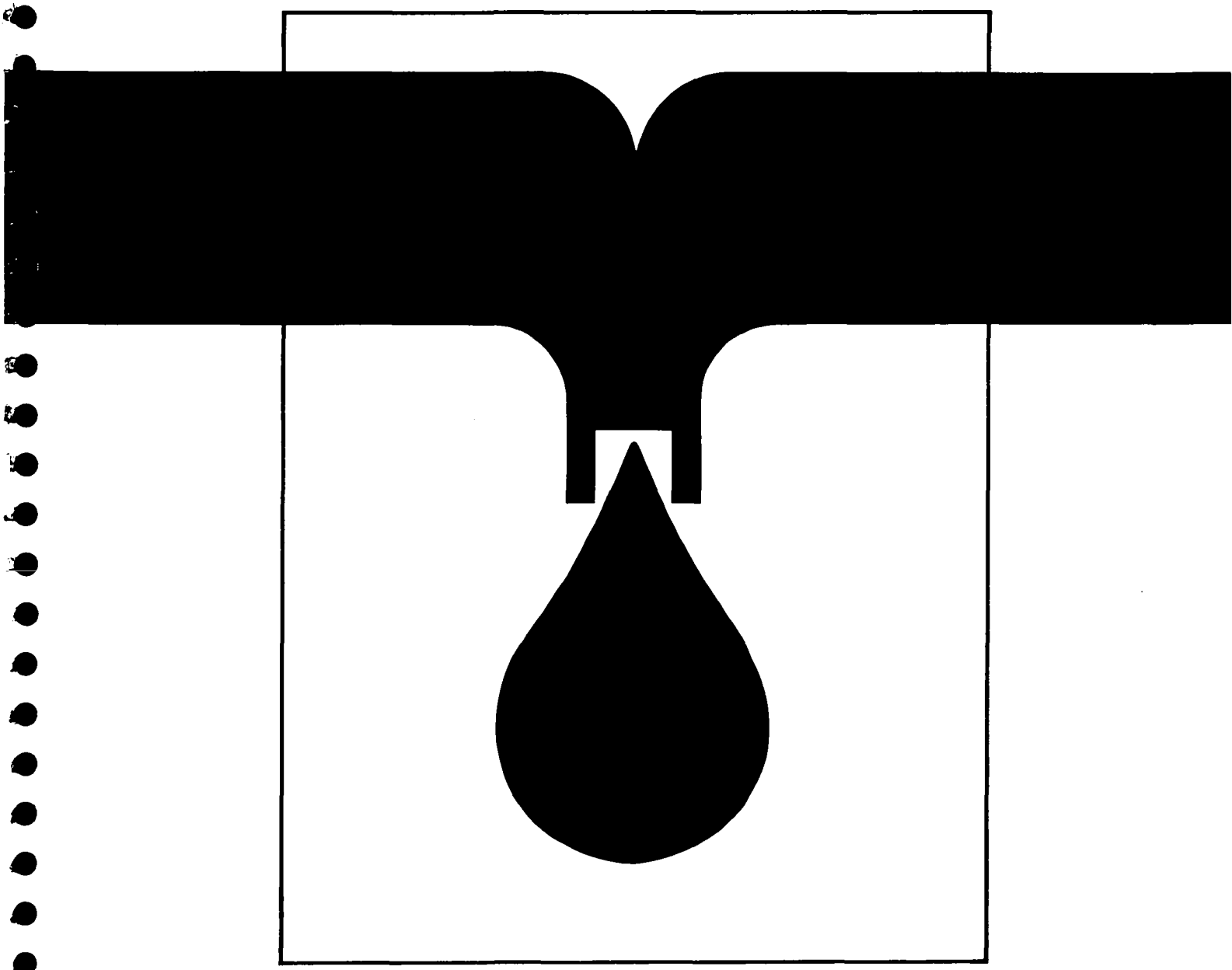
TRAINING MODULES
FOR
WATERWORKS PERSONNEL



Special Skills

3.3 a

Design and working principles
of diesel engines and petrol engines

Foreword

Even the greatest optimists are no longer sure that the goals of the UN "International Drinking Water Supply and Sanitation Decade", set in 1977 in Mar del Plata, can be achieved by 1990. High population growth in the Third World combined with stagnating financial and personnel resources have led to modifications to the strategies in cooperation with developing countries. A reorientation process has commenced which can be characterized by the following catchwords:

- use of appropriate, simple and – if possible – low-cost technologies,
- lowering of excessively high water-supply and disposal standards,
- priority to optimal operation and maintenance, rather than new investments,
- emphasis on institution-building and human resources development.

Our training modules are an effort to translate the last two strategies into practice. Experience has shown that a standardized training system for waterworks personnel in developing countries does not meet our partners' varying individual needs. But to prepare specific documents for each new project or compile them anew from existing materials on hand cannot be justified from the economic viewpoint. We have therefore opted for a flexible system of training modules which can be combined to suit the situation and needs of the target group in each case, and thus put existing personnel in a position to optimally maintain and operate the plant.

The modules will primarily be used as guidelines and basic training aids by GTZ staff and GTZ consultants in institution-building and operation and maintenance projects. In the medium term, however, they could be used by local instructors, trainers, plant managers and operating personnel in their daily work, as check lists and working instructions.

45 modules are presently available, each covering subject-specific knowledge and skills required in individual areas of waterworks operations, preventive maintenance and repair. Different combinations of modules will be required for classroom work, exercises, and practical application, to suit in each case the type of project, size of plant and the previous qualifications and practical experience of potential users.

Practical day-to-day use will of course generate hints on how to supplement or modify the texts. In other words: this edition is by no means a finalized version. We hope to receive your critical comments on the modules so that they can be optimized over the course of time.

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Prof. Dr.-Ing. H.P. Haug
and
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It is my sincere wish that these training modules will be put to successful use and will thus support world-wide efforts in improving water supply and raising living standards.

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Eschborn, May 1987

Title: Diesel engine, petrol engine

Table of contents:

1. Introduction

Every new internal-combustion engine comes with a manufacturer's operating manual, which details maintenance intervals, technical data and repair instructions to be observed in the event of faults. This manual must be carefully preserved.

Numerous skills are required for performing maintenance and repairs on internal-combustion engines (see Module 3.1).

2. Maintenance

The term "maintenance" refers to all inspections and operations which must be performed at specific intervals in order to ensure that the engine and its auxiliaries operate properly and that consequently the necessary operational reliability and the expected service life are achieved. Correct maintenance calls for knowledge of the scope of the work, maintenance intervals, degrees of difficulty, engine type and tools.

Particular importance must be attached to the careful recording of the major works undertaken and replacements of spare parts as shown in the example below.

Date	Operating hours	Operation	Remarks
11.3	552	Oil change Air cleaner replaced Spark plugs cleaned Spark gap adjusted Fuel filter replaced	10 W - 50 W
2.7	850	Spark plugs replaced Spark plugs adjusted Oil change	Bosch W 175 Oil filter replaced

The intervals specified in the table on the next page are based on recommendations and specifications from the engine manufacturers. In view of the wide variety of makes and types, however, the operating manual should always be consulted.

Table 1 : Maintenance work (1)

Type-specific	Air cooling	Water cooling	Four-stroke engine	Two-stroke engine	Spark-ignition engine with carburettor	Spark-ignition engine with fuel injection	Diesel engine	System Component / Interval	Before every start-up	Upon refuelling	10 hours	50 hours	100 hours	150 hours	200 hours	300 hours	Monthly	Six-monthly	Every 2 years	As required
			x		x	x	x	ENGINE: Valve clearance					x							
			x	x	x	x	x	Compression							x					
			x				x	Oil level - injection pump				x								
		x	x	x	x	x	x	V-belt					x							
	x		x	x	x			V-belt							x					
								EXHAUST SYSTEM: Condition of intake and exhaust manifold mountings												
			x	x	x	x	x	Check					x							
			x		x	x	x	LUBRICATION SYSTEM: Engine oil level		x										
				x				Lubricating oil level		x										
			x		x	x	x	Engine oil change				x								
			x		x	x	x	Check lubricating oil type									x			
		x	x		x	x	x	COOLING SYSTEM: Coolant	x	x										
		x	x		x	x	x	Freedom from leaks				x								
		x	x		x	x	x	Replace coolant											x	
		x	x		x	x	x	Clean radiator fins									x			
x		x	x		x	x	x	Lubricate water pump									x			
x	x	x	x				x	FUEL SYSTEM: Hand primer							x					
	x	x	x	x	x	x	x	Fuel pump filter							x					
x	x	x	x	x	x	x	x	Fuel filter							x					

Table 1 : Maintenance work (2)

Type-specific	Air cooling	Water cooling	Four-stroke engine	Two-stroke engine	Spark-ignition engine with carburettor	Spark-ignition engine with fuel injection	Diesel engine	System Component / Intervall	Before every start-up	Upon refuelling	10 hours	50 hours	100 hours	150 hours	200 hours	300 hours	Monthly	Six-monthly	Every 2 years	As required
	x	x	x	x	x	x	x	Freedom from leaks				x								
	x	x	x	x	x	x	x	Fuel level	x											
			x	x	x			CARBURETTOR SYSTEM: Clean carburettor										x		
			x	x	x			Idle adjustment					x					x		
			x	x	x			Lubricate carburettor linkage					x							
x			x		x			Oil level in a Stromberg carburettor				x								
			x	x	x			Carburettor mounting								x				
x	x	x	x		x			INTAKE SYSTEM: Intake air preheating										x		
	x	x	x	x	x	x	x	Air cleaner								x				
								POWER SUPPLY: Clean battery					x							
								Charge battery												x
								Battery electrolyte					x							
								Generator										x		
								Battery condition									x			
								Battery voltage									x			
x			x	x	x	x		IGNITION SYSTEM: Contact breakers					x							
			x	x	x	x		Firing point						x						
			x	x	x	x		Spark plugs					x					x		
			x	x	x	x		Distributor							x					

Revised:

3. Tools

Use of the correct tools is a decisive factor in successful maintenance work. As a result of the various engine types and the differences - some of them design-related - between components and systems of the same type, different tools are often required for performing the same maintenance work.

In the table below, "special tools" refers to special-purpose tools and workshop equipment (machines, testers).

A cross in the "Type-specific" column means that with regard to the tools indicated, the appropriate version for the engine type in question must be selected.

Table 2: Tools required for maintenance work (1)

System Component / Tool	No tools	Special tool	Type-specific	Spark-plug spanner	Feeler gauge	Compression tester	Screwdriver	Points file	Test lamp of stroboscope	Open-end wrench	Socket wrench	Allen key	Hammer	Flat-nose pliers	Brush	Compressed air	Grease gun	Strap for opening oil filter
Engine: Valve clearance		x	x		x					x	x							
Compression				x		x												
Cylinder head gasket	x																	
Oil level in fuel-injection pump	x																	
Clutch	x																	
V-belt	x																	
Exhaust system:	x																	
Lubrication system: Engine oil level	x																	
Engine oil change										x	x							x
Check lubricating oil type	x																	
Cooling system: Coolant	x																	
Freedom from leaks	x																	
Replace coolant	x																	

Table 2: Tools required for maintenance work (2)

System Compoment \ Tool	No tools	Special tool	Type-specific	Spark-plug spanner	Feeler gauge	Compression tester	Screwdriver	Points file	Test lamp of stroboscope	Open-end wrench	Socket wrench	Allen key	Hammer	Flat-nose pliers	Brush	Compressed air	Grease gun	Strap for opening oil filter
Clean radiator fins	X															X		
Lubricate water pump	X																	
Fuel system: Hand primer	X																	
Fuel-pump filter										X								
Fuel filter	X																	
Freedom from leaks	X																	
Carburettor system: Clean carburettor							X			X	X				X			
Idle adjustment							X											
Lubricate carburettor linkage	X																	
Oil level in a Stromberg carburettor	X																	
Air cleaner	X															X		
Intake air flap	X																	
Fuel-injection system: Air cleaner	X															X		
Fuel pump							X			X	X					X		
Power supply: Clean battery														X				
Charge battery		X																
Battery electrolyte level	X																	
Generator							X			X	X							
Battery condition		X																
Ignition system: Contact breakers					X			X										
Firing point			X						X	X								
Spark plugs				X														
Distributor								X										
Miscellaneous: Screw connections							X			X	X	X	X					

4. Faults

Procedure and fault diagnosis:

If a fault occurs, the following step-by-step procedure should be followed in order to ensure optimum fault finding and fault elimination.

Step	Operation	Aim
1	Fault overview	Fault diagnosis, system
2	Fault table	Fault diagnosis, component
3	Repair work	Fault elimination

Table 3: Fault overview (engine)

Problem \ System	Engine casing	Crankgear	Valvegear	Mechanical fuel-injection system	Fuel system	Carburettor system	Lubrication system	Cooling system	Exhaust system	Power supply	Starter motor system	Ignition system	Electronically controlled fuel-injection system	Electrical system
Engine difficult to start	x	x	x	x	x	x	x		x		x	x	x	
Starter motor does not turn										x	x			
Starter motor speed <		x					x			x	x			
Starter motor speed normal Engine does not start	x			x	x	x			x			x	x	
Engine stops suddenly					x	x						x	x	x
Engine misfires during acceleration												x		
Engine does not idle smoothly						x							x	
Engine speed <	x	x	x	x		x	x		x			x	x	
Engine speed fluctuates	x		x	x		x						x	x	
Engine output <	x	x	x	x		x	x	x	x			x	x	
Engine output fluctuates	x		x			x						x		
Engine temperature >		x		x		x	x	x	x			x		
Engine temperature <	x		x	x		x		x				x		
Engine temperature fluctuates			x	x										
Knocking noise				x	x							x		
Pinging noise				x	x				x			x		
Squeaking noise								x						
Rattling noise		x	x	x			x	x	x			x		
Throbbing noise									x					
Fuel consumption >		x	x	x	x							x	x	
Oil consumption >	x	x	x	x			x	x						
Coolant loss >	x						x	x						
Failure of an electrical device										x				x

The fault overview aids in rough localization of a fault. The system which may contain the fault can be determined on the basis of the problem.

In order to achieve rapid and reliable fault diagnosis, it is essential to be familiar with the structure and mode of operation of the various systems and, where appropriate, with the way in which they interact.

Table 4: Fault overview (engine electrics)

Fault / Cause of fault	Lamp does not light up with ignition on	Lamp lights up when n >	Lamp goes out when n ↓ and glows when n >	Lamp glows with engine running if additional loads are switched on	Lamp flickers	Battery charge <	Regulator defective	Terminal voltage <	Voltage drop if load >
Power supply: Charging voltage <		x							
Battery charge <	x								x
Battery wrongly connected							x		
Interturn short circuit in generator						x			
DC generator commutator						x			
Consumption by loads >				x					
Battery defective	x					x			x
Battery sulphated									x
Generator defective		x				x			
Generator brushes worn						x			
Components: Bulb defective	x								
Ignition/starter switch	x								
Regulator defective	x	x				x			
Regulator setting			x						
Engine: V-belt loose		x			x	x			
V-belt broken		x							
Wiring system: Circuit interruption	x	x				x			
Contact resistance >		x	x	x		x		x	
Short circuit to chassis		x				x			x
Loose connection					x			x	

In conjunction with this topic, possible causes of a rise in engine temperature are briefly listed below:

- Thermostat sticking
- V-belt is broken or slips
- Water pump defective
- Radiator core clogged
- Radiator cap defective
- Insufficient coolant
- Radiator blind not open
- Cylinder head gasket defective

4.1 Assessment of engine condition according to the appearance of the spark plugs

The spark plug face is an important indicator. The term "spark plug face" refers to the appearance of the insulator nose and the electrodes after a lengthy period of use. It shows whether the correct spark plug has been chosen and whether the engine is operating properly, in particular whether the carburettor setting is correct.

Spark plug face:	Conclusion:
Insulator nose fawn-coloured, housing and electrodes covered with fine grey soot deposit, or with greyish-yellow deposit in the case of leaded petrol.	The spark plug has the right heat rating, the mixture composition is correct and the engine is operating properly.
Insulator nose is burned white (beads), melted grey deposit in the case of leaded petrol, corrosion on the electrodes.	The spark plug has too low a heat rating and becomes too hot. The mixture is too lean or the spark advance too great.
Insulator nose, electrodes and breathing space are contaminated with soot and carbon residue	The spark plug has too high a heat rating and remains too cold, or the mixture is too rich.

4.2 Battery maintenance

Every four weeks, fill up with distilled water to the level indicated in the operating instructions (generally 10 to 15 mm above the plates). Determine the state of charge by measuring the electrolyte density, recharging if necessary. Keep the battery clean and dry. Grease all metal parts and keep the air holes of the vent

plugs clear. Do not allow batteries with plastic cases to come into contact with petrol, benzene, paraffin, oil spray and similar liquids.

On installation, first connect the positive terminal, then the negative terminal; on removal, first disconnect the negative terminal, then the positive terminal (in the case of negative earth).

A battery's life will be extended if its state of charge is always correct. It should never be completely discharged or continuously overcharged. When the engine is idling or at rest, ensure that no load is unnecessarily switched on. Do not overstress the battery when starting: start for a maximum of 10 seconds, then pause. Neutralize spilled electrolyte with soda solution or ammonium hydroxide and replace with fresh acid of the same density. Have the battery expertly checked in spring and autumn.

When not in use a filled and charged battery loses approximately 1 % of its ampere-hour capacity daily. If a battery which is not in use for a lengthy period of time exhibits a white deposit on the plates (lead sulphate), it should be charged for 40 hours applying one-quarter, then the full charging current specified in the operating instructions. Unused batteries should be recharged approximately every six weeks and stored in a cool, dry place. However, if the battery is not to be used for a prolonged period, the acid should be replaced by distilled water after charging; the battery should then be recharged for six hours, the water drained off and the battery refilled with distilled water.

During charging, the positive terminal of the battery should be connected to the positive terminal of a DC current source (battery charger) and the negative terminal of the battery to the negative terminal of the source. Ensure that the prescribed charging current is supplied (in most cases, approximately one tenth of the rated capacity, i. e. 6.6 A for a 66 Ah battery). Charge until the cells have gassed for half an hour, the voltage has ceased to increase and the electrolyte density is 1.28 kg/l. Ventilate the charging room (formation of oxhydrogen explosion hazard, do not perform soldering or welding work on batteries using an open flame). During charging, the electrolyte temperature should not exceed 55°C. Upon completion of charging, check the electrolyte level, filling up if necessary with distilled water.

5. Bibliography

The literature used in Module 3.3a is listed below.

Passages have in some cases been taken word for word from the sources mentioned.

a. Riedl, Heinrich — Kraftfahrzeuge, Störfälle - Fehlerbehebung

b. Riedl, Heinrich — Kraftfahrzeuge, Wartung - Pflege

c. Schwoch, Werner — Das Fachbuch vom Automobil Westermannverlag, 1976

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TRAINING MODULES FOR WATERWORKS PERSONNEL

List of training modules:

Basic Knowledge

0.1 Basic and applied arithmetic
0.2 Basic concepts of physics
0.3 Basic concepts of water chemistry
0.4 Basic principles of water transport
1.1 The function and technical composition of a watersupply system
1.2 Organisation and administration of waterworks

Special Knowledge

2.1 Engineering, building and auxiliary materials
2.2 Hygienic standards of drinking water
2.3a Maintenance and repair of diesel engines and petrol engines
2.3b Maintenance and repair of electric motors
2.3c Maintenance and repair of simple driven systems
2.3d Design, functioning, operation, maintenance and repair of power transmission mechanisms
2.3e Maintenance and repair of pumps
2.3f Maintenance and repair of blowers and compressors
2.3g Design, functioning, operation, maintenance and repair of pipe fittings
2.3h Design, functioning, operation, maintenance and repair of hoisting gear
2.3i Maintenance and repair of electrical motor controls and protective equipment
2.4 Process control and instrumentation
2.5 Principal components of water-treatment systems (definition and description)
2.6 Pipe laying procedures and testing of water mains
2.7 General operation of water main systems
2.8 Construction of water supply units
2.9 Maintenance of water supply units Principles and general procedures
2.10 Industrial safety and accident prevention
2.11 Simple surveying and technical drawing

Special Skills

3.1 Basic skills in workshop technology
3.2 Performance of simple water analysis
3.3a Design and working principles of diesel engines and petrol engines
3.3b Design and working principles of electric motors
3.3c –
3.3d Design and working principle of power transmission mechanisms
3.3e Installation, operation, maintenance and repair of pumps
3.3f Handling, maintenance and repair of blowers and compressors
3.3g Handling, maintenance and repair of pipe fittings
3.3h Handling, maintenance and repair of hoisting gear
3.3i Servicing and maintaining electrical equipment
3.4 Servicing and maintaining process controls and instrumentation
3.5 Water-treatment systems: construction and operation of principal components: Part I - Part II
3.6 Pipe-laying procedures and testing of water mains
3.7 Inspection, maintenance and repair of water mains
3.8a Construction in concrete and masonry
3.8b Installation of appurtenances
3.9 Maintenance of water supply units Inspection and action guide
3.10 –
3.11 Simple surveying and drawing work

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