagrams, their symbols, dimensions and tolerances:*
  - *orthographic*
  - *isometric*
  - *oblique*
  - *perspective*
  - *electrical*
  - *block*
  - *schematic*
  - *sectional*
  - *blueprint*
  - *logic flow chart*
  - *Identification of the following information from the title block:*
  - *drawing and revision number*
  - *reference number*
  - *scale*
  - *weight*
- *Understanding of the use of maintenance data in Specification 100 and 2100 of the Air Transport Association (ATA) of America*

7.3.10 Electrical cables and connectors

- *Wire types: insulation, strand metal composition, strand number and diameter, wire gauge rating, voltage and current-carrying capacity and rating, temperature characteristics, uses, identification of wire codes, and braiding*
- *High-tension cables: precautions, identification, and routing*
- *Coaxial cables: identification, uses, methods of attaching connectors, testing, and installation precautions*
- *Crimping: types of crimp ends, in-line, lug, bayonet, wrist joint, blind end, and terminal*

- *Identification of crimps: colour code, identification marks, insulation grip, wire grip, and crimp form*
- *Testing of crimp joints: millivolt drop test, crimp pull test, etc.*
- *Crimp tools: types, colour codes, ratchet devices, jaws and chucks, testing and go/no-go gauges*
- *Connector types, pins, pin removal and insertion, insertion and removal tools, plugs, sockets, insulators, current and voltage rating, coupling, and identification codes*

7.3.11 Soldering

- *Soldering irons: types, sizes and uses*
- *Solder: tin/lead content, melting point, and chemical combinations*
- *Flux: types, uses and purpose of flux, core flux, flux removal, flux corrosion and flux temperatures*
- *Special solder for non-ferrous metals*
- *Soldering techniques*
- *Anti-static considerations when soldering*
- *Heat shunts and de-soldering*
- *Dry joints and soldering defects*

7.3.12 General test equipment for avionics

- ***Operation, construction, functions and uses of the following: AC and DC voltmeters,** ammeters, ohm- meters, multimeters, bonding testers, Meggers, decade boxes, attenuators, frequency meters, watt/meters, Wheatstone bridge, volt amps reactive (VAR) meter, logic probe, cathode ray oscilloscope (CRO), dummy loads, audio frequency (AF) and radio frequency (RF) output power meters, voltage standing wave meter (VSWR), spectrum analyser, and AF/RF signal generators*

7.3.13 Aerodynamics

- *Atmosphere, pressure, temperature, humidity and density*
- *Newton's Laws of Motion, general gas laws, and Bernoulli's Theorem*
- *Airflow in relation to a body, steady or moving*
- *Aerofoils, shape and aspect ratio, and pressure distribution*
- *Lift, weight, thrust and drag*
- *Conditions of flight, centre of gravity, loads and forces*
- *Flight stability: longitudinal, lateral and directional*
- *Slip and skid*
- *Control surfaces: elevators, ailerons, rudders, elevons, ruddervators, stabilators and canards*
- *Boundary layer control: aerodynamic balancing*
- *Considerations and factors affecting high speed and supersonic flight*

7.3.14 Aircraft handling

- *Aircraft towing: safety precautions, towing arm types, weak links, locking devices, weight and balance limits, turn angle limits, aircraft brake control, lookouts, tugs and tractors*
- *Aircraft jacking: principles of aircraft jacking, safety precautions, weight and balance limits, jack types, jacking points and jacking techniques*

7.4 ELECTRICAL & ELECTRONIC FUNDAMENTALS: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES

7.4.1 Electron theory

- Structure and distribution of electrical charges within atoms, molecules, ions and compounds
- Molecular structure of conductors, semiconductors and insulators

7.4.2 Static electricity and conduction

- *Static electricity and distribution of electrostatic charges*
- *Electrostatic laws of attraction and repulsion*
- *Units of charge*
- *Coulomb's Law*
- *Conduction of electricity in solids, liquids, gases and in a vacuum*

7.4.3 Electrical terminology

- *Definition of the following terms, their units and the factors affecting them:*
  - *potential difference*
  - *electromotive force*
  - *voltage*
  - *current*
  - *resistance*
  - *conductance*
  - *charge*
  - *conventional current flow*
  - *electron flow*
- *Definition of the following units and conversion from one unit into another unit: giga-, mega-, kilo-, milli-, micro-, nano-, pico-, and degrees (Fahrenheit, Celsius/ Centigrade and Kelvin)*

7.4.4 Generation of electricity and heat

- *Production of electricity by the following methods: light, heat, friction, pressure, chemical action, magnetism and motion*
- *British Thermal Unit: calorie, specific heat and latent heat*
- *Heat transfer, convection, conduction and radiation*
- *Thermal expansion*
- *Coefficient of linear expansion*
- *Bimetallic strips*

7.4.5 DC sources of electricity

- *Construction and basic chemical action of the following: primary cells, secondary cells, lead acid cells, nickel cadmium cells and other alkaline cells*
- *ells connected in series and in parallel*
- *Internal resistance and its effect on a battery*
- *Construction, materials and operation of thermocouples*

7.4.6 DC circuits

- *Ohm's Law*
- *Kirchoff's Voltage and Current Laws*
- *Calculations to find resistance, voltage and current by using Ohm's Law, Kirchoff's Voltage and Current Laws, etc.*
- *Significance of the internal resistance of a supply*

7.4.7 Resistors and resistance

- *Resistance and affecting factors*
- *Specific resistance*
- *Positive and negative temperature coefficient conductance*
- *Fixed resistors including their stability, tolerance and limitations: carbon composition, carbon film, wire wound, and metallic film*
- *Variable resistors: wire wound, carbon film, thermistors, voltage dependent resistors and varistors*
- *Resistor colour code, values and tolerances, preferred values, and wattage ratings*
- *Resistors in series and in parallel*
- *Calculation of total resistance by using series, parallel and series-parallel combinations*

7.4.8 Power

- *Dissipation of power by a resistor*
- *Power, work and energy (kinetic and potential)*
- *Conversion of horsepower to watts and vice versa*
- *Power formula*
- *Maximum power transfer theorem*
- *Calculations involving power, work and energy*

7.4.9 Rheostats and potential dividers

- *Construction, operation and use of potentiometers and rheostats, and the effect of varying the load on the output voltage*
- *Construction and operation of Wheatstone bridge*
- *Polarities of potential differences in resistive circuits*

7.4.10 Capacitors and capacitance

- *Principles of the operation and function of a capacitor*
- *Factors affecting the capacitance area of plates, distance between plates, number of plates, dielectric and dielectric constant*
- *Units of capacitance and their interrelationships*
- *Working voltage, voltage rating, and relationship between capacitance and working voltage*
- *Construction and function of the following capacitors: paper, mica, ceramic, electrolytic and tantalum*
- *Capacitor colour coding and preferred values*
- *Variable capacitors: air and solid dielectric*
- *Calculations of capacitance and voltage in series and parallel circuits*
- *Exponential charge and discharge of a capacitor, and time constants*
- *Testing of capacitors using an ohmmeter for short circuit, open circuit, and leaky capacitor*

7.4.11 Magnetism

- *Properties of a magnet*
- *Theory of magnetism, molecular and domain*
- *Laws of attraction and repulsion*
- *Action of a magnet suspended in the earth's magnetic field*
- *Magnetization and demagnetization*
- *Artificially-made magnets*
- *Magnetic shielding*
- *Various types of magnetic material*
- *Electromagnets: construction and principles of operation*
- *Hand-clasp rules to determine magnetic field around current-carrying conductor: north and south poles; the direction of current flow through a coil*
- *Factors affecting field strength in electromagnets*
- *Magnetite force (MMF): field strength (H), magnetic flux density (B), permeability, B/H curves, hysteresis loop, retentivity, coercive force, reluctance, saturation point, and eddy currents*
- *Precautions for care and storage of magnets*

7.4.12 Inductors and inductance

- *Faraday's Law*
- *Action of inducing a voltage in a conductor moving in a magnetic field*
- *Effects of the following on the magnitude of an induced voltage:*

- *magnetic field strength*
- *rate of change of flux*
- *the number of conductor turns*
- *Mutual induction*

- *Effect of the rate of change in primary current and of mutual inductance on induced voltage*
- *Factors affecting mutual inductance:*
  - *number of turns in coil*
  - *physical size of coil*
  - *permeability of coil*
  - *position of coils with respect to each other*
  - *Unit of inductance*
- *Lenz's Law and the rules determining polarity*
- *Back electromotive force (EMF) and self-induction*
- *Calculation of total inductance in series, parallel and series-parallel circuits*
- *Inductive resistive circuit: functions and time constants*
- *Saturation point*
- *Principal uses of inductors*
- *Construction and functions of fixed inductors: laminated iron core, iron dust core, air core and ferrite core*
- *Methods of varying inductor value: tapped coil, slider contact on coil, adjustable slug, and variometer*
- *Testing inductors for faults, open circuit coil, and shorted turns*

7.4.13 DC motor/generator theory

- *Construction and purpose of components in DC generator*
- *Operation of and factors affecting output and direction of current flow in DC generators*
- *Operation of and factors affecting output power, torque, speed and direction of rotation of DC motors*
- *Series wound, shunt wound and compound motors*

7.4.14 AC theory

- ***Analysis and terms related to sinusoidal waveform: radian, angular velocity, phase,*** *period, frequency and cycle*
- *Harmonic: effects of even and odd harmonics on fundamental waveform*
- *Current and power calculations of the following values in relation to voltage: instantaneous, average, root mean square, peak and peak-to-peak*

7.4.15 Resistive (R), capacitive (C) and inductive (L) circuits

- *Phase relationship of voltage and current in L, C and R circuits: parallel, series and series-parallel*
- *Power dissipation in L, C and R circuits*
- *Factors affecting inductive and capacitive reactance*
- *Calculations of inductive and capacitive reactance*
- *Impedance, phase angle, power factor and current calculations*
- *Calculations of true power, apparent power and reactive power*

7.4.16 Series and parallel resonance

- *Definition of resonance*
- *Changes in circuit properties at resonance of parallel- and series-tuned circuits*
- *Effects of circuit prior to and after resonance*

- *Effects on impedance, current and phase angle when frequency of a series or parallel resonant circuit is varied*
- *Frequency response curves for series and parallel resonant circuits*
- *Voltage magnification factor (Q) of a circuit*
- *Effects of resistance on circuit "Q" and resonance curves*
- *Calculation of circuit resonant frequency*
- *Calculation of bandwidth*
- *Operation and use of tank circuit*

7.4.17 Transformers

- *Operation of transformer*
- *Transformer: losses and methods for overcoming them*
- *Transformer action under load and no-load conditions*
- *Power transfer, efficiency, and polarity markings*
- *Calculation of primary and secondary current, primary and secondary voltage, turns ratio, power, and efficiency*
- *Auto transformers and variacs.*

7.4.18 Filters

- *Operation, application and uses of the following filters: low pass, high pass, band pass and band stop*
- *Interpretation of filter response curves*
- *Function of and differences between active filters and passive filters*

7.4.19 AC generators

- *Rotation of loop in a magnetic field and the waveform produced*
- *Principles, operation and construction of revolving armature and revolving field type AC generators*
- *Single-phase, two-phase and three-phase alternators*
- *Three-phase star and delta connections: advantages and uses*
- *Calculation of line and phase voltages and currents*
- *Calculation of power in three-phase system*

7.4.20 AC motors

- *Construction, principles of operation and characteristics of AC synchronous motors and induction motors (both single and polyphase)*
- *Methods of speed control and direction of rotation*
- *Methods of producing a rotating field: capacitor, inductor, shaded or split pole*

7.4.21 Signal processing devices

- *Principles, operation and uses of the following signal processing devices: summing networks or points, integrators, limiters, modulators, demodulators, adders and subtracters*

7.4.22 Servo-mechanisms

- *Understanding of the following terms:*
  - *open and closed loop*
  - *follow-up*
  - *servo-mechanism*
  - *analogue*
  - *transducer*
  - *null*
  - *damping*
  - *feedback*
  - ***dead band***
  - ***hunting***
- *Construction, operation and uses of the following synchro-system components:*
  - *resolvers*
  - *differential*
  - *control*
  - *torque*

- *E and I transformers*
- *inductance transmitters*
- *capacitance transmitters*

- *Control and displacement: rate/rate, rate/displacement, displacement/rate, and displacement/displacement*
- *Servo-mechanism defects, reversal of synchro leads, and hunting*

7.4.23 Semiconductors (diodes)

- *Materials (silicon and germanium): electron configuration, crystalline structure, and electrical properties*
- *P and N type materials: effects of impurities on conduction, doping process to produce P and N type materials, majority and minority characters*
- *PN junction in a semiconductor*
- *Development of a potential across a PN junction in unbiased, forward biased and reverse biased conditions*
- *Diodes: symbols*
- *Characteristics of diodes: ideal, silicon, germanium and Zener*
- *Parameters of diodes: peak inverse voltage, maximum forward current, temperature, frequency, leakage current, and power dissipation*
- *Diodes in series and in parallel*
- *Zener effect*
- *Operation and function of diodes in the following circuits: clippers, clampers, full- and half-wave rectifiers, bridge rectifiers, voltage doublers and triplers (multipliers)*
- *Testing of diodes with an ohmmeter*
- *Operation and characteristics of the following devices: tunnel diode, silicon-controlled rectifier (SCR), light emitting diode (LED), Shockly diode, photo conductive diode, varactor diode, varistor, Shottky barrier diode, diacs and triacs*

7.4.24 Semiconductors (bipolar junction transistors)

- *Construction and operation of PNP and NPN transistors*
- *Base, collector and emitter junctions*
- *Transistor parameters: IB, IC, IE, beta, alpha, Vbe, power gain, distortion and saturation, input and output impedance, and frequency response*
- *Diagrammatical symbols for PNP and NPN transistors*
- *Amplification, current voltage and power*
- *Temperature effects on transistors*
- *Biasing required to operate a transistor as a switch, class A amplifier, class B amplifier and class C amplifier*
- *Characteristics of the following amplifiers: class A, class B and class C*
- *Methods of bias stabilization: negative feedback, temperature stabilization resistor, thermistor, diode and transistor*
- *Transistor configurations, operation and characteristics of the following: common base, common collector and common emitter*
- *Transistor data sheets: interpretation of specification*
- *Identification of standard transistor package forms*
- *Testing transistors by using an ohmmeter*

7.4.25 Types of transistor

- *Characteristics, operation and application of the following devices:*
  - *injunction transistor*
  - *programmable injunction transistor*
  - *opto isolator*
  - *power transistor*
  - *photo transistor*
  - *small signal transistor*
  - ***hall effect devices***

7.4.26 Field effect transistors (FET)

- *Operation, characteristics and basic circuit configuration of the following FET:*
  - *junction (JFET)*
  - *metal oxide silicon (MOSFET)*
  - *insulated gate (IGFET)*

7.4.27 Operational amplifiers (OPAMP)

- *Operation and function of an operational amplifier used as:*
  - *an integrator*
  - *a differentiator*
  - *a voltage follower*
  - *a comparator*
  - *Parameters of OPAMP:*
  - *open loop gain*
  - *and current*
  - *bandwidth*
  - *slew rate*
  - *input and output impedance*
  - *drift*
  - *input offset voltage*
- *Operation and function of the following amplifiers:*
  - *inverting amplifier*
  - *non-inverting amplifier*
  - *summing amplifier*
  - *differential amplifier*
  - *Operation and connecting methods of amplifier stages:*
  - *resistive capacitive (RC)*
  - *inductive (transformer)*
  - *inductive resistive (IR)*
  - *Advantages and disadvantages of positive and negative feedback*

7.4.28 Transistor circuits

- *Operation and characteristics of the following circuits:*
- *push-pull amplifiers*
- *darlington pairs*
- *complementary symmetry configuration*

7.4.29 Multi-vibrators and oscillators

- *Characteristics and operation of the following multi- vibrators:*
  - *astable or free running*
  - *bistable or flip-flop*
  - *monostable or one shot*
  - *Operation and function of the following transistor and FET oscillators:*
  - *Hartley*
  - *colpitts*
  - *resistive capacitive (RC)*
  - *inductive capacitive (IC)*
  - *crystal*

7.5 DIGITAL TECHNIQUES, COMPUTERS & ASSOCIATED DEVICES: REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES

7.5.1 Decimal to binary conversion

- *Comparison of decimal and binary numbering systems*
- *Conversion of decimal into binary, and vice versa*
- *Addition and subtraction of binary numbers*

7.5.2 Octal and hexadecimal conversion

- *Conversion of decimal into octal and hexadecimal, and vice versa*

7.5.3 Signed numbers

- *Conversion of positive and negative numbers into their 1's and 2's compliment*
- *Addition of numbers in the 2's compliment*

7.5.4 Digital calculation

- *Addition and subtraction in binary coded decimal (BCD) and hexadecimal forms*
- *Conversion of hexadecimal numbers into 2's compliment form*

7.5.5 Logic circuits

- *Expression of logic diagrams in terms of Boolean algebra*
- *Conversion of Boolean algebraic expressions*
- *Identification of logic circuits*
- *Identification of the following logic gates symbols, their truth tables and equivalent circuits:*
  - *AND*
  - *NAND*
  - *OR*
  - *NOR*
  - *EXCLUSIVE OR*
  - *INVERTER*

7.5.6 Flip-flop terminology and operation

- *Understanding of the following flip-flop terms:*
  - *set*
  - *up and hold times*
  - *asynchronous input*
  - *synchronous input*
  - *clock frequency*
  - *transition (positive and negative)*
  - *propagation delay*
  - *maximum*
- *Symbols used to indicate clocked inputs and negative going transition (NGT)*
- *Operation and identification of symbols and truth tables for the following types of flip-flop: SC or RS, JK, and D type*
- *Operation and application of digital counters, shift registers, and data storage devices*
- *Operation, advantages and disadvantages of serial and parallel data transfer*

7.5.7 Data conversion

- *Operation and application of analogue to digital, and digital to analogue converters, inputs and outputs, and limitations of various types*

7.5.8 Computer-related terminology

- *Understanding of the following computer-related terminology:*
  - *bit*
  - *byte*
  - *address*
  - *nibble*
  - *operand*
  - *op code*
  - *label*
  - *software*
  - *mnemonic*
  - *hardware*
  - *firmware*
  - *instruction*
  - *instruction word*
  - *language*
  - *machine language*
  - *CPU (central **processing unit)***
  - ***accumulator***

7.5.9 Basic microcomputers

- *Operation, layout and interface of the major components in a microcomputer, including their associated bus systems*
- *Information contained in single and multi-address instruction words*

7.5.10 Memory devices

- *Understanding of the following memory-associated terms:*
  - *memory cell*
  - *memory word*
  - *capacity*
  - *read option*
  - *write option*
  - *access time*
  - *cycle time*
- *Operation of typical memory devices during READ and WRITE modes*

- *Operation, advantages and disadvantages of the following data storage systems: magnetic disk, magnetic bubble, magnetic core and magnetic tape*

7.5.11 Integrated circuits (IC)

- *Operation and use of encoders and decoders*
- *Function of the following encoder types:*
- *binary coded decimal (BCD) to decimal or (4 ~o10)*
- *binary to octal or (1 to 8)*
- *octal to binary or (8 to 3)*
- *priority encoders*
- *Understanding of the uses of:*
- *medium scale integration (MSI)*
- *large scale integration (LSI)*
- *very large-scale integration (VLSI)*

7.5.12 Displays

- ***Function and operation of the following types of display:***
  - *liquid crystal display (LCD)*
  - *LED*
  - *Nixie tube*
  - *gas discharge*

7.5.13 Multiplexers, de-multiplexers and tristate devices

- *Operation, application and identification in logic diagrams of multiplexers, de-multiplexers and tristate devices*

7.5.14 Microprocessors

- *Understanding of the overall operation and functions performed by a microprocessor*
- *Basic operation of each of the following micro- processor elements:*
  - *control and CPU*
  - *clock*
  - *register*
  - *arithmetic logic unit (ALU)*

7.5.15 Encoding and decoding

- *Understanding of binary coded decimal (BCD), excess 3, and grey codes and their uses in converting binary and decimal numbers*
- *Understanding of the structure and uses of the ASCII code*
- *Understanding of the use of the parity method of error detection*
- *Information transmission via data buses, including various bus languages used by interconnecting systems*

7.5.16 Cathode ray tubes (CRT)

- *Principles of electrostatic and magnetic deflection as applied to cathode ray tubes*
- *Construction and basic operation of monochromatic and colour tubes*
- *Understanding of the following terms:*
- *raster scanning*
- *stroke pulse scanning*
- *rho-theta and X-Y screen formats*
- *interface scanning*

7.5.17 Electrostatic sensitive devices (ESD)

- *Sources of electrostatic sensitive devices (ESD) and the type of damage that static electricity can cause*
- *Special handling, identification, packaging, and protection requirements for ESD*

- *Personal anti-static protection devices*
- *Awareness of dangerous situations where there is a possibility of static charge build-up*

7.5.18 Fibre optics

- *Advantages and disadvantages of fibre optic data transmission over electrical wire propagation*
- *Fibre optic data bus*
- *Understanding of the following terms and effects relating to fibre optics:*
  - *absorption*
  - *attenuation*
  - *active medium*
  - *black body*
  - *coherent light*
  - *coherent bundle*
  - *dark current*
  - *diffraction*
  - *dopant*
  - *dispersion*
  - *flux rise time*
  - *LED*
  - *multimode fibres*
  - *optical attenuators*
  - *signal-to-noise ratio*
  - *fibre data bus*
  - *bit rate*
  - *two-state modulation*
- *Topology: passive star, active star and transmissive star*
- *Terminations: cleaving, stripping, splicing, and termination losses*
- *Couplers, control terminals and remote terminals*
- *Application of fibre optics in aircraft and systems*

7.5.19 Software management control

- *Awareness of the necessary restrictions, airworthiness requirements and possible catastrophic effects of unapproved modifications or alterations to manufacturers' software programmes*

7.6 AIRCRAFT ELECTRICAL SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES

7.6.1 Power supplies: Lead acid batteries

- *Plate materials, insulators, electrolyte, casing, terminals, specific gravity, capacity and capacity testing, determination of state of charge, constant current charging and constant voltage charging, gassing, sulphation, temperature, hydrometer, insulation and resistance (I/R) checks, and venting*
- *Safety precautions to be taken when dealing with lead acid batteries*
- *Neutralization of acid spills, action to take in the event of an acid spill and battery boil in an aircraft, cleaning, maintenance, storage and shipping requirements*
- *Environmental hazards associated with lead acid batteries*
- *Battery maintenance facilities, separation of location from nickel cadmium battery servicing area, ventilation, storage of acid and distilled water, mixing and dilution of sulphuric acid, protective clothing, battery service life and records of maintenance*

7.6.2 Power supplies: Nickel cadmium batteries

- *Plate materials, insulators, electrolyte, casing, terminals, capacity and capacity testing, determination of state of charge, gassing, venting, constant current charging and constant voltage charging, cell imbalance, cell voltage reversal, cell removal and replacement, cell leak testing, thermal runaway causes and prevention, temperature monitoring and warning, deep cycle recovery, and insulation and resistance (I/R) testing*
- *Neutralization of electrolyte spills, cleaning, maintenance, storage and shipping requirements*
- *Environmental hazards associated with nickel cadmium batteries*
- *Battery maintenance facilities, separation of location from lead acid servicing area, ventilation, storage of potassium hydroxide, protective clothing, battery service life and records of maintenance*

7.6.3 DC generation

- *Operation and characteristics of separately excited, shunt, series, compound wound and permanent magnet generators*
- *Generator construction: yoke, interpole and compensation windings, auxiliary interpoles, armature assembly, end frame assembly, brushes and gear assembly, terminal blocks, spark suppression, and installation*
- *Residual magnetism and effects of "flashing the field"*
- *Voltage regulation: carbon pile, vibrator type, cut-out, transistor type, solid state, and reverse current relays*
- *Multi-generator distribution: load sharing/paralleling, system layouts, and interlock circuits*
- *Starter generator systems, control, switching, and generator control units (GCU)*

7.6.4 AC generation

- *Cycle and frequency, instantaneous and amplitude values, root mean square values, phasing and phase relationships, and interconnection of phases*
- *Generator power ratings, power factor, effective power, apparent power, and reactive component (KVAR)*
- *Frequency wild generation systems: operation and application*
- *Generator construction: rotor, stator, brushes and gear assembly, slip rings, cooling fan, casing and end frame*
- *Constant frequency generation systems: operation and application (including brushless units)*
- *Generator construction: rotor, stator, exciter shunt field and stabilizing windings permanent magnet, exciter main poles, cooling system, and temperature compensation*
- *Constant speed drives (CSD): operation and construction, CSD and generator disconnect mechanisms*
- *Integrated drive generators (IDG): construction and operation*
- *Air driven generators (ADG) and ram air turbines (RAT): operation, function, and deployment*
- *Multi-generator distribution*
- *Load sharing and paralleling, real load sharing and reactive load sharing*

7.6.5 Auxiliary power units (APU)

- *Operation, control and protection of auxiliary power units*
- *Function of power generation*
- *Fire protection and warning*

7.6.6 Power conversion equipment

- *Rectifiers (conversion of AC into DC): selenium rectifiers, silicon rectifiers, operating limitations of rectifiers, silicon-controlled rectifiers (SCR), rectifier circuit connections, and three-phase rectifiers*
- *Transformers: auto transformers, current transformers, potential/parallel transformers, control transformers, winding configuration star/delta, transformer ratings, and transformer rectifier units (TRU)*
- *Rotary conversion equipment: rotary converters, motor generators, rotary inverters and static inverters*
- *Frequency, voltage and current control*

7.6.7 Power distribution systems

- *Classification of power service requirements into vital, essential and non-essential*
- *Operation and layout of split and parallel bus systems, load shedding systems, priority bus systems, emergency bus, battery bus and ground power bus*
- *Defect analysis and fault finding*

- *Wire and cable types: identification, uses, characteristics, screening, protection, pressure and moisture sealing, looms, conduit and ducting, and clamping*
- *Bonding, earth/ground points, and DC/ACIRF earths*
- *Plugs and connectors and associated insertion and removal tooling*
- *Auxiliary power unit (APU) and ground power unit (GPU) interlocks and interface*

7.6.8 Circuit protection devices

- *Fuses, fuse holders, current limiters, limiting resistors, circuit breakers, reverse current cut-out relay, reverse current circuit breaker, over voltage protection, under voltage protection, over frequency protection, under frequency protection, Merz-Price protection system, and power contactors*

7.6.9 Circuit controlling devices

- *Switches, single and multi-pole/throw varieties*
- *Toggle and tumbler switches, push switches, rocker-button switches, roller switches, micro-switches, time switches, rheostats, pressure switches, mercury switches, thermal switches, relays, proximity switches, attracted-core heavy duty relay, attracted-armature light duty relay, polarized armature relay, slugged relay, and magnetic amplifiers*

7.6.10 DC motors and actuators

- *Operation and construction of DC motors and actuators*
- *Characteristics and uses of shunt, series and compound motors (normal compound, stabilized shunt and shunt limited), and split field motors*
- *Speed direction and travel control, regulation and position feedback*
- *Clutches and brakes*

7.6.11 AC motors and actuators

- *Operation and construction of AC motors and actuators*
- *Methods of speed and rotational control: single-phase, two-phase and three-phase*
- *Clutches and brakes*

7.6.12 Flight controls

- *Principles, operation and maintenance of power control units (PCU), flap motors protection and control, and trim motors*
- *Position indication*
- *Fly-by-wire flight control systems (both digital and analogue), full authority systems and manual reversion systems*

7.6.13 Fuel systems

- *Fuel booster pump operation, control, construction and indication*
- *Function and operation of electrically controlled fuel valves*

7.6.14 Hydraulic systems

- *Function, operation, location and construction of electric pumps (indication and control)*
- *Function and operation of electrically controlled hydraulic valves*

7.6.15 Pneumatic systems

- *Operation of control indication and protection devices*
- *Function and operation of electrically controlled air valves*

7.6.16 Landing gear systems

- *Operation and function of electrical landing gear control and position indication*
- *Air/ground sensor systems*
- *Function and control of automatic braking systems*
- *Function, testing and operation of electric anti-skid system (covering each situation: no skid, skid and landing)*

7.6.17 Propeller and engine control systems

- *Function, operation, testing and maintenance of electrical propeller synchronizer and synchro-phaser systems*
- *Function, operation and testing of electric propeller feathering systems*
- *Function, operation and control of electronic engine control systems (both digital and analogue) including Full Authority Digital Engine Control (FADEC)*
- *Function and operation of electrical engine temperature and speed limiting systems*

7.6.18 Ignition systems (piston engines)

- *Safety precautions associated with aircraft ignition systems*
- *Function, operation and testing of magneto ignition (high- and low-tension systems), magneto and distribution speeds, "E" gap significance and adjustment, auxiliary starting devices, impulse couplings, compensating cams, ignition switches, dual ignition, and ignition leads*

7.6.19 Ignition systems (turbine engines)

- *Safety precautions associated with aircraft ignition systems*
- *Operation and layout of high energy ignition units (HEIU) (both AC- and DC-powered)*
- *High-energy igniter plugs: types, construction and maintenance*

7.6.20 Fire detection and extinguishing systems

- *Construction, operation, layout, testing and trouble- shooting of the following fire detection systems:*
  - *thermal switch*
  - *continuous loop (fire wire)*
  - *continuous element or pressure type sensor responder*
- *Operation, construction, layout, testing and trouble- shooting of the electrical aspects of aircraft fire extinguisher systems*
- *Safety precautions to be observed when dealing with aircraft fire extinguisher systems (including handling of explosive cartridges)*
- *Construction and operation of the following smoke detection systems: carbon monoxide, photoelectric and visual*
- *Typical fire and smoke cockpit warning indications, lights, bells, annunciator panels, and audio warnings*

7.6.21 Aircraft lighting

- *Operation, control layout and testing of typical aircraft lighting systems (both internal and external)*
- *External lighting: navigation lights, anti-collision lights (rotating and flashing), strobe lights, landing and taxi lamps, ice inspection lights, area inspection lights and logo lights*
- *Safety precautions when handling high-energy strobe light components*
- *Internal lighting: cockpit area lighting, instrument panel lights, instrument integral lighting, flood lighting, electroluminescent lighting, passenger cabin lighting, passenger instructional lighting (no smoking and fasten seat belts), strip lighting and passenger service unit (PSU) lighting*
- *Emergency lighting including crash inertia switches, floor proximity emergency escape path lighting and emergency exit lighting*

7.6.22 Ice and rain protection systems

- *Function of system control and overheat components*
- *Windscreen heating: control, indication and failure*
- *Windscreen wiper, washer and rain repellent systems*
- *Engine, propeller and airframe anti-ice protection: thermal, pneumatic and electrical*
- *Sensor ice protection: pitot head, static port, angle of airflow, and temperature probes*
- *Waste water and toilet drain heaters*

- *Antenna heaters*
- *Overheat indications and protection*
- *Ice warning and sensing devices indications*

7.6.23 Air conditioning and heating systems

- *Principles and operation of air conditioning*
- *Understanding of the following terms:*
  - *sensible heat*
  - *latent heat*
  - *conduction*
  - *convection*
  - *radiation*
- *Principles, operation, construction and maintenance of typical vapour cycle air conditioning systems*
- *Refrigerant types and uses, and physical and environ- mental hazards associated with each type*
- *Principles, operation, construction and maintenance of typical air cycle machines*
- *Control, monitoring, protection, maintenance and airflow of typical air conditioning systems*
- *Operation, construction and maintenance of typical combustion heater*
- *Heater warning and protection devices*

7.6.24 Centralized warning and indication systems

- *Operation of central warning and indication systems including inputs, output warnings and priority philosophy*
- *Galley and toilet service systems*
- *Operation, safety devices and control of service power: supplies, water heaters, ovens, toilets and associated systems and equipment*

7.6.25 Ground electrical power supplies

- *Understanding of the operation and control of typical ground supply equipment including:*
  - *DC battery carts*
  - *DC GPU*
  - *AC/DC GPU*
  - *rectifiers and inverters*
- *Ground power supply plugs: types/patterns*
- *Ground power and aircraft interface, interlocks and safety devices*

7.7 AIRCRAFT INSTRUMENT SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES

7.7.1 Introduction

- *Information required by pilot and crew*
- *Mandatory instruments*
- *Classification of aircraft instruments by type*
- *Classification of aircraft instruments by principles*
- *Classification of aircraft instruments by function*
- *Information presentation and dial design*
- *Instrument panel configurations*

7.7.2 Atmospheric physics

- *Understanding of the atmosphere, its layers and pressure, temperature and density variance with altitude*

- *Methods for measuring atmospheric pressure*
- *ICAO Standard atmosphere*
- *Operation of aneroid and mercury barometers for measuring atmospheric pressure*

7.7.3 Terminology and conversion

- *Understanding of the following instrument terminology:*
  - *hysteresis error*
  - *parallax error*
  - *absolute, differential and gauge pressure*
- *Methods of compensation of instrument mechanisms for temperature variations*
- *Reasons for hermetically sealing instruments*
- *Conversion from and to:*
- *millimetres (mm) of mercury to inches of mercury, to millibars, to hectopascals, to pounds per square inch*
- *knots to miles per hour*
- *US gallons to imperial gallons to litres to pounds*

7.7.4 Pressure measuring devices

- *Operation, function and construction of capsules (absolute and differential), diaphragms, bellows (absolute and differential) and bourdon*

7.7.5 Pitot static systems

- *Operation and construction of pitot static probes and static vents (primary and alternate)*
- *Layout of typical pitot static systems*
- *Pressure (position) error and its effect on pitot static instruments*
- *Pitot static system maintenance and leak testing*

7.7.6 Altimeters

- ***Operation and construction of counter pointer altimeters including the effects that** variation in temperature and atmospheric pressure have on their indications*
- *Understanding of the "Q" code terms: QFE, QNE and QNH*
- *Effect of QFE, QNE and QNH settings on the reading of an altimeter*
- *Effects and conditions associated with altimeters:*
  - *after effect*
  - *scale error and barometric scale error*
  - *friction*
  - *Altimeter testing procedures*

7.7.7 Vertical speed indicators (VSI)

- *Operation and construction of vertical speed indicators, including instantaneous vertical speed indicators*

7.7.8 Air speed indicators (ASI)

- *Understanding of the following ASI-related terms:*
- *indicated, calibrated and true air speed*
- *speed of sound (subsonic, sonic, transonic and supersonic)*
- *mach number and critical mach number*
- *maximum operating speed/velocity (VMO)*
- *maximum operating mach number (MMO)*
- *Operation, function and construction of: ASI and switches, Machmeter, mach/ASI, maximum allowable indicators*
- *ASI testing procedures*

7.7.9 Miscellaneous altitude systems

- *Operation, function and construction of typical altitude alerting and reporting systems, including encoding altimeters*

7.7.10 Servo altimeters and air data computers

- *Operation, function and construction of servo altimeters*
- *Principles of operation and layout of a typical air data computer system, including inputs and outputs*
- *Signal processors: mechanical, electrical and electronic*

7.7.11 Instrument pneumatic systems and direct reading gauges

- *Operation, function, construction and layout of a typical aircraft instrument pneumatic system*
- *Operation and construction of direct reading pressure, capillary type pressure and temperature gauges*

7.7.12 Temperature indicating systems

- *Wheatstone bridge application to instrument indication*
- *Operation and construction of various types of thermocouple*
- *Measurement of static air temperature indicating systems and total air temperature*
- *Cold junction compensation, material and construction of thermocouple leads and probes*
- *Operation and construction of radiation pyrometer type temperature indicating system*
- *Operation, construction and advantages of radiometer type indicators*

7.7.13 Fuel flow and fuel quantity indicating systems

- *Principles, operation, function and layout of typical float, capacitance and electronics type fuel quantity indicating systems*
- *Effects of temperature on fuel indicating system*
- *System compensation, adjustment and power supplies*
- *Principles, operation, function and location of typical fuel indicating system, including indicator, transmitter and power supplies*

7.7.14 DC synchronous systems and engine speed indicating system

- *Operation and construction of DC desyn and selsyn systems*
- *Operation, construction and maintenance of mechanical and electrical engine speed indicating systems and associated components*

7.7.15 Engine indicating systems

- *Operation, construction and maintenance of the following engine instruments:*
  - *manifold pressure gauges*
  - *torque meters*
  - *exhaust gas temperature gauges*
  - *engine pressure ratio gauges*
  - *system*
  - *turbine inlet temperature gauges*
  - *engine vibration systems*
  - *AC inductor*
  - *ratio meter oil pressure*
- *Understanding of terminology associated with engine indicating/data systems*

7.7.16 Gyroscopic principles

- *Understanding of gyroscopic principles and terminology, including axis and plane of spin, degree of freedom, input and output axis, displacement gyro, topple and precession*
- *Relationship of Newton's First Law of Motion to Gyroscopes*
- *Gyroscopic precession and determination of the direction of precession resetting from applied forces*
- *Apparent precession and calculation of earth rate*
- *Rigidity and its affecting factors*
- *Gimbal lock, gimbal layout for two and three gimbal gyroscopes*

- *Drift (real and apparent) and affecting factors*
- *Gyro types: free, rate, tied and earth*
- *Precautions associated with the use and handling of gyroscopic instruments*

7.7.17 Artificial horizons (AH)

- *Operation, function and construction of air- and electrically-driven AH*
- *Understanding of the information displayed on AH*
- *Errors, acceleration, turn and erection, and methods for overcoming them*
- *Operation of the following erection systems: pendulous vane, ball type, torque motor and levelling switch*
- *Operation and precautions associated with fast erect systems*

7.7.18 Turn and bank and turn coordinators

- *Operation, function and construction of air- and electrically-driven turn coordinators, and turn and bank indicators*
- *Understanding of the information presented on turn coordinators, and turn and bank indicators*

7.7.19 Directional gyros (DG)

- *Operation, function and construction of directional gyros*
- *Operation and use of manual caging knobs*
- *Effects of gimbal re-balancing and gimbal errors on instrument operation*

7.7.20 Compass systems

- *Understanding of the following in relation to terrestrial magnetism:*
  - *true magnetic and geographic poles*
  - *magnetic meridian*
  - *variation or declination*
  - *isogonal lines*
  - *agonic lines*
  - *magnetic equator*
  - *angle of dip or magnetic inclination*
  - *isoclinal lines*
  - *aclinic lines or magnetic equator*
  - *deviation*
  - *isodynamic lines*
- *Effects on compass readings of soft and hard iron magnetism*
- *Methods used to overcome inherent errors and deficiencies in compass systems*
- *Problems associated with navigation over polar regions*
- *Understanding of the terms related to remote reading compasses: nutation, null, synchronized, slaved and free*
- *Operation, function and layout of remote compass system, including remote sensors, flux detectors, power supplies and heading reference outputs*
- *Modes of operation: slaved, free and directional gyros (DG)*
- *System synchronization methods*
- *Compass swinging: calculation of (from information obtained) and removal of errors in coefficients A, B and C*
- *Calculation and completion of compass calibration card*

7.7.21 Ground proximity warning systems (GPWS)

- *Requirements for GPWS*
- *Visual and aural indications for modes 1 to 5 (including sub-modes)*
- *Inputs required for operation of a typical GPWS and aircraft system interface*
- *Operation and function of typical GPWS*
- *Interpretation of mode and sub-mode envelope graphs*
- *Override and inhibit functions*

7.7.22 Flight data and cockpit voice recording systems (FDR/CVR)

- *System requirements, operation, protection and installation of FDR/CVR, including the following primary parameters: time, pressure altitude, vertical acceleration, magnetic heading, and press-to-transmit (radio transceiver)/event marker*
- *Methods of recording information: trace recording and electromagnetic*
- *Function of system components including signal conditioning units, entry and encoding panels*
- *Interface with aircraft systems*
- *Data recovery, analysis and verification*

7.7.23 Electronic instrument and information display system

- *Display types: CRT, LED and LCD*
- *Symbol generation and symbol generators*
- *System operation, system layout and interpretation of information presented on the following:*
- *electronic centralized aircraft monitoring system (ECAM)*
- *engine indicating and crew alerting system (EICAS)*
- *flight management system (FMS)*
- *electronic horizontal situation indicator (EHSI)*
- *electronic attitude direction indicator (EADI)*
- *Head-up displays and presentation*
- *Moving map and flight tracking systems*

7.7.24 Vibration measurement

- *Sensing devices*
- *signal conditioning and process*
- *display and indication*
- *alarm levels and warnings*

CHAPTER 8 (ICAO Manual)

Advanced Avionics and Avionics Systems: Knowledge

AVIONICS – AFCS/NAVIGATION/RADIO

8.1 INTRODUCTION 64
8.2 TRAINING OBJECTIVES 64
8.3 AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS): FIXED WING: 64
8.4 AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS): ROTARY WING: 66
8.5 AIRCRAFT INERTIAL NAVIGATION SYSTEM (INS): 67
8.6 AIRCRAFT RADIO AND RADIO NAVIGATION SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES 68

8.1 INTRODUCTION

8.1.1 In order to be able to satisfactorily assimilate training on individual aircraft avionics systems, the Aircraft Maintenance (Technicians/Engineers/Mechanics) (AMEs) must have a good fundamental understanding of the principles and functions of operation generally used in aircraft avionics systems of all types.

8.1.2 *In order to be able to perform or supervise "hands-on" tasks of mechanic/technician on the aircraft avionics systems or its components, the AME must have a very complete* ***knowledge of all the associated maintenance practices that are likely to be used.***

8.2 TRAINING OBJECTIVES

Conditions: The trainees will be provided instructions about the aircraft, avionics automatic flight control, navigation and radio electronic engineering principles related to the avionics components, materials, installations, specifications and functional systems of the aircraft.

Performance: The trainees will describe the characteristics and applications of the aircraft avionics, automatic flight control, navigation and radio systems, including the principles of installation and function, connection techniques, interface with associated aircraft and powerplant systems, and flight deck instruments and displays.

Standard of accomplishment: The trainees will describe the characteristics and applications of the materials, installation, construction system, operational principles and maintenance practices in accordance with the actual application on existing aircraft and systems.

8.3 AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS): FIXED WING:

8.3.1 Fundamentals of AFCS

- *Understanding of the following terms:*
  - *authority*
  - *single axis autopilot*
  - *wing leveller and auto-stabilizer*
  - *couple*
  - *engaged*
  - *capture*
  - *crosswind effect*
  - *gain*
  - *washout*
  - *cone of confusion*
  - *versine generation and application*
- *Operation and typical layout of a single axis (roll) AFCS*
- *Operation of moving vane and E and I bar sensors*
- *Understanding of inner loop stabilization and outer loop control*
- *Purpose, advantages and disadvantages of control signal limiting and gain adjustment*
- *Methods by which roll and roll/yaw error signals are sensed in rate, displacement and inclined rate gyros*

- *Operation and construction of duplex, electro-pneumatic, electro-mechanical and electro-hydraulic servo-motors*
- *Differences between series and parallel connected servo-motors*
- *Operation and methods of torque limiting*
- *Methods of achieving and factors affecting artificial feel*
- *Understanding of the basic operation of a fly-by-wire system of controlling an aircraft's control system*
- *Understanding of power-assisted and power-operated flight controls*

8.3.2 Command signal processing/turbulence penetration

- *Methods by which attitude changes are detected in roll, pitch and yaw*
- *Methods and purposes of achieving the following signal processes within an autopilot system:*
  - *synchronization*
  - *limiting*
  - *gain and adaptive control*
- *Operation and layout of control wheel steering*
- *Operation and function of trim indicators*
- *Methods of reducing or eliminating the effects of turbulence on the operation of a flight control system*

8.3.3 Modes of operation: Roll channel

- *Selection and the operation of the following modes:*
  - *basic stabilization*
  - *turn command*
  - *radio range (VOR)/localizer (LOC)*
  - *heading hold*
  - *VHF omnidirectional*

8.3.4 Modes of operation: Pitch channel

- *Selection and the operation of the following modes:*
  - *basic stabilization*
  - *pitch command*
  - *altitude hold*
  - *vertical speed*
  - *mach hold*
- *Operation and purpose of a Mach trim system*

8.3.5 Yaw dampers

- *Operation and function of yaw damping systems*
- *Interaction of a yaw damper with an autopilot (including autopilot interlocks)*
- *Understanding of Dutch Roll phenomenon*
- *Aileron and rudder control interaction during turns*

8.3.6 Automatic trim control

- *Operation of automatic pitch trim systems*
- *Operation and function of flap compensation systems*
- *Operation and function of mach trim*
- *Operation and function of alpha trim*
- *Operation and function of centre of gravity (CG) trimmers*

8.3.7 Autopilot navigation aids interface

- *Operation and function of the following navigation system inputs and their effects and interface with an autopilot:*
  - *VOR*
  - *LOC*
  - *glideslope systems (G/S)*
  - *inertial navigation*
  - *Doppler*
  - *compass systems*

- *Operation of crosswind compensation*

8.3.8 Flight director systems

- *Operation, function and construction of an altitude direction indicator (ADI) and a horizontal situation indicator (HSI)*
- *Operation and layout of typical flight director systems operating in both coupled and uncoupled modes*
- *Information display, both analogue (mechanical instruments) and electronic flight instrument system (EFIS)*

8.3.9 Maintenance data

- *Understanding of the use of maintenance data to Specifications 100 or 2100 of the Air Transport Association (ATA) of America*

8.4 AUTOMATIC FLIGHT CONTROL SYSTEM (AFCS): ROTARY WING:

8.4.1 Fundamentals of AFCS

- *Understanding of the following terms and their interaction with each other:*
  - *air density*
  - *centrifugal force*
  - *tip path plane*
  - *coning angle*
  - *lift thrust vector resultant*
  - *pitch angle*
  - *angle of attack*
  - *collective pitch*
  - *cyclic pitch*
  - *blade loading*
  - *relative airflow*
  - *thrust or virtual axis*
  - *axis of rotation or shaft axis*
  - *feathering*
- *Understanding of the relationship between: lift, thrust, weight, drag, and CG range*
- *Understanding of the terms and the relationship between: vortex ring state, power settling, and over pitching*
- *Torque reaction and its effect on directional control of helicopter*
- *Gyroscopic precession and the use of this effect in providing control of the main rotor disc for forward, sideways and rearward flight*
- *Dissymmetry of lift and its control*
- *Understanding of corriolis effect and features (lead/lag hinges and underslung rotor) used to relieve stresses it creates*
- *Ground effect and translational lift and their relationship*
- *Translating tendency and its correction by mast offset and cyclic rigging*
- *Understanding of the reason for blade tip stall and why it results in nose pitch up of the helicopter*

8.4.2 Rotary wing stability

- *Understanding of static and dynamic stability and why most helicopters are considered to be statically stable and dynamically unstable*
- *Understanding of how the inherent dynamic instability is overcome by the use of the following design methods: stabilizer bar, offset flapping hinges and delta three hinges*
- *Ground resonance and its causes, and remedial maintenance action to be taken should it occur*

8.4.3 Roll and pitch control

- *Operation, function and layout of basic helicopter flight control system, particularly the operation of pitch and roll channels*

8.4.4 Helicopter yaw control and trim

- *Operation, purpose and layout of the yaw channel*
- *Function of yaw and gravity trim systems*

8.4.5 System operation

- *Operation of helicopter automatic flight control system when operating collective or power axis mode, coupled or instrument flight rules (IFR), and stability augmentation system (SAS)*

8.4.6 Autopilot and navigation aids interface

- *Operation and function of the following navigation system inputs, their effects and interface with the autopilot system: VOR, LOC, glideslope and marker and instrument landing system (ILS)*

8.4.7 Flight director systems

- *Operation, function and control of altitude direction indicator (ADI) and HSI*
- *Operation and location of typical helicopter flight director system operating in both coupled and uncoupled modes*
- *Information display, both analogue mechanical instruments and EFIS*

8.4.8 Maintenance data

- *Understanding of the use of maintenance data to Specification 100 or 2100 of the Air Transport Association (ATA) of America*

8.5 AIRCRAFT INERTIAL NAVIGATION SYSTEM (INS):

8.5.1 Terminology

- *Understanding of the following terms:*
  - *Bearing*
  - *Course*
  - *Latitude*
  - *Longitude*
  - *Drift*
  - *rhumb line*
  - *Align*
  - *cross couple*
  - *great circle*
  - *gyrocompass*
  - *local vertical*
  - *orthogonal*
  - *grid*
  - *heading*
  - *dead reckoning*
  - *cross track*
  - *azimuth*
  - *pendulum*
  - *elevation*
  - *coordinate system*
  - *waypoint*
  - ***track angle error***

8.5.2 Fundamentals and components of inertial navigation system (INS)

- *Relationship of Newton's Second Law of Motion to Inertial Navigation*
- *Understanding of inertia, velocity, acceleration and displacement, variation of velocity and displacement with time*
- *Construction, operation and function of mechanical gyroscopes and accelerometer used in a typical system*
- *Construction and layout of a typical platform*
- *Understanding of gimbal lock, random drift and cross couple error and how they may be eliminated*

8.5.3 Reference system stabilization

- *Operation of the following items in maintaining the stable element level:*
  - *gyroscopes*
  - *accelerometers*
  - *gimbal system*
  - *azimuth resolver*
- *Methods by which aircraft heading and altitude are measured*
- *Operation of a wander azimuth inertial system and its advantage over a typical nor· pointing system*

8.5.4 Operational platforms

- *Effects of earth rate and transport rate on the orientation of the stable element including methods of compensation for the overall operation of the system*

- ***Factors affecting the Schuler pendulum***
- ***Effect of the Schuler pendulum on the INS and how a platform is Schuler tuned***

8.5.5 Accelerometer corrections

- *Effect of centripetal and corriolis errors on the output of an accelerometer*
- *Factors affecting centripetal and corriolis errors and methods by which these errors are overcome in a typical system*

8.5.6 Platform alignment

- *Operation of an INS during the following modes of self-alignment: rough alignment (caging), fine alignment (levelling) and gyro-compassing*
- *Differences in the alignment between a typical north pointing system and wander azimuth inertial system*

8.5.7 System integration

- *Purpose and layout of the components in a typical INS*
- *Inputs to and outputs available from a typical INS*
- *Procedures for aligning an INS before flight and indications provided during flight*

8.5.8 Strap-down systems

- *Operation and construction of a strap-down INS and the differences with the conventional gimbal system*
- *Differences between INS and inertial reference system (IRS)*

8.5.9 Laser gyros

- *Operation, function and construction of a typical laser gyro*
- *Limitations and methods of improving limitations of laser gyros*

8.5.10 Inertial reference system (IRS)

- *Operation, function and construction of a typical IRS*
- *Information transfer between system components and capacity for system redundancy (various data buses)*
- *Conversion of true heading into magnetic heading*
- *Inputs required for system operation and outputs available*
- *Indications presented by the system during various modes of operation*
- *Built-in test equipment (BITE), its operation and limitations*
- *Provisions and procedures for obtaining maintenance data*

8.6 AIRCRAFT RADIO AND RADIO NAVIGATION SYSTEMS: REQUIRED KNOWLEDGE, SKILLS & ATTITUDES

8.6.1 Radio wave propagation

- *Radio frequency spectrum, bands, uses and propagation characteristics*
- *Causes and effects of absorption, scatter, reflection, refraction, fading, cyclic and irregular variations, critical frequency, maximum usable frequency, temperature inversion, and ducting*
- *Relationship between velocity of propagation, frequency and wavelength*
- *Understanding of the following terms:*
  - *ground wave*
  - *sky wave*
  - *surface wave*
  - *radiation angle*
  - *skip distance*
  - *diffraction*
  - *field strength*
  - *Doppler effect*
- *Effect that water and various land surfaces have on radio wave propagation*

8.6.2 Fundamentals of antenna

- *Operation, construction and radiation field patterns of the following antenna types:*
  - *dipole (half wavelength and folded)*

- *Marconi*
- *long wire*
- *Yagi antenna*
- *parabolic*
- *loop*

- *Voltage and current distribution along antennae of various lengths*
- *Alteration of the electrical length of antennae*
- *Ground planes and their characteristics*
- *Understanding of the following terms:*
  - *antenna impedance*
  - *radiation resistance*
  - *radiation power*
  - *polarization*
  - *effective height*
  - *reciprocity*
  - *gain*
  - *directivity*
  - *bandwidth*
  - *beamwidth*
  - *lobes*
  - *isotropic radiator*

8.6.3 Circuit analysis

- *Analysis of capacitance, capacitive reactance, inductance, and L, C and R circuits*
- *Resonant circuits: series and parallel*
- *Diodes, triodes, pentodes, gas tube, bipolar transistor, field effect transistors (FET), uni-junction transistor, variac diode, darlington pair, biasing, electronic voltage regulators, resistance coupled amplifiers, impedance and transformer coupled amplifiers, phase splitters, audio power amplifiers, the Hartley oscillator, colpitts oscillator, crystal oscillator, voltage controlled oscillator (VCO) and phrase locked loop (PLL)*
- *Operational amplifiers (inverting/non-inverting), comparators, voltage followers, adders and subtracters*

8.6.4 Transmission lines

- *Characteristics and construction of the following types of transmission lines:*
  - *parallel wire*
  - *coaxial cable*
  - *waveguide*
  - *skin effect*
- *Understanding of the following terms:*
  - *characteristic impedance*
  - *reflected power*
  - *forward power*
  - *standing wave ratio balanced line*
  - *unbalanced line*
  - *velocity factor*
- *Effect upon a transmission line when it is terminated in: a short circuit, an open circuit, and an impedance equal to its characteristic impedance*

8.6.5 Principles of receiver

- *Amplitude modulation (AM) and frequency modulation (FM)*
- *Stages and characteristics of superheterodyne (AM) receiver:*
  - *radio frequency (RF) amplifier*
  - *local oscillator*
  - *mixer*
  - *intermediate frequency (IF) amplifier*
  - *detector*
  - *audio frequency (AF) amplifier*
- *Stages and characteristics of FM receiver:*
  - *RF amplifier*
  - *local oscillator*
  - *mixer*
  - *wide filter*
  - *IF amplifier*
  - *limiter*
  - *frequency discriminator*
  - *AF amplifier*

- *Noise: sources, precautions to prevent random and non-random noise, and others*
- *Understanding of the following terms:*
  - *sensitivity*
  - *selectivity*
  - *stage gain*
  - *bandwidth*
  - *resonance*
  - *image rejection*
  - *adjacent channel rejection*
  - *noise factor*
  - *distortion*
- *Operation, construction and characteristics of head- phones, speakers and microphones*
- *Methods used for tuning, including:*
  - *ferrite materials*
  - *variable capacitors*
  - *voltage variable capacitors*
  - *frequency synthesis*
  - *voltage controlled oscillators*
  - *phrased locked loops*
- *Understanding in both time and frequency domains of the following signals and methods used to demodulate them:*
  - *amplitude modulation (AM)*
  - *frequency modulation (FM)*
  - *single sideband (SSB)*
  - *continuous wave*
- *Operation of simple and automatic gain control*
- *Operation and function of noise limiters, limiters, clarifiers, squelch control and automatic frequency control (AFC)*

8.6.6 Principles of transmitter

- *Characteristics and principles of the stages which comprise both FM and AM transmitters*
- *Function and characteristics of the modulators used to generate the following types of signal:*
  - *AM*
  - *FM*
  - *SSB*
- *Understanding of the following terms:*
  - *bandwidth*
  - *modulation index*
  - *clipping*
  - *harmonics*
  - *high-level modulation*
  - *low-level modulation*
  - *frequency stability*
  - *output power*
  - *parasitic oscillation*
  - *neutralization*
- *Operation and function of variable frequency oscillators, crystal oscillators, and multipliers*
- *Principles of time and frequency division*
- *Muting of receivers during transmission*
- *Classes of operation of transmitter power output stages*
- *Operation and limitations of regulated power supplies and switched mode power supplies (DC to DC converter)*

8.6.7 Principles of communication

- *Frequency bands allocated to high frequency (HF) and very high frequency (VHF) airborne communications systems*
- *Methods of signal propagation and expected ranges (both day and night)*
- *Calculation of approximate ranges of communication (line of sight)*
- *Characteristics and performance levels of typical HF and VHF communications systems including frequency range, power output, sensitivity, stability, and channel spacing*
- *Characteristics, advantages and disadvantages of the following HF/VHF antennae:*
  - *wire*
  - *notch*

- *probe*
- *whip*
- *blade*

8.6.8 High Frequency (HF) communication systems

- *Principles and operation of a typical HF transceiver (including the functions at each stage)*
- *Principles of operation and characteristics of typical antenna tuning units, both pre-set and automatic and their respective advantages and disadvantages*
- *System controls, their operation and limitations*
- *Interference: types and sources associated with HF systems and methods of eliminating interference*
- *System installation including location of equipment, antenna position, power supplies and audio system interface*
- *Functional testing of system and communication with other stations*

8.6.9 Very High Frequency (VHF) communication systems

- *Principles and operation of a typical VHF transceiver (including the functions at each stage)*
- *System controls, their operation and limitations*
- *Interference: types and sources associated with VHF systems and methods of eliminating interference*
- *System installation including location of equipment, antenna position, power supplies and audio system interface*
- *Functional testing of system and communication with other stations*

8.6.10 Emergency Locator Transmitter (ELT)

- *Purpose and function of an emergency locator transmitter*
- *Frequency/frequencies of operation*
- *Methods for activating system*
- *Methods for testing system*
- *Installation: location, antenna and switching*
- *Safety precautions to be observed particularly* ***with regard to spurious/unintentional transmissions***

8.6.11 Audio systems

- *Characteristics of sound, upper and lower limits of hearing*
- *Microphones types: carbon, dynamic and piezoelectric*
- *Output levels, frequency response, and directional properties*
- *Operation of noise-cancelling microphones*
- *Matching transformers: uses in system, calculation of impedance and turns ratio*
- *Understanding of the uses and characteristics of the following:*
  - *isolation amplifiers*
  - *attenuators*
  - *distribution networks*
  - *side tone*
  - *muting*
- *insertion losses*
- *Principle, operation and functions of an audio integration system*
- *Typical performance levels and specifications expected from an aircraft audio system*
- *Noise and other undesirable influences associated with audio systems and their elimination*
- *Installation interface with other aircraft systems*
- *Battery power supplies: condition, life and others*

8.6.12 Cockpit voice recorder system (CVR)

- *Purpose and requirements of a CVR*
- *Performance levels expected and specifications of typical CVR*
- *Theory of operation of a typical CVR*
- *Cockpit microphones including locations and concept of "hot" and "area" microphones*
- *Understanding of the following terms:*
  - *crosstalk*
  - *wow and flutter*
  - *record head*
  - *erase head*
  - *bias oscillator*
  - *bulk erase*
  - *track*
  - *frequency response*
  - *monitor head*
- *Installation of CVR, interface with audio system, power supplies, and favourable location*
- *System testing in aircraft (both audio and visual), downloading of recordings, etc.*
- *Underwater locator beacon (ULB): purpose, function, testing, battery type and life*
- *CVR protection against shock, fire, immersion in fluids, and erasure of recordings*

8.6.13 Automatic direction finder (ADF) systems

- *Principles of aircraft navigation using an ADF system*
- *Understanding of the following terms:*
  - *relative bearing*
  - *magnetic bearing*
  - *drift angle*
  - *homing*
  - *position fixing*
  - *aural bearing*
- *Antenna field patterns for or radiated by: non- directional radio beacon (NDB) — ADF ground station, loop antenna, sense antenna, and combined loop/sense antennae*
- *Composite field pattern created by loop and sense antenna (cardioid), phase relationship between loop and sense antenna output signals, antenna feeder lengths, sense antenna quality factor and sense antenna critical capacitance*
- *ADF frequency range, accuracy, sensitivity and hunting*
- *Principles of operation of a typical ADF receiver including: channel selection, loop antenna and goniometer, frequency synthesis, balanced modulator, beat frequency oscillators, and gain control ADF to radio magnetic indicator (RMI) adaptors*
- *Information presentation: relative bearing indicator (RBI) and RMI*
- *System installation (including location and mounting), power supplies, interface with audio system and navigation system*
- *Kinds of interference and errors affecting ADF systems, and their elimination or reduction of quadrantal error, loop alignment error, night effect, coastal refraction, vertical effect, mountain effect, static interference and station interference*
- *Calibration — loop swinging both air and ground functional testing of ADF systems*

8.6.14 Very High Frequency omnidirectional radio range (VOR) systems

- *Principles of aircraft navigation using VOR systems, homing directly to a VOR station, intercepting an inbound track and intercepting an outbound track*
- *Understanding of the following terms: radial, heading, automatic VOR, manual VOR, selected course, track, and cone of confusion*
- *Field pattern and signals radiated by VOR ground stations*
- *Operation and characteristics of a typical VOR receiver, including frequency range, channel spacing, signal polarization, variable phase circuitry, resolver, reference phase amplifier, VOR warning and TO/FROM circuitry, and omni-bearing selection*
- *Information presentation: RMI and omni-bearing indicator (OBI)*
- *VOR system outputs/interface with other systems: distance measuring equipment (DME) channelling, audio output, autopilot output, RMI/OBI, TO/FROM, warning, and deviation from selected radial*

- *Compensating load resistors in place of indicators*
- *VOR system errors: course error, reciprocal error and VOR site error*
- *VOR antennae: types, dual systems run from single antenna, receiver duplexer, diplexers, and critical cable lengths*
- *System installation (including location and mounting) and antenna location*
- *Testing of VOR systems by using appropriate bearing simulation test set*

8.6.15 Instrument landing system (ILS)

- *Operation of an ILS, including ground station position with respect to runway, signal format, range, and information displayed to pilot*
- *Difference in depth of modulation (DDM)*
- *Systems comprising an ILS: localizer, glideslope and marker*
- *Localizer (LOC) systems: frequency range, channel spacing, modulation, signal polarization, pairing of localizer and glideslope channels, and joint VOR/LOC antennae*
- *Glideslope systems (G/S): frequency range, channel spacing, modulation, signal polarization, and antenna*
- *Marker system (MKR): operating frequency, modulation and antenna*
- *Localizer back course switching and operation, and precautions to take when using back course particularly concerning glideslope*
- *Load compensating resistors in place of indicators*
- *Principle and operation of a localizer receiver including: receiver element, filters, oscillators, metre circuits, flag circuits, and power supplies*
- *Principle and operation of a glideslope receiver including: receiver element, filters, oscillators, metre circuits, flag circuits, and power supplies*
- *Principle and operation of a marker receiver including: receiver element, sensitivity circuitry, filters, lamp circuits, and power supplies*
- *ILS information presentation on the following indicators: course deviation indicator (CDI), HSI, ADI, and marker lights and tones*
- *System outputs: audio, autopilot, warning, and LOC/G/S*
- *System installation including mounting, location and antenna location*
- *Interface of ILS/MKR system with audio and navigation systems*
- *Testing of system by using an appropriate ILS/MKR signal simulator test set*

8.6.16 Microwave landing system (MLS)

- *Principles of time referenced scanning beam system (TRSB)*
- *Operation of a MLS (including ground station position with respect to the runway, beam patterns, signal format, antennae P-DME): transmission data and structure, flair guidance, curved approach and terminal waypoints*
- *Range and information displayed to pilot*
- *Interface of MLS with other aircraft systems*
- *Testing of MLS by using appropriate test set*

8.6.17 Very Low Frequency (VLF) and hyperbolic navigation systems

- *Characteristics and factors affecting the propagation of VLF and low frequency (LF) electromagnetic waves*
- *Understanding of the following terms:*
  - *great circle*
  - *circular lines of position (LOP)*
  - *hyperbolic LOP*
  - *lane*
  - *lane slip*
  - *lane ambiguity*
- *Principles of position fixing by the following means:*
  - *pulsed hyperbolic*
  - *continuous wave hyperbolic*
  - *CW rho rho*
  - *CW rho rho rho*

- *Signals radiated by Omega navigation system (ONS), including: transmission format, transmitted frequencies, phase locking of signals, useful range, and rate aiding*
- *Characteristics of a typical ONS*
- *Construction, function and characteristics of ONS antennae and its couplers*
- *Function of operating controls and presentation of information of a typical ONS*
- *Principles and operation of a typical ONS control display unit (CDU), receiver computer unit (RCU), operational equipment unit (OEU) and power supplies*
- *Interface of ONS with other aircraft systems*
- *ONS testing using built-in test equipment (BITE)*
- *Principles and operation of Loran-C navigation system including: signal transmission format, transmitter frequency, station synchronization, and useful range*
- *Operation of a typical Loran-C navigation receiver, including:*
  - *receiver element*
  - *phase decoder*
  - *master and slave phrased locked loops*
  - *gate pulse formers*
  - *time difference measurement*
- *Presentation of information from a typical Loran-C system*
- *Installation of Loran-C system, including mounting, location and antenna position and power supplies*

8.6.18 Distance measuring equipment (DME)

- *Principles of operation of DME systems (including ground station responses)*
- *Characteristics of interrogation and reply pulse trains*
- *Location of ground beacons including co-located VOR/DME (or VORTAC, VOR and Presentation of data on ATC radar display*
- *Principles of operation of ATC transponder systems, including transmitter, receiver, reply, code, mode, and side lobe suppression*
- *Transponder transmitter frequency, receiver frequency, typical power output, antenna polarization, suppression and system range*
- *Functions of modes "A" and "C", and attitude reporting function*
- *Mode "S" interface with Traffic Alert and Collision Avoidance System (TCAS)*
- *Characteristics of ground transmitted interrogations and transponder reply pulse trains*
- *Interface of transponder with other aircraft systems*
- ***Testing of transponder systems by using appropriate test set***

8.6.19 Radio altimeter systems

- *Aircraft altitude measurement using the following radio/radar techniques: pulsed, frequency modulated carrier wave (FMCW) and constant difference frequency modulated carrier wave (CDFMCW)*
- *Understanding of the terms with respect to FMCW radio altimeters:*
  - *frequency modulation*
  - *frequency deviation*
  - *modulation index*
  - *system errors*
- *Operating frequencies, accuracy, typical output power, modulation frequency, maximum and minimum height*
- *Antenna types, microwave and transmission line feeds*
- *Interface with other aircraft systems*
- *Testing of radio altimeter systems*

8.6.20 Doppler navigation system

- *Principles of Doppler navigation system*

- *Understanding of the following terms:*
  - *drift angle*
  - *track*
  - *heading*
  - *ground speed*
  - *vertical velocity*
  - *across heading velocity*
  - *along heading velocity*
- *Radiation patterns of antenna, and antenna stabilizations*
- *Interface of Doppler navigation system with other aircraft systems*
- *Testing of Doppler navigation system*

8.6.21 Satellite navigation systems

- *Principles of global positioning system (GPS)*
- *Differential GPS*
- *Characteristics of GPS*
- *Receiver autonomous integrity monitoring*
- *Antennae and transmission lines*
- *Installation and operation of GPS*
- *Testing and maintenance of GPS*

8.6.22 Weather avoidance systems

- *Principles of weather radar operation including:*
  - *pulse repetition frequency (PRF)*
  - *pulse width*
  - *radar mile*
  - *frequency of transmission*
  - *received signal strength*
  - *beam width*
  - *automatic frequency control (AFC)*
  - *sensitivity time control (STC)*
- *Antenna types, stabilization, tilt, scan, waveguides (flexible and rigid), rotary joints, choke joints, non-resonant lines, resonant lines, resonant cavities, and T/R switches*
- *Microwave devices: magnetrons, klystrons, travelling wave tube (TWT), Gunn diodes, circulators, and Impart diodes*
- *CRT displays, information presentation, ranges, weather and mapping*
- *Interface with other aircraft systems TACAN beacons)*
- *Understanding of the following terms:*
  - *jitter*
  - *automatic standby*
  - *squitter*
  - *search*
  - *track*
  - *memory*
  - *percentage reply echo protection*
  - *suppression*
- *Characteristics of DME system: transmitted frequency, received frequency, transmitter power, useful range, number of channels, and outputs*
- *Principles of operation of a typical DME transmitter receiver, including interrogation function, reply and decoding circuitry, indicator, power supplies, and antenna*
- *Interference with and from other avionics systems*
- *Installation of DME (including mounting, location and antenna position)*
- *Testing of DME systems by using an appropriate DME test set*

8.6.23 Area navigation (RNAV)

- *Principles of area navigation using VOR and DME systems*
- *Understanding of waypoint offset computation*
- *Control of system including data entry, output information presentation and interpretation*
- *Installation of RNAV system and its interface with DME and VOR systems and other aircraft systems*

- *Switching and annunciation of mode of operation of RNAV system*
- *Testing of RNAV system by using appropriate VOR and DME test sets*

8.6.24 Air traffic control (ATC) transponder systems

- *Differences between primary and secondary surveillance radar systems*
- *Precautions to be observed when operating radar systems*
- *Principles of operation of Stormscope weather detection system: range, area coverage, antenna and limitations*
- *Interface with weather radar and other systems*
- *Testing of weather avoidance systems*

8.6.25 Traffic alert and collision avoidance system (TCAS)

- *Principles of operation of a TCAS*
- *Range, altitude and resolution of operating area including warning indications (both visual and aural) of potential and immediate threats*
- *Resolution advisory (RA): corrective and preventive*
- *Interface of TCAS with other aircraft systems*
- *Testing of TCAS*

8.6.26 ARINC communication and reporting system (ACARS)

- *Principle, operation and function of ACARS*
- *Information/data processed by ACARS: parameters and limitations*
- *ACARS ground stations*
- *Typical aircraft ACARS installation, including interface with other systems*
- *Testing of ACARS*

8.6.27 Passenger entertainment systems

- *Principles and operation of passenger video and audio entertainment systems, including interface with other aircraft systems*
- *In-flight telephone (air/ground) systems.*

CHAPTER 12 (ICAO Manual)

Practical Training Avionics — Electrical, Instrument, Autoflight and Radio Trade

12.1 INTRODUCTION 77
12.2 TRAINING OBJECTIVES 77
12.3 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — ELECTRICAL 78
12.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: AVIONICS — INSTRUMENT 79
12.5 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — AUTOFLIGHT 80
12.6 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — RADIO 80
12.7 REPAIR, MAINTENANCE AND FUNCTION TESTING OF AIRCRAFT SYSTEMS/COMPONENT: AVIONICS 82
12.8 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES 82

12.1 INTRODUCTION

12.1.1 In order to be able to satisfactorily assimilate training on individual types of aircraft avionics systems, the Aircraft Maintenance (Technicians/Engineers/Mechanics) (AMEs) must have good fundamental practical skills and understand the maintenance processes and principles generally used in aircraft hangars and workshops.

12.1.2 In order to be able to perform or supervise "hands-on" tasks of mechanic/technician on the aircraft and avionics systems, the AME must have a very complete knowledge of all the tools and associated maintenance processes that are likely to be used in hangars and workshops.

12.1.3 For future aircraft hangar or workshop technicians, their basic workshop training should commence with Phase Two — Skills and should be completed before the students begin working on airworthy aircraft and avionics equipment in Phase Three — Experience. For this purpose, the Performance parameters required to meet the Training Objectives outlined in 12.2 of this chapter are divided into two sections: Section a) requires basic manual skills and Section b) refers to the application of these skills to non-airworthy avionics components, systems or specially-designed practice rigs. The level of manual skills to be developed varies according to the category of technician being trained. For example, bench fitting is of importance to all categories of technicians, while radio technicians may require skill in soldering but they only need an introduction to welding.

12.1.4 The recommended facilities, tools and equipment are described in Appendix 1 to this chapter.

12.2 TRAINING OBJECTIVES

Conditions: The trainees will be provided with appropriate facilities; tools (both hand and machine); materials; test/demonstration avionics, electrical, instrument, auto-flight items of equipment, necessary parts and raw materials or specially-made repair, assembly and rigging test exercises. (See Appendix 1 to Chapter 12.)

Performance:

(a) The trainees will practice equipment removal, replacement, dismantling, inspection, decision-making regarding repair or replacement, reassembly and function testing using simple engineering drawings and manufacturers' maintenance, overhaul and repair tests (real or simulated).

b) The trainees will practice fault finding, dismantling, inspecting, repairing, decision-making regarding repair or replacement, reassembly and testing of avionics units. They will also use engineering drawings and engine manufacturers' maintenance, overhaul and repair manuals.

Standard of accomplishment:

During workshop training, the standard is a function of the variety of exercises completed and the time spent in workshop training. The trainees/students should work individually on the avionics exercises so that they have "ownership" of the standard.

If necessary, they should practice and repeat increasingly complex exercises to develop greater manual skills within their respective areas of competence. Finally, they should function test the units or systems on a test rig.

12.3 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — ELECTRICAL

12.3.1 Lead acid batteries

- *Checking of battery condition, adjustment of specific gravity of electrolyte, battery charging practise; capacity, discharge and insulation tests; others*
- *Overhaul procedures, including leak test of cells and cell replacement*
- *Safety precautions*

12.3.2 Nickel cadmium batteries

- *Checking of battery condition: determining state of charge, cell balancing, charging, etc.*
- *Checking of electrolyte level and insulation tests*
- *Safety precautions*
- *Cell replacement*
- *Deep cycling of nickel cadmium units*

12.3.3 Wire and cable work

- *Making up of wire lengths and specimen cable looms: soldering and crimping ends, identification of cables, using routing charts, and fitting plugs and sockets*
- *Cable tracing practise: continuity and insulation checks on cable runs*
- *Practice in aircraft wiring as carried out during modification or repair work: full tests of circuit*

12.3.4 Bonding, continuity and insulation testing

- *Bonding checks: use of bonding tester*
- *Continuity and insulation tests on aircraft circuit; use of Megger testers*
- *Millivolt drop checks at cable joints and terminal ends*

12.3.5 Generators and electric motors

- *Dismantling, examination and reassembly*
- *Demonstration of generator test*

12.3.6 Voltage regulators, cut-outs and relays

- *Partial dismantling, followed by examination and reassembly, of carbon pile and other types of voltage regulators*
- *Dismantling, examination and reassembly of accumulator cut-outs, reverse current relays, solenoids and relays from various circuits, and thermal circuit breakers*

12.3.7 Generators and alternators

- *Strip inspection: undercutting of commutators, checks for brush wear, brush spring loading and brush bedding*
- *Testing of generator elements: armature testing, continuity tests on field coils, armature shaft alignment, and wear of ball races and housings*
- *Reassembly and insulation test of generator*
- *Testing of generators and alternators on test rig*
- *Voltage regulators: overhaul procedure, correction of basic setting and adjustments making*
- *Adjustment and rig testing of cut-outs and relays*
- *Current balancing adjustments of DC power circuits on simulator of multi-engined aircraft electrical system*
- *Electromagnetic relays: inspection and polishing of contacts, setting and adjustment, and millivolt drop tests on test rig*
- *Constant speed drives (CSD): removal from alternator and testing*
- *Integrated drive generator (IDG): dismantling, inspection, and overhaul*

12.3.8 Electric motors

- *Starter motors for piston and turbine aero engines: dismantling, examination for condition and wear, check for brush gear and commutator, check of clutches and geared drives; reassembly and test*

- *Dismantling, inspection, reassembly and test of motors for fuel line pumps, hydraulics, propeller feathering, and windscreen wipers*
- *Linear and rotary actuators: dismantling, reassembly, and bench testing*

12.3.9 Inverters and converters

- *Rotary inverters and converters: dismantling and check for brushes and commutators, cleaning and testing of armature, and reassembly and adjustment*
- *Testing: checking of input and output voltages; adjustment of frequency control*
- *Static inverters and converters: inspection, adjustment and testing of output voltage and frequency*

12.3.10 Equipment

- *Magnetos: overhaul and test procedure for high- and low-tension systems*
- *Spark/igniter plug testing, ignition lead testing and inspection, and booster coil testing*
- *Engine high-energy ignition units: overhaul and test procedure*
- *Safety precautions*

12.3.11 Electrical circuit equipment

- *Examination and partial overhaul of a wide range of miscellaneous electrical components such as transducers, magnetic amplifiers, rectifiers, transformers, Wheatstone bridge and other balancing devices, and sensing elements*
- *Adherence of all testing in accordance with manufacturers' instructions*
- *Dismantling (as appropriate), examination and reassembly of electrical components, including converters, inverters, switchgear, heating units, and actuators*

12.4 BASIC WORKSHOP & MAINTENANCE PRACTICES: AVIONICS — INSTRUMENT

12.4.1 Pressure indication

- *Mechanically-operated gauges (e.g. Bourdon tube gauges): partial dismantling, examination, strip inspection, reassembly and calibration with dead weight c tester*
- *Pressure transducers, electrically-operated transmitters, ratio metres, etc.: strip inspection,*
- *reassembly and calibration*
- *Electrically-operated gauges: strip inspection, reassembly and calibration*

12.4.2 Flight instruments

- *Calibration checks of flight instruments*
- *Pitot heads and static vents: maintenance checks*
- *Altimeters: dismantling, inspection, reassembly and calibration checks*
- *Air speed indicators (ASI): dismantling, inspection, reassembly and calibration checks*
- *Machmeters: dismantling, inspection, reassembly and calibration checks*
- *Rate-of-climb indicators: dismantling, inspection, reassembly and calibration checks*

12.4.3 Gyroscopic instruments

- *Air-driven gyroscopic instruments: partial dismantling, examination and reassembly*
- *Electrically-driven gyroscopic instruments: partial dismantling, examination and reassembly*
- *Artificial horizon: dismantling, inspection and reassembly*
- *Directional gyro: dismantling, inspection and reassembly*
- *Turn and bank indicator: dismantling, inspection and reassembly*
- *Zero reader: dismantling, inspection and reassembly*
- *Calibration checks on gyroscope test turntable*

12.4.4 Engine speed indication (ESI)

- *ESI generators (DC and AC types): partial dismantling, inspection and reassembly*
- *ESI gauges: partial dismantling, inspection and reassembly*

- *Engine speed synchronizing gear: examination and demonstration of principles*
- *Generators and gauges: dismantling, inspection, reassembly and calibration checks*

12.4.5 Thermometers and temperature indication

- *Engine temperature thermocouples: demonstration of cylinder head, jet-pipe temperature and other types*
- *Radiometer temperature gauges: partial dismantling, examination and reassembly of transmitter and indicator units*
- *Dismantling, reassembly and testing of temperature, and measuring instruments of various kinds*
- *Tests on various kinds of temperature sensing units (e.g. fire and overheating detectors, cabin air duct stats, and inching controls for cooler shutters)*
- *Use of portable test kits for checking gas turbine powerplant thermocouple installations*

12.4.6 Fuel contents indication

- *Float-operated desynn contents gauges: examination and demonstration of operation dismantling, inspection, reassembly and test*
- *Capacitance type contents gauges: examination and demonstration of operation reassembly and test*
- *Flowmeters: dismantling, inspection, reassembly and test*

12.4.7 Compass systems

- *Magnetic compasses: friction and damping tests, practice compass swing, and compensation*
- *Remote compass: examination and demonstration*
- *Tests of compass swinging site*
- *Swing of compass in available aircraft: compensation practice*
- *Remote compass: partial dismantling, inspection, reassembly and test*

12.4.8 Miscellaneous instruments

- *Examination and demonstration of other types of instruments (flowmeters, navigation and landing aid presentations)*

12.5 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — AUTOFLIGHT

12.5.1 Autopilots

- *Examination and demonstration of autopilot mock-up and components*

12.5.2 Flight control systems

- ***Autopilots (electrical or electronic): dismantling, examination of components,*** *reassembly, and*
- *installation in aircraft or on simulator by following manufacturer's test programme; practise with portable test kit*
- *Autopilots (pneumatic or hydraulic actuation):*
- *dismantling of component parts, reassembly, installation in aircraft or simulator, and function tests*
- *Examination and testing of elements of flight director systems, automatic flare and automatic landing systems, as required*

12.6 BASIC WORKSHOP AND MAINTENANCE PRACTICES: AVIONICS — RADIO

12.6.1 Radio workshop: fundamental techniques

- *Safety precautions associated with radio equipment hazards: high voltages, radio frequency (RF) emissions and microwave emissions, electrostatic discharge, etc.*
- *Wiring and cabling: demonstration and practice in*
- *wiring and soldering radio circuits*
- *Multimeters, Megger and bonding testers:*

- *demonstrations and practice*
- *Identification and inspection of antenna: external*
- *wire aerials, blade, rod and rail aerials, D/F loops,*
- *and suppressed aerials; viewing on aircraft, and*
- *inspection for physical condition*
- *Aerial masts, static dischargers, etc.: inspection and*
- *servicing*
- *Chassis: sheet metalwork using drawings*
- *Simple receiver assembly kit: study of circuit,*
- *demonstration of assembly, operation and testing*
- *Measurements and experiments with circuit*
- *demonstration units simulating the following*
- *system elements:*
  - *TRF receiver*
  - *intermediate frequency amplifier*
  - *frequency converter*
  - *superheterodyne alignment*
  - *buffer-doubler amplifier*
  - *RF amplifier*
  - *modulation*
  - *transmission lines*
  - *• reactance tube modulators*
  - *• interference (filtering and shielding)*
- *Troubleshooting practice*

12.6.2 Demonstration of test procedures on airborne equipment

- *Identification: identity and location of principal types of airborne communication and navigation equipment: racking systems, power supplies, antennae and other interconnections*
- *Demonstrations of bench tests on sample equipment, including use of screened rooms*

12.6.3 Wiring, cabling and soldering techniques

- *Wiring: practice in stripping insulation; splicing; wiring to lugs; terminals and tube sockets; and dismantling, soldering and reassembly of connectors*
- *Cables: lacing of wires to form a cable, termination and soldering of cable ends, and serving of coaxial cables*
- *Soldering: practice with different sizes of soldering irons, different grades of solder, fluxes and types of connectors*
- *Micro-miniature precision soldering techniques*
- *Handling of electrostatic sensitive devices*

12.6.4 Instrumentation

- *Multimeter: practice in measuring and calculating series and parallel resistance; voltage and current measurements on various circuits; others*
- *Megger: continuity and insulation tests on aircraft cable assemblies' structure; practice with circuit boards; others*
- *Simple valve voltmeter*
- *Frequency metres, absorption and heterodyne:*
- *practice in frequency measurement*
- *"Q" metres: practice in measuring L, R, C and Q*
- *Signal generators: demonstration of cathode ray oscilloscope; demonstration of use to examine wave- forms, wave envelopes, and DC measurements*

12.6.5 Antennae

- *External wire aerials: splicing, tensioning and making connections*
- *Static dischargers: inspection, servicing and renewal procedures*
- *Fibreglass and resin laminate aerial masts: maintenance and repair*

- *External blade, rod and rail aerials: removal, maintenance and repair, and replacement*
- *Suppressed aerials: care and maintenance, maintenance and repair of dielectric covers*
- *DF loops: inspection, routine maintenance, ground calibration, and preparation of correction chart*
- *Reflectors and directors: care and maintenance*

12.7 REPAIR, MAINTENANCE AND FUNCTION TESTING OF AIRCRAFT SYSTEMS/COMPONENT: AVIONICS

12.7.1 Airborne and test equipment practice

- *Use of representative airborne radio and radar equipment and practice in servicing, installation and overhaul according to procedures laid down in the manufacturers' approved manuals*
- *Removal and replacement of equipment from aircraft racks, checks on power supplies, and remote controls*
- *Routine maintenance inspections of equipment in situ*
- *Operational checks*
- *Bench tests, measurement of performance characteristics, tuning, adjusting, fault finding, aligning and repairing*
- *Understanding and use of remote specialist communications, navigation and radio test equipment for both ramp and workshop*
- *Understanding and use of system built-in test equipment (BITE), including comprehension of output data*
- *Power supplies, installation and wiring, signal tracing, and use of cathode ray oscilloscope (CRO)*
- *Audio amplifier, installation and wiring, fault tracing and rectification*

12.8 JOB/TASK DOCUMENTATION AND CONTROL PRACTICES

12.8.1 Aircraft heavy maintenance check: Avionics

- *Preparation for Heavy Maintenance Check:*
- *documentation (task/job cards), logbooks, defect records,*
- *modification instructions; selection and display of equipment; tools required*
- *Selected heavy maintenance operations*
- *Compliance to the aircraft maintenance manual and typical airline major check schedule for each job*
- *Conclusion of Heavy Maintenance Check:*
  - *replacement of components; function tests;*
  - *preparation for flight test; completion of documentation*

12.8.2 Aircraft repair or modification: Avionics

- *Selection of repair scheme or modification: damage to be studied and related to approved repair scheme as shown on manufacturers' drawings*
- *Selection of material (to be checked for compliance with specification)*
- *Embodiment of repairs according to prepared drawings or manufacturers' manuals*
- *Testing to destruction of selected repair specimens to demonstrate strength of repair*
- *Experience in workshop processes as applicable to testing, repair and reconditioning of aircraft parts*
- *Acceptance tests and final inspection*
- *Completion of documentation*

CHAPTER 9 (ICAO Manual)

Human Factors

9.1 INTRODUCTION 83
9.2 MAINTENANCE RESOURCE MANAGEMENT (MRM) AND HUMAN FACTORS 84
9.3 PHASE I — HUMAN FACTORS AWARENESS PHASE 84
9.4 PHASE II — HUMAN FACTORS PRACTICE AND FEEDBACK PHASE 85
9.5 PHASE III — HUMAN FACTORS CONTINUAL REINFORCEMENT PHASE 85
9.6 TRAINING OBJECTIVES 85
9.7 REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES 85

9.1 INTRODUCTION

Lapses in human performance are cited as causal factors in the majority of accidents. If the accident rate is to be decreased, there must be better understanding of Human Factors and broader application of Human Factors knowledge. Increasing awareness of the importance of Human Factors in aviation presents the international aviation community with a significant opportunity to make aviation both safer and more efficient. The purpose of this chapter is thus to introduce the fundamental Human Factors concepts in aviation to Aircraft Maintenance (Technicians/ Engineers/Mechanics) (AMEs).

“Human Factors” as a term has to be clearly defined because these words, when used in the vernacular, are often applied to any factor related to humans. The human element is the most flexible, adaptable and valuable part of the aviation system, but it is also the most vulnerable to influences that can adversely affect its performance. Throughout the years, some three out of four accidents have resulted from less than optimum human performance.

Human Factors is a technology that deals with people. It is about people in their working and living environments, and it is about their relationship with machines, equipment and procedures. Just as importantly, it is also about their relationship with each other as individuals and in groups. It involves the overall performance of human beings within the aviation system. Human Factors seeks to optimize the performance of people by the systematic application of the human sciences, often integrated within the framework of system engineering. Its twin objectives can be seen as safety and efficiency.

Human Factors has become concerned with the diverse elements in the aviation system. These include the following:

- *human behaviour*
- *decision-making and other cognitive processes*
- *the design of controls and displays*
- *flight deck and cabin layouts*
- *air traffic control display systems,*
- *aircraft maintenance activities and documentation, and*
- *training*

Cultural differences have been recognized as issues of concern to Human Factors. The subject has been studied by many Human Factors specialists. In the context of the AME’s training, cultural differences should be addressed in the light of the misunderstanding that may occur among AMEs ground and flight crew members of differing cultural backgrounds and the resulting possible break in communication and coordination. When addressing this issue, instructors must exercise caution as discussion on cultural differences is prone to misunderstanding and can result in unnecessary friction. During this phase of the training, emphasis should be placed on the development of an organizational culture that encourages a teamwork approach to the aircraft maintenance activity.

In spite of the reliance on the academic sources of information, Human Factors in aviation is primarily oriented toward solving practical problems in the real world. There is a growing number of integrated Human Factors techniques or methods; these varied and developing techniques can be applied to problems as diverse as accident investigation and the optimization of personnel training.

It is most important that everyone concerned with the operation and administration of the aviation system recognizes the inevitability of human error. No person, whether designer, engineer, manager, controller, flight dispatcher or crew member, can perform perfectly at all times. In addition, what could be considered a perfect performance in one set of circumstances might well be unacceptable in another? Thus, people need to be seen as what they really are; to wish that they be intrinsically "better" or "different" is futile, unless such a wish is backed by a recommendation for remedial action. Such a recommendation can be further supplemented by providing the means to achieve better design, training, education, experience, motivation, etc., with the objective of positively influencing the relevant aspects of human performance.

An understanding of the predictable human capabilities and limitations and the applications of this understanding are the primary concerns of Human Factors. Human Factors have been progressively developed, refined and institutionalized since the end of the last century and is now backed by a vast store of knowledge which can be used by those involved in enhancing the safety of today's complex commercial air transport system.

9.2 MAINTENANCE RESOURCE MANAGEMENT (MRM) AND HUMAN FACTORS

The importance of teamwork in the aviation maintenance activity is widely recognized. One result has been the emergence of Human Factors training and Maintenance Resource Management (MRM) programs. In summary, the following principles are fundamental:

Improved communication (both verbal and written)

Establishment of a "Safety Culture", i.e. a pervasive, positive attitude towards safety

Improvement of the inter-team and intra-team coordination and communication

Linking and integration of the Human Factors training with improved equipment design, environ- mental standards and workload

MRM training is but one practical application of Human Factors. Although MRM can be approached in many different ways, there are some essential features. Training should focus on the functions of the AME as part of a larger team (which may include managers and occasionally flight crew members) and not simply a collection of technically-competent individuals. The Human Factors program should teach AMEs how to use their interpersonal and leadership styles in ways that foster flight safety. The program should also teach AMEs that their behaviour during normal, routine circumstances can have a powerful impact on how well or safely the flight is conducted. Similar situations experienced in training increase the probability that AMEs will handle actual stressful situations more competently.

Research studies from the behavioural sciences strongly suggest that behaviour change in any environment cannot be accomplished in a short period of time, even if the training is very well designed. Trainees need time, awareness, practice and feedback, and continual reinforcement to learn lessons that will endure. The Human Factors training should address the challenge of optimizing the person/machine interface and related interpersonal issues. These issues include effective team building and maintenance of teams, information transfer, problem solving, decision-making, maintenance of situational awareness and dealing with automated systems.

Accordingly, Human Factors training should include at least three distinct phases:

the awareness phase where Human Factors issues are defined and discussed;

the practice and feedback phase where trainees gain experience on Human Factors techniques; and

the continual reinforcement phase where Human Factors principles are addressed on a long-term basis.

9.3 PHASE I — HUMAN FACTORS AWARENESS PHASE

Awareness is the essential first phase and usually comprises instructional presentations focusing on the roles of interpersonal and group factors. It is important because it provides a common terminology and a conceptual frame work for AMEs to begin thinking about maintenance, communication and coordination problems and how such factors may have contributed to accidents and incidents. A useful way to begin the awareness phase might be to introduce Human Factors skills as they pertain to communication, situation awareness, problem solving, etc. Actual situations in which a maintenance error had a direct impact on the outcome of the event should be examined and the positive and negative interactions reviewed.

It is important to recognize that awareness is only a first step. Classroom instruction alone will probably not significantly alter the attitudes and behaviour of AMEs in the long term.

9.4 PHASE II — HUMAN FACTORS PRACTICE AND FEEDBACK PHASE

As part of the practice and feedback training, some programmes use role-playing techniques to provide group skills practice. Attitude-measuring questionnaires are also used as a means of providing feedback to individuals on their own interpersonal styles, some aspects of which they probably have not previously evaluated. Attitude insights allow individuals to recognize some of their strengths and weaknesses. On their own, however, they may not provide guidance on how those attitudes will positively or negatively affect each situation. Role-playing or group exercises can provide useful practice in the areas of dispatcher decision-making and other skills discussed in the awareness phase of the Human Factors curriculum. They can also demonstrate the critical responsibility of AMEs and the effect of various factors on their ability to perform their tasks under actual situations.

Videotape feedback is particularly effective because the third-person perspective creates a level of awareness not possible with other techniques. This perspective provides insight and provokes "self-critique" which appears to be a strong stimulus for attitude and behaviour change. It is easy to identify less-than-optimum managerial or interpersonal styles if one sees it for oneself. Moreover, these video feedback exercises will provide opportunities for peer critiques. There is ample evidence of the effectiveness of the video feedback technique, which should be used whenever possible. If video feedback is not possible, each exercise must be followed by a carefully guided debriefing session. Participants should be able to identify the objectives of each exercise and be encouraged to provide constructive feedback on performance ("peer review" should be highly encouraged), identify areas of concern, propose alternatives and relate all exercises to practical experience.

9.5 PHASE III — HUMAN FACTORS CONTINUAL REINFORCEMENT PHASE

No matter how effective the Human Factors classroom curriculum, interpersonal drills and feedback techniques are, a single exposure will be insufficient. Undesirable attitudes and norms which contribute to ineffective AME performance are ubiquitous and may have developed over a lifetime. It is unrealistic to expect a short training programme to counteract a lifetime of development. For maximum effect, MRM must be embedded in the total training programme, be continually reinforced, and become an integral part of the organizational culture. This last factor is often overlooked; it is clear however that effective Human Factors training requires the support of the highest levels of management.

9.6 TRAINING OBJECTIVES

Conditions: The trainees will use guidance already developed for flight crew members and other groups with respect to training in resource management. They will also use role playing to simulate conditions that require the application of Human Factors concepts.

Performance: The trainees will be able to apply concepts learned in Human Factors training in the performance of their role-playing duties and responsibilities. They will be able to develop awareness of "good" versus "poor" performance, accept the need for supportive and cooperative interrelationships between AMEs and crew members, and cope with difficult situations.

Standard of accomplishment: During training, the recorded role-playing performance of the trainees can be compared with models provided as references.

9.7 REQUIRED KNOWLEDGE, SKILLS AND ATTITUDES

The following is a recommended outline of topics for Human Factors training:

- *General programme overview;*
- *Purpose: Training goals and objectives;*
- *Content: Training content;*
- *Concepts: Human Factors concepts and definitions which form part of the course;*
- *Cost of maintenance errors;*
- *Human Factors knowledge;*
- *Understanding maintenance operations as a system: seeing the "big picture";*
- *Understanding basic Human Factors issues and human limitations: vision, hearing, information processing, attention and perception, memory, and the associated ergonomic issues related to workplace and task design;*
- *Recognizing the contributory causes to human errors: interactions with organizational procedures, groups and individual factors; reason model and the "Dirty Dozen";*

- *Communication skills;*
- *Understanding the consequences of poor communication;*
- *Communication methods (written, verbal, etc.);*
- *Communication content: relevance, correctness, conciseness and completeness;*
- *Communication purpose and target audience;*
- *Communication behaviour/style: assertiveness, aggression and feedback;*
- *Active listening, feedback, body language and facial expression;*
- *Effective writing;*
- *Recognizing approved or unapproved data;*
- *Overcoming barriers to the use of approved data;*
- *Shifting turnover/handover process;*
- *Teamwork skills;*
- *Team definition and discrimination from group;*
- *Team dynamics (positive/neutral);*
- *Team leadership: telling or selling, involving or delegating;*
- *Team building;*
- *Inter- and intra-team communication;*
- *Coordination and decision-making;*
- *Understanding the characteristics of an effective team;*
- *Understanding norms, their definition and identification;*
- *Effective meetings and different roles: chair, shaper, worker and finisher;*
- *Performance management;*
- *Stress: identifying stressors e.g. communication, role conflict, others;*
- *Pressure: be organized, get help and facts, and delegate;*
- *Shift work: fatigue, working hours, sleep, stress, and environmental factors;*
- *Complacency: identification and management;*
- *Situation awareness;*
- *Error chain recognition and control;*
- *Workload management: learning to say no.;*
- *Supervision and leadership;*
- *Human error;*
- *Error models (latent and active);*
- *Error classification and prevention;*
- *Task analysis: be proactive; "plan — do — check"; others;*
- *Defences: documentation; don't assume — check and ask; others;*
- *Changing conditions rather than changing people;*
- *Reporting and investigating errors;*
- *Company and state regulatory requirements;*
- *Immunity statements and disciplinary issues;*
- *Confidential reporting systems;*
- *Investigation responsibilities and procedures;*
- *Maintenance error data analysis and reporting of results;*
- *Feedback;*
- *Management decision-making;*
- *Monitoring and auditing;*
- *Team or individual: composition;*

- *Purpose: quality, ergonomic or others;*
- *Process and procedure;*
- *Audit findings, reporting and data analysis;*
- *Feedback and corrective action;*
- *Document design;*
- *Information content and readability;*
- *Writing well: be clear, concise and accurate;*
- *User involvement and field testing.*

Note 1. *— Items B to G are generally representative of modules recommended for Maintenance Resource Management (MRM) training.*

Note 2. *— Items H to J can be suitably added, as appropriate, to the basic Human Factors Course (items A to G) as specialist modules for staff such as managers, planners, auditors, quality engineers and incident investigators.*