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# HANDBOOK

# ON

# OPERATION AND MAINTENANCE OF EQUIPMENT AND BASIC VILLAGE INFRASTRUCTURE PROJECTS

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**FEBRUARY 1989**
**O&M-T-1(E)**

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*O&M group is extending its gread thanks and gratitude to all those who contributed in preparing and editing this handbook.*

*It is our hope that the O&M group has succeeded in spreading maintenance awareness among O&M officials, and adding new relevant materials that illustrate both scientific and practical aspects of O&M*

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# INTRODUCTION

The operation and maintenance of infrastructure projects are one of the basic factors for the efficient continuity of those projects. Accordingly, it is very important to train personnel in the ideal techniques of operation and develop a good maintenance system.

Operation and maintenance is a very profitable investment since it ensures quality and regularity of service, and maintains project assets for the longest possible utilization period.

Thus, the main purpose of this handbook is to provide assistance in the field of O&M to engineers and technicians working on infrastructure projects. It demonstrates O&M techniques with rules, organization, planning and management.

Whenever there is work, there are problems and difficulties. This is natural but should not stop projects operating and people benefiting from them. This would be a waste of public money. Practice and follow up experiences show that the cause of difficulties can be basically summarized as lack of understanding of maintenance techniques and performance at all levels. Some problems are caused by neglect of O&M cost considerations in project planning. This results in poor selection of projects and equipment, either because the selected technology is too sophisticated, or the choosen equipment is not adequate for the planned work. Lack of good design guidelines for maintenance workshops and centers can result in poor site selection and access, inaccurate technical specifications of work items, and lack of enough space inside MCs for easy movement. All these have negative effects on project efficiency and adequacy.

The handbook introduction is followed by the first chapter which discusses O&M considerations at planning and design stages and the drawing up of equipment technical specifications and maintenance contracts.

The second chapter presents equipment operation instructions, either for the operator or the authority responsible for operation.

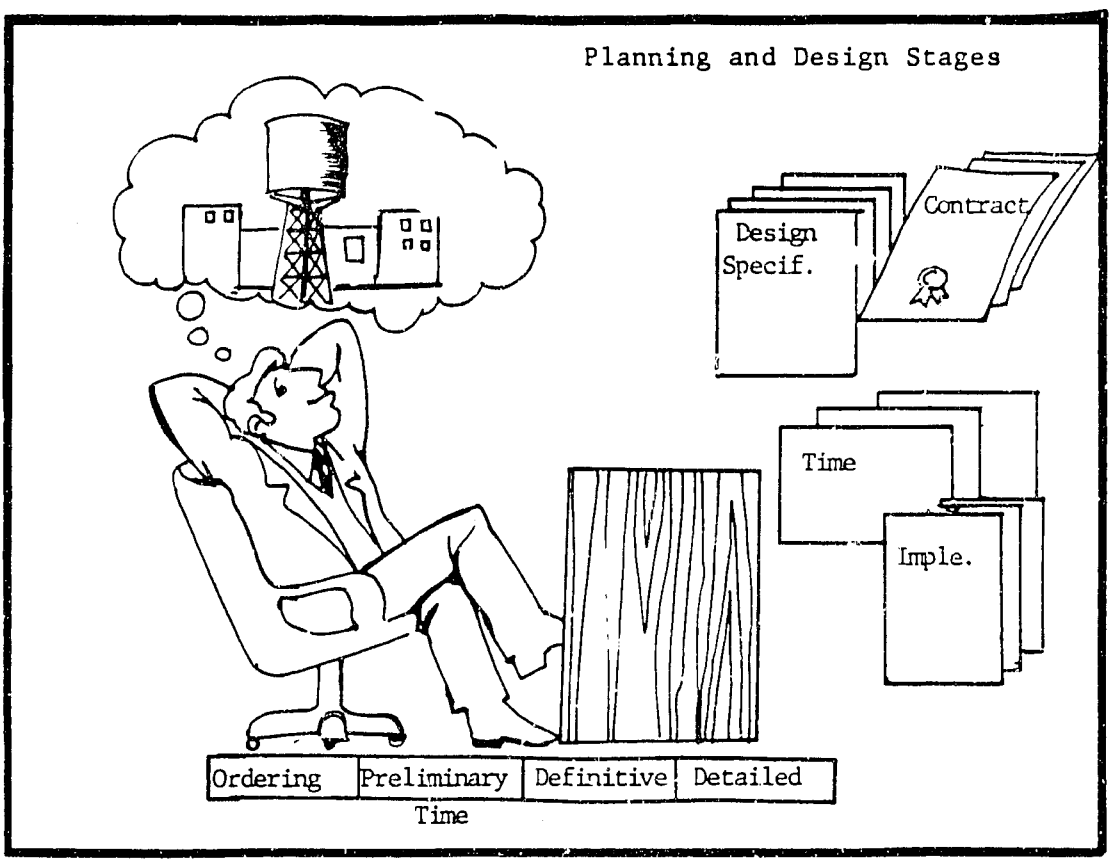
The third chapter discusses types of periodic maintenance for water, wastewater and road projects, heavy equipment, and vehicles. This includes maintenance periodicity and required technical procedures and operations for each type of maintenance.

The fourth chapter discusses troubleshooting for diesel engines, electric motors, water pumps, vehicles and equipment.

The fifth chapter discusses organization and management of maintenance workshops and centers with regard to organizational and functional structure, the documentary cycle of maintenance and repair, the way of managing those centers, warehouse planning systems, and management of stored spare parts. In addition, there is a proposed incentive system for maintenance center personnel and the assessment factors that should be considered when determining the incentive value to raise performance rates. The chapter also reviews different types of vocational training for O&M personnel and training methods. Finally, the chapter presents industrial safety instructions when using hand tools, mechanical and electrical devices, and when operating cranes.

# Section 1

OPERATION AND MAITENANCE
CONSIDERATIONS DURING
PLANNING AND DESIGN STAGES



## SECTION ONE
## OPERATION AND MAINTENANCE CONSIDERATIONS DURING PLANNING AND DESIGN STAGES

### 1.1 OPERATION AND MAINTENANCE CONSIDERATIONS DURING PROJECT PLANNING STAGEO

Maintenance in itself is an independant investment as it results in the ideal utilization of operation capacities and the growth of production revenues. Maintenance is a productive operation that should not start at the beginning of a project's operation, but at the early planning stages. It should be taken into consideration when deciding the project specifications and before project selection.

If we do not take long term O&M costs into consideration when planning a project, it could result in poor selection of project type (dirt or asphalt roads), poor selection of the type of equipment purchased (cheap, high operation and maintenance costs). Thus project maintenance and productivity are two connected and concurrent operations which imply giving attention to O&M considerations at a project's selection and planning stage. As is well known, projects give a service, while maintenance is concerned with the quality of that service.

The basic role of maintenance is shown by the fact that it:

- o Maintains the project or equipment in good operating condition during its operational period
- o Ensures operation continuity with a high level of effectiveness and efficiency, with the utmost economy of time and cost.

Accordingly, it is necessary to take O&M into consideration when starting to plan for project or equipment requirements.

Project Planning Considerations:

There are several considerations that should be taken into account when planning projects. Planning start with identifying the reasons behind establishing the project, and ends with necessary the O&M procedures. Figure 1.1 shows a summary of different planning stages and procedures and O&M location at all project stages. These steps or procedures can be summarized as follows:

---

o The word "project" is used occasionally to express the equipment, machine, facility or different installations, in addition to its common meaning of a series of connected operations which lead to achieving certain objectives.

A. Project Needs Description:

This includes the preliminary description of project size, and whether it is going to solve an existing problem or future ones in the framework of a long term plan.

B. Preparation of a Feasibility Study:

This specifies the beneficiary authorities and persons, and the project's social and economic and environmental effects. This study will be prepared by the authority requesting the project.

C. Project Size and Costs Study:

This is done using the project preliminary description. This study should be prepared by a work team of technicians and financial affairs personnel at the markaz level at least. It takes into consideration the feasibility study, and suitability of the proposed site for the project. The study should include determining the required annual cost for operation and maintenance of a project's units during its estimated life-span.

D. Study of Project O&M Funding Resources Until the End of its estimated life span:

This includes: o Studying different available project funding resources (government-grants, loans, popular contribution, ... etc). o Studying O&M funding resources and proposed style of operation (governmental, investing, economical)

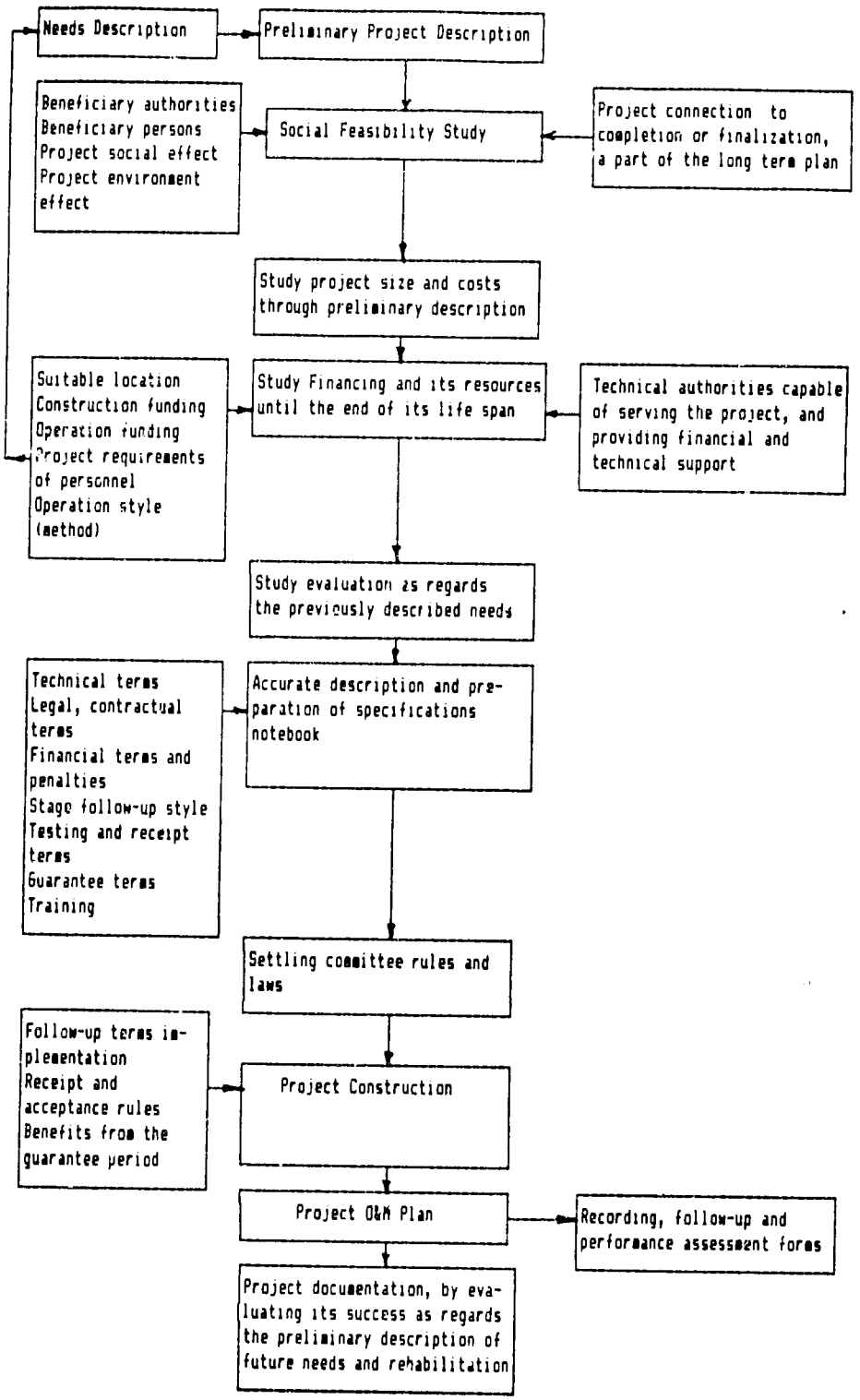
- o Technical bodies capable of operating and maintaining the project (public or private sector)
- o Ways of recruiting required technical labour
- o Necessary training programs
- o Identifying O&M funding resources future needs (if it is implemented in stages)
- o The ways of funding rehabilitation.

The study contents show that it should be prepared at the markaz or governorate level according to the project size, nature and location. The study could be also assigned to external specialized bodies such as universities, consulting offices ... etc.

E. Evaluation Study:

This is carried out by the technical and financial authorities at the markaz or governorate level according to project type, in cooperation with local popular councils. It will determine the extent of achieving projects' described needs, and the volume of popular contribution at the different implementation stages up to the rehabilitation stage: Also, reference is made to the project request in case there are any remarks or specifications that need amendment or should be included before starting to prepare the terms and specifications notebook.

Figure 1.1
PROJECT PLANNING STAGES



F. Preparation of Projec[illegible]urate Technical Description, and Terms and Specif[illegible]ns Notebook for Tendering:

The following items are considered:

- o Legal and contractual terms
- o Financial terms and penalties
- o Technical specifications of work items and the contractor [illegible]r supplier responsibility. This includes that the supplier of the projects' mechanical or electrical components or complete equipment should provide a list of fast wearing spare parts (filters, gaskets, bearings, etc) equivalent to at least 10% of the equipment price.
- o Interim follow up methods during implementation, responsible personnel and correspondence and notifications style.
- o Primary receipt, te[illegible]ng and final receipt terms
- o Guarantee period te[illegible]
- o Terms of training on different implementation stages and operation
- o Stipulation of presentation of implementation schedule

A higher level committee should be formed to inspect and review the terms and specifications notebook before tendering and requesting bids and fixing a date for the awarding session.

G. Studying bids and Awarding:

In evaluating bids, those matching the projects' technical terms and specifications and requiring less O&M costs should be selected. This is done by studying the economics of the project, taking into account unifying equipment types as much as possible to make easier provision of spare parts and materials in the projects' operation and maintenance.

H. Project Implementation:

An engineer responsible for the project should be assigned to do the following:

- o Follow up implementation according to the standard technical terms and specifications
- o Ensure the contractor abides by the implementation schedule
- o Take primary receipt of project according to the technical basis previously mentioned in the terms and specifications notebook.

- Organize benefits to be obtained from the guarantee period after the testing operation is finished. The engineer's connection with the project should continue until the guarantee period is finished and operation is regular.
- The engineer will prepare and present the site register as a complete documentation of the implementation period.

I. Project Operation:

- A plan should be prepared for project O&M after final handover, showing time tables for different types of maintenance, and annual needs for spare parts, raw materials, and components.

- A record or register of follow up O&M must be kept on a prepared form in order to evaluate performance.

- A record of the actual costs of the project must be kept as soon as it in operation in order to rectify any deficit or increase in prices when determining the next year's budget.

J. Project Documentation:

All previously mentioned project documents and papers should be collected, in addition to the site register, financial acquittances, final account, primary and final receipt, testing results, performance report during guarantee period and O&M QPR during first year, as all of these are a record of experience to be used and referred to when planning a similar project in the future.



5

## 1.2 O&M CONSIDERATIONS DURING MAINTENANCE WORKSHOPS AND CENTERS DESIGN STAGE

Before starting to design and implement maintenance facilities, such as village workshops and maintenance centers, a program should be prepared specifying the work to be done, the time required and a suitable date to start. This program should show a logic sequence of work so as to avoid difficulties during implementation and to achieve objectives quickly and with minimum effort.

The work program can be divided into the following:

A. Project selection and preparation of preliminary design with all technical details.

B. Construction maintenance facilities buildings which includes the following:

- o Selection of maintenance facility final location
- o Preparation of building and constructions designs
- o Tendering the buildings and construction

C. Description of required machines and equipment, including:

- o Detailed specifications of tools, machines and equipment
- o Tendering the supply of tools, machines and equipment

Presented here are summarized guidelines on how to design maintenance units usually required at the local level (VC's worksnops, MMC's). These guidelines could be also used for designing larger maintenance units, such as governorate maintenance centers, but some modifications to allow for the increased size would be needed:

a. The design should be suitable for the function of the facility that will use both the site and the building in future. This requires determining adequate dimensions, aerial connections (on site and building), special fittings, installations, finishings and features.

b. The design should be flexible and expandable: The site and building designs should take into consideration possible future expansion, as building utilization changes over a period of time which could require more area or changes in the use of existing space. Figure 1.2 shows some types of site plan with their expansion potential.

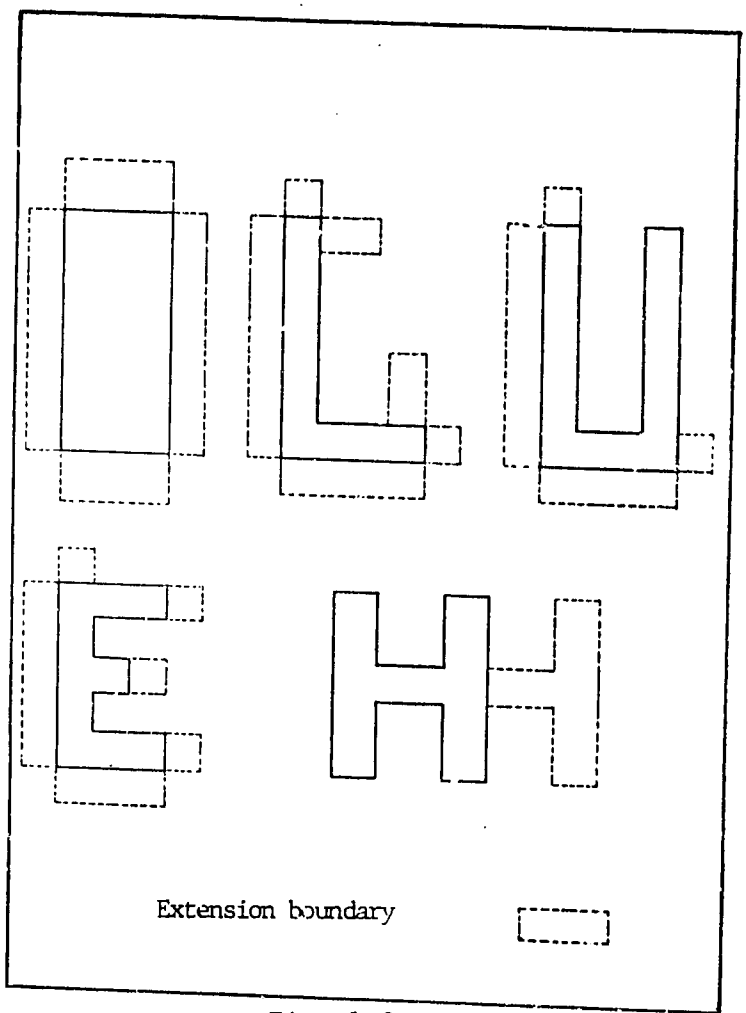



Fig. 1.2
Type of site planning and extension boundary

c. The design should allow for ease of maintenance: Both the site and building are part of the public infrastructure that should be operated and maintained. Therefore, the preliminary design should allow for ease of O&M by ensuring the use of adequate materials and adhering to finishing specifications.

d. Design should consider safety, and ease of control: Correct dimensions of stairs, entrances and corridors, doors opening to the outside, the provision of fire-extinguishers, protection from water overflows, and placing circuit-breakers in proper places are design safety considerations.

To raise the efficiency control of operations, management offices should be centralized and movement inside the building facilitated.

Figures 1.3, 1.4 and 1.5 show some proposed models presenting internal planning of maintenance units according to available space, and the level at which the unit is established.

In addition to good design, achieving the required final result will not be accomplished without:

- Direct supervision of construction
- Choosing the contractor who is capable of implementing the job (not just the lowest bidder)
- Continuous and interim inspection of construction operations on site (preferable daily)
- Refusing to accept poor quality work by suspension of any performance rewards and final payments until the job is done correctly as required

Table 1.1 shows what is recommended as regards building selection and design considerations, and its application capabilities to different maintenance facilities, in order to assist in developing and reviewing design.

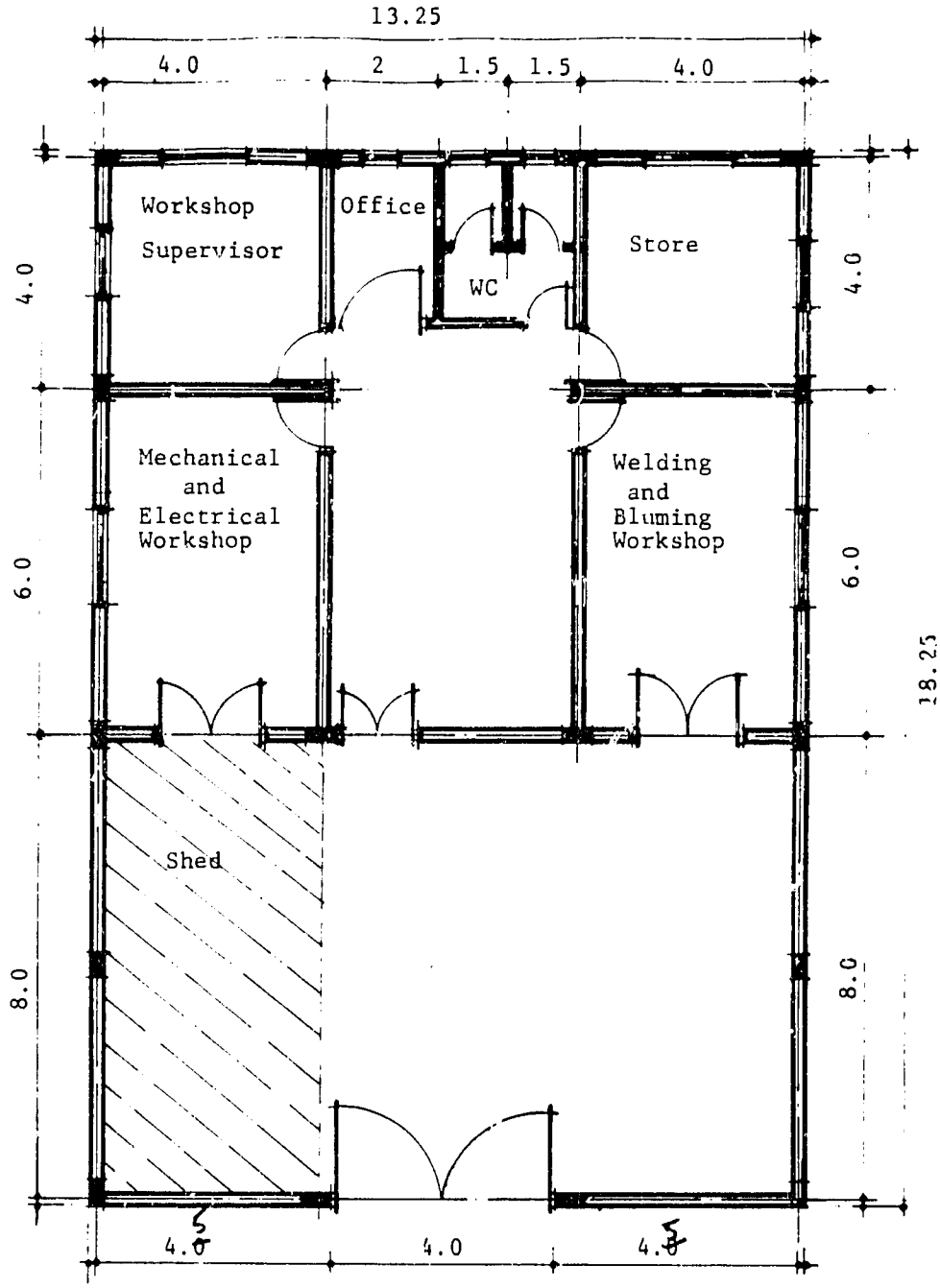



Fig. 1.3

V/C Workshop Model (A)

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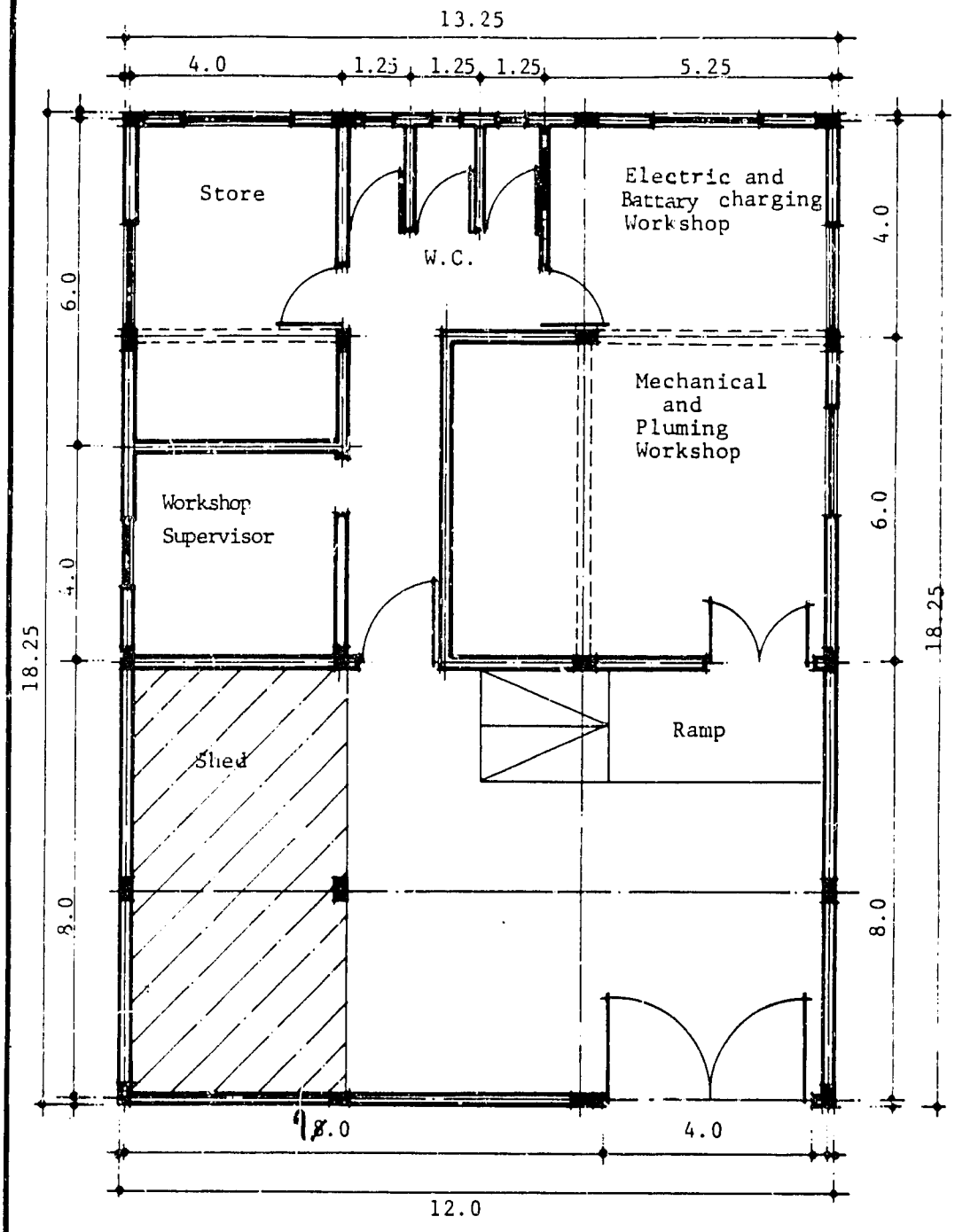


Fig. 1.4
V/C Workshop Model (B)

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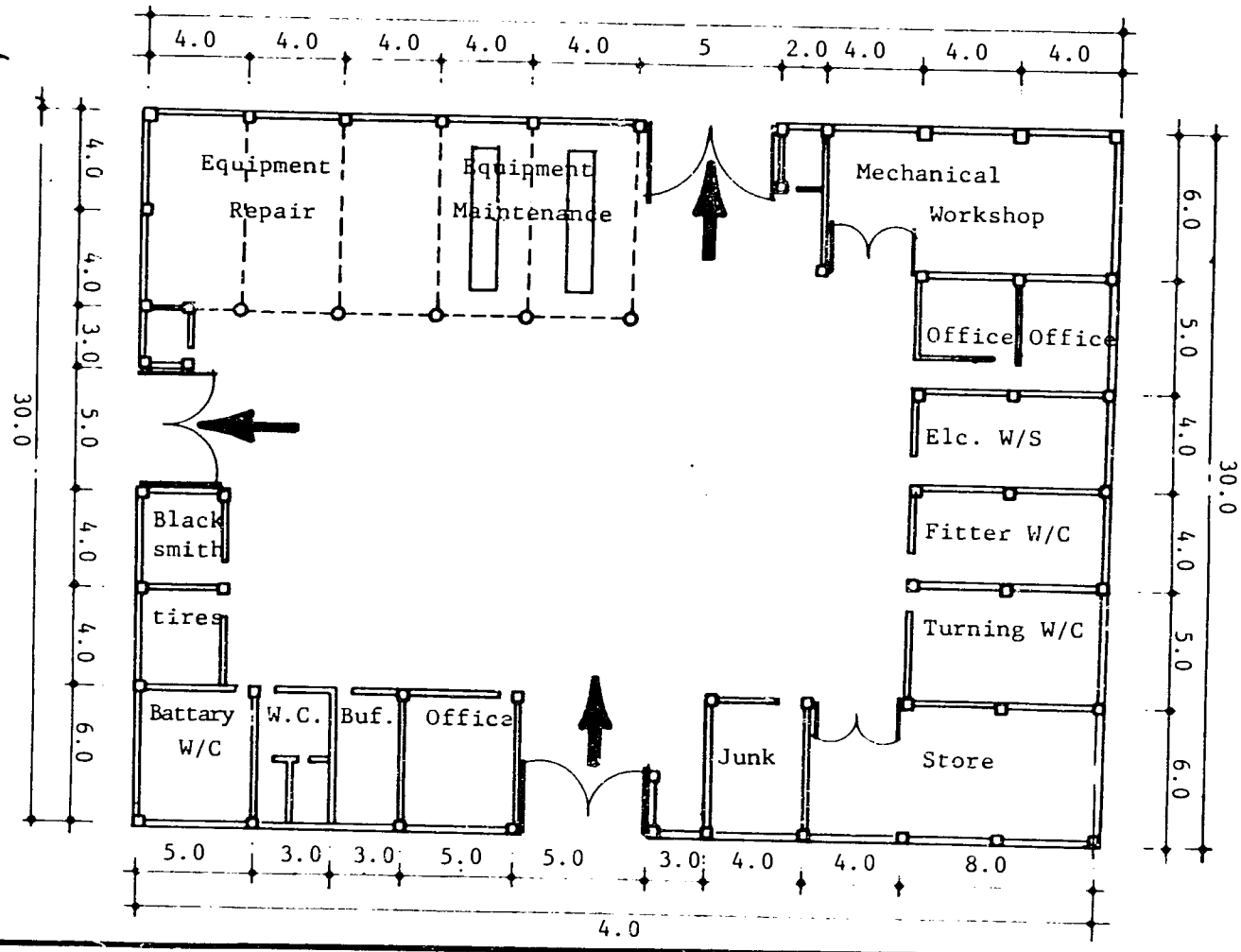
Fig. 1.5
Markaz Maintenance Center Model



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## MAINTENANCE FACILITY SITE SELECTION AND DESIGN GUIDELINES

| SITE SELECTION CONSIDERATIONS | VILLAGE WORK-SHOPS | MARKEZ MCs & GARAGE | WATER WORK-SHOPS | OTHER |
|---|---|---|---|---|
| *Site should be level and flat | YES | YES | YES | YES |
| *Site should have direct & easy access to a main road | MAYBE | YES | YES | MAYBE |
| *Site should be located in industrial or non-residential area | MAYBE | YES | YES | MAYBE |
| *Site should have space for expansion | YES | YES | YES | YES |
| *Site should have adequate space for buildings, parking and storage | MAYBE | YES | MAYBE | MAYBE |
| *Site should be roughly square in proportion | YES | YES | YES | YES |
| SITE DESIGN CONSIDERATIONS | | | | |
| *Site design should arrange buildings and circulation to allow ease of future expansion and upgrading, as well as O&M | YES | YES | YES | YES |
| *Site design should have large (minimum 20x30m) courtyard for turning, parking and maneuvering vehicles and equipment | MAYBE | YES | MAYBE | MAYBE |
| *Courtyard should be partly covered by lightweight roof or trees to provide shade for outside work | YES | YES | YES | YES |
| *Courtyard should be paved with gravel over a compacted fill subgrade | MAYBE | YES | MAYBE | MAYBE |

Note: MAYBE indicates that judgement depends on a case-by-case assessment.
N/A indicates that the consideration is generally not applicable.

## MAINTENANCE FACILITY DESIGN GUIDELINES

| BUILDING DESIGN CONSIDERATION | VILLAGE WORK-SHOPS | MARKEZ MCs & GARAGE | WATER WORK-SHOPS | OTHER |
|---|---|---|---|---|
| *Building layout should arrange spaces and circulation to allow ease of future expansion and upgrading, as well as O&M | YES | YES | YES | YES |
| *Main workshops should be large rooms (minimum 4x8m) with layout and size depending on required activities, equipment and materials | YES | YES | YES | YES |
| *Offices should generally be located on the first floor, not the ground floor | MAYBE | YES | MAYBE | MAYBE |
| *Manager's office should have good sightlines to workshops and be raised in large facilities | YES | YES | YES | YES |
| *Toilets should be located away from public view and be well-ventilated | YES | YES | YES | YES |
| *Design should feature pull-through vehicle repair and maintenance bays | NO | YES | NO | MAYBE |
| *Vehicle and equipment bays should have reinforced concrete flooring | N/A | YES | MAYBE | MAYBE |
| *Workshops should have smooth concrete flooring with tile or concrete to other areas (i.e. offices, stores, toilets) | YES | YES | YES | YES |
| *All workshop flooring and pavement should slope to grated drains and then to collection sump | YES | YES | YES | YES |
| *Workshops should have grade access or ramps from ground level | YES | YES | YES | YES |
| *Greasing and service bays should have floor hoists or built-up ramp, instead of grease pits below grade | N/A | YES | N/A | MAYBE |
| *Main workshops should have wide doors (minimum 2.4m, overhead roller type) to accommodate vehicles and equipment | YES | YES | YES | YES |

(continued)

MAINTENANCE FACILITY DESIGN GUIDELINES

| BUILDING DESIGN CONSIDERATION | VILLAGE WORK-SHOPS | MARKEZ MCs & GARAGE | WATER WORK-SHOPS | OTHER |
|---|---|---|---|---|
| *Ground floor structure should have heavy columns or protective bollards for lightweight columns | MAYBE | YES | MAYBE | MAYBE |
| *Ceilings should be high (minimum 3.5m) for cooling in summer and accommodation of large vehicles and equipment | YES | YES | YES | YES |
| *Rooms should have ceiling fans and through ventilation at high level | YES | YES | YES | YES |
| *Workshops should have high windows with security bars and shutters but no glass | YES | YES | YES | YES |
| *Workshop ceilings should have built-in hoist hooks | YES | YES | YES | YES |
| *All workshop light fixtures should have protective covers | YES | YES | YES | YES |
| *Storerooms and workshops should be fitted with built-in shelves, cabinets, workbenches, etc. | YES | YES | YES | YES |
| *Workshops should have circuitbreakers and appropriate fire extinguishers by the entry door (especially in workshops for welding and batteries) | YES | YES | YES | YES |
| *Workshops should have a wash-up sink by the entry door (with taps at or a hose to other room locations) | YES | YES | YES | YES |
| *Large facilities should provide compressed air via a central pump with a hose reel | MAYBE | YES | MAYBE | MAYBE |
| *Specialized workshops (for injectors, hydraulic pumps/cylinders, fuel pumps and control valves) should be located in dust-free clean rooms | N/A | YES | N/A | MAYBE |

## 1.3 GENERAL CONSIDERATIONS FOR DRAWING UP EQUIPMENT TECHNICAL SPECIFICATIONS AND MAINTENANCE CONTRACTS

### 1.3.1 General Considerations for Equipment Technical Specifications

Accurate technical descriptions of equipment are one of the most important factors to be emphasized during the planning stage. Accordingly these specifications should be accurately prepared by technicians as they are the only criteria or basis on which equipment is received from the supplier.

The following are some of the general considerations to be taken into account when drawing up equipment technical specifications:

1. Specification of required year of manufacture of the equipment.
2. Definition of required engine specifications in detail, showing the engine type (diesel - gasoline), horsepower, required cooling system, and type of air, fuel and oil filters.
3. Accurate specification of driving cabinet, the metal used in manufacturing it and the components of the gauges and indicators' tableau.
4. Type of body, structure and required fittings.
5. Type of transmission (either manual or automatic), required number of front and rear speeds, and type of front or back traction, or both.
6. Power steering type (either mechanical or hydraulic).
7. Type and number of required tires, including spare.
8. Type of brakes required (either hydraulic or with compressed air, or both).
9. Electric circuits and the required battery voltage.
10. It should be stipulated that the bid should be accompanied by a list of fast wearing spare parts equivalent to at least 10% of the equipment price.
11. The bid should include a list of hand tools, whether ordinary or special ones, necessary for maintenance or repair.
12. The provision of a sufficient number of O&M, spare parts and repair catalogues.
13. The bid should include a maintenance and repair contract for at least two years beyond the guarantee period.

Appendix "A" includes some examples of the items to be mentioned when drawing up equipment general technical specifications. They are:

- Bulldozer on tires
- Motorgrader
- Road roller
- Scraper
- Small sewage dump truck
- Small refuse dump truck
- Water spray truck, rear spray, small
- Sewage pipe cleaning truck, jet type
- Light columns repair and maintenance truck
- Tractor
- Workshop equipped truck

### 1.3.2 General Considerations for Equipment Service Contract Items:

As most heavy equipment (specially road equipment) is highly sophisticated, preventive maintenance and repair are usually beyond the capacities of personnel working in local maintenance workshops and centers.

Therefore, when equipment is purchased it is preferable to draw up a maintenance and repair contract, so that the supplier is committed to perform all the maintenance and repairs stipulated in the contract. This ensures the efficient continuity of equipment operation because repairs will be made as soon as possible according to standard specifications.

Accordingly the terms and specifications of the contract are most important as they control the equipment's maintenance and repair during operation. Below are listed some basic terms to be taken into account when tendering such a contract, but local units should add any other terms according to their particular situation.

Terms to be considered in a maintenance and repair contract:

- The supplier will perform quarterly periodic inspection of the equipment on site. This will include testing all parts, engine system, braking system and hydraulic system according to each type of equipment and on the basis of the manufacturer's instructions.

- The supplier agrees to repair troubles discovered during inspection and pay for required technical labour. The governorate will be responsible for the expense of spare parts, materials, oils and greases either by paying cash to the supplier if he provides them, or the governorate will provide them from its warehouses if they are available there.

- The supplier agrees to perform biannual equipment maintenance on site, including all system adjustments and changing damaged components.

- If the equipment breaks down during the three months guarantee period, the supplier should be notified of the details of the trouble, and he is committed to repair it within 15 days. Such repair is done on site except when it requires using equipment in the supplier's workshop that cannot be moved to the site.

- The equipment supplier is committed to providing all spare parts necessary for O&M operations for the period decided on by the governorate technicians. Spare part prices will be agreed upon in the light of required quantities and the technicians' opinions on the suitability of prices. Payment will be paid in local currency.

- The supplier agrees to perform all equipment and parts repairs except for the engine overhaul. This will be at the expense of the governorate according to a detailed bill of quantities presented by the supplier. This bill must include details of all required spare parts and their prices, and the cost of repairs. The governorate may provide spare parts (included in the bill of quantities) that it has available. The value of governorate provided parts will be deducted from the total cost.

- In all cases the supplier bears transportation, and lodging expenses for personnel performing equipment inspections, maintenance and repairs inside the governorate.

- The supplier should use a sufficient number of specialized and skilled labourers, and be responsible to the governorate (or the requesting authority) for delivering the equipment in good condition on a fixed date. If there are any delays he will be subject to penalties until handing over.

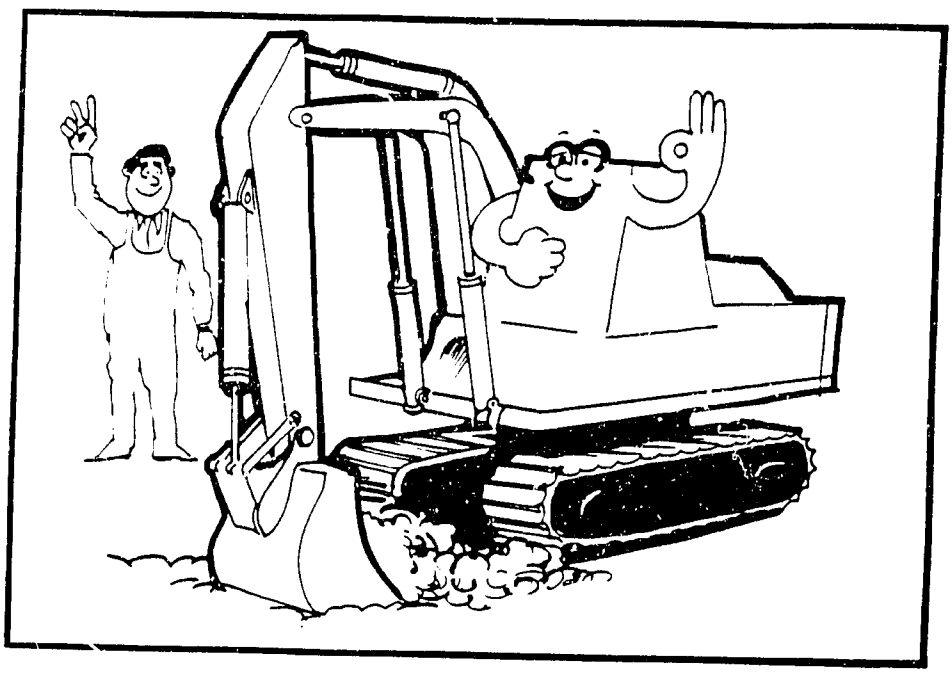
- The supplier will be fully responsible for taking necessary procedures and precautions against any accidents or injuries to workers during operation. He is also solely responsible for any damage to government or individuals property. The governorate bears no responsibility for any deaths, injuries, robbery or compensation.

- The supplier should abide by all relevant government and local laws and regulations.

- This contract is valid for two years starting from the signing date, aside from the equipment guarantee period.

# Section 2

OPERATION



## SECTION TWO

### Operation

Proper operation of equipment is one of the most important factors in maintaining it, reducing repairs, extending of preventive maintenance periodicity and saving expenses. If the equipment is misused this will result in increased troubles, low performance, increase of operation costs and the equipments' work program will not be implemented.

If equipment operated as a service is not used properly, the interests of citizens will be affected. If it is used for production, productivity will decrease together with that of the facility. This will mean losses or decrease in profits. Therefore, operation is one of the most important factors to be taken into consideration regarding projects and equipment. It should even be placed first, as a successful project depends mainly on proper operation.

Operation is a series of steps performed on any piece of equipment according to the producers' instructions.

Because of the variety of equipment, whether mobile or fixed, this subject will be presented generally and from two aspects:

- The operators' role
- The operating authority role

### 2.1 The Operator's Role

The driver/operator will do some maintenance on the equipment he is operating. Some of this is done before starting the equipment, some during operation, some before shutting-off the equipment and, finally, some after stopping the equipment. This is in addition to the manufacturer's instructions for the equipment.

#### 2.1.1. Pre-Start Procedures:

A. Check the equipments' general appearance (cleanliness, polish, any bumps on the body) and ensure there are no loose parts.
B. Check tires and their rated pressure
C. Check front and back lights and indicators
D. Check for leaks in cooling, oil, and fuel systems. Check radiator water level, engine oil level. Check drive belt tensions and change if necessary.
E. Start engine to check any for irregular sounds in all systems. Test brakes, clutch, hand brake. Check engine oil pressure, charging, and level of fuel tank from gauges. Check windshield wipers and horn.

F. If the engine fails to start, notify repair and maintenance team without persisting in trying to start it.

G. Check driver's tools and legal permits and license.

Figures 2.1, 2.2, 2.3 and 2.4 show examples of procedures done on equipment before starting.

2.1.2 Control Instructions During Operation:

A. Mobile Equipment:

- Observe any irregular features during operation such as: Engine overheat, low oil pressure, increase or decline in any gauges' readings from normal.
- Any route deviation caused by steering system, brakes or tires.
- Any irregular sounds in engine, systems or fittings.

B. Fixed Equipment:

- Observe any irregular features during operation such as overheating, low oil pressure, and irregular engine sounds.
- Observe any vibrations during the running of the engine, and check any wobble in torque connections between the engine and the pump.

2.1.3 Operations to be done before and after stopping the equipment:

A. Mobile Equipment:

- Ensure the equipment has stopped by applying hand brake
- Run the engine at idling speed for at least one minute to check gauges for any irregular readings
- Check cooling water and fill to correct level before stopping the engine.
- After stopping the engine check for any water, fuel or oil leaks, or anything else unusual.

Figure 2.1
Inspection Chart for an Excavator

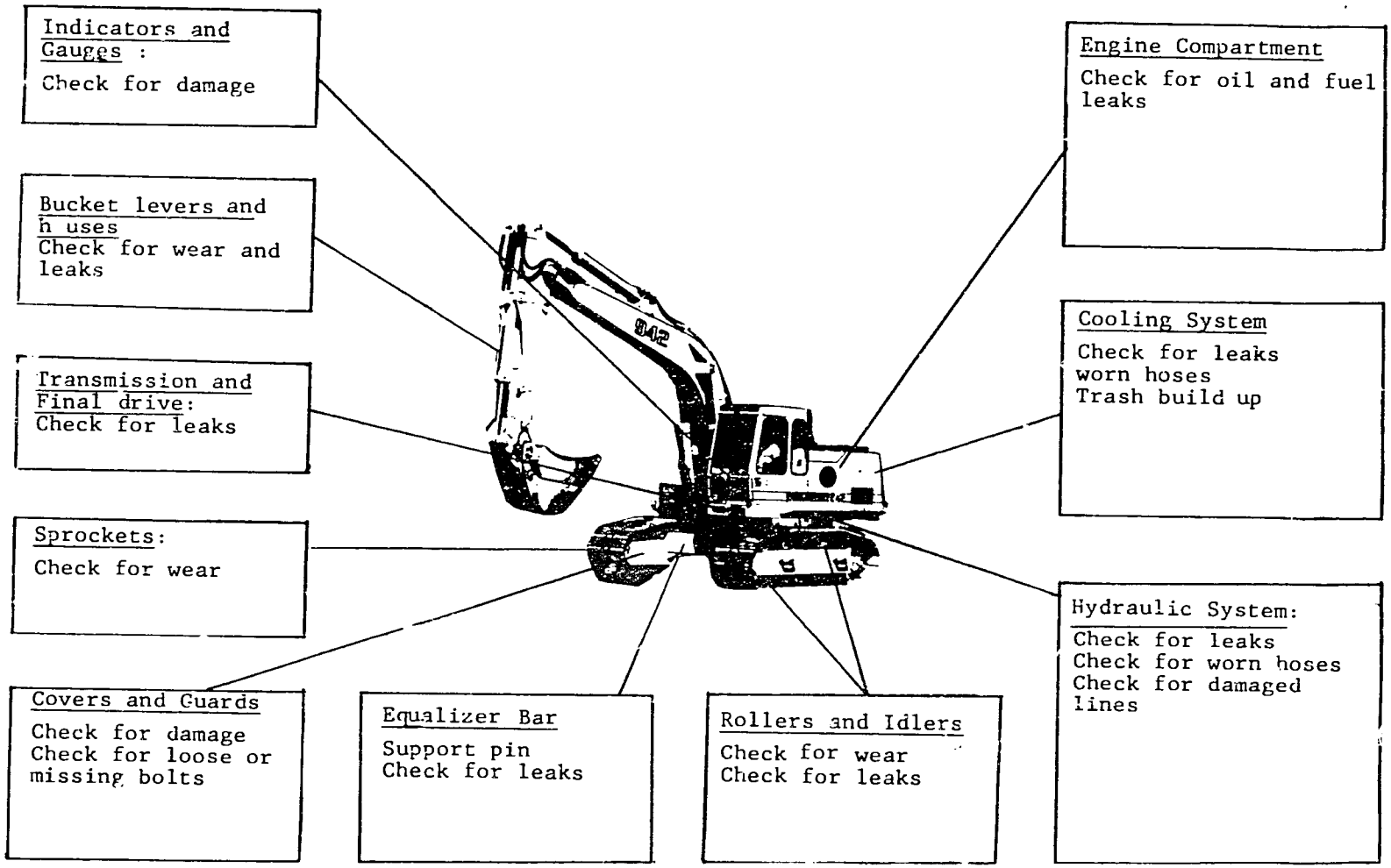





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Figure 2.2
Inspection Chart for a Grader

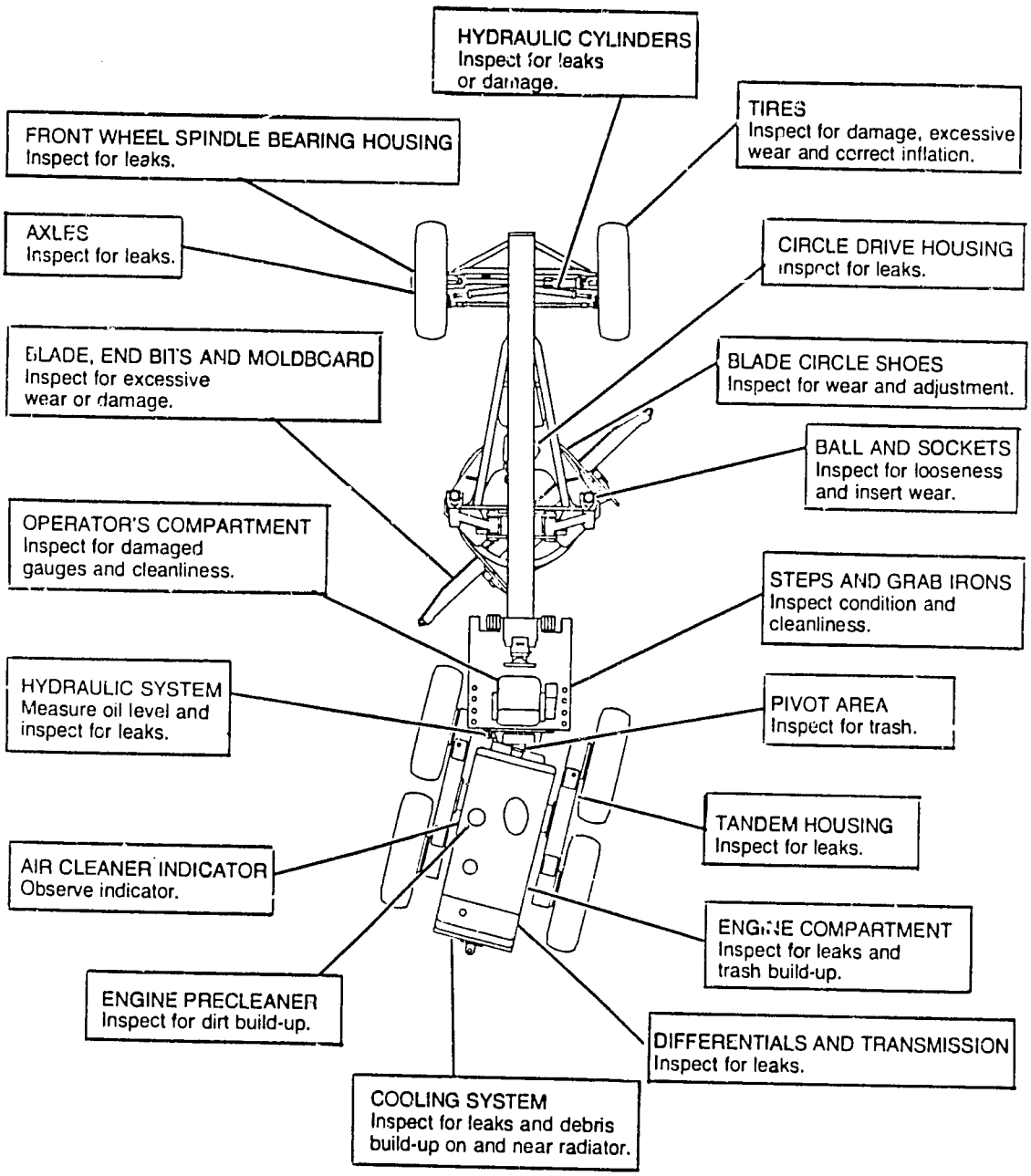




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Figure 2.3
Inspection Chart for a Loader

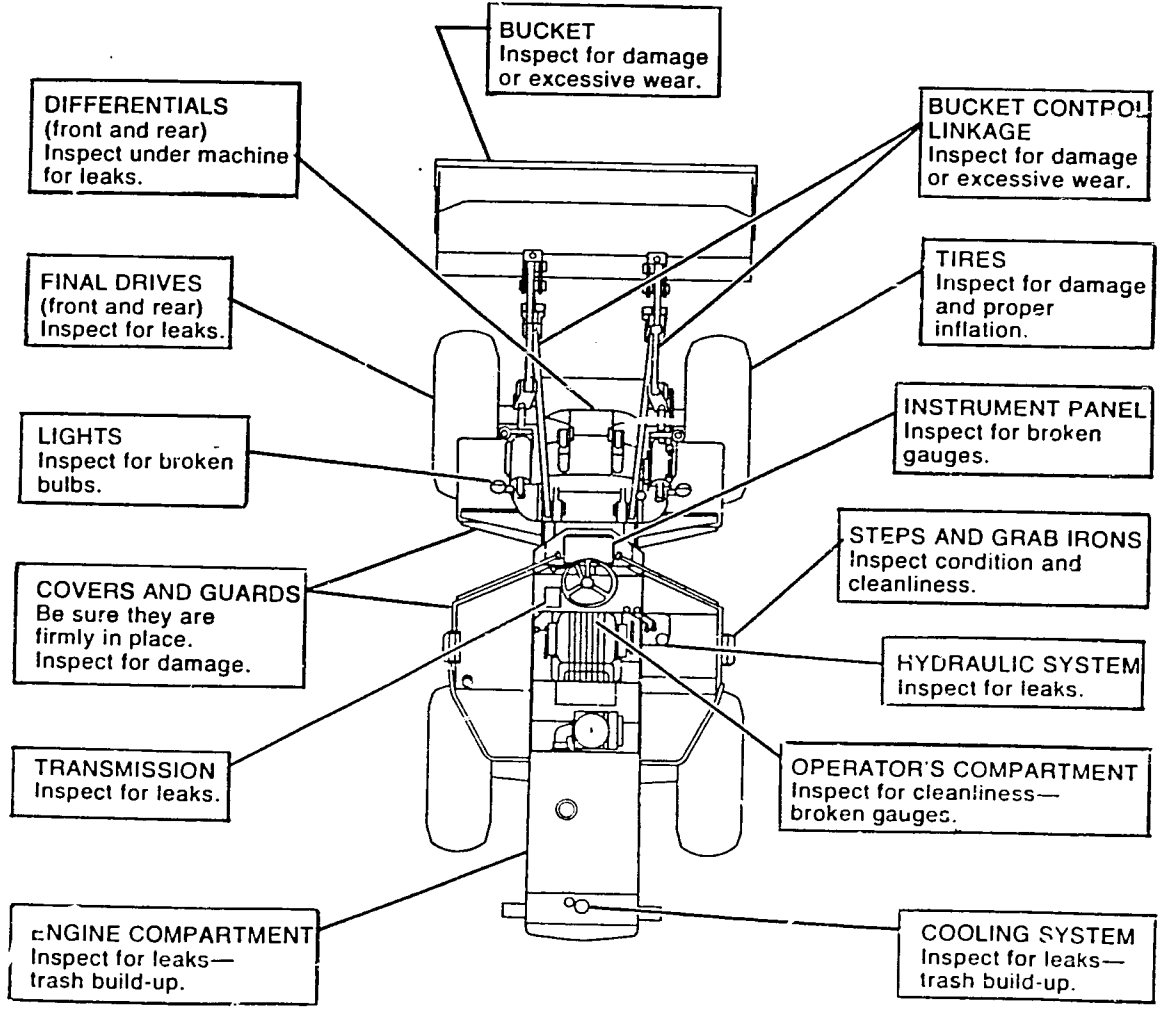




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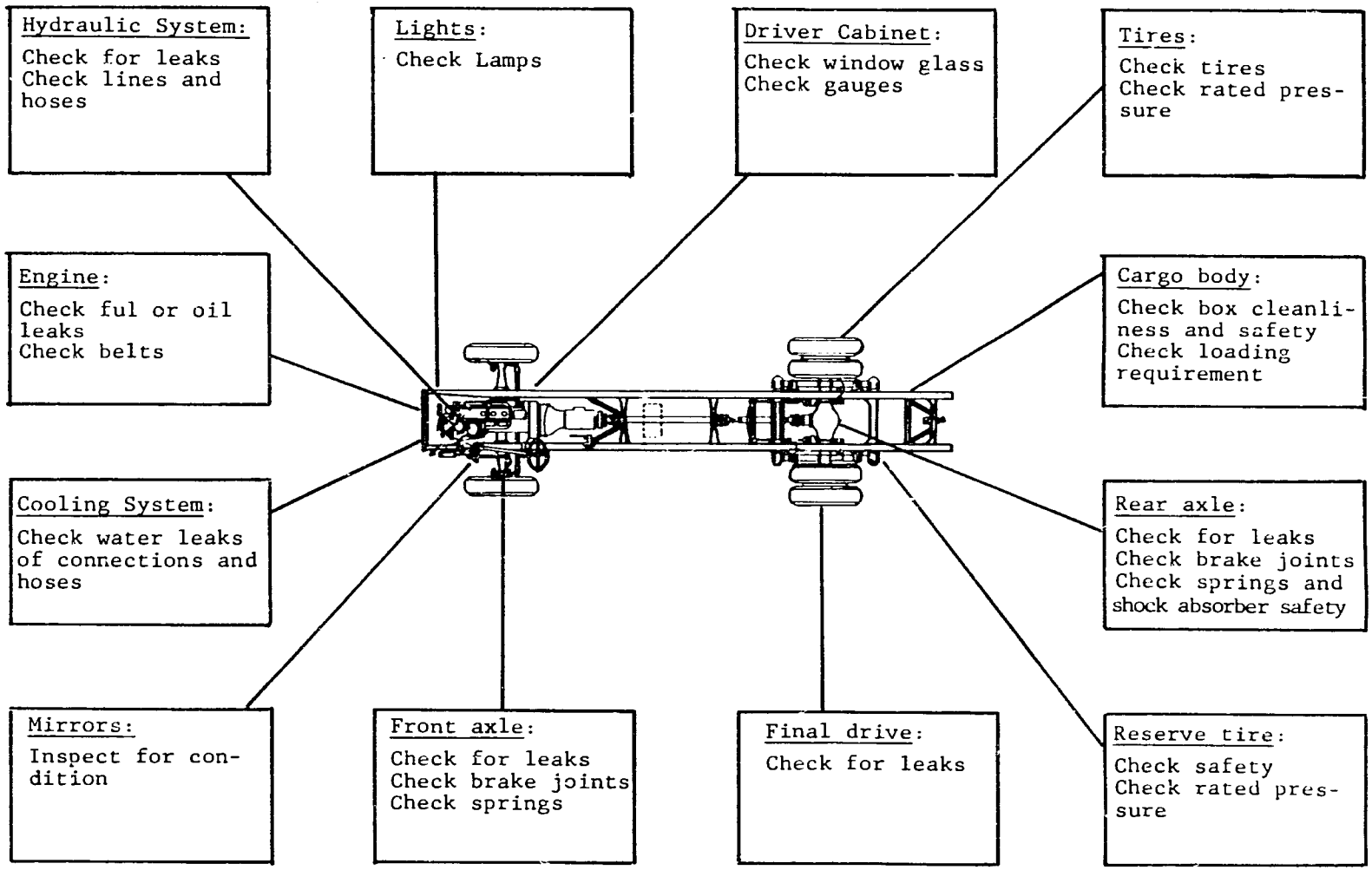
Figure 2.4
Inspection Chart for a Truck



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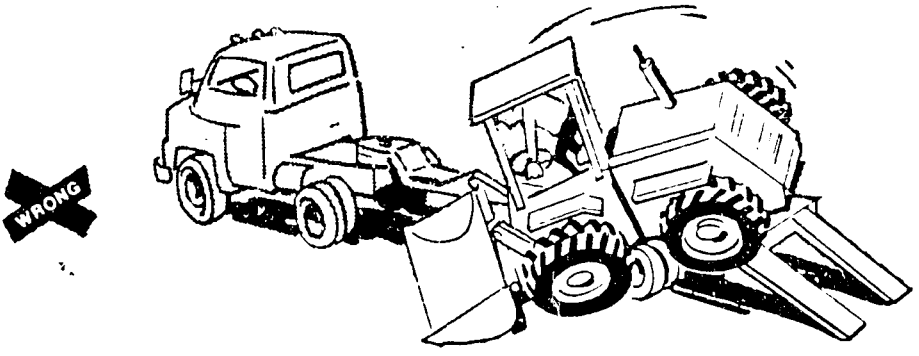
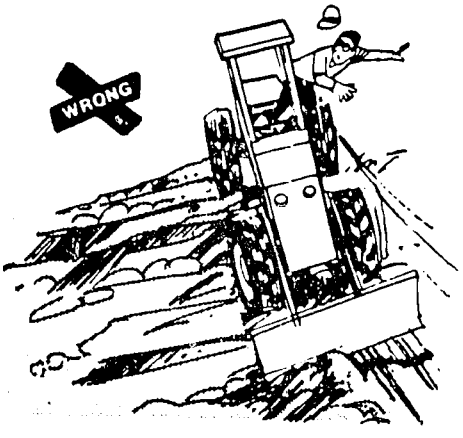
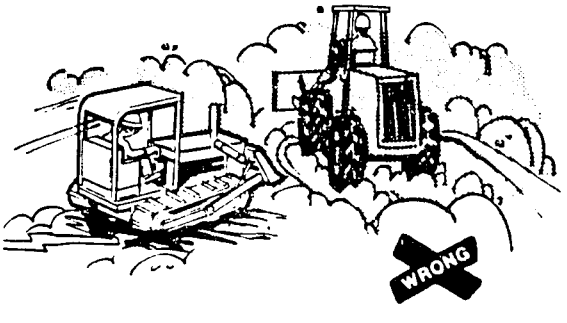
# LOAD AND UNLOAD YOUR MACHINE SAFELY

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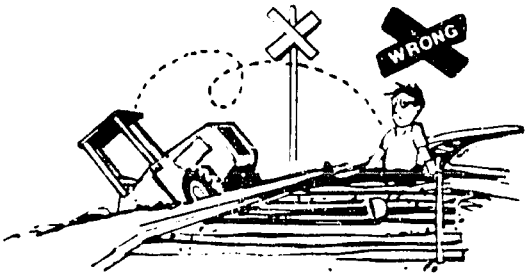


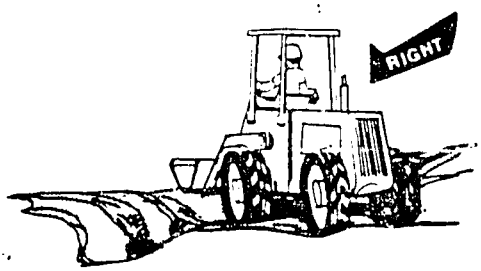


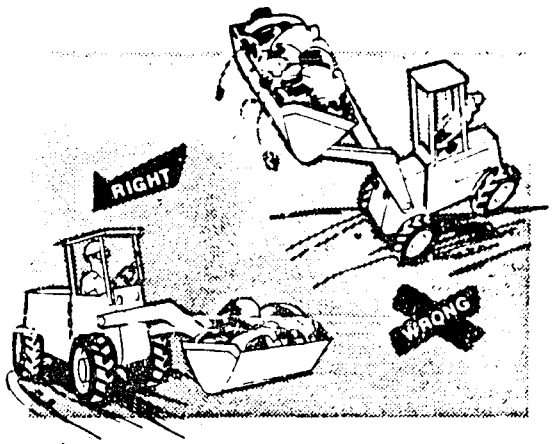


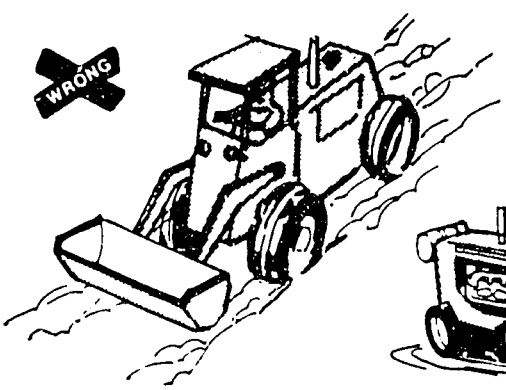


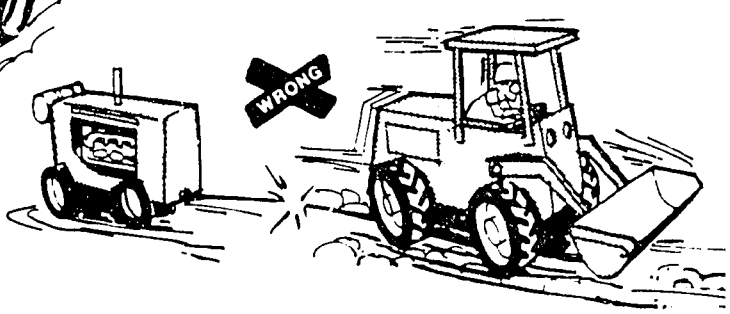


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B. Fixed Equipment:

- o Disconnect load from engine after taking necessary procedures (such as closing cocks, etc)
- o Run the engine at idling speed for two minutes to check any irregular readings of gauges.
- o Follow the rest of instructions mentioned under mobile equipment.

2.2 The Operating Authority's Role:

Authorities responsible for operating equipment (either mobile or fixed) in VC's workshops, MMC's, city garages or marakez Roads Departments and governorate Road Directorate should consider the following:

A. Operate the equipent in ways suitable for its nature and function and according to loading rules mentioned in the producers' instructions and directions.

B. Consider features indicating misuse or hard operation. These include overloading and utilization in inadequate jobs (such as using the grader to clean city asphaltic streets). These will cause irregular wearing of the equipment and its fittings.

C. Calculation of fuel and oil consumption rates as follows:

Fuel:

Fuel consumption rate can be calculated by one of the two following methods:

First: Depending on the quantity of fuel consumed for each unit, usually we use the following measurement: litres of consumed fuel/100 km.

Second: Depending on the consumed quantity during operation time, usually we use the following measurement: litres of consumed fuel/working hour.

Calculation of fuel consumption rates is for evaluation purposes.

Oils

Ensure that operators have checked oil levels and refilled if necessary. Register data in the relevant records. Also register quantities of changed oils according to O&M plan in order to calculate the amount of outgoing oils for the equipment either to refill, add or change.

D. Observe maintenance implementation schedule, which includes the different kinds of maintenance, when planning equipment operation. This ensures that the equipment is not loaded with work at a time that would cause postponment of the maintenance until a later date.

E. Each driver or operator should be in charge of operating one piece of equipment, and must not be replaced by another operator whatever the reasons are. This is in order to ensure that equipment is safely and properly operated. Equipment could be misused by its temporary driver or operator.

F. Draw up a costs pattern to prepare for an economical method of operation.

G. Record data on equipment operation forms and records, in order to:

- Calculate the actual cost of fuel, oil and operation requirements for each separate piece of equipment.
- Calculate monthly working and inoperative days for each piece of equipment, and its daily production rate.
- Calculate timing needs and requirements and plan the storage of operation requirements.
- Calculate the estimated budget for equipments' operation.

## 2.3 Operation Planning:

Projects and equipment maintenance depends mainly on having an accurate operation system. This includes loading tables with a good system for recording data, in order to make an analysis to assist the concerned department in obtaining information about the efficiiency of projects and equipment utilization. It also helps decision makers to define projects and equipment types and numbers when planning for the future. To properly prepare for operation, the following should be taken into account:

A. Preventive maintenance dates for equipment should be included in the maintenance plan.
B. The possibility of using one piece of equipment to do jobs on more than one site if the other sites are nearby. This reduces operation costs and saves time wasted in transportation.
C. The volume of required work in relation to equipment capacity should be considered to avoid overloading.
D. Observance of operators' vacations.
E. Observance of technical conditions when assigning equipment for jobs on different sites.
F. Assignment of a percentage of each type of equipment to work as a standby for operating equipment, bearing in mind the need for maintenance on the standby equipment.

2.4 Operation Cost:

There are several ways of calculating equipment operation cost, but they all depend mainly on the operation conditions, such as if the equipment is being operated in dusty or hot conditions or is being overloaded. These conditions increase equipment wear compared with equipment operated in normal weather conditions and with suitable loading. Also operator efficiency affects equipment operation and maintenance cost.

Costs elements can be summarized as follows:

A. Wages:

Including operator and assistants wages, social insurances and incentives.

B. Petroleum Materials:

Including fuel (solar - gasoline), oils and greases used for O&M daily operations.

C. Other Expenses:

Includes the cost of chemical materials used in some water operations (chlorine, alums ... etc). "Register and follow-up O&M plan implementation guidelines" - Chemonics - October 1988, included the forms for calculation of total operation cost for fuel, oil, grease, raw materials and components.

## 2.5 Equipment Productivity and Utilization:

To calculate equipment productivity it is necessary to provide some basic data such as the distance (kilometrage), number of operating hours, and actual operation days, and days when equipment was idle. In Table 2.1 is a register of equipment type, driver name, operator, kilometrage or number of operation hours, actual operation days, inoperative days, reasons for inoperation or stopping. If this data is available for any piece equipment, its producdivity can be calculated as follows:

Equipment productivity =

$$= \frac{\text{Number of actual operation days monthly}}{\text{Number of formal operation days monthly}} \times 100$$

If estimating total productivity for all equipment, the equipments' data should be registered in table 2.2 which includes the afore-mentioned data after accumulation from table 2.1 as follows:

Equipments' Productivity =

$$= \frac{\text{Equipments' operating days monthly}}{\text{Formal working days monthly x No. of pieces of equipment}} \times 100$$

Through analyzing data listed in table 2.2 we can identify existing weak points (such as lack of operators, too many faults, underloading and overloading) so as to avoid them.

Table 2.1

EQUIPMENT'S DAILY OPERATION REGISTER

Markaz : _____

Month : _____

| S.N. | Type and Brand | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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Kilometrage or daily operation hours are registered in front of each piece of equipment, it is not operated, write down reasons using the following symbols:

D = No driver N = No work I = Idle M = Maintenance

Table 2.2

PRODUCTIVITY REGISTER AND EQUIPMENT UTILIZATION
DURING THE THREE MONTHS (  /  /  )

Governorate: _____

Markaz : _____ _____

| Equipment | Type | Operator or Driver Name | Distance Covered or Operating Hours | No. of Operating Days | No. of Days Out of Order | Reasons of Non-Operating Days | | | | Productivity = Operating Days / No. of Working Days |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | No Driver | Not Needed | Out of Order | Maint. | |
| | | | | | | | | | | |
| Total | | | | | | | | | | |

* State number of non-operation days in the right column.



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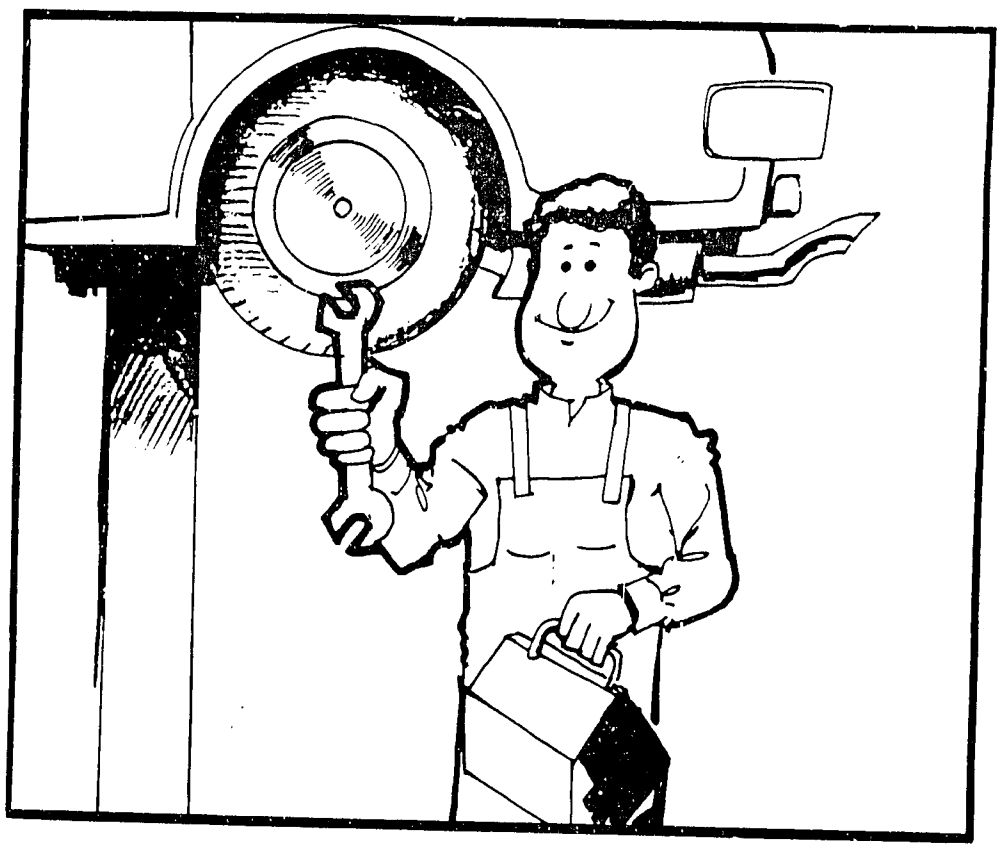
# Section 3

MAINTENANCE



## SECTION THREE
## MAINTENANCE

Recent economic and technical studies have proved that maintenance provides an indirect profit as it protects a machine against unexpected failures and breakdowns during operation and extends it utilization life-span. Consequently, it is necessary to understand all the operation elements technically, the duties and responsibilities of the maintenance units at all levels and, in addition, the periodicity of carrying out each type of maintenance. This chapter covers different types of maintenance for infrastructure projects and equipment, and daily service and inspection work carried out on different kinds of equipment whether fixed or mobile. It also covers checking equipment before operation to ensure efficiency all day long.

Daily service is usually connected to operation (specially as regards equipment, vehicles and lifting units in water and wastewater projects) as the operator does the daily service. In the case of road projects, the labour appointed on the road is responsible for this kind of service.

Daily servicing for different projects and equipment will be presented in turn after presentation of its preventive maintenance.

Daily inspection of equipment is extremely important for detection of any failures and deciding what operations are to be taken into consideration when performing daily servicing.

Preventive Maintenance: (Periodic - Routine) is called periodic because it is carried out periodically as recommended by the producer in the equipment manual depending on the hours it has worked. So this maintenance takes place either every 50, 100, or 150 working hours. (In the case of vehicles the working hours are interpreted in kilometers, so its is every 1250 km, 2500 km, 5000 km ... etc) However these limits are flexible in operation and can be changed provided that they do not exceed 10% + or -. It also depends on other conditions, as the maintenance routines mentioned in the manuals do not take into consideration the local environment and its difference from the equipments' original environment, or the increase in load beyond the maximum designed load in manuals.

Working hours between each maintenance are calculated in working days, so periodic maintenance could be weekly, monthly, or bi-annual (assuming we have one shift daily).

## 3.1 Factors Affecting Maintenance Periodicity:

The following factors determine preventive maintenance periodicity:

1. Utilization
2. Climatic conditions
3. Labour technical standard
4. Fuel, oils and greases
5. Raw materials and spare parts

### First: Utilization

This means the operation period, and the type or kind of loads. Loads can be classified as hard, ordinary and light.

A. Hard Utilization Conditions:

Utilization is considered hard if operation exceeds 2000 hours annually for fixed or slow moving equipment, and 60,000 km annually for vehicles. This is accompanied by complete loading during most operation periods.

B. Ordinary Utilization Conditions:

Operation is considered ordinary if annual operation varies between 1000 to 2000 hours, or between 30,000 to 60,000 kilometers. This is not accompanied by overloads.

C. Light Utilization Conditions:

Light utilization is when operation does not exceed 1000 hours or 30,000 kilometers. This is accompanied by partial loads during most of the operation periods.

### Second: Climatic Conditions:

Weather conditions in Egypt vary from hot (summer) to moderate (winter) with a percentage of moisture and dust that differs from one place to another. These conditions require increasing the rate of maintenance operations (shorter periods in between) from the rate mentioned in the manual. The increased rate is needed generally in summer, and specially when there is an increase in dust.

### Third: Labour Technical Standard:

The low technical standard of labour in operations and maintenance means that the equipment manual instructions (recommended by the producing companies) are not followed either because of negligence of some items or inaccurate and low quality implementation.

This results in the increase of sudden breakdowns and the need for repairs which represents a waste of money.

Maintenance periods can not be adjusted to take this into consideration, but this problem could be addressed using two basic methods:

- Development or upgrading of field training levels and standards.
- Accurate inspection of labour performance quality in order to improve or correct it.

Fourth: Fuel, Oils and Greases:

A. Fuel:

As the sulfate and phosphor percentages in the fuel used is higher than recommended the maintenance periodicity implementation is affected. This is especially important in the periodicity of changing an engine's oil as the residue of sulfate combustion is combined with the water vapor (resulting from combustion inside the cylinder) forming diluted sulfuric acid which damages the cylinder sides in addition to slopping the engine's oil and changing its characteristics. This accelerates the necessity for changing it.

B. Oils:

The difference between local oils specifications and international standards results in the speedy change in characteristics of an oil in use and, therefore, the need to change it more frequently. It is recommended not to change the type of oil used in an engine from the beginning of operation until the date of the engine's overhaul.

C. Greases:

The grease used should be suitable for the operating conditions of the parts needing to be greased as regards speed, load, high temperature and exposure to water. For example, grease used for cooling-fan or belt-tension pullies should be able to withstand high temperatures, be suitable for low temperatures, and not wash away in water.

The following should be considered:

- Different kinds of grease should not be mixed and then used for greasing.
- Too little grease, or too much grease, are equally in-effective.
- Manufacturers' instructions and recommendations should be followed otherwise sudden breakdowns will result.

D. Cooling Liquids

Cooling liquid and cooling components are most important in the operation and maintenance of liquid cooled engines. The cooling liquid generally used is fresh water. Anti-freezing liquid is added to it in cold weather countries. Rust and sediment preventer can also be added.

The used water should not be hard (hardness degree should not exceed 300 p.p. million) as the existence of calcium and magnesium elements in water results in a layer of sediment building up in the engine's cooling system. This leads to inefficiency as heat is not conducted from the engine to the cooling system and this results in the engine overheating. The existence of chlorine and sulfate in the water should not exceed 100 p.p. million as they cause errosion of engine parts and hoses.

Fifth: Raw materials and Spare Parts:

Using the original spare parts as specified by the producer extends the equipment's lifespan, and helps in conforming to the maintenance periodicity as instructed. Alternative spare parts are often used because of lack of the original ones in the local market or the high price of originals. This leads to shortening the life span of the equipment and decreases the period of time between maintenance. The same problem occurs when the alternative spare parts are manufactured locally using inadequate materials. This results in decreasing the period of time between maintenance by half.

On the basis of the aforementioned factors affecting the equipment and vehicle maintenance periodicity, the following timetable is suggested to implement maintenance according to weather conditions:

Table 3.1
MAINTENANCE PERIODICITY ACCORDING TO WEATHER AND UTILIZATION

| Maintenance Type / Factors | P1 | P1 | P2 + P1 | P1 | P1 | P2 + P1 | P1 | P1 | P3+ P2+ P1 |
|---|---|---|---|---|---|---|---|---|---|
| *uIn Summer*w: | | | | | | | | | |
| Hard Utilization | 1000 km | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 |
| Ordinary " | 1500 | 3000 | 4500 | | | 9000 | | | 13500 |
| Light " | 2000 | 4000 | 6000 | | | 12000 | | | 18000 |
| *uIn Winter*w: | | | | | | | | | |
| Hard Utilization | 1500 | 3000 | 4500 | 6000 | 7500 | 9000 | 10500 | 12000 | 13500 |
| Ordinary " | 2000 | 4000 | 6000 | | | 12000 | | | 18000 |
| Light " | 2500 | 5000 | 7500 | | | 1500 | | | 2250 |

## 3.2 Preventive Maintenance of Water Projects:

Water projects usually consists of engines (diesel and electrical), pumps, wells, tanks, pipes networks and valves.

Types and models of engines used in water projects are numerous. It is therefore, recommend adopting the following method in implementing engines' preventive maintenance without prejudice to the producers' instructions where there is contradition. As it is not possible to present maintenance programs for all types and models, this method handles the subject generally. Diesel engines do not differ to such an extent that the maintenance pattern is affected. The basic preventive maintenance activities are:

- o Checking
- o Inspection
- o Fastening
- o Cleaning
- o Adjusting
- o Lubricating

Each maintenance activity includes a list of the parts and sets that are needed according to its type and periodicity.

The remainder of these project's components resemble each other. There is no big difference, for example, between maintenance of a pipeline network 4" or network 6".

### 3.2.1 Diesel Engines:

First: Operation and Daily Maintenance

Operators of water stations and pump units are responsible for carrying out the engines' daily service before starting operation. This service includes the following:

- o Cleaning the engine
- o Checking and inspection of:
  engine oil level (figure 3.1)
  cooling water level
  leakage of water/oil/fuel
- o Operating the engine and monitoring and recording all readings and any unusual sounds.

Second: Preventive Maintenance (I) (P1)

Frequency: Every week, or 50 working hours

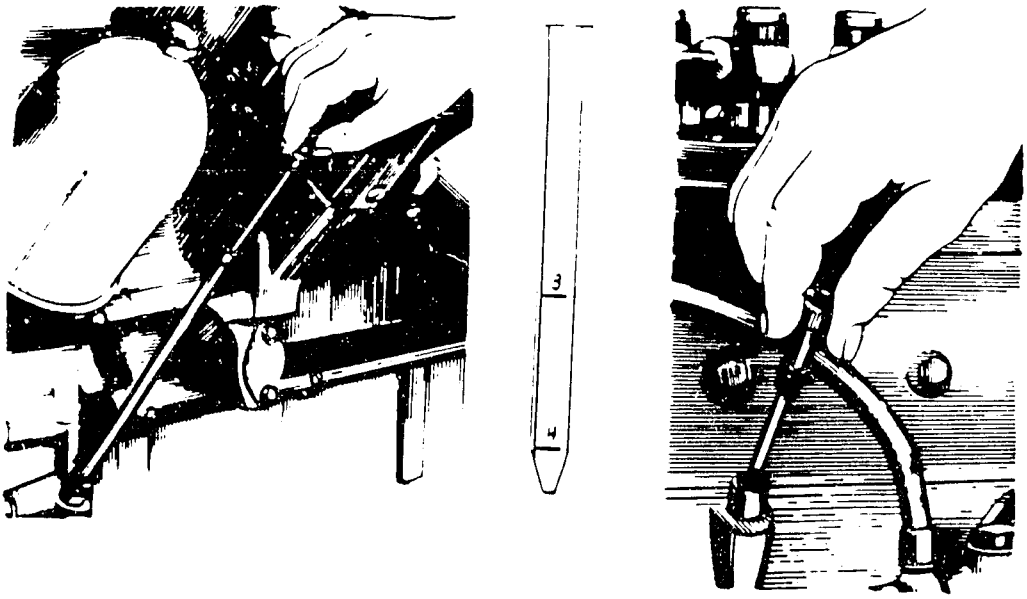
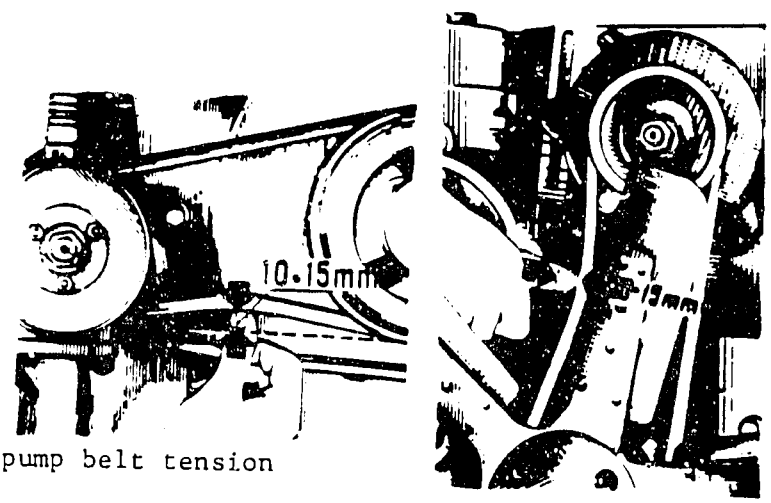



Figure 3.1
Checking of Engine Oil Level




Water pump belt tension

Generator belt tension

Fig. 3.2 Belt Tension Method

Personnel: Mechanic, electrician, operator

Tools: Mechanic's tools, electrician's tools, funnel, hydrometer, voltimeter, torque wrench, oilcans.

Materials and Spare Parts: Motor oil, grease, distilled water, sand paper, gaskets, cleaning cloth, water pump stuffing.

Operations:

- Wash and clean all engines parts
- Check engine's oil or change it, and check the air filter oil or change it if necessary using the correct type of oil
- Fasten all engine parts and all chassis anchor bolts, and pump coupling bolts, and fasten the bolts that fix the pump to the chassis
- Check the water pump packing
- Check the battery the solution level and density, battery voltage, and supply it with distilled water (fig. 3.3)
- Check the starter, the dynamo, the cutout, the accumulation (charging) regulator and oil and grease them if needed
- Check the tightness of the water pump vee belt and generator (fig. 3.2)
- Operate the engine and the pump to check if there are any unusual sounds after maintenance and report any breakdowns to be repaired
- Clean the engine and the water pump after maintenance

Third: Preventive Maintenance (II) (P2)

Frequency: Every month, or every 200 working hours.

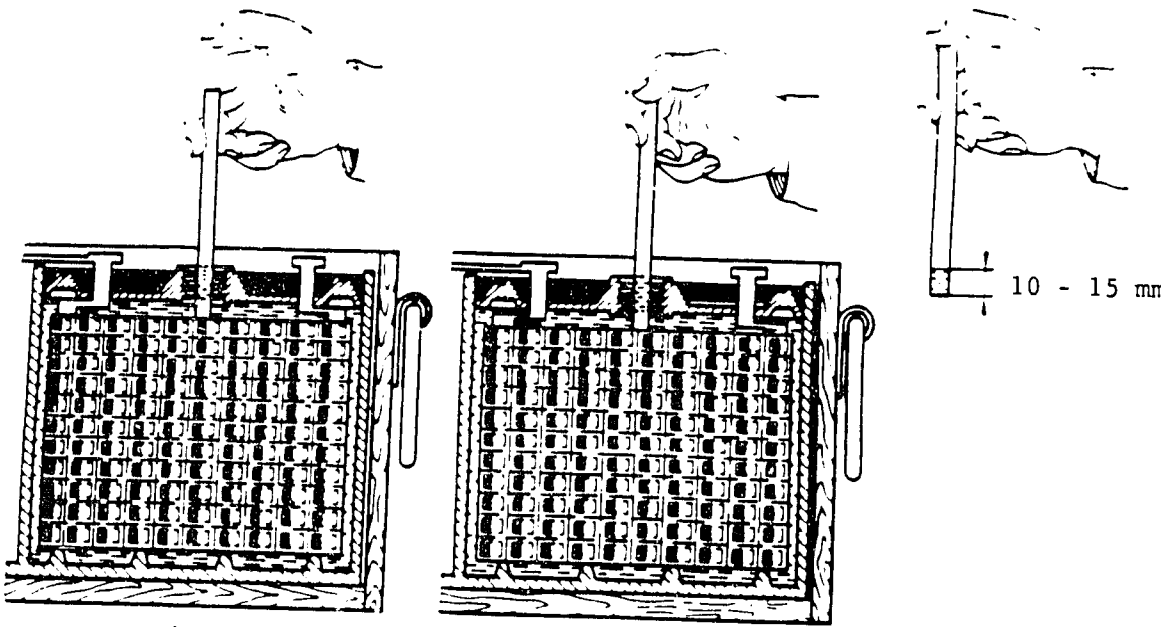
Personnel: Mechanic, electrician, operator, pipe fitter

Tools: A set of mechanic's tools, electrician's tools, pipe fitter's tools, funnel, oilcans, hydrometer, voltimeter, torque wrench, vise.

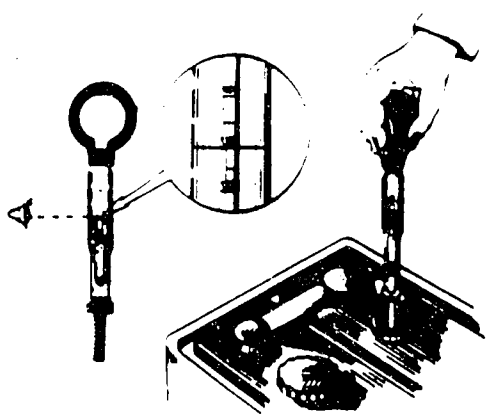
Materials and spare parts: Engine oil, distilled water, grease water pump packing, gaskets, sand paper, cleaning cloth, fuel filter element, oil filter element, etc.

Operations: This maintenance includes all steps described in Preventive Maintenance I plus the following:

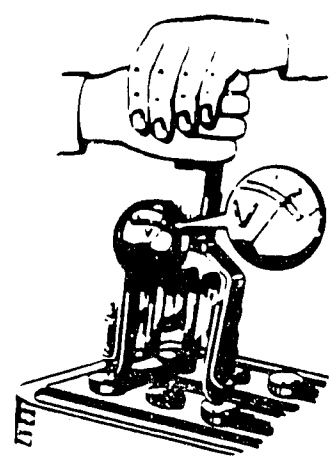
Fig. 3.3 Battery Inspection




Check Solution Level



Check Density



Check Voltage

- Change/clean the filtering elements in oil, fuel and air filters
- Check any water leakage from the engine cooling pump, and fasten it if needed
- Check the cooling fan for tightness
- Check the rust preventer in the radiator water, and add it if needed
- Operate the engine to check if there are any unusual sounds
- Check the water pump ball bearing roulement or bearings according to their type and way of installation
- Check all connections and valves for any leakage

Fourth: Biannual Maintenance

Frequency: Every 6 months, or every 1000-1200 working hours

Personnel: Mechanic, experienced electrician, operator

Tools: Same as in PM2 plus an injector adjusting device

Materials and Spare Parts: Same as in PM2 plus injector nozzles

Operations: This maintenance includes all operations mentioned in PM2 plus the following:

- Adjust the injector pressures and change nozzles if needed
- Fasten cylinder head according to sequence
- Adjust the valve clearances
- Adjust fuel pump coupling
- Check the fuel pump closing lever
- Check the accelerator and adjust the silencer speed
- Check the meters (oil - fuel - water pressure - water quantity)
- Check the water pump shaft to ensure the coincidence of the pump and engine axles
- Check the engine and water pump mountings and change them if needed
- Disassemble the dynamo and the starter to check all parts
- Check the water elevation pump and change packing if necessary

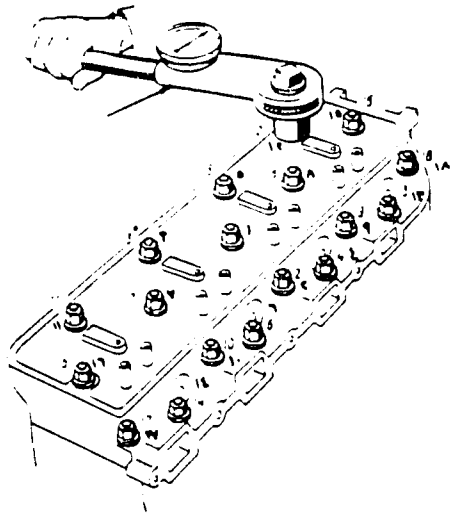



Fig. 3.5
Cylinder Head Tightening
according to the sequence

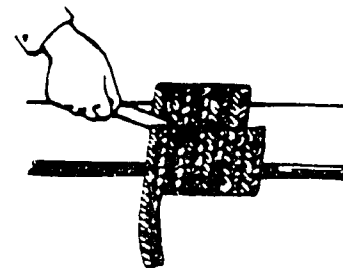


Fig. 3.4
Pump Stuffing Material

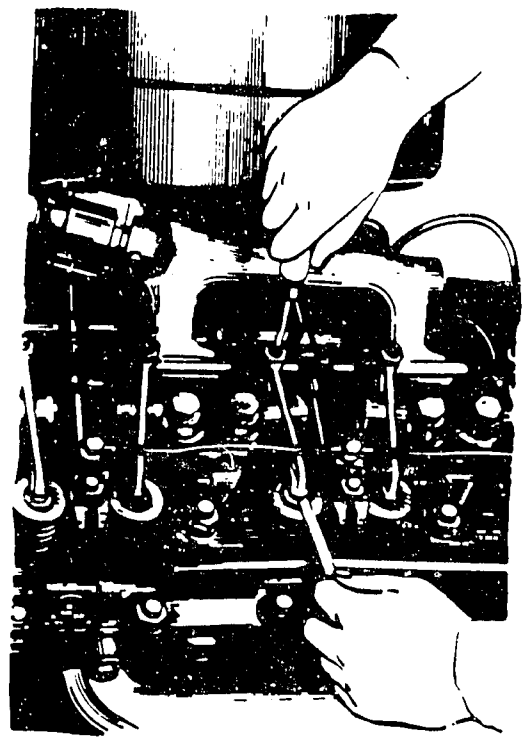


Fig. 3.6
Valve Clearance Adjusting

### 3.2.2 Electric Motors:

**First:** Operation and Daily Maintenance

The operator should do the following before operating the electrical units:

- o Clean the motor
- o Turn the motor by hand to make sure that the bearings are in good condition and there is no unsual resistance.
- o Check the electrical connections to make sure the insulation is intact.
- o Run the motor and observe the indicators on the distribution board and record any unusual readings or disturbances.

**Second:** Preventive Maintenance (I) (P1)

**Frequency:** Every week, or evry 50-75 working hours.

**Personnel:** Electrician and operator

**Tools:** One set of electrician's tools

**Materials and Spare Parts:** PVC tape, cleaning cloth, water pump packing.

**Operations:**

- o Check bolts holding the engine to the chassis
- o Clean out the connection box and check the cables
- o Check the inulation of cables and connections
- o Check that there is no spark between the brusher and the commutator segments and clean them
- o Check the operation of the cooling air fan
- o Check the water pump packing and change it if needed

**Third:** Preventive Maintenance (II) (p2)

**Frequency:** Every month, or every 200 working hours

**Personnel:** Electrician, operator

**Tools:** One set of electrician's tools, multimeter, grease gun.

Materials and Spare Parts: PVC tape, grease, electricity oil, alcohol, cables, iron sand paper, water pump packing.

Operations: This maintenance includes all operations mentioned in Preventive Maintenance I plus the following:

- Grease the motor bearings using the grease recommended by the producer
- Clean the sleeve bearings using alcohol
- Clean the brushes with sand paper
- Operate the motor and load gradually to check any sounds or breakdowns
- Clean and grease water pump bearings and install new packing if required.

Fourth: Biannual Maintenance

Frequency: Every six months, or every 1000 - 1200 working hours.

Personnel: Electrician, operator

Tools: Same as in M2 plus 500 V megger.

Materials and Spare Parts: Same as in M2.

Operations: This maintenance includes all operations in M2 plus the following:

- Check the motor insulation resistance
- Check the windings and record reading before replacing terminal box cover
- Clean the bearing with flushing oil and refill to correct level using the specified grade of oil according to the motor type
- When sleeve bearing are being used measure the clearance between the rotor and the windings - air gap - at all points and record readings and adjust if needed
- Check the motor coupling alignment with the water pump axle

### 3.2.3 Maintenance of Pipelines, Valves and Tanks:

Frequency: Every month

Personnel: Pipe fitter, official of the markaz health directorate.

Tools: One set of pipe fitter's tools, tank washing tools.

Materials and Spare Parts: Stuffing materials, nails, gaskets, chlorine, pipe sleeves.

Operations:

- Monthly inspection of pipelines and valve chambers to check its operation and the existence of any leakage
- Inspection of valve chambers to remedy any leakage
- Wash elevated and ground water tanks and decontaminate them according to the health directorate instructions
- Wash the network for disposal of sediment, rust ... etc

## 3.3 Maintenance of Wastewater Projects:

This type of project consists of a pipe network, pump stations and wastewater treatment units. Pump station maintenance is very similar to that of potable water station maintenance whether diesel engines or electric motors are used (items 4.4.1 and 4.4.2) consequently, we will describe the maintenance of wastewater pipes networks. Producers' instructions should be followed for treatment units.

### 3.3.1 Targets of Wastewater pipe Maintenance:

- To reacquire the pipes' maximum capacity by cleaning out the sediments that block them, and to keep the sweeping speed
- To detect location of fractuces and cracks and weak connections in the pipes in order to replace them
- To provide time necessary for preliminary operations prior to repairing of pipelines, and thus ensuring its cleanness and reducing the repairing time

### 3.3.2 Wastewater Pipelines Maintenance Methods:

There are several methhods of maintenance clarified in Table (3.2). Some of them are automatic and some manual.

As modern equipment is highly sophisticated in its operation (as is the work done by the operators) we recommend the necessity of following literally the producing company's instructions to get the best results and secure the safety of equipment and operators.

First: Hydraulic Cleaning:

This method depends on the water pressure generated in a hose that has holes at certain angles fitted with nozzles. This lets out water at great pressure and speed (250 atmospheric pressure). This leads to a surging of the jet from the hose inside the pipes similar to jet propulsion. The water will hit the sides of the pipes removing sediment and occlusions. There is a vehicle equipped for this purpose.

This method is less effective for heavy and big disposals and leads to damage of corroded pipes. So, this method should not be used if there are any signs of collapse or a leakage or accumulation of sand and mud inside the line. This jet method would cause the total collapse of the damaged pipe sector.

The jet nozzle equipment is generally used to push and remove sludge, mud, sand, gravel, and stones from pipes with a diameter of 300 millimetre or less. It can also be used to clean, manholes and flushing basins.

Table 3.2

DIFFERENT CLEANING METHODS
ACCORDING TO THE NATURE OF EACH PROBLEM

| Cleaning Method | Nature of Problem | | | | |
|---|---|---|---|---|---|
| | emergenc. occlusion | grease | solid inclu-sions | Sand and small in-clusions | odors smells |
| Cleaning with a jet nozzle | o | o | | o | o |
| Washing with water | | | | | o |
| Using the lines scavenger | | o | | o | |
| Bucket cleaning machines | | | | o | |
| Automatic or manual clearing stick | o | o | o | | |

When using the jet scavenging equipment it is necessary to provide the following equipment:

- Sand, sediments and disposal trap
- Manhole Dredger
- Disposals bucket and manual line
- Manhole elevator

Operation Instructions for Using the Jet Nozzle

- Before starting any cleaning of the wastewater pipelines, always make sure that the jet nozzle is tightly fixed to the hose.

- The jet nozzle should never be operated while workers are inside the manhole

- The jet nozzle machine should never be operated with maximum water pressure on the ground surface unless the nozzle is fixed tightly

- Utmost attention and carefulness is a must when handling the moving water hose. Accordingly leather gloves should be used in case there are some sharp fragments of glass or other deposits stuck to the hose which may cut or inflame the hands

- No repairing of pumps or other equipment should be done before stopping the machine completely

It is allowed to use high speed jet nozzle equipment to remove and push stagnant water in sinks and gutters unequipped with an outlet.

Second: Mechanical Cleaning:

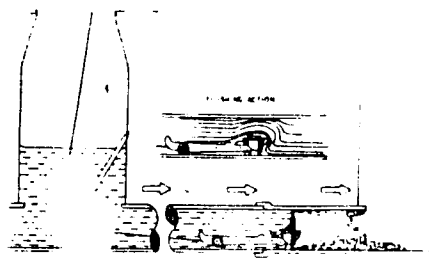
This includes all mechanical equipment that scrapes and drags all sediments from inside the pipes, such as scavenging sticks, and manual or mechanical bucket machines.

A. Line Scooter:

This is one means of effective cleaning. It works by water pressure and is easy to use and highly efficient in removing sand, mud and, some times, big sediments buildups. It is used in big lines to remove grease but should not be used when there are occlusions that lead to overflow until the occlusion is removed. The scavenger is a structure on metal wheels with a metal shield. Control and operating lines are fixed at the front and rear of the scavenger. There are usually different sizes of scavengers to be used for different diameters of pipelines see fig. 3.7 and 3.8.

The following tools are used with the scavenger:

Flushing Action



Sewage Scooter

Scooter set up in line

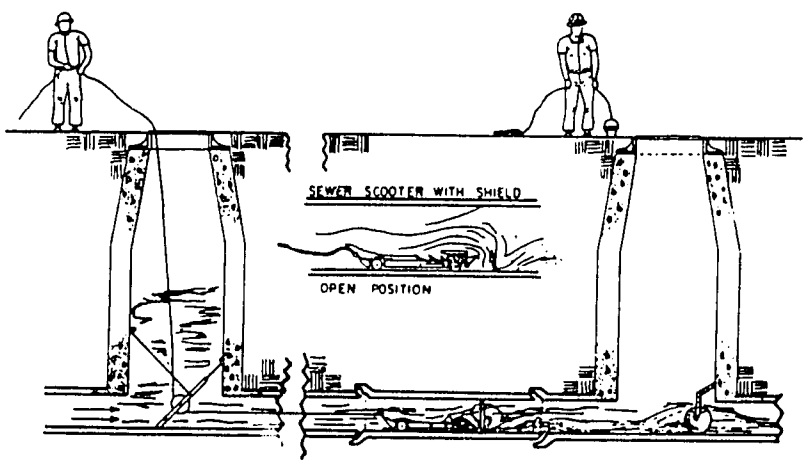
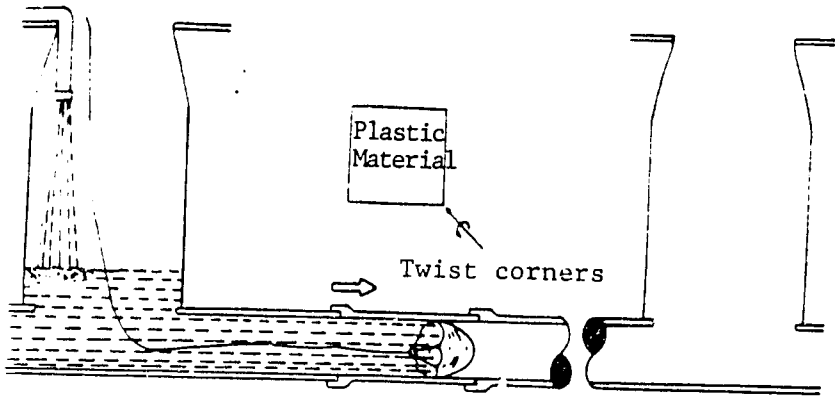



Fig. 3.7
Scooter Operation




Parachute set up in line (water driven)

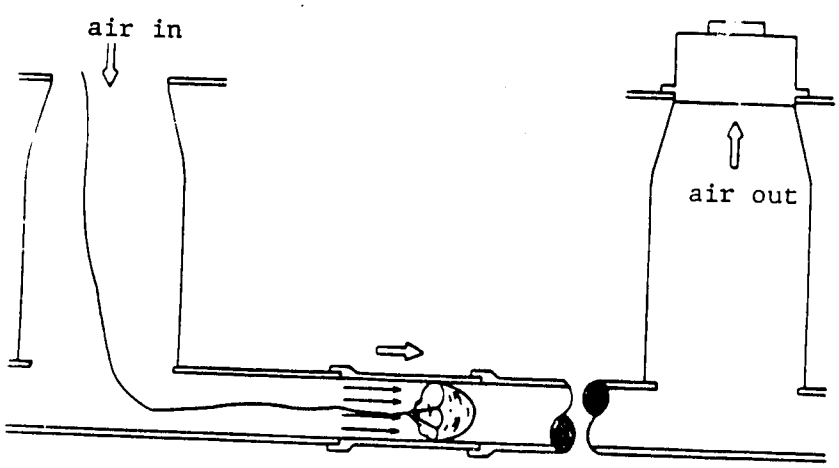



Fig. 3.8

Parachute set up in line (air driven)

- Front are rear scavenger cables
- Cable reels
- A pushing umbrella inside the pipelines
- Sand trap
- A sucking compression pump
- Sewage evacuation (dump) trucks

The scavenger is operated by inserting it in the pipes using the control lines, and directing it to the parts to be cleaned. This is done by pushing an umbrella fixed to the front cable in a manhole at one end of the pipe. This is then pulled from a manhole at the other and of the pipe. The scavenger is pushed inside the exit pipe from an above current manhole while directing the scavenger shielded end in a direction under the current. The manhole elevators should be fixed. Then the sand trap should be placed in a manhole beneath the current. The sucking compressing pump is then dropped in the sewage line. The shield plate will stop the sewage water flow behind it, which leads to a slight level difference at the scavenger shield sides. The higher level will be in a direction above the current and thus the scavenger is pushed forward until it stops because of the accumulated deposits in front of it. The operator will then pull the control cable backward to open the shield's upper part allowing the detained water to flow at high speed and pressure pushing the accumulated deposits in front of the scavenger and washing the line. When the operator loosens the control cord, the shield valve will close and the scavenger will move forward.

B. Buckets Machine:

This machine is a mechanical way to clean deposits from sewage pipelines by scraping and dragging. It is usually used for removing and transferring sand, gravel, stones, bricks and tree roots, in addition to mud and grease. The buckets machine is used mostly for removal of large quantities of heavy solid materials, but it is a slow operation, and should only be used when other methods fail. It should be used with extreme caution to avoid causing any damage to the sewage pipes.

Bucket diameters vary from 6" to 26". The two bucket machines are loaded on two trailers. The first is positioned at a manhole over the current, and the second at a manhole under the current. The cable will be pushed through the sewage line so that the buckets are dragged through the pipe by the machine. After removal of deposits precipitated in small, low-flow pipes, the machine is usually placed at an under current manhole. It is placed at an above current manhole when removing deposits in large diameter pipes.

A single bucket machine cannot operate alone. There have to be two of them, one to pull and drag and the other to feed. As soon as the cable starts running, the machine parts (other than the crank and steering arms) should not be touched. If any complications occur or sudden excess looseness of the cable, the operator of the other machine should be signalled to stop it completely.

C. Clearing Machine:

The cleaning machine uses flexible steel joints to push or drag different cleaning tools and instruments through the sewage lines. It is suitable for removing obstacles. With the right tools, and proper washing water, this machine can also remove and push sludge, mud and grease. It does not require pushing ropes. As it can be pushed for 150 m in the lines, it is considered a good method to overcome blockages in emergency cases. This machine is not suitable for pipes with diameters of more than 380 mm, for joints tend to be curved, and then a lot of water would be needed for washing. In addition it is generally weak and incapable of dislodging and lifting heavy solid materials.

Industrial Security Instruction:

- The clearing stick should not be inserted or pushed into any obstacle. The operating process should be performed smoothly

- The clearing stick should not be whirled in one spot for a long time as it might generate heat and damage the tools. Consequently the stick should moved in and out constantly.

- The cleaning tool should never be touched before both the tool and the stick pushing machine are completely stopped. If the stick is broken be sure that the rotation torque is removed before handling or holding it.

D. Manual Cleaning Stick

Manual clearing is very similar to the mechanical method, but its use and capacity are limited, because the stick is pushed manually in the line making the process slow. Standard joints are connected as required to lengthen and push the stick inside the sewage line.



SS

The manual clearing stick is usually used in emergency cases, routine service requests, and if there is any blockage after working hours. After removing such a blockage, the complete cleaning operation can be performed later.

### 3.3.3 Tools and Equipment Required for Personnel Protection and Safety:

Gloves:

Workers must wear protective rubber gloves for protection from chemical materials used in sealing and seclusion operations.

Glasses:

Workers must wear protective glasses to avoid injuries caused by scattered solid materials and protective glasses must also be worn during the chemical mixing process.

Fresh air mask:

Workers should wear this mask for protection against poison gases inside the pipes, and for easy respiration during the carrying out of maintenance operations.

Fresh air compressor:

Because of the existence of poison gases inside the pipes and lack of oxygen, pipes should be ventilated. This is specially important if work is going to last for a long time.

Fire fighting equipment:

Personnel should have fire-extinguishers in all vehicles specially those transporting petroleum or chemical materials.

First aid kit:

All vehicles should include first aid kits and persons should be trained how to use them.

Rubber boots:

There are used to protect workers against sharp solid objects in the sewerage.

Protective jackets

These orange coloured jackets are used to distinguish persons working and protect them from traffic accidents when they are standing in the traffic flow and exposed to danger.

Solid helmet:

This is used to protect workers against any solid objects falling on their heads, if they or bump into hard bodies.

Protective belt:

This belt is put on when workers descend manholes deeper than 1.75 meter to allow the pulling out of injured persons. It is also necessary when workers go far into large-diameter pipes to protect them from drifting away as a result of the strong flow. This belt is attached to a rope to facilitate pulling out the workers from the lines.

3.3.4 Precautions to be followed while cleaning sewerage and ways of handling:

- The detection of homogeneous soil, crockery pieces or stones on the bottom floor of a manhole is a positive indication of the occurance of cracks or collapse in a part of the over current sewerage line in this location. In this case extreme caution must be taken before performing any cleaning operations.

- There is a great possibility that a sewage pipe might break during cleaning operations if it is corroded or collapsing or has any other structural defects. In these cases it is necessary to make an on site check to determine the possibility of carrying out cleaning operations.

- Cleaning instruments filling the pipe including hydraulic fans often stick to incohensive joints (with discentered axes), household connections, protrusions, roots, lumps and piles, or any other similar obstacles.

  Therefore, whenever possible a pulling rope should be used with the drawing winch to recover the cleaning tools and instruments.

- Cleaning devices, tools and instruments should be chosen on the basis of their suitability for the nature of work, and the condition of pipes in order to avoid any possible damage.

- Check the possibilty of sewage overflow in basements whenever hydraulic operated equipment is used.

### 3.4 Maintenance of Road Projects

Road projects in governorates are divided into three main kinds:

A. Dirt roads
B. Gravel and Macadam roads
C. Asphalt roads

Maintenance of these roads is done in order to compensate for erosion due to traffic and weather, and soil movement at their edges. It aims at keeping the roads in good condition and safe for travel. Negligence of such maintenance in due course results in doubling work and costs, in addition to endangering lives and damaging equipment. As maintenance allocations are usually limited roads should be kept in good condition with the minimum cost.

Road maintenance is divided into:

A. Routine Maintenance (watering, signs ... etc).
B. Periodic Maintenance (improvement of surface and shoulders, shade trees ... etc).
C. Corrective Maintenance (applying a surface course).
D. Emergency Maintenance (floods, pits, road damage... etc).

#### 3.4.1 Routine Maintenance

This is the daily road maintenance done by the road workers and is usually carried out for dirt roads in the governorates to keep the road at its original level and protect it from any encroachements.

Personnel: Road workers, generally appointed by the road directorate

Equipment and Tools: axe, lifting jack, scuttle, bucket, grass cutting tools, bricklayer's tools.

Materials: Water and earth filling.

Operations:
- Remove corrugations (wavings and zigzags) from the road surface
- Fill pits
- Clean grooves
- Water the road surface
- Maintain walls and side coverings
- Remove grass
- Remove all habitations encroaching the road
- Maintain longitudimal and cross section elevations

- Maintain the cohensiveness of the road surface and side slopes
- Renovate all road signs (if necessary)
- Retain and protect trees by trimming and watering
- Repair damage at intersections
- Repair damage at bridge entrances

### 3.4.2 Periodic Maintenance

This is usually called "improvement maintenance". It aims at improving the surface of dirt, gravel and asphalt roads, maintaining their elevations, and protecting them against erosion factors.

Frequency:
- Once every month for dirt roads
- Once every two months for gravel and stone roads
- Once every 6 months for asphalt roads

Personnel: Specialized labourers and technicians.

Required Equipment: Grader, roller, water tanks, loader.

Required Material: Earth filling, asphaltic materials, water, gravel, soil (according to the kind of road).

Operations:

A. Road alignment in some parts, or modification of critical areas, in order to ensure safety and smooth flow of traffic:

- Elevate the parts of the road which are lower in level than the cultivation areas
- Road widening
- Improve elevations and longitudinal slopes
- Improve of elevations and slopes of cross sections
- Increase radius of dangerous horizontal curves
- Widen the road on horizontal curves
- Remove obstructions preventing adequate visibility on horizontal curves

B. Improving road surface, shoulders and side slopes in order to improve the soil and reduce surface losses.

- Water, specially during summer
- Spray bitumen (when the road is not used for traders' traffic)
- Supply sand roads with clay soil to improve cohesion
- Supply sand to clay soil roads to prevent water suction
- Fix side sloppes and construct retaining walls for collapsing slopes
- Improve cross slopes (3 - 4%) to facilitate drainage of surface water
- Cover areas likely to erode and construct side slopes
- Renovate side slopes by planting wedge - root trees
- clean canals
- Make curvatures for upper and lower slope edges

C. Improvement of Road Shoulders:

- Place the minimum of different road signs for warning, kilometrage ... etc
- Fix new steel marks on the road
- Plant trees for demarcating and shading the road
- Remove obstructions whether buildings or cultivation ... etc
- Allocate crossings for pedestrians, bicycles or cattle

### 3.4.3 Corrective Maintenance

This is done to repair erosion of the road surface due to traffic or corrosion and wear. It also includes laying and leveling a new surface course.

Level of Implementation The markaz roads' department or the governorate roads' directorate or a contractor

Material: According to type of road (earth fillings, grave soil, limestones, asphaltic mixture, liwuid asphalt.

A. Dirt Roads:

Frequency: Every 2-3 years

Personnel: Specialized labourers

Equipment: Water pumps, street sprinkler, buckets, axe, scuttle, loader, grader, forks.

Materials: Water, earth filling (a layer 10-20 cm thick)

Operations:

- Apply earth filling of clay soil or sand, according to type of road (layer thickness 10-20 cm i.e., 15 x 5 x 1000 = 750 m3/km)
- Level road surface using available equipment. Levelling is both longitudinal and cross levelling
- Water with a sufficient amount of water

N.B. If the road does not need an additional layer, maintenance will be as follows:

- Level road surface and adjust it in longitudinal and cross directions using the afore-mentioned equipment
- Water
- On sand roads layers of clay soil should be added to sand parts to maintain cohesiveness
- On clay roads a layer of sand should be added to ease its levelling
- Remove of stones and rubble from the road surface using forks

B. Gravel and Macadam Roads

Frequency: Every 12 - 18 months

Personnel: Specialized Labourers.

Equipment: Grader, roller (5 tons)

Materials: Bitumunous materials, gravel soil, stones and rubble, sand

Operations:

- Fill pits and gaps, and lay a new surface course
- Level road surface with grader and remove unacceptable materials
- Spray with liquid asphalt (1.5 kg/m2) to give a preliminary varnish layer
- Apply another layer of liquid asphalt (medium volatilization asphalt) to road surface
- Cover with clean sand
- Compact with roller

C. Asphalt Roads

Frequency: According to damage (such as cracks, grooves, settlement, and surface course damage due to ground water).

Personnel: Specialize chnical labour.

Equipment: Roller, vibrator, dump truck.

Materials: Hot asphalt mixture with adjusted asphalt percentage.

Operations:
- o Locate the areas that needs repairing
- o Cut the edges of the damaged areas and spray an adequate quantity of bitumen to form a layer
- o Lay the asphalt mixture. This should not be pushed from the middle to the sides
- o Compact layer using an ordinary roller or a vibrator or lorry tires
- o Maintain shoulders. Fill the grooves and pits. Level the shoulders. Add earth filling to the shoulders' surface. Protect by draining the water from settlements, and upkeeping the cross slopes

Asphalt roads need a new surface course every 10 years on average. This is considered a new construction project.

3.4.4 Emergency Maintenance:

This maintenance covers speedy repairs of the road including all sudden and unexpected works obstructing the traffic. It is usually a result of:

- o Sand storms which result in the accumulation of sand on the road
- o Floods and excess water resulting from plunging irrigation
- o Sudden breakdowns of construction beneath the road such as bridges or pipes, etc as a result of an accident or wear or overloads

Personnel: Road department labourers + any other personnel as needed.

Tools and Equipment: Same as in routine preventive maintenance, as these repairs can be done by labourers or by using suitable road repair equipment. This will vary depending on the type of emergency.

Materials: According to type and location of emergency.

Operations: o Remove sand adjacent to the road

o Repair collapsed area, and drain off water. Concrete bridges should be built or pipes should be layed beneath the parts of roads exposed to floods to facilitate water draining. Repair or renew collapsed bridges or pipes

It is obvious that some preventive measures could reduce sudden road collapses and the need for repairs. These measures include planting trees, construction of water drainage systems, and soil fixing.

3.4.5 Examples of Asphaltic Paving Patching:

1. Alligator Cracks:

Those are cracks consisting of several small squares that looks like the crocodile's skin. They are usually a result of an unfixed base course leading to severe curvature of the asphalt surface. Water saturation is the basic reason for unfixdness.

Permanent Repair:

A. Remove the cracked surface deeply enough to reach a solid fixed layer. The cutting should be square or rectangular, with straight vertical sides. The two sides should also be perpendicular to the traffic. The asphalt saw will cut swiftly and cleanly. (figure 3.9)

B. The asphalt cement layer will be placed on the vertical sides (figure 3.10).

C. To get the best results the pit should be filled with high quality hot asphaltic mixture (figure 3.11) and then spread carefully so as not to separate its granules (figure 3.12). This asphaltic mixture, because of its depth, does not need an absorption layer.

D. If the depth exceeds 15 cm, the pit should be filled with layers. Each layer should not be more than 15 cm after compaction. Paving equipment differs according to the work volume. Regular rollers and vibrators (figure 3.13) can be used.

E. If the asphaltic mixture materials are not available, the pit is filled first with gravel materials and sprayed with a liquid asphalt layer. Then a surface course of hot or cold asphaltic concrete is applied. The area is then compacted to the same level as the surrounding pavement.

1. Alligator Cracks:

Fill with asphalt mix

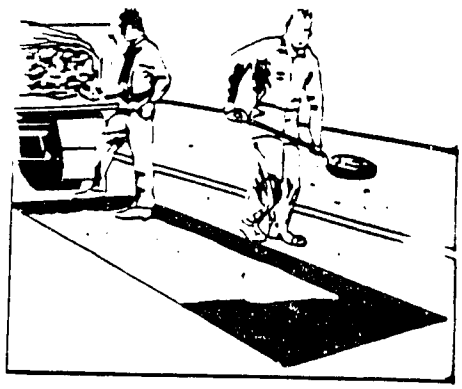


Fig. 3.11

Remove the cracked surface to reasonable depth (surface and base-coarse)

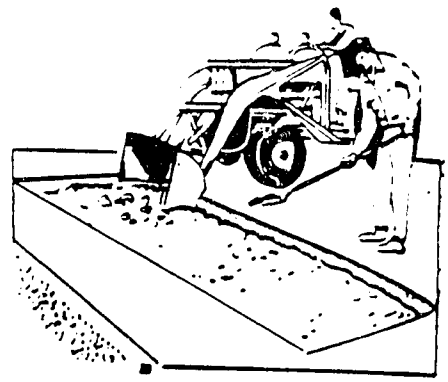
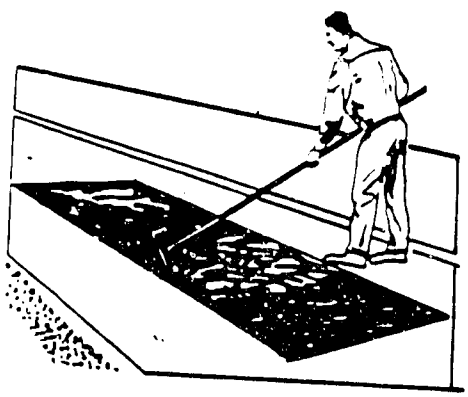
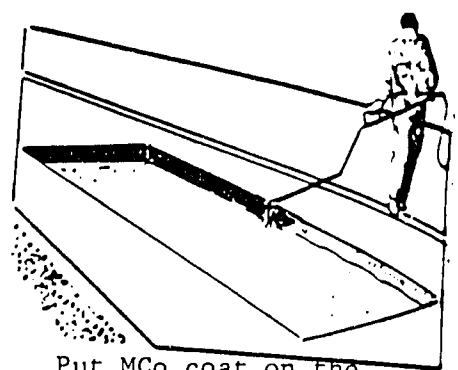


Fig. 3.9



Spread the asphalt mix carefully

Fig. 3.12



Put MCo coat on the vertical edges

Fig. 3.10

F. Longitudinal and cross levelling bars are used to level the surface for traffic (figure 3.14).

2. Slippage Cracks

These are a result of the traffic, tires, and brakes friction.

Repair:

A. Remove the surface around the sliding space until reaching the fixed pavement. Provided that the cutting surface is straight and vertical, this can be done using the asphalt saw (figure 3.15).

B. The lower surface should be cleaned with brushes and compressed air (figure 3.16).

C. Spray a light asphalt cement layer (3.17).

D. An adequate quantity of hot asphaltic mixture should be placed in the removed area and compacted until as it has the same level as the surrounding surfaces (figure 3.18).

E. The mixture surface should be levelled properly with the fork back without any separation occuring (3.19).

F. The surface should be tested with the levelling bar (3.20).

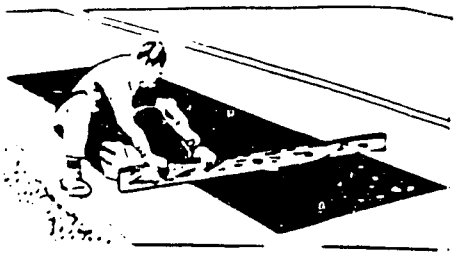
G. The mixture should be compacted properly using the regular or vibrating roller (figure 3.21).

3. Distortion:

These are small locational cavities, sometimes with cracks, and their depth varies from one inch to 1.5 inches. During winter, water accumulates in them causing troubles for drivers. These cavities are usually a result of insufficient layer thickness and compaction upon construction, the sinking of the pavement lower layers, or traffic heavier than load the pavement was designed for.

Repair:

The cavities should be filled with hot asphaltic mixture and compacted to the same level as the adjacent pavement, as follows:



Assure Surface Levelling

Fig. 3.14

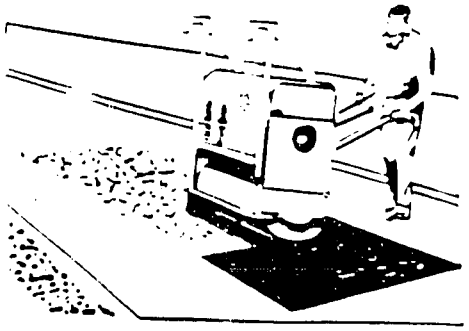


Fig. 3.13

2. <u>Slippage Cracks</u>:

Cutting with asphalt saw

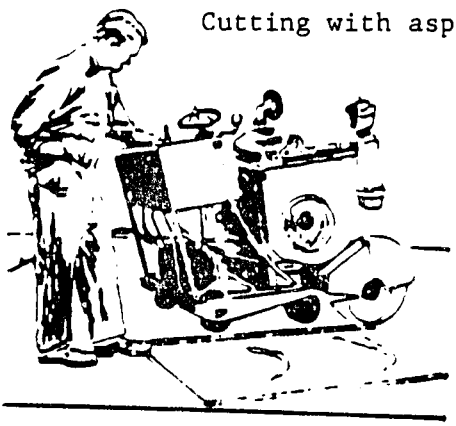


Fig. 3.15

Asphalt tack coat

Fig. 3.17

Clean the removed surface with brush

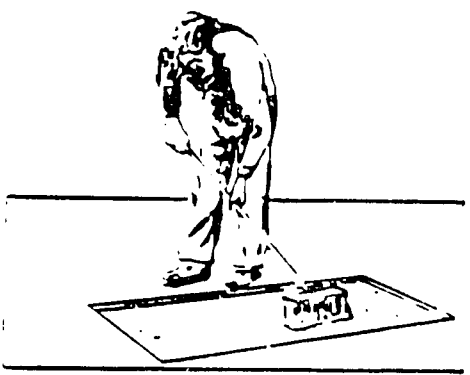


Fig. 3.16



66

Check surface levelling

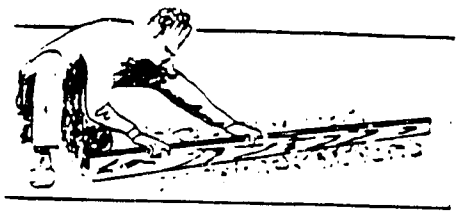


Fig. 3.20

Lay asphalt mix in the removed area

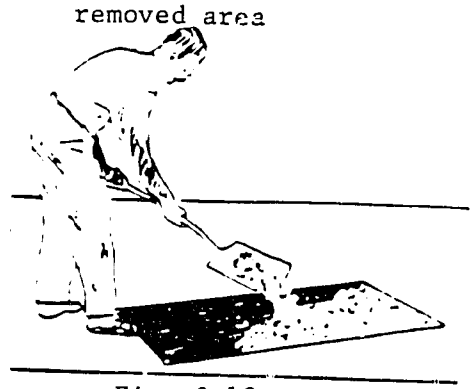
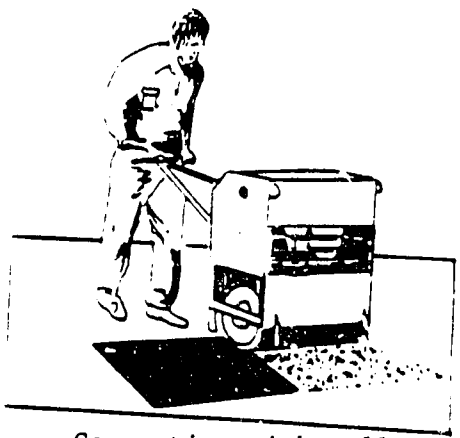
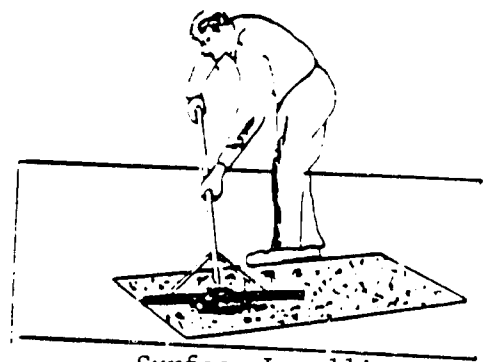


Fig. 3.18



Compaction with roller

Fig. 3.21



Surface Levelling

Fig. 3.19

A. Delimit the cavity place with the levelling bar and [illegible] it on the pavement (figure 3.22).

B. Cut the cavity edges to make its sides vertical. This can be done manually or by using a cutting device (figure 3.23).

C. Clean the cavity surface and surroundings (figure 3.24).

D. Spray tack coat (1.5 kg per square meter of asphaltic emulsion dissolved in water with 1:1 proportion) on the clean surface (figure 3.25).

E. Wait until the tack coat evaporates and dries.

F. Spread an adequate layer of hot asphaltic material on the cavity surface so that, after compaction, it will be the same level as the surrounding pavement (figure 3.26). A cold asphaltic mixture could be used. This should be left for a while until the water and dissolving materials evaporate and the bitumen precipitates.

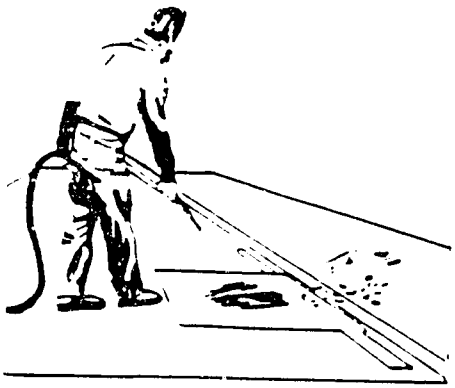
G. Level the cavity sides if their surfaces are not vertical. This can be done with forks. Make sure not to separate the granules.

H. Check the surface flatness using the levelling bar (figure 3.27).

I. Compact the cavity patching mixture using a regular or vibrating roller (figure 3.28).

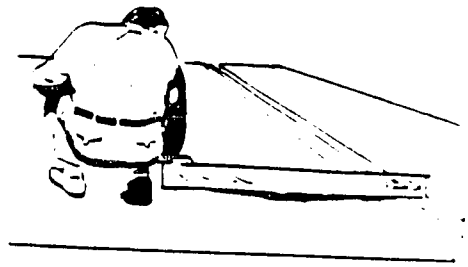
J. Place a sealing sand layer on the patched compacted surface to prevent water leakage (figure 3.29). Do not use a large percentage of asphalt.

III. Distortion:



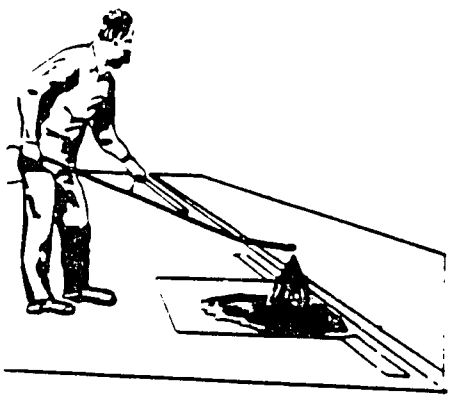
Cleaning by compressed air

Fig. 3.24



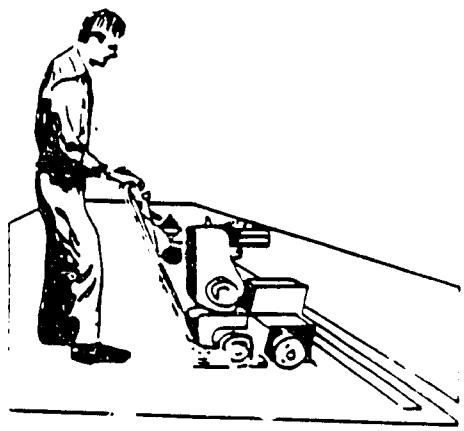
Locating the distortion area

Fig. 3.22



Laying asphalt tack coat

Fig. 3.25



Cut vertical edges

Fig. 3.23

Compaction

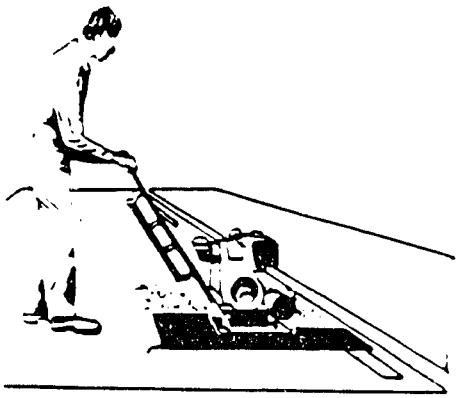


Fig. 3.28

Spread asphalt mix

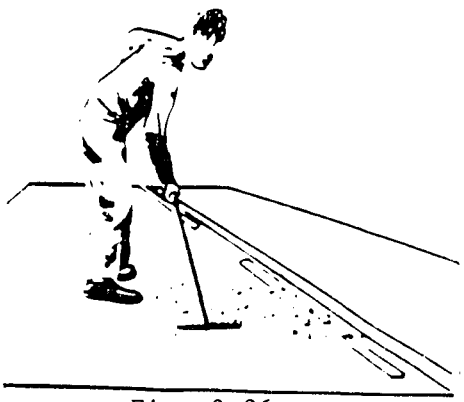
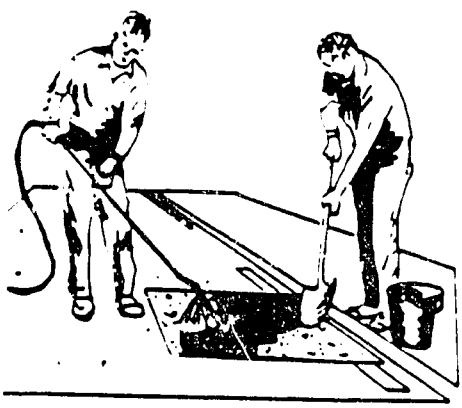
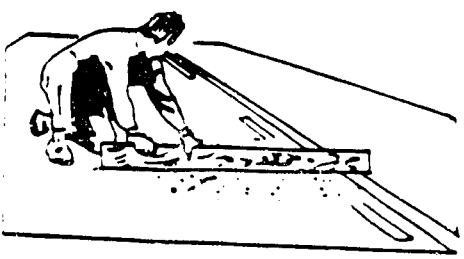


Fig. 3.26



Laying sand seal coat

Fig. 3.29



Levelling

Fig. 3.27

### 3.4.6 Types of Asphaltic Mixtures for Maintenance Work:

The most common mixtures used for maintenance are:

1. Hotlaid asphalt concrete:

These mixtures are designed to have high solidity and to be long lasting. They consist of high quality hotlaid asphalt concrete that differ in grades and type of gravel and asphaltic bitumen. They should be compacted before the mixture temperature goes down below 90 degrees centigrade.

2. Coldlaid plant mix with asphaltic bitumen

This is a mixture of metallic gravel, asphaltic bitumen, liquefaction element, and slaked lime. It is used where temperatures are sufficient to dry the gravel granules surface and melt asphalt. It can be spread directly if it is aired before compaction, and can be stored for future use.

3. Coldlaid plant mix with liquid asphalt

This is mechanical mixture of local gravel and liquid or emulsified asphalt. It can be spread directly or stored for future use.

4. Local mechanical mixture with coldlaid asphalt

This is a local mixture consisting of local gravel and medium or slow liquid asphalt.

## 3.5 Maintenance of Heavy Equipment

This section covers maintenance of equipment used in maintenance of roads and constructions, such as graders, bulldozers, loaders of all kinds.

### 3.5.1 Operation and Daily Maintenance:

The operator should carry out the following work before operating the equipment:

Frequency: Daily or each 10 working hours

Personnel: The operator and equipments' mechanic

Tools: A set of mechanic tools, equipment's tool.

Spare Parts: Cleaning cloth - fuel, oil, water, battery fluid.

- Clean the equipment inside and outside
- Check levels of water, oils, battery solution
- Refill with fuel if needed
- Check tyre pressures fig. 3.30
- Check chain connections
- Check belt tensions
- Start the engine and observe indicators aand meters in the dashboard and report anything unusual
- Operate the equipment fittings and report any unusual observations
- Check brakes, clutch and steering
- Clean air filter with compressed air fig. 3.31

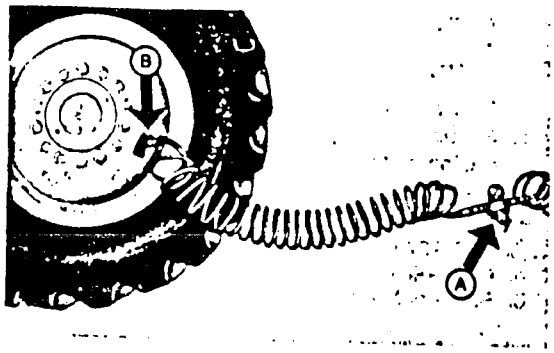



Fig. 3.30

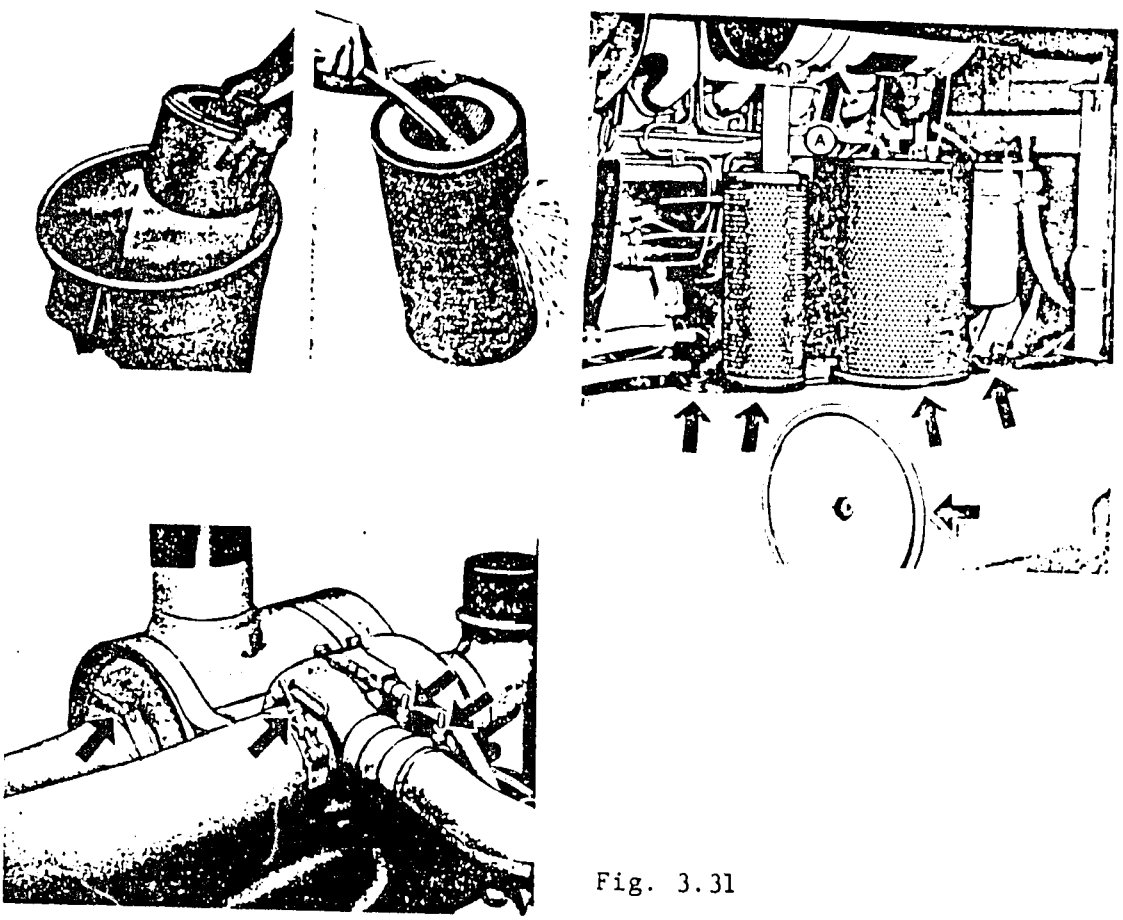



Fig. 3.31

Cleaning Air Filter with Compressed Air

3.5.2 reventive Maintenance each 50 operating hours:

Frequency: Weekly, or every 50 working hours

Personnel: Equipment's machanic and the operator

Tools: A set of mechanic's tools, the equipment's

Materials and Spare Parts: Grease, engine oil, hydraulic oil, battery solution

Operations:
- o Grease all greasing nozzles according to producers' instructions
- o Check the battery, the solution level, and cleanliness of connections
- o Check the tires' air pressure
- o Defecate sediment from the fuel tank
- o Check the hydraulic oil level fig. 3.32
- o Check the engine's oil level fig. 3.33.
- o Check the differential gearbox oil level fig. 3.34

3.5.3 Preventive Maintenance each 200 operating hours:

Frequency: Every month, or every 2000 working hours

Personnel: Equipment's mechanic, operator

Tools: A set of mechanic's tools, equipment's tools

Materials and Spare Parts: Grease, engine oil, battery solution, oil filter, gear oil, hydraulic oil.

Operations:
- o Same as in Maintenance I plus the following:
  - o Grease nozzles that need greasing according to the equipment manufacturer's instructions
  - o Defecate sediment from the fuel tank
  - o Change engine's oil
  - o Change engine's oil filter fig. 3.35
  - o Check the oil level in the gearbox
  - o Check the hydraulic oil
  - o Adjust dynamo belt tension and the cooling fan
  - o Check the lights and electrical connections

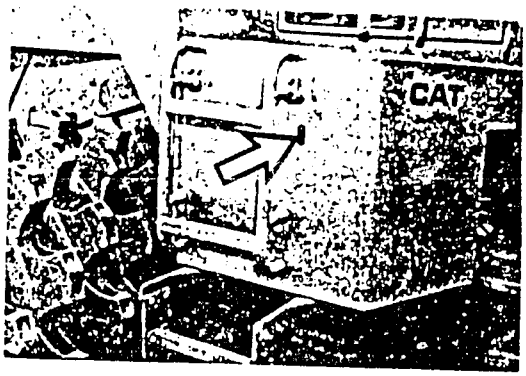



Fig. 3.32

Check Hydraulic Oil Level

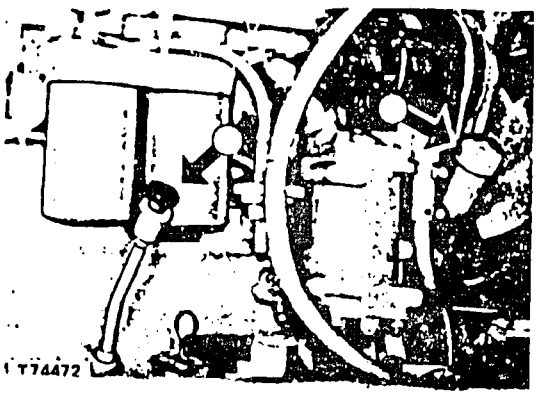



Fig. 3.33

Check Engine Oil Level

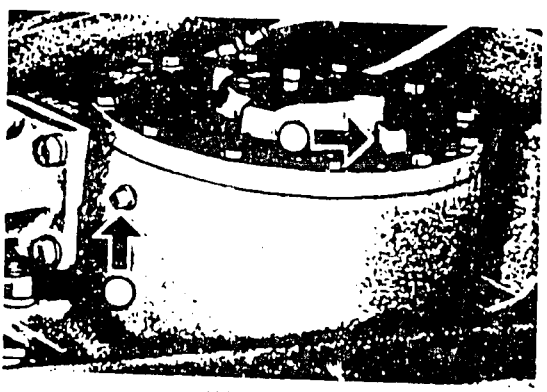


Fig. 3.34

Check differential Oil Level

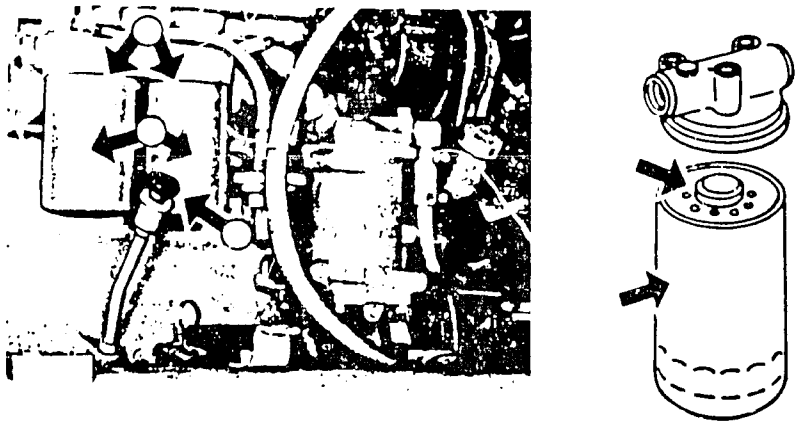


Fig. 3.35

Changing Engine Oil Filter

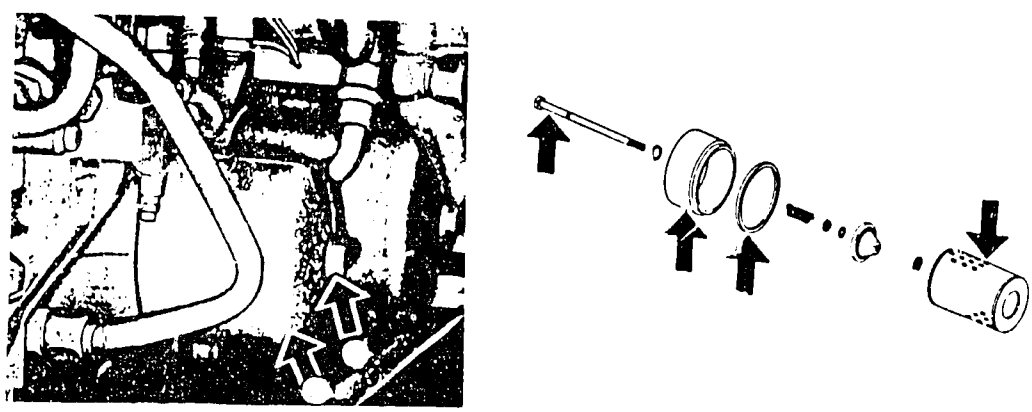


Fig. 3.36

Changing Transmission Oil Filtering Element

### 3.5.4 Preventive Maintenance each 500 Operating Hours:

Frequency: Every six months, or every 500 working hours

Personnel: Equipment's mechanic, operator

Tools: A set of mechanic's tools - equipment's tools

Materials and Spare Parts: Same as in Maintenance II plus gear oil filter element, hydraulic oil filter element, air filter element, fuel filtering element.

Operations: Same as in Maintenance II plus the following:

- Change gearbox oil
- Change filter element of gearbox oil filter fig. 3.36
- Change filter element of hydraulic oil filter
- Clean the fuel strainer if it exists
- Change the air filter element, or clean it if it is in good condition
- Check and grease the roulement balls and adjust clearances according to producer's instructions
- Change filter element of fuel filter
- Check compressed air hoses, and hydraulic oil pipes and hoses, and change them if needed
- Adjust fuel pump fig. 3.37
- Disassemble and adjust injectors fig. 3.38.

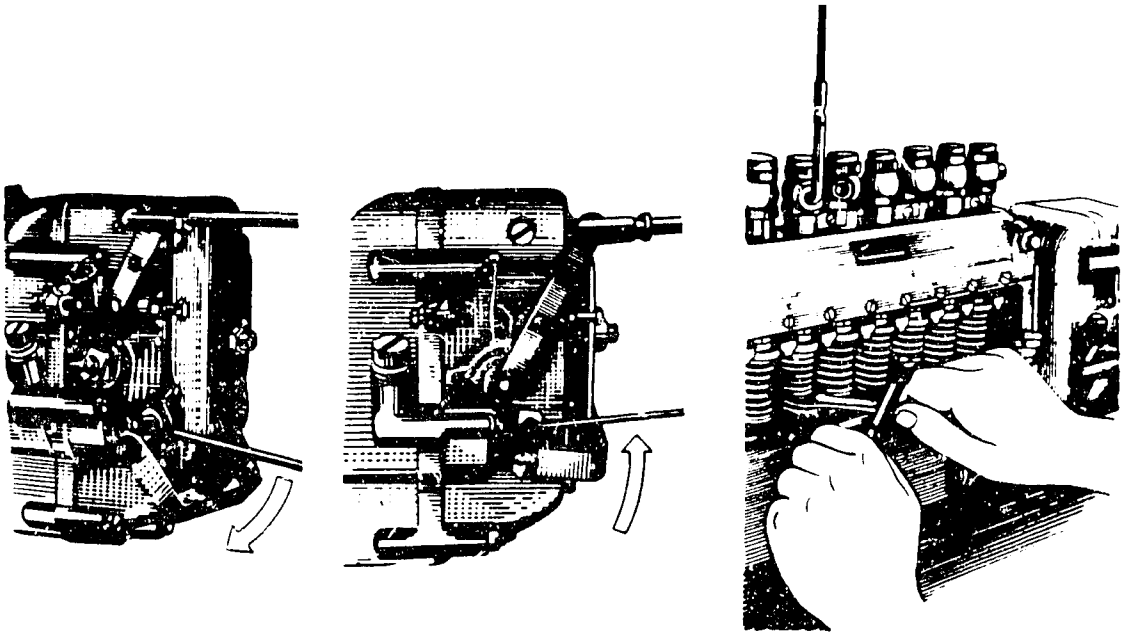


Fig. 3.37
Adjusting Injection Pump Timing

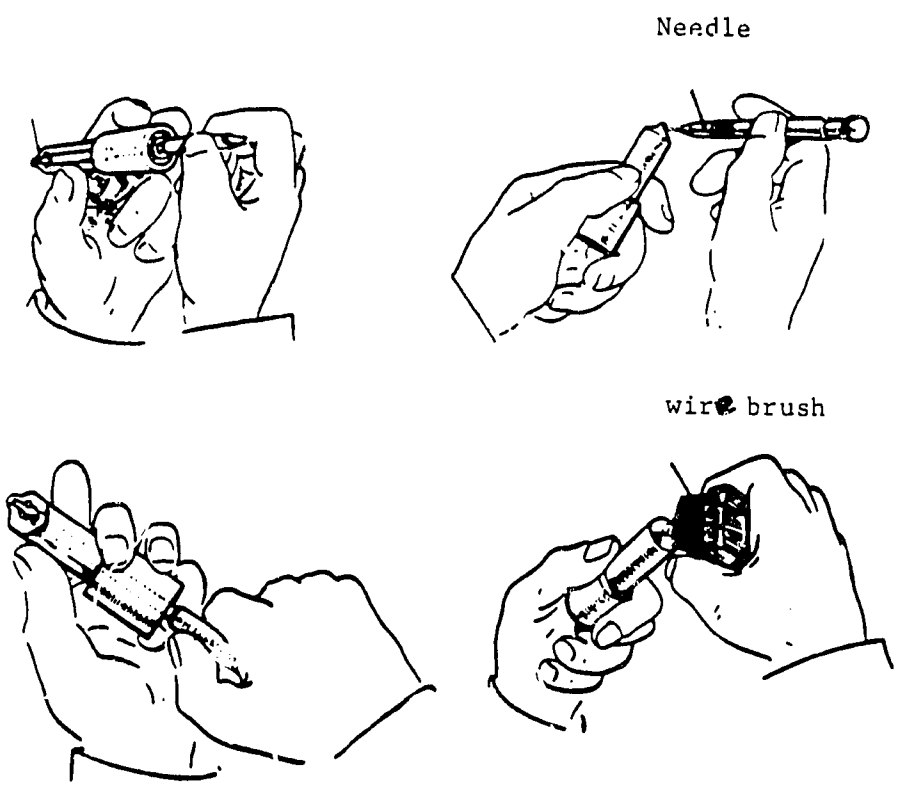



Fig. 3.38
Cleaning of Injectors

### 3.5.5 Preventive Maintenance each 1000 operating hours

Frequency: Every 1000 operating hours or each 6 months

Personnel: Equipment's mechanic, operators

Tools: Equipment special tools, devices and equipment in the maintenance center

Spare Parts and Materials: Oils, grease, filtering element, fuel, compressed air, water.

Operations: In addition to the 500 operating hours maintenance do the following:

- Valve clearance adjusting fig. 3.39
- Check brakes and adjust if necessary
- Check cluch operation and adjust
- Check and adjust hand brake
- Greasing of all points according to the equipment greasing chart

### 3.5.6 Preventive Maintenance each 2000 Operating hours:

Frequency: Each 2000 operating hours

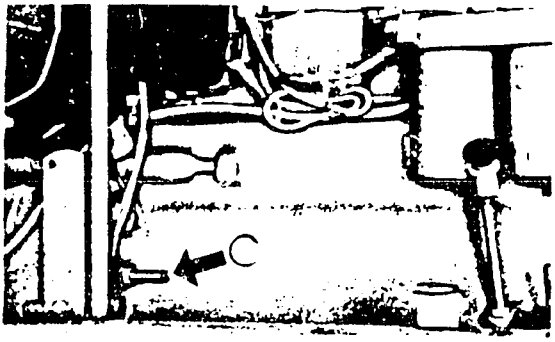
Personnel: Qualified technicians in the maintenance center

Tools: Special tools, devices, and equipment

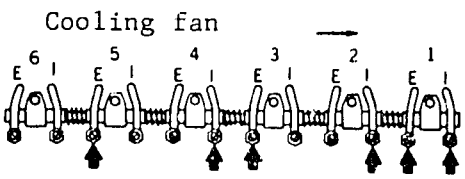
Spare Parts and Materials: Same as in the previous maintenance.

Operations:

- Check the hydraulic devices
- Check all engine circuits (fuel, oil, cooling, ...)
- Inspection of engine components (fuel injection pump, generator, starter, ... etc)
- Inspection of transmission, differentials, steering, ... etc)
- Replace or repair all components which were discovered during inspection
- Body repairs, painting, ... etc.




Remove valves cover and adjusting pin




1st cylinder in comp. stroke

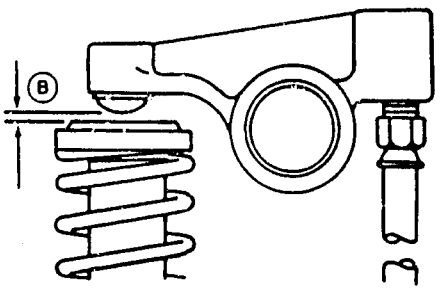
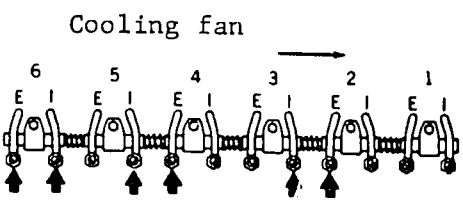



Fig. 3.39

Valves adjustment




6th cylinder in comp. stroke

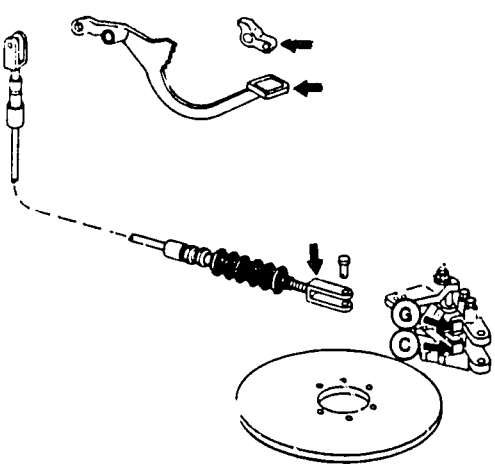



Fig. 3.40

Check hand brake

### 3.5.7 Quarterly Inspection:

The main purpose of inspection for any equipment each 3 months, is to identify its technical condition and its suitability to perform its tasks. Also to determine the technical capabilities of operators and to inspect the equipment aggregates and driver's tools and to assure the implementation of preventive maintenance according to its duration. Thus providing the officials at all levels with information on equipment technical condition to enable them to make the necessary decision to upgrade O&M capability. Table 3.3 presents equipment technical form to determine the technical status of all form to determine the technical status of all equipment aggregates to prove its availability. Finally to identify the needed repairs to upgrade its performance.

## 3.6 Preventive Maintenance of Cars and Equipped Vehicles:

This section is about maintenance of cars and equipped vehicles (evaluation - water spraying- garbage ... etc) whether they have diesel or gasoline engines.

### 3.6.1 Operation and Daily Maintenance:

The driver should do the following before running the vehicles:

- Clean the vehicle inside and outside
- Check levels of water - oil - brake oil, battery solution (figure 3.41)
- Check belt tensions (figure 3,42)
- Check tire pressures
- Check the brakes and clutch
- Check the driving wheel
- Refill the vehicle with fuel if needed

### 3.6.2 Preventive Maintenance (I) (P1):

Frequency: After 1500 - 2000 km

Personnel: The driver assisted by a mechanic, electrician, and a greasing worker.

Tools: One set of mecnanic's tools, a set of electrician's tool, voltmeter, hydrometer, torque wrench, grease lubricator, oiler, oilcans

Materials and Spare Parts: Engine oil, grease, distilled water, washing oil, washing water, cleaning cloth, brake oil, iron sand, paper.

Table (3-7)

Equipment technical inspection form

| | | |
|---|---|---|
| Governorate : | Markaz : | Location : |
| Equipment : | Brand : | Model ( manf. year |
| Engine S.N. : | Chasit No. : | Plate No. : |
| Hourmeter : .....Hrs. | Operation Hrs. & covered distance during the three months | Engine model & Type : |
| Kilometer : .....Kms. | .....Hrs. / .....Kms. | Engine power : |
| Date of this inspn. : | Date last inspn. : | |

Insert (/) for cases 1,2,3

| Description | L.R/M | | 1 | 2 | 3 | Remarks |
|---|---|---|---|---|---|---|
| | Date | Type | | | | |
| a-Operator cab. | | | | | | |
| 1-Gauges . | | | | | | |
| 2-Pedals & controls . | | | | | | |
| b-Engine | | | | | | |
| 1-Levels (water , oil ) | | | | | | |
| 2-Lekage (water , oil ) | | | | | | |
| 3-Air filter | | | | | | |
| 4-Fuel filter | | | | | | |
| 5-Oil filter | | | | | | |
| 6-Air compressor | | | | | | |
| 7-Fuel pipes | | | | | | |
| 8-Injection pump | | | | | | |
| 9-Priming pump | | | | | | |
| 10-Radiator | | | | | | |
| 11-Fan & belts | | | | | | |
| 12-Cooling fan | | | | | | |
| 13-Heating plugs | | | | | | |
| c-Transmission group | | | | | | |
| 1-Clutch | | | | | | |
| 2-Gearbox | | | | | | |
| 3-Transfer case | | | | | | |
| 4-Front axle | | | | | | |
| 5-Rear axle | | | | | | |
| 6-P.T.O. | | | | | | |
| 7-Final reduction | | | | | | |
| | | | | | | |

L.R/M Last repair or maintenance

1: Satisfactory 2: Needs maintenance adjustment

3: Needs repair or replacment



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| Description | L.R/M Date | L.R/M Type | 1 | 2 | 3 | Remarks |
|---|---|---|---|---|---|---|
| d-Hyd. torque convertor | | | | | | |
| 1-Efficient P.T.O. | | | | | | |
| 2-Feed pump | | | | | | |
| 3-Oil filter | | | | | | |
| 4-Oil leakage | | | | | | |
| 5-Oil press. | | | | | | |
| 6-Oil cooler | | | | | | |
| e-Hyd. control system | | | | | | |
| 1-Hyd. pump | | | | | | |
| 2-Hoses & joints | | | | | | |
| 3-Hyd. cylinder | | | | | | |
| 4-Filters & breathers | | | | | | |
| 5-Control valves | | | | | | |
| 6-Hyd. oil level | | | | | | |
| 7-Hyd. motors | | | | | | |
| f-Brake | | | | | | |
| 1-Park brake | | | | | | |
| 2-Foot brake | | | | | | |
| 3-Oil leakage | | | | | | |
| 4-Drums & joints | | | | | | |
| g-Steerin & suspension | | | | | | |
| 1-Servo | | | | | | |
| 2-Hoses & joints | | | | | | |
| 3-Springs & shock absorber | | | | | | |
| h-Wheels & tires | | | | | | |
| 1-Fastening | | | | | | |
| 2-Tire press. | | | | | | |
| 3-Tire condition | | | | | | |
| i-Cab. | | | | | | |
| 1-Upper & lower roller con | | | | | | |
| 2-Pads | | | | | | |
| 3-Tension group | | | | | | |
| 4-Oil leakage | | | | | | |
| 5-Tandem oil level | | | | | | |
| j-Electrical circuit | | | | | | |
| 1-Batteries | | | | | | |
| 2-Cables & horn | | | | | | |
| 3-Fro.&rear lights,signals | | | | | | |
| 4-Generator & charging | | | | | | |
| 5-Starter | | | | | | |
| k-Chassis & accessories | | | | | | |
| 1-Fastening | | | | | | |
| 2-Chassis condition | | | | | | |
| 3-Front blade | | | | | | |
| 4-Rear blade | | | | | | |
| 5-Bucket | | | | | | |
| 6- | | | | | | |

L.R/M Last repair or maintenace
1: Satisfactory
2: Needs maintenance or adjustment
3:Needs repair or replace

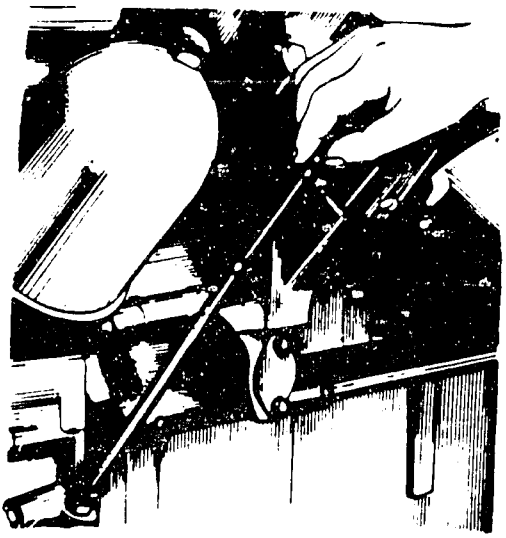
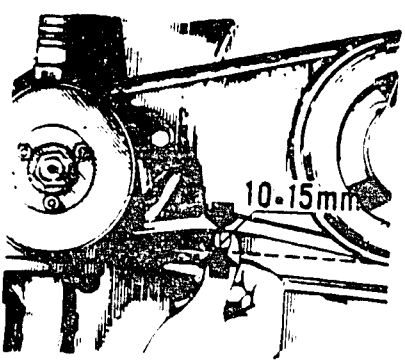
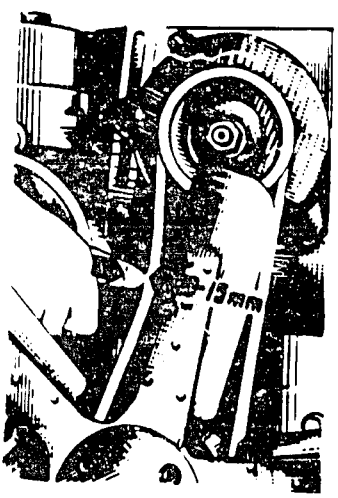


Fig. 3.41

Checking the oil level in engine sump




Checking the water pump



Checking the generator belt tension

Fig. 3.42

Operations: 1. Washing and cleaning-vehicle before maintenance.

2. Fixing and fastening operations.

Engine

- Radiator, water pump, fan, and checking radiator cap valve
- Engine mountings
- Induction and exhaust
- Starter, dynamo, distributor, carburetter, fuel pumps, oil filter, air-fuel
- Battery fixing, connections and caps

Power Train: wheel connections, wheel box, gearbox, carden shafts bearings, carden shaft connections, springs, wheels nuts. Cabin with chassis, box with the chassis, door, mudguards, bumper and any other disjointed parts.

3. Adjusting Operations:

Motor

- Fan belt tightness, platinum clearance
- Carburetter (gasoline motors)
- Injection pump (diesel motors)
- Checking injectors without disassembling them.

Electric Circuits:

Wires, meters, checking lamps, adjusting lights, signals light switch.

Power Train

- Adjust clutch clearance
- Adjust brake clearance
- Adjust wheel movement clearance
- Check the hand brake
- Check brake pedal spring and clutch
- Check the brakes and adjust clearance if needed
- Check tyre air pressures.

4. Oiling and greasing:

Oiling operations: Dynamo, distributor cam, hauling and towing instruments, wheel box, differential transmission shaft hinge connection, changing air filter oil, cleaning paper element with compressed air, oiling should be done using the oils specified in the catalogue technical specifications.

Greasing Operations:

Grease the vehicle wherever there are greasing nozzles in it, and in accordance with the greasing board specified in the producers' instructions.

5. Repairing discovered breakdowns:

- Run the motor to detect any unusual sounds or defects, and repair it if needed
- Operate the equipment to check its performance and repair defects if there are any
- Drive the vehicle to check the brakes (response to sudden braking), steering, power train components (clutch, gearbox, axles)

6. Maintain equipment in the vehicle according to its type and on basis of the producers' instructions.

7. Wash and clean the vehicle after maintenance

3.6.3 Preventive Maintenance (II) (P2):

Frequency: After 4000 to 5000 km according to type of utilization and weather.

Personnel: Driver assisted by a mechanic, electrician and a tyre worker

Toold: Same as in Maintenance 1 plus cylinder pressure gauge, wheel clearance adjusting device, wheel toe pincement device.

**Materials and Spare Parts:** Same as in Maintenance I plus gear oil, spark plugs, (nozzles) injectors soldering tape, electric wire, filters (air - oil - hydraulic - fuel) according to vehicle type.

**Operations:** Same as in Preventive Maintenance I plus the following:

1. **Motor:**
   1. Fasten cylinder caps using the specified torque wrench in the producers' instructions 3.43
   2. Check the air filter oil level, or the cleanliness of paper filtering element 3.44.
   3. Adjust valves clearance fig. 3.45
   4. Disassemble and check the injectors figure 3.46
   5. Adjust the air compressor valves clearances
   6. Disassemble the starter and dynamo to wash, clean and check their parts
   7. Adjust the platinum clearance or replace it with the spark plugs

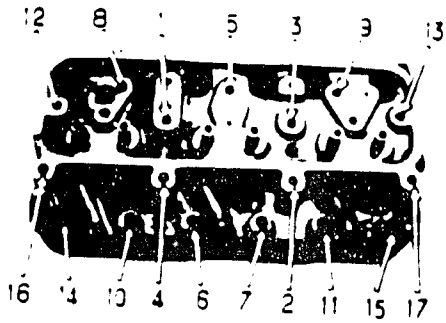



Fig. 3.43

Tighten Cylinder Head
According to the Sequence

Fig. 3.44

Check oil level in the Air filter

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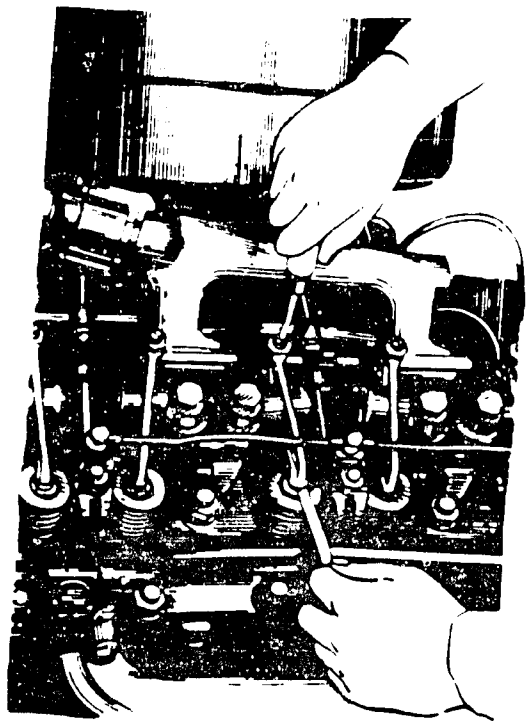

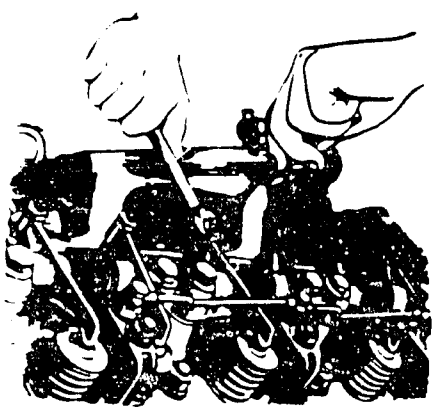

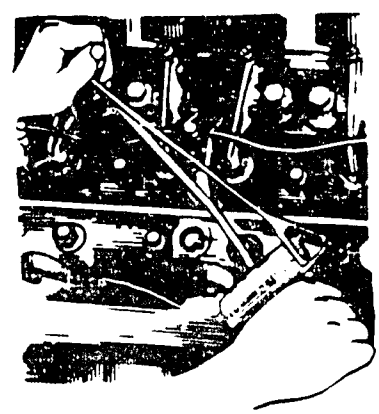

Fig. 3.45
Adjusting Valve Clearances

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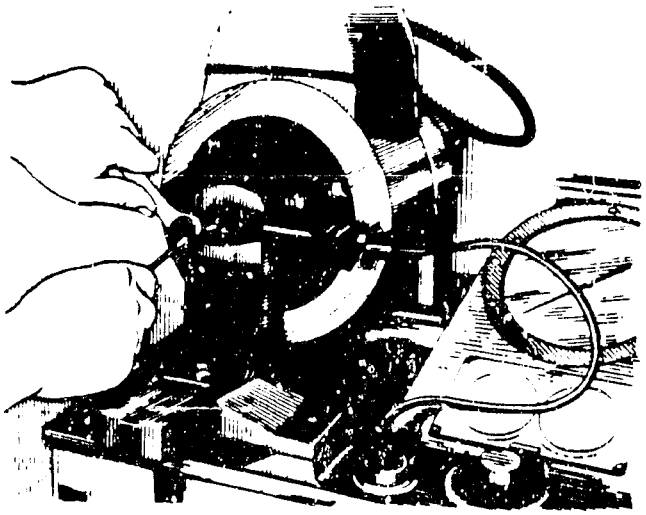

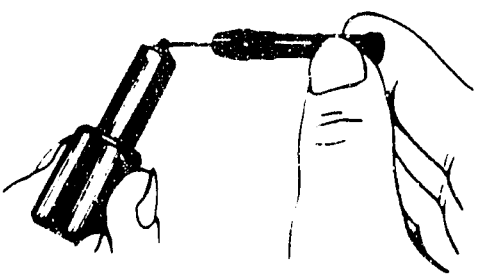

Fig. 3.46

Injectors Adjusting

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2. Power steering

- o Check and adjust the steering wheel clearance according to the producers' instructions 3.47
- o Check the wheel axle clearance
- o Check the steering box oil level fig 3.48
- o Check the hydraulic circuit

3. Power train:

- o Check and adjust the brakes and clutch clearances
- o Check and adjust the wheel toe
- o Check the springs and shock absorbers and fasten and change if needed fig. 3.49

4. Brake

- o Empty the air tanks of sediment or filling oil in the circuit defecation can
- o Lining and pullies: emery and adjust clearance according to producers' instrucions
- o Fasten connections and plugs, and grease if needed
- o Check the servo

5. Tyres:
   - o Check the tire pedal
   - o Replace tires according to sequence instructions fig. 3.50
   - o Tighten wheel nuts

6. Greasing and Oiling: Same as in Maintenance I, run the vehicle and check the motor and all components. Repair defects if there are any.

7. Perform maintenance for vehicles' equipment according to instructions.

8. Wash and clean the vehicle after maintenance

3.6.4 Preventive Maintenance III (P3):

Frequency: After 10,000 - 15000 km, or every six months according to utilization and weather.

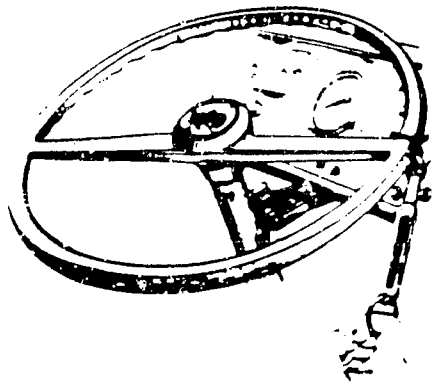

Fig. 3.47

Checking effort on steering wheel rim

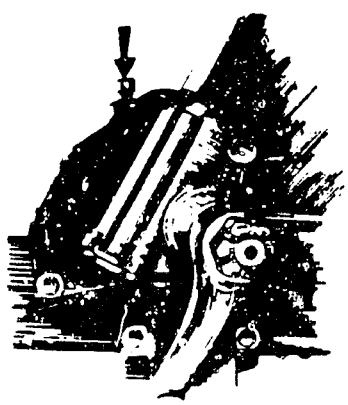

Fig. 3.48

Checking oil level in steering box

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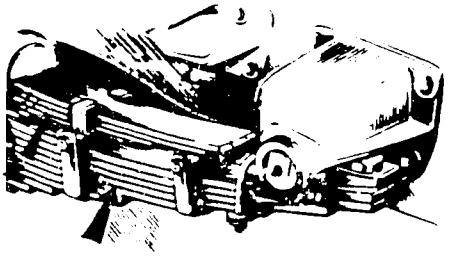

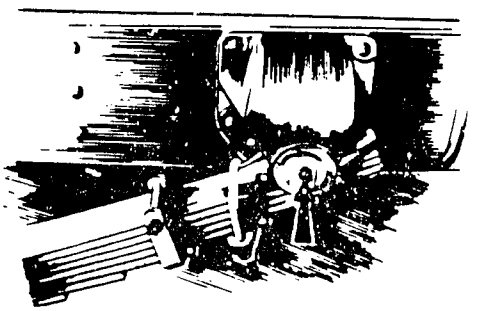

Fig. 3.49

Greasing front and rear leaf springs

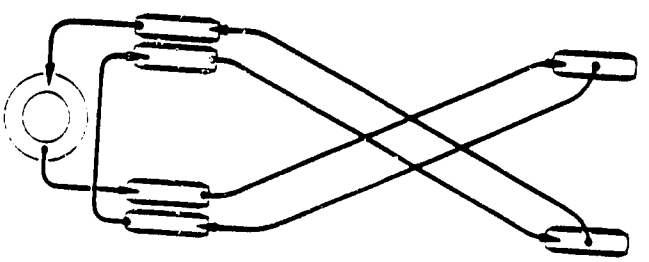

Fig. 3.50

Replace tires according to their sequence

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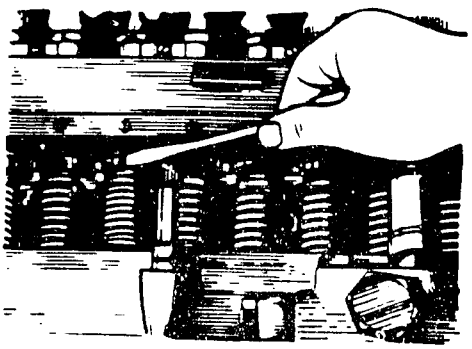
Personnel: Same as in Maintenance II.

Tools: Same as in Maintenance II.

Materials and Spare Parts: Same as in Maintenance II plus rust preventer solution.

Operations: Same as in Maintenance II plus the following:

- Adjust injection pump 3.51
- Change gearbox oil and grease wheel box and axles
- Wash fuel tanks
- Wash cooling circuit with a rust dispeller solution and add rust preventer according to the instructions for using such solutions
- Disassemble, clean and adjust the carburetter (for spark ignition engines)
- Start the engine and drive the car. Operate the equipment to detect defects and repair them
- Wash and clean the car after maintenance



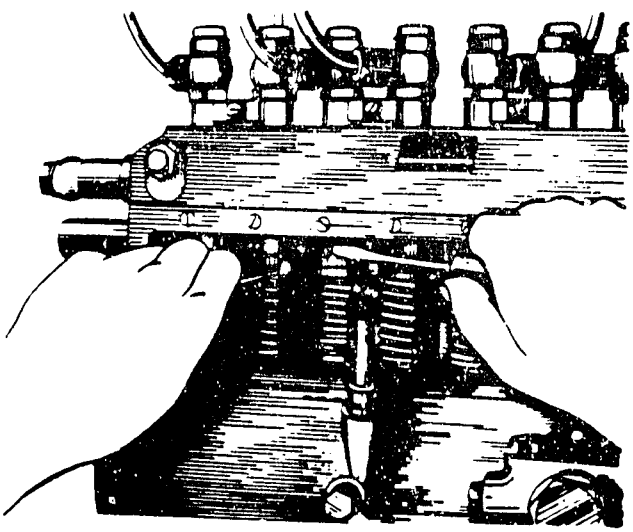


Fig. 3.51

Adjusting the timing of injection pump

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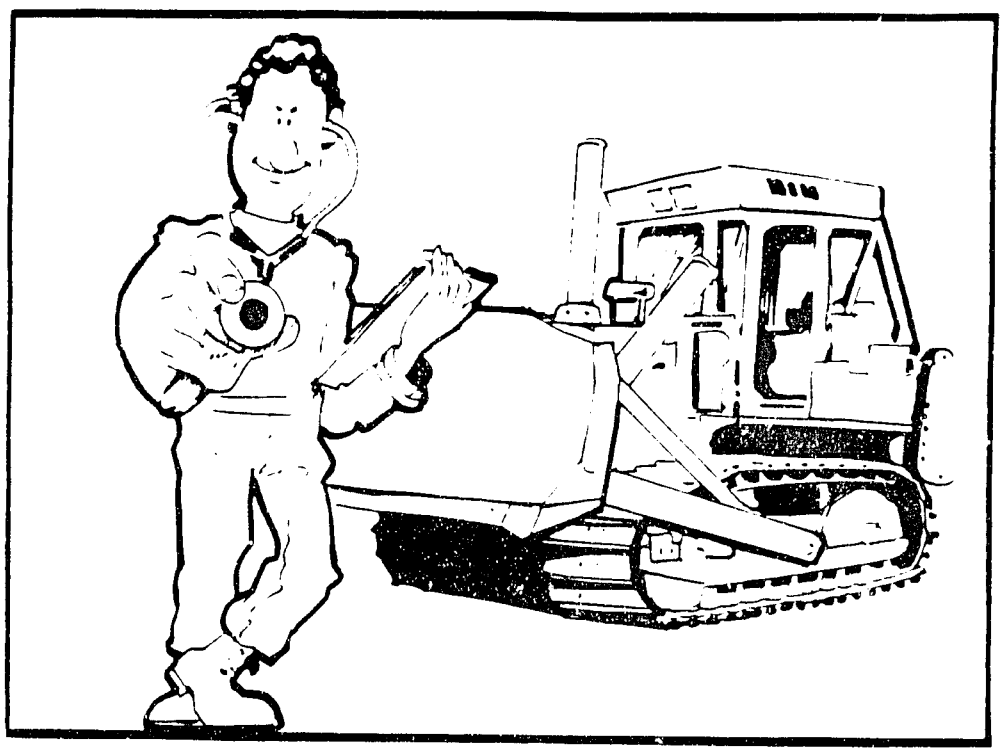
# Section 4

TROUBLE SHOOTING OF DIFFERENT
EQUIPMENT



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# SECTION FOUR

## Troubleshooting on Different Projects:

### 4.1 Diesel Engines (Water pump units)

Before defining the cause of breakdowns in the fuel system of different diesel engines, the personnel carrying out testing, maintenance and repair operations should be well informed about the different installation manuals of those engines. These manuals contain all the information explaining utilization, maintenance, organization and possible breakdowns and the ways to detect and repair them.

#### 4.1.1 Troubleshooting on full system

In order to define the breakdown cause in a diesel engine fuel system we have first to be sure that the fuel system is completely free of air and that fuel reaches the injector nozzles.

Generally, we can divide fuel system major breakdowns into the following:

A. General system breakdowns. This includes the fuel flow from the tank to the fuel injection pump through the fuel filters and the preparation pump.

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| The engine does not run because the fuel does not reach the fuel injection pump | A. The fuel trap is closed | A. Open the trap |
| | B. The fuel tank is empty or there is not enough fuel | B. Refill the tank |
| | C. Air in the pipes because of leaking allowing air inside. | C. Bleed air during installation and fasten the bolts tighly |
| | D. Fuel filter occlusion | D. Clean the filter with fuel oil |
| | E. Occlusion of expulsion and conduction pipes | E. To be cleaned by compressed air |
| | F. A defect in the fuel preparation pump | F. Take necessary procedures to detect the defect |

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| The engine does not run, or runs with difficulty although the fuel reaches the fuel injection pump. | A. Air in the fuel conduction pipes | A. Bleed air in the pipes and fasten the conduction bolts tightly |
| | B. The engine stopping cable is fixed in the stopping position | B. Loosen the cable |
| | C. A defect in the injectors | C. Test and repair the injectors |

B. Troubles of the Fuel Injection Pump:

The lower part of the pump functions as an oil can for its moving parts and pistons. Therefore the oil level should be regularly checked and topped up if necessary. Also, check governor of the parts.

If the pump is correctly adjusted, it rarely causes any engine troubles, but if any breakdowns occur such as starting difficulty or irregularity, the cause could be detected by disconnecting the pipes joining the pump to the injectors where they join the injectors. Then turn the metering rod to the position where the pump gives the maximum amount of fuel, and start the pump. If the fuel does not come out of all the pipes, that means there is a defect affecting all pump parts, such as lack of fuel in the tank, the occlusion of the pump charging (induction) pipes, or the existence of air bubbles. If the fuel comes out of one pipe and not the other, that means there is a breakdown in this injectors' injection unit.

The following table shown the major injection breakdowns and their causes related to the fuel injection pump.

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| The fuel injection pump does not discharge fuel or the discharging pressure is very low. | A. The pump pistons are stuck.<br>B. Broken pump piston spring<br>C. The loosness of the expulsion valve on its base, or it is not fixed to the base. | A. Take off the pump cap. After starting the engine check whether the pistons are moving up and down. Repair by disassebling the pump parts and check any damage to the piston and replace it if necessary with a new one with its skirt. This operation should be performed by an injection pump specialist.<br>B. Replace with another one of the same type.<br>C. Clean the valve and the base, or tighten it if necessary. |
| No engine intake as the incoming fuel is not sufficient | A. Fuel leakage from the pump expulsion valve<br>b. Fuel leakage somewhere | A. Check and clean the valve or carryout the tightening operation between the valve and base.<br>B. Check for the leak and stop it. |
| The irregularity of fuel feeding from the pump. | A. An air bubble in one of the pump parts.<br>B. Broken pump piston spring or the corrosion of its lifter<br>C. Insufficiency of the fuel to the pump because of the induction pump's occlusion or dirty filter | A. Check the pump. Test the parts and replace the damaged ones. In addition clean the pipes and bleed air |

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| The engine does not run regularly | A. The pump ruck is stuck<br>B. The time of starting fuel injection is not fixed.<br>C. The slowdown organization is very weak. | A. Loosen the rack<br>B. Adjust the injection start after checking that there is no damage between the pump shaft and the engine shaft.<br>C. Readjust |
| The existence of heavy black plumes in the exhaust gas | A. The injection pump flow is very high because the joint or rack are damaged<br>B. The pump division is not adjusted.<br>C. Dirt in the air filter<br>D. The injectors are partially occluded or used up. | A. Correct the systematization by a specialist<br>B. Readjust the division<br>C. Disconnect the filter and clean it using solar 1, or replace it with a new one<br>D. Clean or renew the injectors' nozzles holes. |
| Changing fuel injection start | A. Change in adjustment of the piston lifter<br>C. Corrosion of the cam affecting the lifter | A. Organize the adjusting<br>B. Replace the cam and the filter |
| The speedy heating of the engine | A. The uneven flow of the pump injection units<br>B. Other reasons unrelated to the injection pump and no need to mention them here | A. Perform necessary adjustment and fixing |

C. Injector Troubles:

The injector is often the cause of breakdowns in the fuel injection system. In order to detect the cylinder with the broken injector disassemble the feeding pipe of each cylinder separately. Disconnecting the cylinder with the good injector will affect the engine running sound. If the engine sound is not affected it means there is a defect in the injector and it should be disconnected for checking.

The following table shows the major breakdowns caused by injectors, the reasons for them and ways of detection avoidance, or repair.

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| Black smoke from exhaust | A. Needle spring breakage or non pressure of spring<br>B. Injectors are partially occluded or used up<br>C. Injectors leak because of dirt between the needle and its base or bad adjustment either of the injector spring, or the start of injection. | A. Readjust the spring pressure or replace it if broken or impossible to adjust<br>B. Clean or renew the injectors' nozzles holes<br>C. Disconnect the injector and clean it with solar oil or replace the injector and the needle. If impossible to organize injector spring adjustment, then adjust the injection start. |
| The engine the runs intermittently because of wear in cylinder | A. Occlusion of nozzle holes.<br>B. A crack in the nozzle body | A. Disconnect and clean, by a specialist<br>B. Replace damaged parts |
| The occurance of engine sounds | A. The injector's needle is stuck because of dirt or overheating | A. Test the injector in its position in the cylinder by placing the hand on the clasp while running the engine, if the needle movement is not felt it indicates that the needle is stuck and the spring damaged |

### 4.1.2 General Diesel Engine Troubles:

This part discusses the diesel engine and its components generally, possible causes and disgnoses.

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| The engine fails to run: The starter does not run the engine | - The battery is discharged<br>- Battery cable is disconnected<br>- Defect in the starter button<br>- A defect in the contact switch<br>- Starter failure | - Change battery<br>- Connect battery cables<br>- Repair starter button<br>- Repair contact switch<br>- Repair starter |
| The starter runs the engine slowly | - The battery is partially discharged<br>- The battery cable is not tightly fastened. Joints are dirty<br>- Engine oil is not of the required viscosity | - Replace engine oil |
| Mechanical Trouble | - Injection timing is not fixed<br>- Pressure inside the cylinder is weak<br>- The air filter is occluded | - Adjust injection pump<br>- Clean air filter or replace |
| Fuel does not reach the injection pump | - Not sufficient fuel in the tank<br>- Fuel pipes are occluded<br>- A defect in the preparation pump<br>- Fuel filter is occluded or obstructed<br>- A leak in the pipes allowing air inside | - Fill fuel tank<br>- Replace fuel pipes<br>- Check preparation pump and repair<br>- Replace fuel filter<br>- Replace pipe or tighten fastening |

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| Fuel reaches the injection pump | - Defect in the injectors<br>- Air in the fuel system<br>- The engine stopping cable is stuck at stopping position | - Check injectors<br>- Remove air from fuel<br>- Check stopping cable position |
| The engine becomes hot the engine slowly | - Insufficient water in the radiator<br>- Insufficient oil in the engine<br>- Fan belt is loose or cut<br>- Radiator pipes are occluded<br>- The thermostat is not working<br>- Injection timing is unadjusted<br>- Water pump needs repairing<br>- Engine needs an overhaul | - Add water to the required level<br>- Add oil to the required level<br>- Tighten fan belt<br>- Clean the radiator pipes<br>- Replace the thermostat<br>- Adjust injection timing injection<br>- Repair water pump<br>- Clean air filter or |
| Engine knock | - A defect in the injectors<br>- Air in the fuel system | - Adjust injectors<br>- Remove air from fuel system |
| Stem are sticking or suspended | - Crankshaft axles and connecting rods are corroded<br>- Extra corrosion between the pistons and the cylinder walls<br>- The valves' are suspended<br>- One or more of the valves springs are broken<br>- Injection timing needs adjusting | - Engine needs an overhaul<br>- Check springs and replace if needed<br>- Adjust injection pump |

| Trouble | Possible Cause | Remedy (repair) |
|---|---|---|
| A lot of black smoke in the exhaust | - The fuel injection pump division is unfixed | - Adjust injection pump |
| | - A defect in the injectors | - Repair injectors or adjust |
| | - A defect in the fuel injection pump | - Repair injection pump |
| | - Excess fuel due to non adjustment of pump rack | - Ajust pump rack |
| | - The extra fuel device is suspended | - Check cylinder and piston rings |
| | - The pressure inside the cylinder is weak | |
| The engine is intermittent | - A defect in the injectors | - Repair or adjust injectors |
| | - Air in the fuel system | - Remove air from fuel system |
| | - A defect in the fuel injection pump | - Adjust injection pump |
| | - Suspended valves | - Replace springs |
| | - The rings are sticking to the pistons | - Check piston and rings |
| | - Engine needs an overhaul | - Replace injector pipe |
| | - A broken injector pipe | |
| The engine runs then stops | - Air in the fuel system | - Remove air from fuel system |
| | - A defect in the preparation pump | - Adjust and repair preparation pump |
| | - Fuel filter is | - Replace fuel filter |
| | - Indufficient fuel in the tank | - Fill fuel tank |
| | - Suspended valves | - Replace springs |
| | - The regulator is not adjusted at slow speed | - Adjust regulator |

## 4.13. Distinction of Engine Sounds:

Engine sounds differ according to their causes, and distinguishing them needs a lot of experience. Different sounds can be distinguished as follows:

1. Piston Hammering (knock)

This is a metallic sounding knock that is heard in the engine while the engine is running slowly. The piston collides with the cylinder walls at the beginning of the power stroke. If this sound is heard constantly it indicates that the cylinders are corroded. If it disappears after the engines becomes hot and the piston dilated it is not of importance. This sound may also be caused by piston pin corrosion or the movement of the rings during the course of the pistons' frequent movement up and down. The piston causing the sound can be detected by disconnecting in succession the pipe joints to the injectors and the sound will disappear.

2. Carbon Knock

It is heard as a metal sound upon loading the engine, and is caused by the accumulated carbon firing at the cylinder heads which leads to pre-firing. This sound is usually accompanied by engine heating and power loss.

3. Valve Noises

This a continous metal knock caused by the lack clearance adjustment between the valves' rod (or shaft) and the lifter. It disappears upon adjusting the clearance.

4. Big end knock of the connecting rod (piston rod):

This is caused by too big a clearance between the crank pin and the connecting rod big end as a result of the shells' wear. It is characterized by a medium grade metal sound (not as sharp as the piston knock). This sound comes from the bottom of the engine when it is operated at high speed without loading and is usually accompanied by a drop in the oil gauge reading.

5. Engine Main Bearing Knocks:

This a low level, large volume sound caused by the clearance pins between the crankshaft and the main bearings. It is heard when starting to run the engine and accelerating its speed.

## 4.2 Electric Motors (water pump units):

### 4.2.1 General Troubles and their Repair

| Troule | Cause | Remedy |
|---|---|---|
| The motor starts and suddenly stops | - The electricity is off | - Check connections, fuses and protection instruments |
| The motor stops suddenly | - Wrong operation | - Operate according to catalogues instructions |
| | - Over loading | - Reduce loading |
| | - Shortage of voltage | - Adjust voltage |
| | - Open phase | - Check control circuits |
| The motor does not run when connected | - Open phase | - Check tne electricity supply |
| | - Loase rotor bars | - Check rotor bars |
| | - Overloading | - Reduce loading |
| The motor runs slowly | - In correct use | - Refer to operation manual |
| | - Shortage of voltage | - Use transformer |
| | - Start load is over the limit | - Reduce loading |
| The motor runs in the reverse direction | - One phase is opposite | - Change the motor connections |
| The motor becomes too hot at full load | - Overloading | - Reduce loading |
| | - Occlusion of ventilation vents | - Clean ventilation vents |
| | - Disconnection of one phase | - Check supply cable |
| | - Faulty coil or sets | - Check coil sealing |
| | - Unequal current in the three phases | - Check connection and correct |
| | - Unadjusted voltage or frequency | - Check distribution board and repair the mistakes |
| | - Worn bearings or loose rotor bars | - Check and replace bearings if needed |

| Troubles | Possible causes | Remedy |
|---|---|---|
| The motor vibrates during operation | - Nonalignment of motor and pump axes | - Adjust axes alignment |
| | - Unadjusted rotation transfer connection | - Adjust the connection stability |
| | - Erosion of bearings seats | - Replace seats |
| | - Rotor bar is not stable | - Adjust stability |
| | - Motor operates' with one phase | - Check internal connections |
| Motor noises | - Space between rotor and fixed parts | - Adjust space |
| | - Vibration of bearing seats | - Replace or repair seats |
| Motor sounds due to metal friction with engine | - Ventilation fan friction with the engine cover | - Adjust fan |
| | - The motor is not properly fixed to the base | - Fasten connection bolts |

4.2.2 Major defects and Repair:

1. Blown fuse:

Lift out the fuses and test them using the test lamp as shown in figure 4.1. If the lamp lights up, the fuse is in good shape, if it does not that means there is a blown fuse.

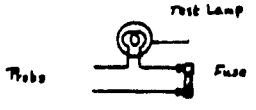


Fig. 4.1

To test the fuses without removing them, put the test lamp circuit across both the fuse and switch as shown in figure 4.2. The fuse at which the lamp lights will be the blown one.

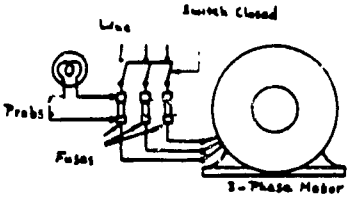


Fig. 4.2
BLOWN FUSE TEST

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If a fuse blows while running a multi-phase motor, the motor will continue to run out as single phase, (figure 4.3) and that means that only a part of the coil is handling all the load. If the motor continues to run this way, even for a short period, the coils will become very hot, then burn.

In addition, the motor will be noisy in operation, and may not be capable of handling the load. In order to find out the cause of failure, stop the motor and try to run it again. The multi-phase motor will not start if there is a blown fuse.

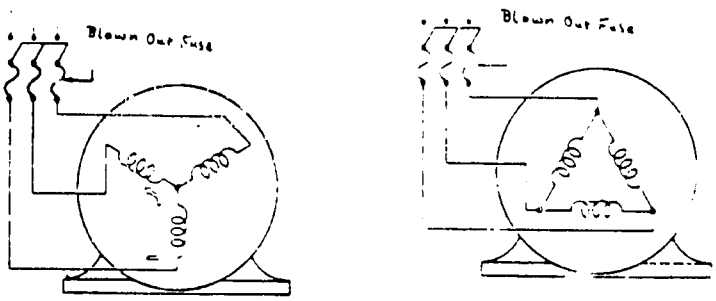


Figure 4.3
SHOWS THAT THE MOTOR RUNS AS A SINGLE PHASE MOTOR

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2. Worn Bearings:

If one of the bearings is worn out, the rotor will cause friction with the stator, causing noise during operation. When the worn bearing reaches the point where the rotor leans completely on the iron core of the stator, the motor will not run. To check for this in a small motor, try to move the shaft up and down as shown in figure 4.4. If it moves in this way it will indicate that the bearings are worn out, and need to be replaced with new ones.

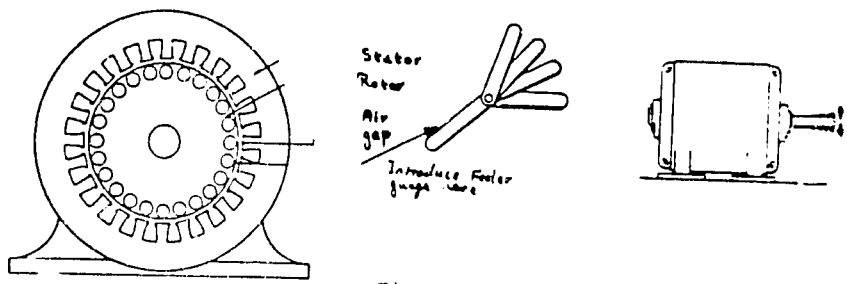


Figure 4.4

WORN BEARING TEST

3. Overloading:

To find out if there is overloading on the 3-phase motor, connect an ampere-meter successively to each of the line wires. If the reading is higher than the number on the engine meter, this indicates overloading.

4. Open Phase:

If an opening occurs while the motor is running, it will continue to run but with less power. The opening could occur in one of the coils or sets connections which will prevent the motor from starting. This could also happen because of a broken wire. If the opening is detected in a coil, it will be necessary to replace the coil. If it is impossible to obtain a new coil, the opening in opened one the old one should be found and both its ends connected together as shown in figure 4.5. This is a temporary solution and can not be used if the coils are wound in groups, (fig. 4.5).

Figure 4.5
REPAIRING OF OPEN PHASE

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5. Faulty Coil or Sets:

Faulty coils produce a lot of noise and smoke when the motor is running. After finding the defective coils by visual inspection or the balance test (the current is numerically equal in all phases), replace then with new ones or disconnect them from the circuit.

Pinpoint the faulty coil from its shape and smell which show that it is burnt. Cut the whole coil at a back point and twist the connections on the two sides. Ensure the removal of the isolator from the coils before twisting. If the whole set is burnt, the engine should be rewound.

6. Loose Rotor Bars:

This defect will produce a noise while the motor is running and will prevent the motor from loading. Also, sparks may appear between the bars and the edge rings. In rotors with covers with fins all the copper bars will be connected to the rotor's two sides to two edge rings. If one or more of those bars are loose and not touching the rings, motor operation breaks down, and in most cases the engine will not run.

The loose rotor bars can be located by just looking. Also there must be a vibration in a manual saw blade at each bar, otherwise the bar is opened. The repair in this case will be tin-welding or ends fusion welding, figure 4.6.

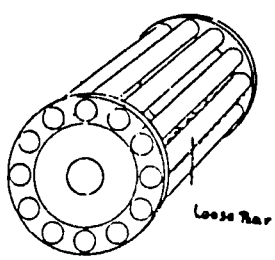


**Figure 4.6**
**LOOSE BAR IN ROTOR BARS**

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7. Error in Internal Connections:

There is a good way to find out whether the multi-phase motor is correctly connected or not, that is by lifting the rotor and placing a big ball bearing in the stator, then close the ball switch on the stator core as shown in figure 4.7. If the connections are not fixed the ball will remain still. Low voltage should be used with large and medium motors, otherwise the fuse will blow.

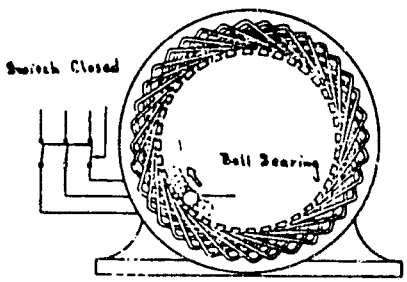


Figure 4.7
ERROR IN INTERNAL CONNECTION TEST

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8. Frozen Bearing:

If oil is not placed on the part of the shaft that rotates in the bearing, the shaft will become hot and expand to the extent of preventing movement. This is called a frozen bearing. During expansion the bearing may weld itself to the shaft making rotation impossible. To repair this try to lift the cover between both sides. The one that does not lift easily will contain the damaged bearing. Lift the side lid and the rotor together as a unit. Hold the rotor in a fixed position and twist the side lid forward and backward. If it is impossible to move the lid, loosen the axle adjusting bolt joining the bearing to the lid, and try to lift the rotor and the bearing together. Be careful to keep the lifting ring separated from the bearing during this operation. Later the bearing can be lifted by hammering it gently. It may be necessary to run the shaft on the lathe to change its size, and make a new bearing. Or replace it with a new one.

9. Earthed Coils:

This defect will produce an electric shock if the motor, is touched. If the coils are tangent in more than one place, there will be a short circuit that will burn the coils and may blow the fuse. Check the earth tangent coils using a test lamp, and carry out the required repair by rewinding or replacing the defective coil.

10. Reversed Phase:

This will cause the motor to run more slowly than usual, and produce an electrical buzzing indicating wrong connections. Check the connections and remake them correctly.

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4.3 Water Pumps:

4.3.1 General Troubles:

| Troubles | Causes | Remedy |
|---|---|---|
| Lack of water delivery | - Failure or lack of preparation | - Pump preparation and water should be free of any air bubbles |
| | - Lack of speed in the rotary engine | - Identify problem and diagnose |
| | - Higher delivery pressure than what is estimated | - Check the pressure gauge valve is opened |
| | - Mistake in the rotation direction | - Assure the pump rotation direction matches the pointer direction on the cover |
| Insufficient water delivery | - Air leakage | - Fasten bolts |
| | - Water leakage from stuffing box | - Check stuffing box |
| | - Non return valve is not sufficiently inundated | - Check valve and repair |
| | - Damaged seals | - Replace seals |
| Decline of delivery pressure | - Air in the water | - Remove air and check its source |
| | - An obstacle in the pumping passages | - Remove obstacles |
| The pump works for a period loosing suction | - Air leakage in suction pipelines | - Prevent air leakage in suction pipes and tighten connections |
| Pump vibration and not prime mover | - Lack of alignment between the pump and rotation prime mover | |
| | - The rotation shaft is bent | |
| | - Deformity of the pump cover | - Check and repair |
| | - Extra tight fastening of the stuffing box bolts | - Fasten according to standards |
| | - A defect in the pump's stuffing | - Replace stuffing |
| | - A defect in rotation of prime mover | - Check the prime mover |

B. Stuffing box:

Where the pump shaft passes inside the cover there is a need for a stuffing box to prevent air or fluid leakage around the shaft. If there is one stuffing box it should be installed at the coupling side, and the pump will be loaded on double ball bearing to ensure balance and rotation of the shaft and the fan.

If there are two stuffing boxes, one will be installed at the coupling side and the other on the opposite side, which is usually the side of the suction opening. The pump will be loaded on two bearings in different directions.

1. Purpose of stuffing:

   a. To prevent air leakage into the pump during preparation or operation.
   b. Prevent water exit in large quantities from the gland during operation causing accidents and injuries to workers or the damage to equipment and ground cables.

2. Types of stuffing:

This depends on the pump operating conditions regarding the required elevation, fluid type, operation conditions, temperature ... etc.

The most important types of stuffing are:

1. Lead: this is a metal stuffing used for pumps exposed to high pressures
2. Asbestos mixed with graphite: this is suitable for pumps exposed to high temperatures
3. Oil saturated cotton twisted belts. This is the usual kind in water pumps as they are suitable for most operation and pressure conditions.

3. When stuffing procedures are carried out:

There are certain situations requiring pump stuffing. They are:

1. When hearing the sound of air entrance from the glands when the pump is stopped, and fastening the gland bolts has no effect.
2. When water flows from glands during operation or inaction
3. When it in impossible to fasten gland nuts. This means that the entire gland is inside the pump's body and may need extra fastening during operation
4. When the stuffing is burning. This is usually indicated by the smell of the burning

4. Stuffing procedures:

1. The pump and set stuffing is done when it is the equipment is stopped
2. Make sure to close the suction, drain cocks, and the preparation cocks
3. Unfasten the gland bolts nuts and take them out
4. Pull out the old damaged stuffing from the stuffing box
5. Prepare the new stuffing ensuring that there are equal pieces with diameters matching the pump's shaft diameter at the gland, according to the required stuffing size. As shown in figure 4.8
6. Grease the stuffing pieces and insert them in the stuffing box ensuring there is a 90 degree angle between the section of every two adjacent pieces

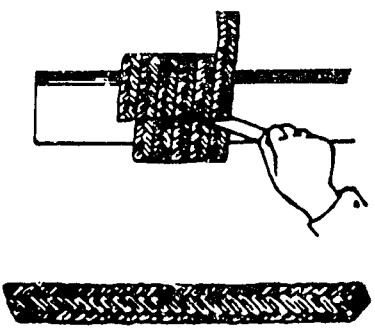

Figure 4.8
Preparation of new stuffing

7. After inserting a sufficient number of pieces, return the gland to its position and fasten the nuts with a suitable wrench
8. Then unfasten the nuts again. Then retighten manually to allow a drop of water to drop on the stuffing during operation - the purpose of this drop is the following:



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A. To cool the stuffing and gland by reducing the heat resulting from friction

B. At the same time to lubricate the pump's shaft

5. Stuffing Deficiencies:

1. Placing stuffing pieces with the thin section on one axle

2. Selecting stuffing which is inadequate for the pump's stuffing box diameter

3. Fastening the gland nuts too tightly, which prevents the dropping of water. This causes metal friction between the pump's shaft and the gland body leading to the errosion of one of them

Note: In the case of pumps with a bearing at the suction side, there is a pipe coming out of delivery to direct water to the stuffing on a perforated disc in the middle of the stuffing. If the pipe holes are occluded the stuffing will burn continuously.

## 4.4 Cars and Equipment Troubleshooting:

### 4.4.1 Engine

| Trouble | Cause | Remedy |
|---|---|---|
| Engine will not start | o Wrong fuel<br>o Out of fuel<br>o Fuel shut-off valve closed<br>o Low battery power<br>o Plugged line or nozzle on starting fluid adapter<br>o Resistance in starting circuit<br>o Plugged fuel tank vent cap<br>o Engine oil viscosity too high<br>o Water, dirt or air in fuel system, or plugged filter<br>o Wide or plugged injection nozzles<br>o Leaks in fuel system<br>o Heating plug will not work | o Use correct fuel<br>o Refill tank<br>o Open valve<br>o Charge or install new battery<br>o Clean line<br>o Clean and tighten battery, cables casing and starter connections<br>o Clean vent cap<br>o Use correct oil<br>o Bleed fuel system Drain sump. Change filter<br>o Clean or change nozzles<br>o Check fuel system connections |
| o Engine knocks, runs irregularly or stops | o Engine oil low<br>o Plugged air intake system<br>o Injection pump faulty or out of time<br>o Plugged fuel tank vent cap<br>o Plugged fuel filter<br>o Water, dirt or air in fuel system<br>o Plugged oil filters<br>o Dirty or faulty injection nozzles | o Add oil<br>o Clean filters and system<br>o Disassemble pump and adjust it in workshop<br>o Clean vent cap<br>o Install new element<br>o Clean system<br>o Change filters<br>o Clean or change injection nozzles |

| Trouble | Cause | Remedy |
|---|---|---|
| Engine has little power | o Restriction in air intake system | o Check air intake system |
| | o Plugged fuel filter or sediments in it | o Change or clean filter |
| | o Plugged or dirty injection nozzles | o Adjust injections and clean nozzles |
| | o Wrong fuel | o Use correct fuel |
| | o Speed control linkage not adjusted correctly | o Adjust and fasten linkages |
| | o Wrong oil | o Use correct oil |
| | o Injection pump not adjusted correctly or out of time | o Adjust injection pump |
| | o Coolant temperature too high | o Follow instructions below |
| | o Wrong valve clearance | o Check and adjust valves |
| o Coolant temperature too high | o Low coolant level | o Check coolant level |
| | o Faulty thermostat | o Change thermostat |
| | o Damaged radiator cap | o Change radiator cap |
| | o Radiator core or grille plugged | o Clean grille and screen |
| | o Injection pump out of time | o Adjust time |
| | o Air cleaner element plugged | o Clean or change element if necessary |
| | o Loose or faulty fan belts | o Tighten or install new belts |
| | o Sedimented or plugged cooling system passages | o Clean passages by washing system |
| | o Faulty temperature gauge | o Change gauge |
| o Coolant temperature too low | o Faulty thermostat | o Change thermostat |
| | o Faulty temperature gauge | o Install new gauge |
| o Low engine oil pressure | o Engine oil level low | o Add oil to correct level |
| | o Plugged oil filters | o Change filter or elements |
| | o Oil leaks | o Check system to prevent leakage |
| | o Engine temperature too high | o Check cooling system |

| Trouble | Cause | Remedy |
|---|---|---|
| o Engine consumes too much oil | o Wrong engine oil<br>o Oil leaks<br>o Engine temperature too high<br>o Plugged air cleaner | o Use correct oil<br>o Check engine drain plug for leaks<br>o Check cooling system<br>o Clean air cleaner or change the element if necessary |
| o Engine consumes two much fuel | o Dirty or faulty fuel injection nozzles<br>o Plugged or dirty air intake system<br>o Injection pump faulty or out of time | o Change injection nozzles<br>o Clean or change cleaner element<br>o Check, repair and adjust injection pump according to need. |
| o Exhaust gases black or gray | o Wrong fuel<br>o Plugged or dirty air intake or exhaust system<br>o Dirty or faulty injection nozzles | o Use correct fuel<br>o Clean air intake and exhaust system<br>o Clean or replace injection nozzles |
| o Exhaust gases white | o Wrong fuel<br>o Cold engine<br>o Faulty or unadjusted thermostat<br>o Injection pump not adjusted correctly or out of time | o Use correct fuel<br>o Allow engine to warm up<br>o Adjust or change thermostat if necessary<br>o Adjust injection pump |

4.4.2 Transmission:

| Trouble | Cause | Remedy |
|---|---|---|
| 1. Gearbox | | |
| Gearbox oil overheats | o Low oil level | o Add oil to correct level |
| | o Oil level too high | o Drain oil to correct level according to instructions |
| | o Engine cooling system faulty | o Check cooling system and repair trouble as mentioned before |
| | o Foaming oil | o Check oil level and kind, and change or add if necessary |
| | o Plugged transmission oil filter element | o Install new filter element |
| | o Wrong operating procedures | o Follow recommended operating instructions |
| 2. Propeller Shaft | | |
| Sound or vibration in the propeller shaft drive | o Sound during operation because of non-lubrication | o Lubricate joints |
| | o Sound during operation due to wear in splines | o Change propeller shaft |
| | o Sound due to wear in universal joints | o Change universal joints |
| | o Vibration in propeller shaft due to bending | o Change propeller shaft |
| | o Vibration in propeller shaft due to big wear in universal joints | o Change propeller shaft universal joints |
| | o Vibration because of faulty or disconnection of balancing weights | o Balance the propeller shaft |



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| Trouble | Cause | Remedy |
|---|---|---|
| **3. Clutch** | | |
| o Clutch disengagement | o Disc wear, or petroleum material on surface | o Disconnect clutch, clean and change if necessary |
| o Clutch incomplete release | o Incomplete release because of trouble in the servo cylinder whether air or hydraulic oil operated | o Check air and oil system according to system type |
| | o Air in the hydraulic oil system | o Check and bleed oil system |
| | o Low hydraulic oil level | o Add oil to correct level |
| | o System leaks (air/oil) | o Check system for leaks |
| o Clutch pedal back to position | o No air or oil inside servo cylinder | o Check and repair servo |
| | o Piston stuck in servo cylinder | o Disassemble and clean servo and oil cylinder of sediments |
| | o Insufficient tension of pedal spring | o Change pedal spring |
| **4. Rear axle** | | |
| Hot differential | o Insufficient lubrication oil | o Add oil to correct level |
| | o Extra fastening of pinion gear ball bearing | o Adjust fastening according to specifications |
| | o Small clearance between pinion gear and crown | o Adjust clearance between gears |
| Irregular sounds in axle while cornering | o Unadjusted mesh of pinion gear and crown | o Adjust mesh between the two gears |
| | o Low oil level | o Add oil to correct level |
| | o Wrong oil | o Use correct oil |

| Trouble | Cause | Remedy |
|---|---|---|
| Oil leaks from crown or axles | o Faulty oil seal | o Check and change oil seal |
| Irregular sound on cornering | o Fault in gear distance washers<br>o Corrosion in differential gears<br>o Faulty shock absorber oil seal | o Change differential gear washers<br>o Change oil seal |
| Sounds in shock absorber | o Loose cylinder nut<br>o Loose piston lock nut<br>o Insufficient shock absorber oil<br>o Corroded rubber rings connecting shock absorber to body | o Fasten nuts<br>o Add enough oil<br>o Replace rubber rings |
| 6. <u>Steering</u> | | |
| Difficulty in steering | o Unlubricated joints<br>o Lack of steering box oil | o Lubricate joints<br>o Add oil to correct level |
| Difficulty in steering with a steering servo | o Low oil level<br>o Unadjusted hydraulic oil pump belt tension<br>o Air in oil system<br>o Plugged oil filter | o Add oil to correct level<br>o Adjust tension or change belt if necessary<br>o Check air leaks in system<br>o Change oil filter element |
| Clinking in servo | o Plugged oil filter<br>o Air in oil system<br>o Low oil level | o Change oil filter element<br>o Check leaks in system<br>o Check oil level and add to correct level if necessary |

| Trouble | Cause | Remedy |
|---|---|---|
| Oil leaks from servo system | o Faulty gaskets or oil seal | o Check system, change gaskets or fastenings or change the oil seal |
| Poor centring on curves | o Unlubricated joints<br>o Wide clearance in joints<br>o Low pressure in front tires<br>o Unadjusted front pump<br>o Wide clearance in front tires ball bearing<br>o Low oil level<br>o Air in system | o Lubricate joints<br>o Check and adjust clearance<br>o Check air pressure in front tires<br>o Adjust front pump<br>o Adjust clearance or change ball bearing<br>o Add oil and check system for leaks<br>o Check system for oil and air leaks |
| 7. <u>Brakes</u> | | |
| Low brake performance | o Worn tires<br>o Low air pressure in tires<br>o Unadjusted brakes<br>o Oil on brake lining<br>o Worn brake lining<br>o Faulty hydraulic system<br>o Air in the brake hydraulic system<br>o Lack of oil in brakes oil can | o Change tires<br>o Adjust tire pressure<br>o Adjust brake clearance between pully and lining<br>o Clean lining<br>o Change brake lining<br>o Check, and repair brake system<br>o Bleed the system and add oil if necessary<br>o Add oil to correct level |
| Uncontrolled brakes | o Wear in master cylinder faulty rubber parts | o Check master cylinder and change rubber parts or master cylinder itself if necessary. |
| Incomplete release of hand brake | o Connecting cable adhesion | o Check hand brake and remove adhesion |

4.4.3 Hydraulic System

| Trouble | Cause | Remedy |
|---|---|---|
| System has no power at start-up | o Low oil level<br>o Faulty or leaky lines<br>o Wrong oil | o Fill to correct level<br>o Check system to stop leaks<br>o Use correct oil |
| Hydraulic oil foams | o Wrong oil<br>o Oil leak in hydraulic oil pump joints<br>o Low oil level<br>o Loose or faulty suction lines<br>o Kinks in hoses<br>o Water in hydraulic oil | o Use correct oil<br>o Check connections or replace oil seals if necessary<br>o Fill to correct level<br>o Tighten or install new lines<br>o Check and straighten hoses<br>o Drain and install new oil |
| System loses power | o Low oil level<br>o Wrong oil | o Fill to correct level<br>o Use correct oil |
| Hydraulic oil overheats | o Wrong oil<br>o Oil dirty<br>o Low oil level<br>o Faulty lines and joints<br>o Oil cooler faulty<br>o Oil level too high<br>o Wrong operating procedures | o Change to correct oil<br>o Drain, flush and fill with clean oil<br>o Fill to correct level<br>o Install new lines and joints<br>o Check oil cooler<br>o Drain to correct level<br>o Check operating procedures |
| Hydraulic functions slow | o Cold oil<br>o Wrong oil<br>o Low engine speed<br>o Worn pump<br>o Plugged oil filter | o Warm the oil<br>o Change to correct oil<br>o Increase engine speed<br>o Check and repair pump<br>o Change filter |
| Low or no hydraulic pressure | o Faulty pressure control valve<br>o Low oil level<br>o Wrong oil<br>o Cylinder packings leak | o Check valve, repair or change it if necessary<br>o Fill to correct level<br>o Change to correct oil<br>o Check and repair cylinder |



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| Trouble | Cause | Remedy |
|---|---|---|
| Decreasing oil pressure in hydraulic circuit | o Faulty cylinder packings | o Check and repair cylinder |
| | o Loose joint bolts | o Tighten bolts |
| Hydraulic oil foams | o Oil leaks from lock out seat during operation because of dirt or sediment in oil | o Remove lever and clean dirt or sediments |
| | o Lock out seat damaged or broken | o Change seat or repair if possible |

4.4.4 Electrical System

| Trouble | Cause | Remedy |
|---|---|---|
| 1. Battery | | |
| Battery will not take a change | o Loose or corroded battery cables | o Clean rust from cables and tighten |
| | o Low battery power | o Install new battery |
| | o Alternator belt loose or faulty | o Tighten or install new belt |
| 2. Starter | | |
| Starter does not start the engine | o Loose or corroded battery cables | o Clean rust from cables and tighten |
| | o Low battery power | o Change battery |
| | o Wrong oil (high viscosity) | o Change to correct oil |
| | o Low air temperature | o Use starting aids |
| | o Battery cables too small | o Use correct sized cables |
| | o Incomplete contact between the brushes and stator segments | o Dismantle the starter and clean the stator segments using sandpaper. Wipe with alcohol. |
| | o Faulty automatic starter | o Check the automatic adjust it and replace if necessary. |
| | o Blown starter system fuse | o Check and change |



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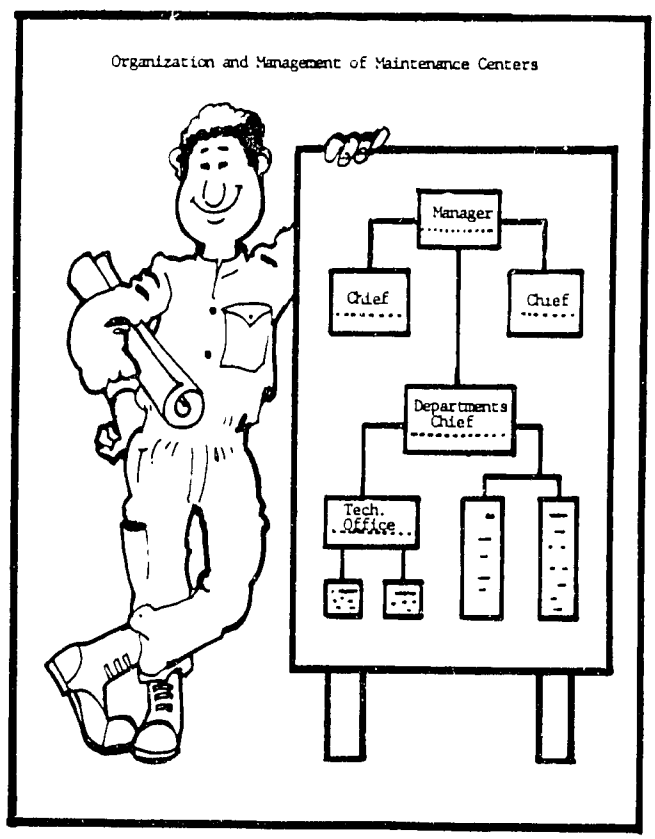
| Trouble | Cause | Remedy |
|---|---|---|
| 3. Generator | | |
| Generator does not charge battery or makes a sound. | o Unadjusted drive belt tension | o Check belt and charge if necessary |
| | o Faulty dynamic internal connections | o Disassemble dynamo to check it |
| | o Windings short circuit | o Check windings and remove the short circuit |
| | o Broken ball bearing | o Change ball bearing |

# Section 5

ORGANIZATION AND MANAGEMENT OF
OPERATION AND MAINTENANCE SYSTEM

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## SECTION 5

## ORGANIZATION AND MANAGEMENT OF OPERATION AND MAINTENANCE

### 5.1 General Organization of Operation and Maintenance

One of the basic factors ensuring the success of an O&M system is to set up an O&M organizational structure that can be implemented according to the local units' circumstances, and indicating the functions and responsibilities of each job in this structure.

This success of any O&M system depends on the support of high-level executives, based on data analysis, review of quarterly progress reports, field visits, and prompt, informed decisions aimed at solving systemic and occasional defects.

These functions and duties have been previously presented in Local Development II-P Planning and Budget O&M Guidelines (Chemonics / August 1987 PP 35 ff.). We will concentrate here on the duties and responsibilities of the Maintenance Coordinator at the governorate level, who heads the O&M organization. These responsibilities are as follows:

- Identify the roles of each of the maintenance personnel at all levels.
- Ensure the provision of tools, machines and trained technical labour for maintenance operations.
- Propose a plan for operation and preventative maintenance for infrastructure projects and equipment at all local levels, and determine allocations and responsibilities at all levels; (this plan must be approved by the Local Development Committee):
- Arrange for the operation of main equipment maintenanace centers for water projects and roads to meet the maintenance needs at the various local levels;
- Prepare a clearly defined standard for measuring the efficiency of operations and maintenance, and a system for recording and monitoring at each level;
- Develop training programs suited to the actual needs of various local levels, and take part in supervising and evaluating these training sessions;

- Submit periodic reports on O&M activities for review by the GLDC;

- investigate the problems and difficulties that obstruct performance, and propose solutions.

The existence of a good recording and follow up system at all levels, including quarterly progress reports collected from those levels, is considered one of the main factors ensuring the success of any O&M system. The incoming information and data from lower levels could assist in establishing the standards to be used in the preparation of maintenance next-year plan and budget. Also this data could help in selection of the most needed equipment for purchase.

For more details on the recording and follow-up system please refer, to the O&M Monitoring Guidelines (Chemonics/Cairo, March 1988).

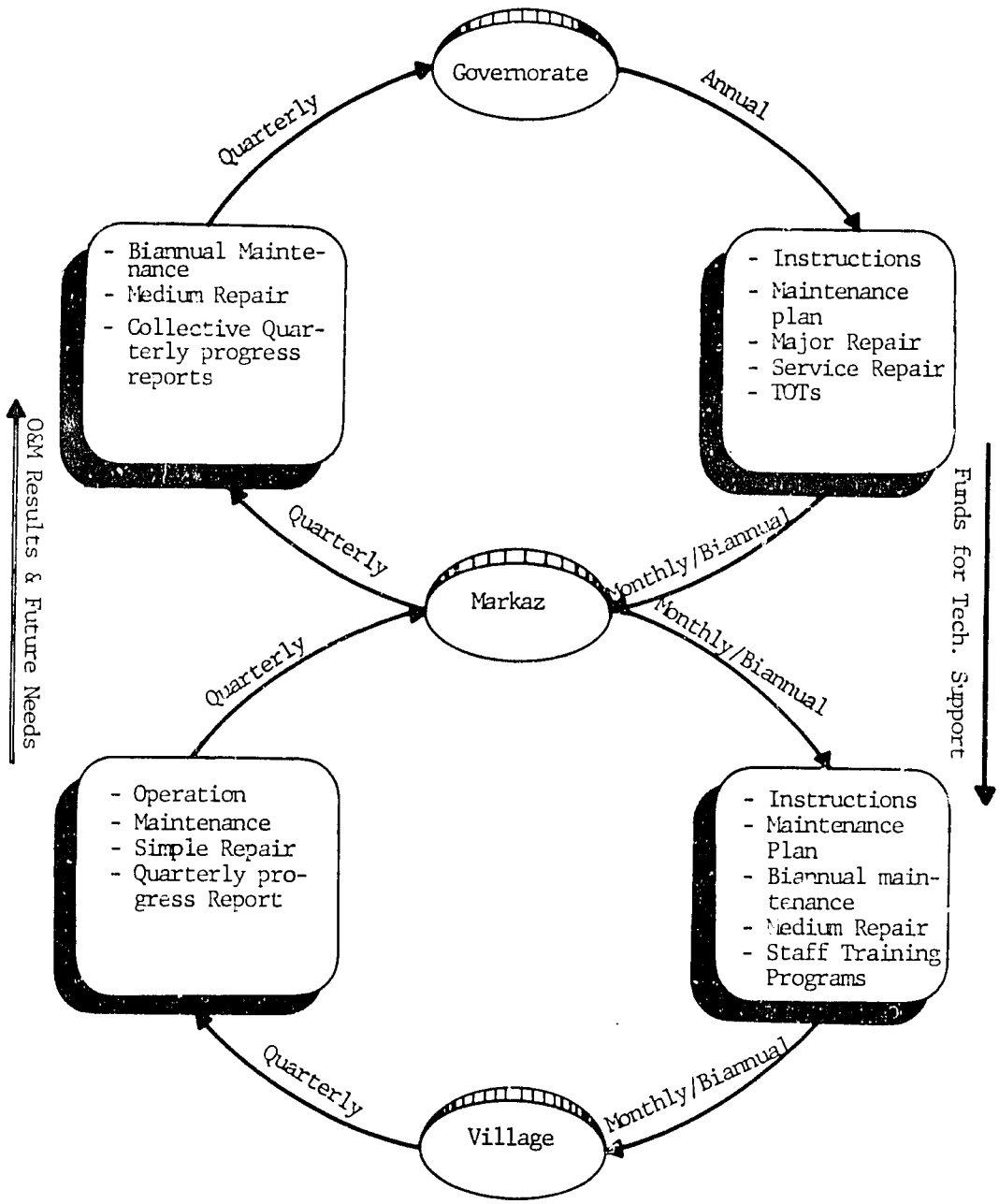
A semi-truck equipped with required tools and equipment for maintenance and repair works should be provided. This will be on grounds that each MMC will have one truck, in addition to assigning a car to the governorate Maintenance Coordinator to supervise maintenance and follow-up its implementataion at the different levels.

In order to provide O&M required funds, we have to look for other sources as Bab II funds could not cover all the needs. Therefore it is necessary to operate maintenance centers (V/C workshops & MMC) as investment projects subordinated to the Services and Development Fund and working on a circulating capital basis. This would allow for the use of local government VC and markaz maintenance facilities, tools, equipment, and personnel in maintenance and repair of infrastructure projects and equipment, and for use of excess capacity in carrying out paid repairs either in the public or private sectors. This latter use will increase the financial resources for public works maintenance and for financial incentives for O&M personnel.

Figure 5.1 shows the proposed general organization of the O&M system at the three administrative and technical levels. It shows administrative instructions and technical support flowing from higher levels to following ones, and O&M results and future needs requests flowing from lower to higher levels. The figure also shows the periodicity of technical support and reporting activities.

Figure 5.1

THE GENERAL ORGANIZATION OF O&M SYSTEM MANAGEMENT



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## 5.2 Maintenance Center Organization

The activity of any maintenance unit includes a number of functions and jobs carried out by a group of individuals. A system should identify the roles and responsibilities of each one of them and how to coordinate their efforts. The efficiency of maintenance units is measured in terms of increase in productive capacity and reduction of costs. Specialization and division of labor are most important means to achieving efficiency.

Therefore, the following considerations should be taken into account when establishing the organization:

- Identification of authority levels and means of communication between them. This requires identifying the responsibility of each level's branches and its contribution to facilitating this task.

- Means of coordination between individual efforts to avoid duplication, contradiction, and interruptions.

- The extent of applying the specialization principle when appointing personnel.

It should be also noted that it is necessary to prepare an organizational structure and a functional one for maintenance centers (M.C). Figure 5.2 shows a model of a proposed organizational structure for one of the maintenance centers; Figure 5.3 shows the functional structure of that model.

The proposed organizational structure depends on dividing the center into different repair divisions (mechanics workshop - electricity --- etc), and maintenance groups whose basic task will be to carry out different kinds of maintenance at project locations. This organizational structure includes a technical section for follow-up, procedures, accounts, costs and purchases.

The system's simplicity, and clearness of responsibility and levels of authority allows for fast and conclusive desisions in a stable administrative atmosphere. But its success requires the availability of a number of personal and technical characteristics in the manager and heads of divisions. Each of them should be familiar with other fields of specializations required for tasks not included in their own specialization.

Figure 5.2
ORGANIZATIONAL STRUCTURE OF MAINTENANCE CENTER

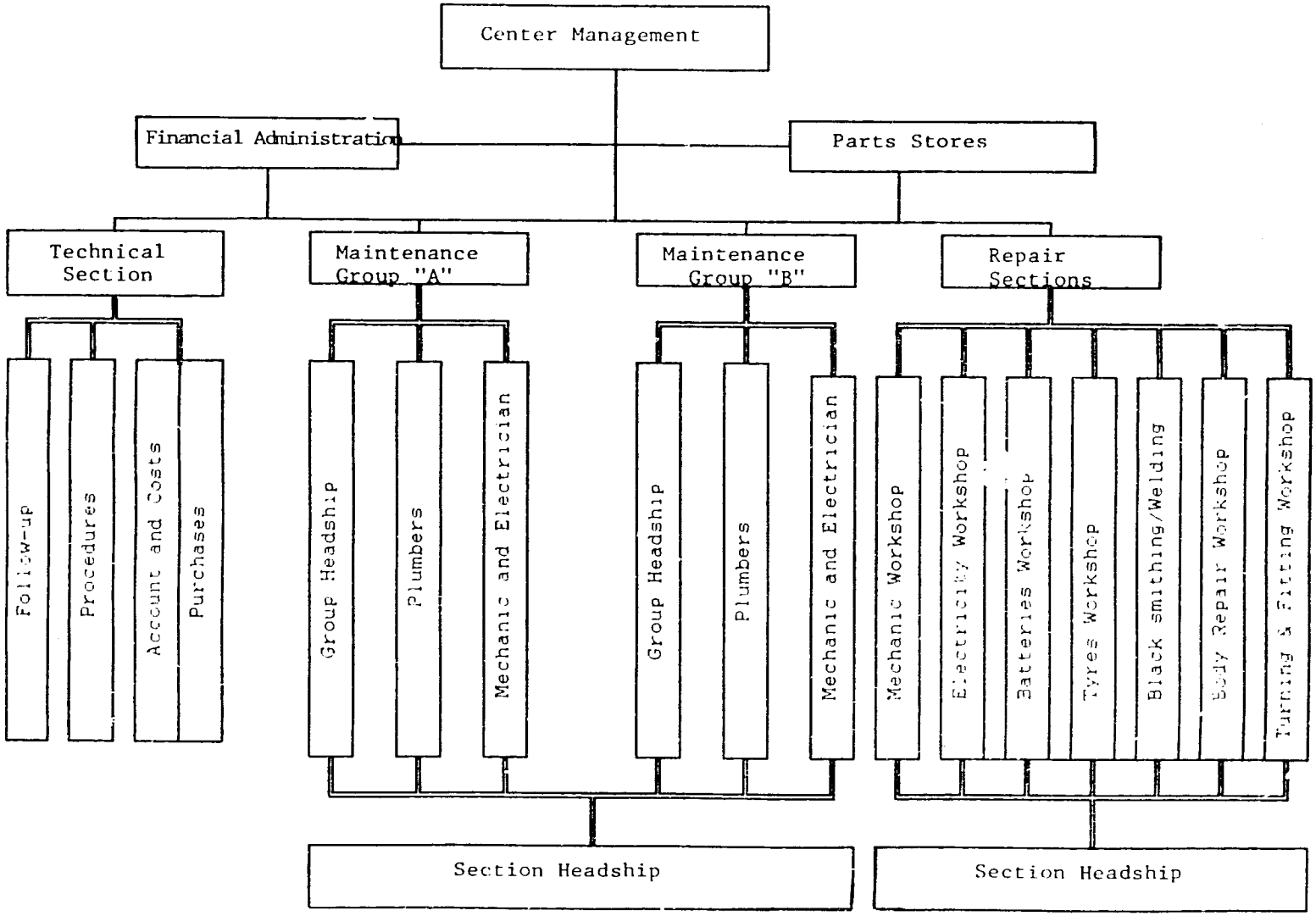
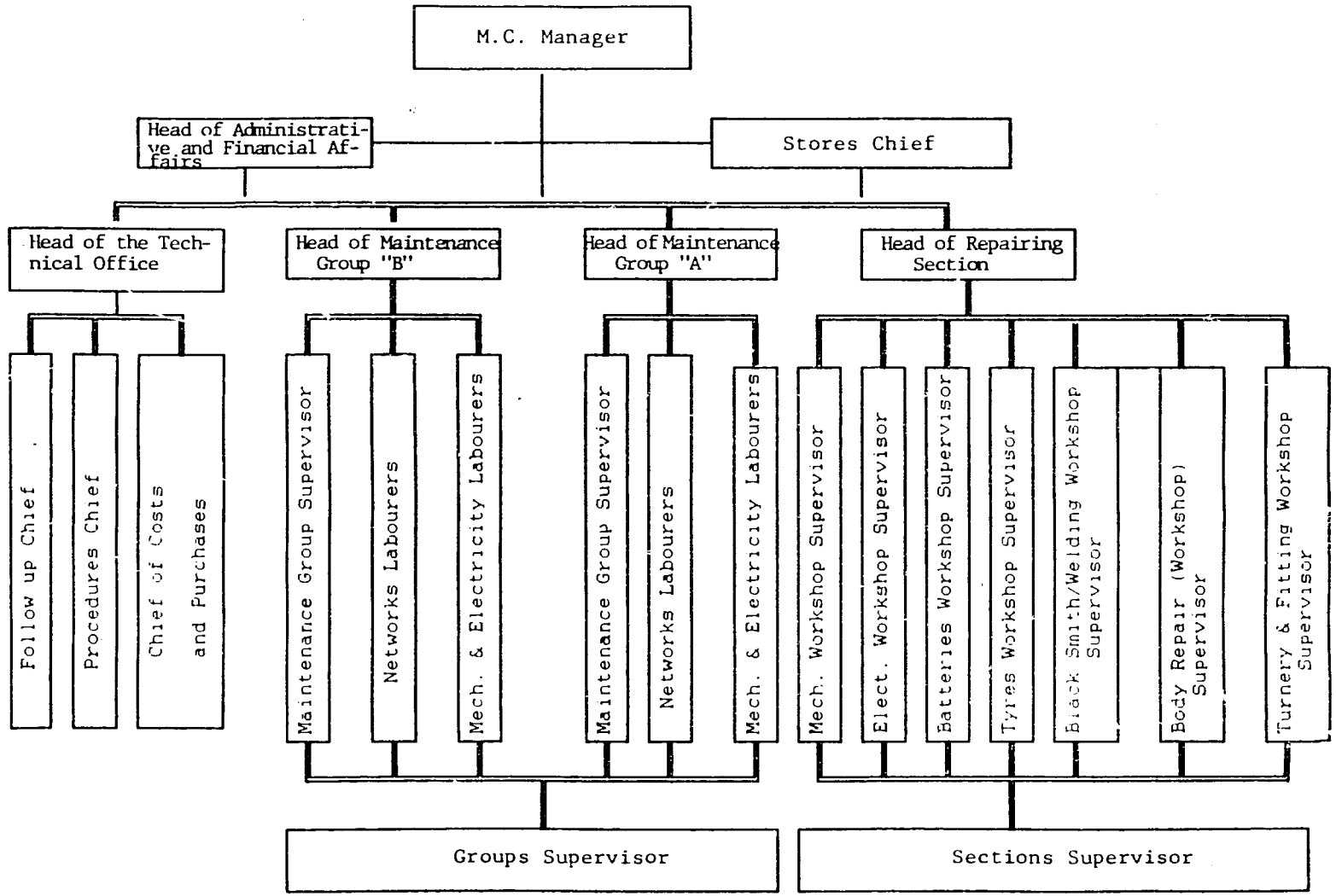


Figure 5.3
FUNCTIONAL STRUCTURE OF MAINTENANCE CENTER



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Duties and Responsibilities:

A. Workers' Level:

Each worker is responsible for performing specific operations at a certain level of maintenance or repair at the rate determined by the maintenance unit leadership. This is explained in section 4.

B. Supervisors Level:

Supervisors are responsible for the following tasks:

- Identification of work methods for each of the workers.
- Distribution of work among workers.
- Supervision of quality and quantity of the workers' performance.
- Supervision of materials and spare parts utilization.
- Keeping order, surveillance of attendance and leave, and estimation of incentives.
- Preparation of bills of quantities upon the request of immediate superior.

C. Section Heads and Managers Level:

Managers and section heads are responsible for:

- Receipt of work, estimation of needs and identification of required labour.
- Development of the work general policy in divisions or in the MC as a whole.
- Arrangement to procure materials and spare parts.
- Distribution of work among different sections, by coordinating the efforts of workers in all sections.
- Supervision of costs and all financial work related to the center.
- Paying wages and identification of bonuses and incentives.
- General supervision of the system at the MC.

## 5.3 The Flow of Maintenance and Repair Work and Information

Work flow is one of the important concepts in organizing work in any workshop. In the O&M context, it means defining an efficient series of tasks or operations to be carried out on an item of equipment starting with its entering the maintenance center until it is returned to the authority that operates it. The flow path indicates the MC's sections and their roles in repairing and maintaining this equipment, in addition to explaining the role of spare parts stores and the releasing of spare parts during the repair or maintenance of this equipment.

This maintenance and repair circuit could be done inside or outside the maintenance workshop or center according to the type of equipment needing repair or maintenance. Mobile equipment could be moved to the maintenance workshop or center to repair it, in this case the work will be inside the maintenance unit.

For fixed equipment such as water stations, operation, maintenance and simple repairs would be done at its location. Medium and major repairs would take place at the maintenance workshop or center.

For purposes of immediate accountability and long-term assessment of labor and materials needs, work-flow operation should be documented. The documentary circuit for maintenance and repair for the two examples just given is presented next.

### 5.3.1 Document Flow for Maintenance and Repair inside the Maintenance Center

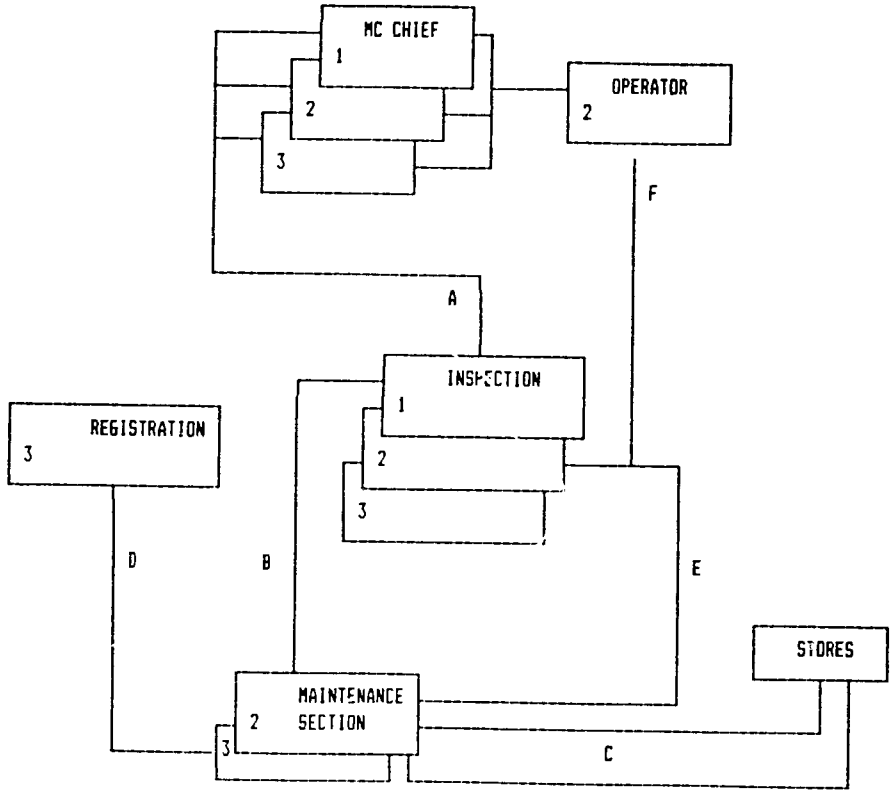
#### A. Maintenance:

Figure 5.4A shows a work flow, with accompanying documentation, for a case of equipment maintenance. When it is time for maintenance of an equipment item, the authority responsible for operations should fill out the maintenance/repair form 5.1 in an original and two copies. The driver/operator should go to the maintenance center chief to sign on the form 5.1 for equipment inspection and approval of its maintenance. One of the inspectors should check the equipment to identify the required maintenance and the repair to be done at the same time.

The equipment should be registered in a registry book for maintenance and repair works, and form 5.1 should be given a work permit number in the procedures section, where the original should be kept.

FIGURE 5.4 A

MAINTENANCE DOCUMENT FLOW




| | PROCEDURE | FORM NO. | FORM COPIES |
|---|---|---|---|
| A | Equipment Maintenance Request | 5-1 | 1,2,3 |
| A | Equipment Inspection | 5-1 | 1,2,3 |
| B | Performing Maintenance at the Maintenance Section | 5-1 | 2,3 |
| C | Release of Spare Parts, raw Material and Oils and grease | 5-2 | 1,2 |
| D | Registering Maintenance Operations | 5-1 | 3 |
| E | Inspection after Maintenance | 5-1 | 2 |
| F | Return to the Operating Authority | 5-1 | 2 |

FORM 5.1
REQUEST FOR EQUIPMENT

Work Permit No.:----------

Governorate:--------

Date:----------

Repair/Maintenance

Markaz:----------

Name of the Operating Authority:----------

| EQUIPMENT NO. | TYPE | MODEL | TYPE OF WORK REQUIRED | DIAGNOSIS | SPARE PARTS RELEASED | | TOTAL PRICE |
|---|---|---|---|---|---|---|---|
| | | | | | TYPE | QUALITY | |
| | | | | | | | |

Inspection Remarks on the equipment of the repair and maintenance:

o ----------
o ----------
o ----------
o ----------
o ----------
o ----------

Inspector Signature
(----------)

Drivers operator name and signature:----------

Name and Signature of the Pre-repair inspector:----------

Maintenance Center Chief
Name:----------

Signature: ---------

Name and Signature of the Operating Authority Chief: ----------

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The equipment will be moved to the maintenance division along with copies number 2 and 3 of the maintenance form.

Required operations will be done and spare parts, materials, and oil and grease will be discharged from the stores according the delivery request showed in form 5.2.

- Upon completion of maintenance the equipment will be moved to the inspection division with copy number 2 of form to check the equipment after maintenance and assess the quality of implementation.

- The equipment will be returned to the operating authority with copy no. 2 of form 5.1, upon which will be listed the type of materials used during maintenance and repair.

- The maintenance division will send copy no. 3 of form 5.1, also showing all types of spare parts and materials used, to the registration division at the center to include it in the records.

B. Repair

- Figure 5-4B shows the work/document flow involved in a case of equipment repair inside the maintenance center. When the driver/operator reports a breakdown in the equipment, the operating authority will fill out form 5.1 for maintenance or repair in an original and two copies.

- The driver/operator will get the MC chief's signature on form 5.1 to inspect the equipment and approve the required repairs.

- One of the inspectors will check the equipment and identify breakdowns.

- The equipment will be registered in the repair works registry and Form 5.1 will be given a work permit number in the Procedures Division, where the original will be kept.

- The equipment will be then moved to the maintenance section/sections with the two copies of the repair form.

FORM 5.2

PERMIT TO RELEASE ITEMS TO THE DIVISION OF ----------

EQUIPMENT NO.: --------
TYPE : --------
MODEL : --------

OPERATING AUTHORITY: ---------
WORK PERMIT NO.: ----------
DATE: ----------

| PART NUMBER | NAME OF ITEM | REQUIRED QUANTITY | RELEASED QUALITY | PRICE PER UNIT | COST |
|---|---|---|---|---|---|
| | | | | | |

Name and Signature of the Section Chief
(___ _____)

Name and Signature of the Store Chief
(_____)

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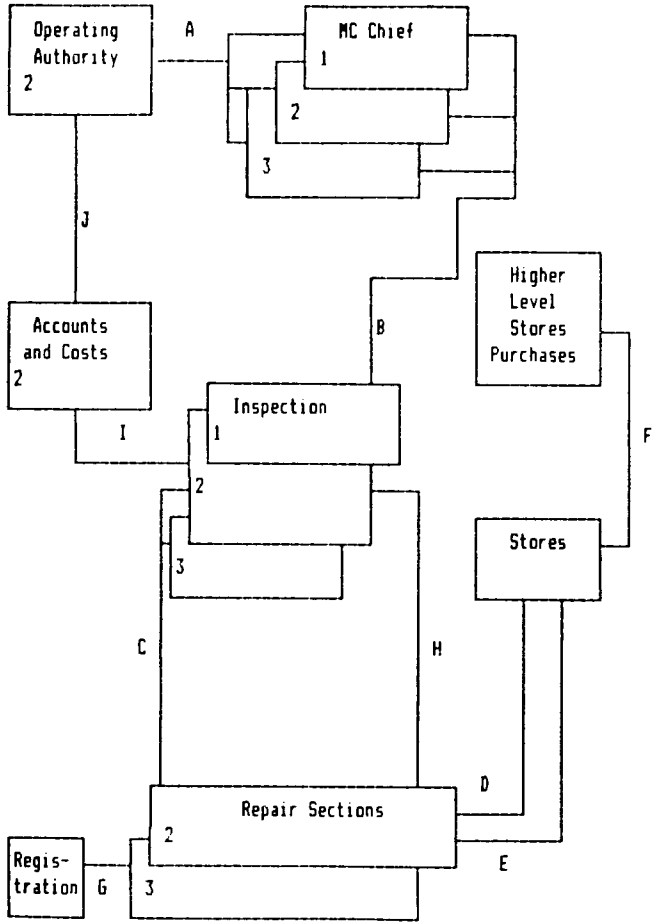
Figure 5.4B
REPAIR WORK/DOCUMENT FLOW




| | Procedure | Form No. | Form Copies |
|---|---|---|---|
| A | Request for repairing equipment | 5-1 | 1,2,3 |
| B | Inspection and approval of repair | 5-1 | 1,2,3 |
| C | Repair section for implementation | 5-1 | 2,3 |
| D | Request for release of spare parts | 5-2 | 1,2 |
| E | Types released from stores | 5-2 | 2 |
| F | Request of spare parts from higher level or purchase | 5-2 | 1,2 |
| G | Registering in the MC books | 5-1 | 3 |
| H | Equipment inspection after repair | 5-1 | 2 |
| I | Pricing of spare parts and materials | 5-1 | 2 |
| J | Return of equipment to the operating authority | 5-1 | 2 |

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- Required operations for repairing the equipment will be performed and spare parts, materials and oils and grease will be discharged from the stores according to the request showed in Form 5.2.

- If required items are not available in the stores, higher-level stores will be contacted and a release request Form 5.2 prepared for those items. After releasing them from the higher level, those items will be delivered to the requesting maintenance section/sections.

- If the required items are not available in the higher level stores, the purchases division will purchase them from the local market and deliver them to the requesting section/sections.

- Upon completion of repair, the equipment will be moved to the inspection division with copy number 2 of Form 5.1 to check the equipment and assess the quality of implementation.

- The equipment will be returned to the operating authority with a copy of Form 5.1, listing all the items used during the repair operations, and attached to it the financial claim for the items that should be deducted from the driver or operator who caused the breakdown. This claim will be prepared by the accounts and costs division shown on Form 5.3.

- The repair division will send the other copy of Form 5.1, showing the spare parts and materials used, to the centers' registration division for filing.

Form 5.3

FINANCIAL CLAIM TO DEDUCT ITEM COST FROM THE RESPONSIBLE WORKER

Equipment Number: _____

Type: _____

Model: _____

Work Permit Number: _____

Date: _____

Operating Authority: _____

| No. | Name of Item | Quantity | Price | Total Price | Other Costs Item | | | Total Costs |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | Total | | | | | | | |

Name and Signature of the Technical Office Chief

_____

Name and Signature of the MC Chief

_____



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### 5.3.2 Flow of Work and Information for Maintenance and Repair Activities Conducted Outside the Maintenance Center

This includes maintenance and repair operations performed on equipment on locations and carried out by the maintenance group according to the maintenance plan schedules and operating conditions. See Figure 5.5

- In this case, the maintenance team will proceed to the equipment location with tools, spare parts and materials required for maintenance and repair. Those materials will be released from the stores by a receipt.

- The operating authority will fill out Form 5.1 for maintenance or repair as appropriate, in an original and two copies.

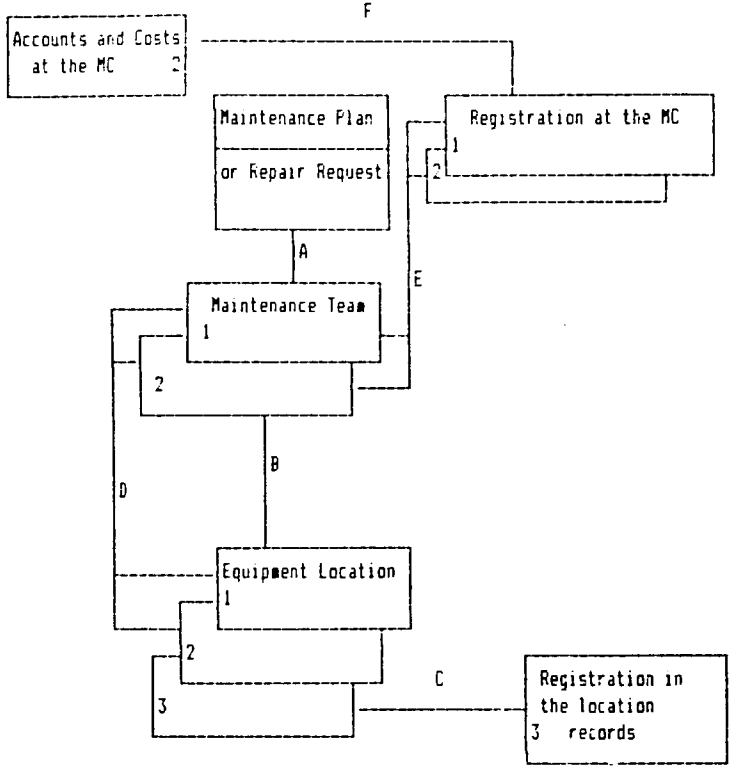
- The maintenance team will perform the required work on the equipment and record it on location records where the second copy of Form 5.1 will be kept.

- The maintenance team will go to the MC with the first and second copy of the maintenance or repair form, where the operations performed on the equipment will be registered. The original will be kept in the office records and one copy will be sent to the accounts and costs section at the MC.

- The costs section will calculate the operations expenses and address the operating authority on Form 5.3 requesting the deduction of those amounts from the operator who caused the breakdowns.

- The maintenance team chief will fill out a release request on Form 5.2 including the items used in maintenance and repair and hand over this form to the stores to get back the receipt by which he acquired the items from the stores.

Figure 5.5
THE DOCUMENTARY CIRCUIT COURSE OF MAINTENANCE OR REPAIR OUTSIDE THE MAINTENANCE CENTER




| | Procedure | Form No. | Form Copies |
|---|---|---|---|
| A | Identification of equipment its location and required work. | -- | -- |
| B | Identifying the maintenance team and proceed to the location where a maintenance request is filled out | 5-1 | 1,2,3 |
| C | Registration in the location records after maintenance | 5-1 | 3 |
| D | Return to the MC | 5-1 | 1,2 |
| E | Registration in the MC registering section | 5-1 | 1,2 |
| F | Calculating the maintenance costs | 5-1 | 2 |

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## 5.4 Management and Operation of Maintenance Centers

As funds required for project operation and maintenance are not adequate and cash incentives for O&M personnel are almost nonexistent or at least not sufficient, it is necessary to consider operating the maintenance workshops and centers with a system of circulating capital or as a profit making project, provided that this profit be used totally or partially as follows:

- Distribution of incentives among O&M personnel
- Maintenance, repair and promotion of maintenance center machines and tools.
- Purchase of required spare parts and materials necessary for repair and maintenance of projects and equipment when allocations for this purpose are not sufficient.
- Rehabilitation of machines
- Construction of extensions of maintenance centers and workshops, as necessary.

If this idea is agreeable to executives and it is decided to convert maintenance centers and workshops from service projects to profit-making projects, it will be necessary to draw up by-laws and regulations organizing work under such a system. These regulations must be consistent with the laws, regulations, and financial and administrative systems used in Egypt to avoid any contradictions or obstacles which would hinder implementation.

### A. Guidelines for Converting the Maintenance Center/Workshop into a Profit-making Project

These guidelines were prepared in order to help the local units in working out executive by-laws in the event that they wish to convert the maintenance unit to operate on the basis of the circulating capital system.

Some local units have already converted some their workshops or maintenance centers into investment projects. These include El-Negaila village in Koum-Hamada markaz, the Etay El Baroud MC in Beheira governorate, Shablanga V/C in Banha markaz, and Batamda VC in Toukh markaz in Qalubiya governorate.

These examples were implemented as individual cases depending solely on the local units' approval, and it is feared that those projects will face some objections from central bodies.



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Therefore, when thinking of operating the maintenance workshop/center, the conversion should be to an investment project with a legal personality aiming basically at contributing to maintenance of public works projects, equipment and utilities as a first priority, and then to serve private citizens in return for nominal fees.

The first steps in the conversion are: 1) to study the idea's feasibility from economic and social stand points. 2) to obtain the local unit executive's approval and 3) to charge the report's department at Central Accounting Authority with studying and drawing up the projects by-laws and rules of procedure, including the incentives system, and 4) to obtain the approval of central bodies such as the MOF and other concerned parties.

### B. Guidelines for Preparation of the Regulations Needed to operate an MC as an Investment Project

When studying and preparing the bylaws and rules of procedures of any investment project for a maintenance workshop/center, the following basic items should be included:

- Form a supervisory committee for the project at the local level. Among its members should be a financial, a legal and a technical department representative.
- Develop an organizationl structure indicating the project's main division, in addition to a functional structure showing the jobs and the technical labor for each division.
- The functions of the projects supervisory committee
- The functions of the projects internal executive functional body, and this includes the functions and responsibilities of: the maintenance supervisor, the administrative supervisor, the chief accountant, the storekeeper, and the heads of maintenance sections according to different specializations.
- Price list of services
- Permanent and temporary loans system indicating each amount and its settlement procedures according to regulations and rules of government accounting and selling and purchasing operations.
- The manner and percentage of distributing the net profit among the following items:

  1. Incentives
  2. Rehabilitation
  3. Services Fund
- A system of monthly incentives and bonuses for all project personnel which connects reward to specific performance measures.

Incentives

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## 5.5 Personnel Incentives System

In order to improve maintenance workshops' and centers' productivity, hard workers should be rewarded and inefficient ones disciplined. To make this possible we must draw up a system motivating the workers to increase their productivity. Incentives could be obtained from a certain percentage of the maintenance unit profits when operated as an investment project. These incentives will be distributed among all excellent workers, starting from the cleaning man up to the skilled mechanic, according to wage rates, i.e., the incentive will be a percentage of the fixed wage.

The system should instill in the workers the feeling that they are an integrated work team, that whenever work is done quickly and efficiently maintenance unit profits will increase and so will incentives. In addition to that the workers will maintain the materials and spare parts to reduce costs.

To ensure justice in incentive distribution, prepared below is one possible rating of several worker qualities that should be taken into consideration in appraisal of each worker's contribution. Each element is weighted according to its relative importance:

| | | |
|---|---|---|
| o | Craft skillfulness | 120 points |
| o | Productivity and efficiency | 40 points |
| o | Reliability | 40 points |
| o | Cleanliness | 40 points |
| o | Work attendance | 20 points |
| o | Skills in other trades | 20 points |
| o | Knowledge of equipment and vehicles | 40 points |
| o | Attendance at training programs | 40 points |
| o | Academic qualifications | 20 points |
| | Maximum total possible points | 400 points |

These elements can be included in a monthly or quarterly incentive scheme card for each worker as shown in Table 5.4. The worker's total score can determine whether and how much incentive he should receive.

Table 5.4
INCENTIVE SCHEME CARD

Name of worker: _____ Division: _____
Profession: _____ month/year of Appraisal: _____

| N. | Characteristics | Maximum point | Point |
|---|---|---|---|
| 1 | Craft skillfulness | 120 | |
| 2 | Productivity and efficiency | 40 | |
| 3 | Reliability | 40 | |
| 4 | Cleanliness in work | 40 | |
| 5 | Work attendance | 20 | |
| 6 | Skills in other trades | 20 | |
| 7 | Knowledge of equipment and vehicles | 40 | |
| 8 | Attendance at training programs | 40 | |
| 9 | Academic qualifications | 20 | |
| | Total | 400 | |

Incentive value: LE _____
Worker Signature: _____
Date: _____
Name of Immediate Supervisor: _____
Signature: _____
Date: _____

Maintenance Center Chief
Name: _____
Signature: _____
Date: _____



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These characteristics can be briefly described:

A. Craft Skillfulness: (120 points)

- The worker should be capable of accomplishing repair and maintenance work without supervision. (to be given 120)
- High level of skill, needing no or supervision (100 points)
- high level of skill, needing minor supervision (90 points)
- Medium skills, no need for supervision (80 points)
- Medium skills, needing supervision (60 points)

B. Productivity and Efficiency: (40 points)

- This means that worker's productivity during the last three months exceeded 100% of what was planned. He does not waste time and is eager for more work. (40 points)
- Worker's productivity during the last quarter is 90% of what was aimed at, and he is eager for more work (30 points)
- Worker's productivity during the last quarter is less that 90% and he needs supervision to complete his assignments. (20 points)

C. Reliability: (40 points)

- He completes his work in the best way and finishes any extra work in time (40 points)
- He performs his work with some minor faults (30 points)
- He performs his work with faults and is unwilling to do extra work (20 points)

D. Cleanliness in Work: (40 points)

- He cleanly performs his work and keeps the place and tools clean. (40 points)
- He cleanly performs his work, but the place and tools are neither clean nor in order (30 points)
- Requires constant reminding about cleanliness (15 points)

E. Attendance: (20 points)

- He is always present during working hours and arrives and leaves on time; also he is ready to start working the minute he arrives. (20 points)
- He arrives in time, but is not ready to start work right away. (15 points)
- He often arrives late and/or leaves early, or is absent during work hours. (10 points)

F. Skills in Other Trades: (20 points)

- He can carry out other crafts in addition to his own, e.g., welding and fitting if his profession is mechanic or electrician (20 points)
- He can perform other crafts but under supervision (15 points)

G. Knowledge of Equipment and Vehicles: (40 points)

- He has vast experience of modern equipment and vehicles including those other than the ones he is working with. (40 points)
- He has little information about modern equipment and vehicles other than the models he is handling (30 points)
- He needs training on modern equipment and vehicles (20 points).

H. Attendance at Training Programs: (40 points)

- He attended recent training programs on equipment and vehicles, and is willing to attend further ones. (40 points)
- He attended training programs more than five years ago on vehicles and equipment (30 points)
- He has not attended any training programs but he is willing to do so (20 points)
- He has not attended any training programs and is not willing to do so (10 points)

I. <u>Academic Qualifications</u>: (20 points)

- He has a certificate that relates to his job (20 points)
- He has got a certificate which is not related to his job (10 points)

After calculating the worker's points by filling out the appraisal card shown in table 5.4, table 5.5 will be used to identify the incentive percentage for each worker on the basis of his acquired points. Then all the worker's incentive percentages will added and the following equation will be used to determine each worker's incentive:

$$\text{Incentive} = \text{The workers percentage} \times \frac{\text{Total value of Incentives allocated to the MC}}{\text{Total percentages of all workers}}$$

<u>Example</u>:

Suppose that the value of incentives to be distributed is LE 60 and the present labor among which the incentives will be distributed is workers A, B, C, D, who have achieved percentages 100%, 80%, 70%, 50% respectively. The total of acquired percentage points is 300.

Accordingly, the share for each worker will be as follows:

$$A = 100 \times \frac{60}{300} = 20 \text{ LE}$$

$$B = 80 \times \frac{60}{300} = 16 \text{ LE}$$

$$C = 70 \times \frac{60}{300} = 14 \text{ LE}$$

$$D = 50 \times \frac{60}{300} = 10 \text{ LE}$$

Total of Incentives = 60 LE

Table 5.3
MANNER OF DISTRIBUTING INCENTIVES ACCORDING TO THE**
WORKERS' ACQUIRED POINTS**

| Total Appraisal Points | 380 400 | 360 379 | 340 359 | 320 339 | 300 319 | 280 299 | 260 279 | 240 259 | Less than 240 |
|---|---|---|---|---|---|---|---|---|---|
| Incentive Percentage | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 |



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## 5.6 Management of Spare parts Stores and Stock Control:

The basic function of stores is to provide the proper spare parts and materials necessary for project and equipment maintenance and repair. Parts must be provided in time, and at a suitable price and be of good quality.

It is necessary, if feasible, to store spare parts in adequate quantities, as their unavailability delays project implementation and leads to the deterioration of equipment and parts, resulting in significant financial and social losses. Purchasing excess quantities of spare parts is equally wasteful of resources.

Therefore it is necessary to provide spare parts in adequate quantities and with suitable price and quality, specially in view of in the fact that spare part costs represent between 40-75% of repair and maintenance costs. This emphasizes the importance of establishing warehouses and running them soundly together with drawing up a control system.

### 5.6.1. General Objectives of Stock Control:

Stock control activities focus on:

- Needs planning
- Needs procurement
- Inspection and receipt
- Storing and protection methods
- Storing, transporting and handing over (delivery) constituents.

It is necessary to integrate and coordinate these activities, with a view to keeping costs low and presenting the best possible service. We can specify the objectives of stock control more generally as follows:

- Planning and determining the required amount.
- Obtaining required quantities of spare parts
- Storage, transport and hand over.

Using these objectives we can define stock control as the integrated management responsible for planning to obtain, purchase, store, handle and supervise spare parts in the way that leads to the best utilization of available resources of facilities, personnel and funds within the framework identified in the plan's general objectives.

5.6.2. Needs Planning:

Planning the governorate's need for spare parts depends on several complicated and overlapping factors such as:

a. Different Maintenance Programs:

- o Preventive (checking - oiling - adjusting - cleaning)
- o Corrective (repairs - major overhauls)
- o Unexpected repairs as a result of accidents and misuse.

b. Volume of the Governorate Equipment and Projects:

It is well known that the value of required spare parts annually for equipment and projects varies from 20-30% of the present value of the equipment and projects. Therefore the spare parts volume needed to serve projects and equipment can be estimated annually, though previous costs are the best indicator, if good records exist and if the funds spent were adequate for needs.

c. Nature of Stored Spare Parts:

Some spare parts need permanent or temporary storing; others can not be stored as they wear away quickly or are needed immediately for planned maintenance operations.

d. Level of O&M Technical Labour:

O&M technical labour must be highly skilled because if maintenance and repair operations are not done correctly or if breakdowns are wrongly diagnosed, this will increase the consumption of spare parts and, therefore, the quantities of them that are required.

e. The Possibilities of Obtaining Spare Parts in the Local Market:

Restrictions imposed on imports lead sometimes to the lack of original spare parts in the local market and the appearance of imitations which are generally of lower quality, resulting in the increase of spare parts consumption. Therefore, warehouses should have stocks of original spare parts available when needed. Although this may appear to be idle capital, it may be considered as an investment as prices are constantly rising.

F. Equipment Local Agents' Capacities for Spare Parts Supply and Maintenance

If local agents have a large stock of spare parts and efficient service centers, this can reduce the need for stock in the governorate stores, as parts are available at the agents. If the agents have no such facilities, the governorate would have to provide the required spare parts and thus increase the stock volume.

g. Dissimilarity of Equipment Models and Types:

Dissimilarity increases stock volume and the difficulty of planning and supervision.

h. Available Funds:

These funds are either in local or foreign currency. The source of funding affects stock volume.

i. Capacities of Available Stores, and Storekeepers:

The availability of storage space and labour required for storing affect the stock volume.

5.6.3. Needs Procurement:

The provision of spare parts in stores depends on a number of factors:

a. The provision of cataloques for different models of equipment.
b. The level of need for the type of spare part to be stored:

   - Permanently required and constantly used spare parts
   - Spare parts to be purchased upon need and stored temporarily
   - Critical spare parts that are not constantly used, but must be available for emergency use.

c. Determining spare parts needs on the basis of manufacturing companies' recommendations.
d. The rate of discharge of a part from the stores should be used in determining the required stock volume of each type, in addition to the minimum stock level. The process of local spare parts purchase takes about one month from order to delivery, while the same process takes about six months if the parts are imported.

e. Means of Providing Spare Parts:

- o Local sources
- o Local or international agreements
- o Import

f. Consideration of economic aspects and adequate quality and quantities of spare parts.

5.6.4. Elements of Storing, Transport, and Delivery:

Good spare parts storage is the basis for provision of such parts in time, suitable quantities, and adequate quality.

Storage includes the following operations:

- o Delivering materials from their sources to the stores
- o Receipt of types with the required specificatins (inspection and receipt).
- o Classification and internal organization
- o Preservative storage
- o Stock supervision
- o Releasing items to workshops

On basis of experience in this field the ideal system is to have three kinds of stores as follows:

a. Main Stores:

All incoming purchase are stored in this store which should be adequate as regards its capacity and furnishings (shelves, containers and hand over means). Also all the governorate equipment catalogues must be available at this warehouse. This kind of warehouse must exist at the governorate level.

b. Central Stores:

Those are central stores for the geographic marakez to serve the cities and villages. These stores will release monthly or quarterly quantities for the different specializations (water, wastewater, garage, etc). The main store will supervise this kind of store.

c. Subsidiary Stores:

These are the village stores. The central stores supervise them. These stores get their needs from the central stock on a monthly or quarterly basis.

### 5.6.5. Stores' Internal Organization

Stores should be organized in order to allow easy access within and outside the store. Figure 5.6 shows good store planning, while figure 5.7 shows poor planning for the same store area.

A. Required Furnishings:

- Adequate hand over equipment
- Ventilation equipment
- Subsidiary devices (catalogues, etc) measuring devices, scales
- Shelves and storage containers (plastic boxes, gasket racks, oil seals - belts hangers, ..... etc)
- Suitable cleaning instruments
- Industrial security, and fire fighting means and instruments

B. Organizational Elements:

- Technical inspection committee (central stores)
- Receiving committee
- Technical office (for studies, technical and stores follow up) (central stores)
- Store divisions (spare parts, materials, tyres, batteries ..... etc)
- Junk division

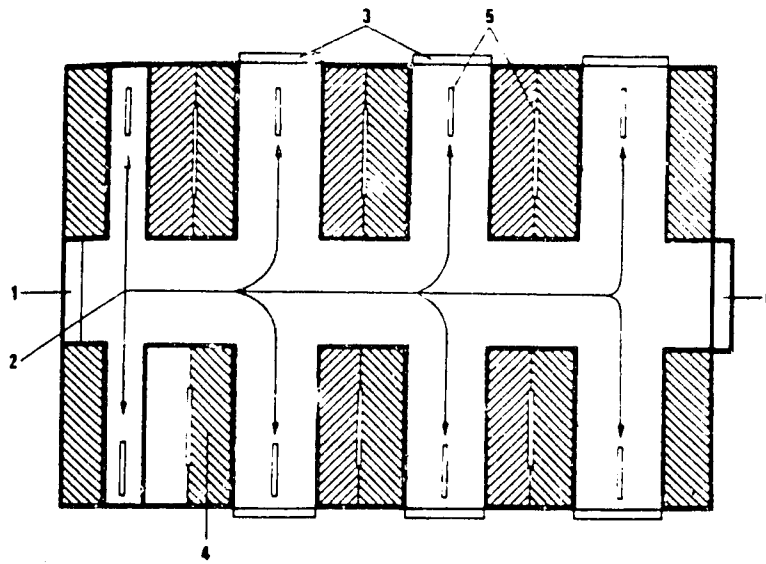
C. Organizationl and Classification of Spare Parts, Materials, Etc.:

Store contents should be divided into separate categories as follows:

- Spare parts for equipment: Each mark and model separately
- Vehicle spare parts - each mark separately
- Water operations spare parts - each mark separately
- Miscellaneous spare parts
- Useless spare parts, grouped together for easy sale
- Materials (copper bars, iron, sheet iron, gaskets, paper, sulfuric Acid, iron, welding bars, copper, etc)
- Batteries
- Tyres (each size separately)

Types that wear away quickly or are constantly required should be stored in an easily accessible place for speedy receipt and release.

Figure 5.6
GOOD INTERNAL STORE




1. Entrance for releasing spare parts.
2. Passage allowing movement at both ends.
3. High side-windows allowing sufficient lighting.
4. Storing-racks with bins.
5. Fluorescent lamps for lighting over storing racks and in passages.
6. Entrance for receiving spare parts before storing.

Note: If there are offices within the store, these should be placed in a way that allows direct supervision of the maximum possible area.



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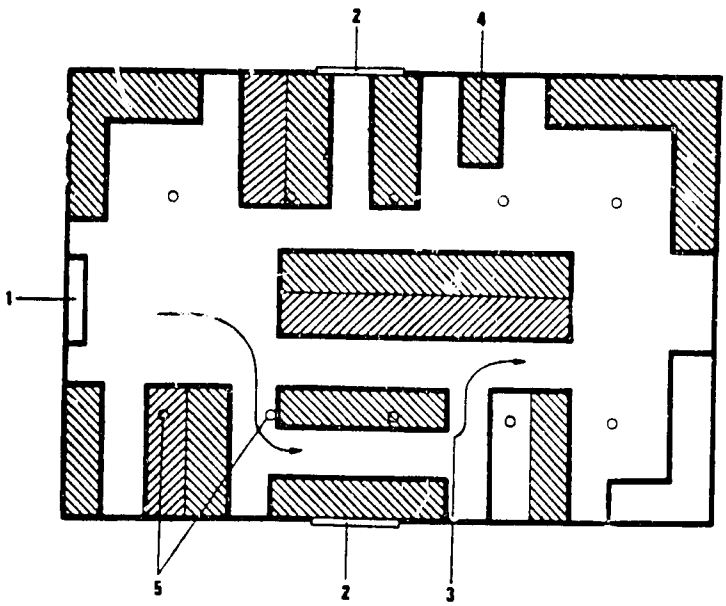
Figure 5.7
POOR INTERNAL STORE PLANNING




1. One entrance for both receiving and releasing spare parts, which causes work disruption, and possibly mixes incoming types with outgoing ones.
2. Loss of natural lighting from windows.
3. Passages are not located to allow free and speedy movement inside store.
4. Unsystematic storing-unit spacing.
5. Badly situated lamps.

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D. Disposal of Useless Spare Parts:

The accumulation of useless spare parts in stores is a serious problem, as they occupy vast areas of most stores sometimes reaching 30% of the available storing area, and give an inflated impression of stock available. Consequently, the disposal of useless items, either by selling or transporting those items to sectors where they can be used, is an important O&M function.

Useless spare parts should be classified according to mark. Then listed for the information of other departments that have similar equipment. Those departments will be given a time limit to present any requirements for those parts. Lists of the remaining items will be sent afterwards to the central stores selling committee for disposal through sale.

E. CARDEX System:

Cardex is a modern system for classifying and locating spare parts in stores. It is easily capable of computerization.

The Cardex system allocates a card for each spare part item. Listed on it are the sample number, a description, the existing quantity and the minimum and maximum stocks of this item. The card (see Table 5.6) includes the place where this item is stored in the storing racks.

Paper cards will be kept in a cabinet with several drawers, each drawer has 60 plastic holders to keep the paper cards inside. A transparent plastic holder is put over each card to make it easy to read the data without taking the card out and to keep the card clean and legible.

The Cardex system's advantages include:

A. It facilitates monitoring and analysis of the rates at which different items are demanded.
B. It facilitates needs identification through comparing available quantities with the minimum and maximum stock margins.
C. It makes it easy to identify the balance of each item.

Physical storage should follow this approach:

A. The store is divided into several divisions according to the kind of equipment the warehouse has. Each kind is assigned an alphabitical capital letter. For example Caterpillar equipment will be given letter "A", and J. Deere equipment will be given letter "F", and so on. The letters G, I, O, Q, V, Z are not used in this system, by international convention.

B. Each equipment division will have a number of storing racks that should have a number and a capital letter e.g. 2B, designating the back side of the B rack. 1B would mean rack B's front side. The storing rack is shown in Figure 5.8.

C. The storing racks are divided into bins. To identify them, each row will be labelled by a small letter (a, b, c....) and each column by a single number (1, 2, 3, 4, 5 .....). For example, the shaded bin in Figure 5.8 is designated A1B3c, meaning:

(A) Caterpillar division
(1B) Storing rack (B), front
(3) Column number 3 in storing rack (B)
(c) Row c in storing rack (B)

Table 5.6
ITEM STORING CARD

| Card No. | | | Equipment | | | Remarks | | | Max. Stock | | Min. Stock |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Qty In | Qty Out | Price | Reference | Balance | Date | Qty In | Qty Out | Price | Reference | Balance |
| | | | | | | | | | | | |

| Part No. | Description | Location |
|---|---|---|
| | | |



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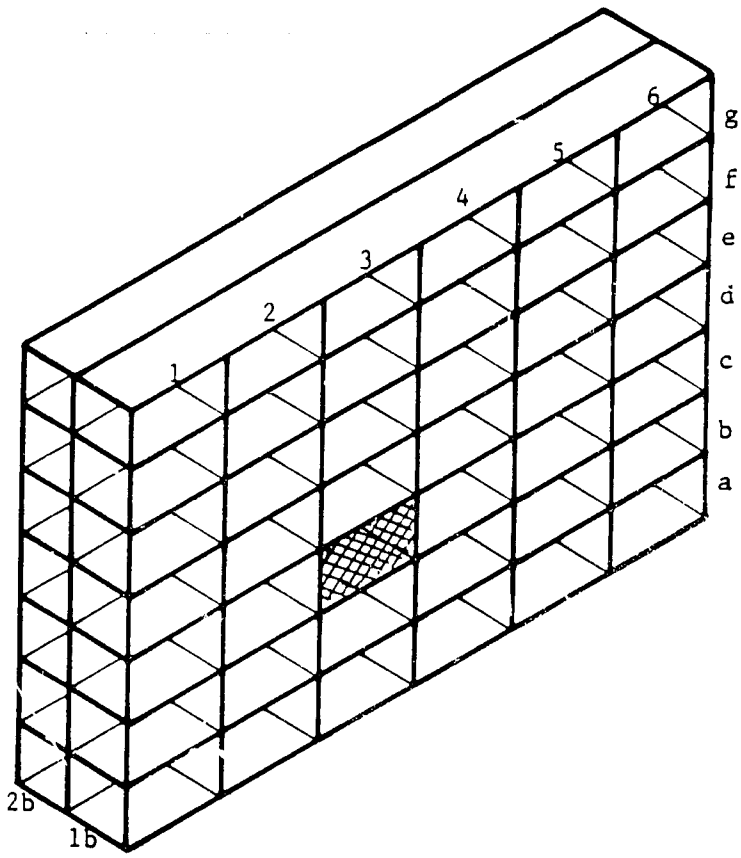


Fig. 5.8
Storing Rack

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## 5.7 Vocational Training:

A lot of attention is given today to vocational training by institutions, organizations and individuals. This kind of training is not limited to workers and employees in companies and factories, as many people think. It covers all fields of work: manual, mental, technical or administrative.

This kind of training is more systematic than that provided by circumstances or old experienced labourers. It is carried out by training specialists who are well informed and acquainted with its origins, methods and objectives, in addition to their having knowledge of educational techniques.

### 5.7.1. Types of Training

Training differs according to type of trainees, their past experiences, the kind of job to be trained for, training location, trainers' qualifications, and the required training level. The training location may be any of the following:

#### a. At the Work place

This is the most common kind of training, during which the supervisor, the chief or one of the skilled workers, will explain to the trainee how to perform the job, then observe and test him occasionally, and help whenever necessary. This is mostly done without previous planning.

#### b. At a Training Center

Some units designate special places to train new workers, and training. This is better than that in "A" as the trainers are dedicated entirely to training and trainees are away from work engagements and problems.

#### c. Industrial Apprenticeship

This is a system combining classroom study and training in capacity centers, especially practical training in factories. It aims at youth, with modern, scientific training for professions needing top-level skills. A good example of this is Productive Capacity and Vocational Training Authority's several centers in most governorates.

### 5.7.2. Training Methods

There are several training methods; selection depends on the purpose of training.

a. Lectures Method

This is a quick and easy way to provide a large number of people with information orally.

This method may include illustrative materials such as pictures, films, records, maps and other visual and auditory samples.

This method has its limits and disadvantages. It is of only limited use in developing motor skills, and so is not appropriate for many types of workers. It also requires a great deal of concentration and follow up and restricts movement during the lecture time. Moreover, the results depend largely on the lecturer's talent.

b. On-the-Job Training

In this case the worker is trained while working. Training may take different forms---it may done on machines, tools and equipment similar to the ones the worker will use afterwards. This method is appropriate for many types of manual labor training.

c. Group Discussion

This method includes involving the trainees in the training operation, and encouraging them to express different points of view and to get used to objective criticism and self-criticism. The number of group members should be limited to make it useful and encourage each member's participation in solving problems they are presented with. These groups are effective in upgrading performance level. This method is often used in training supervisors.

d. Role Play

This is a contemporary method for helping supervisors appreciate the points of view of the various personnel they work with. It is based on the idea of playing roles. Supervisors play different characters such as the authority chief, division head, direct boss, worker, etc. This way helps the trainee to understand those persons' feelings, and the kind of problems that they may face. The trainees are then better able to understand the behaviour of others and thus to change inappropriate attitudes.

5.7.3. Psychology of Training

There are some principles of educational psychology which apply to vocational training:

A. No training without motives

Any person will learn if he has the ability and opportunity to do so, but this is not enough if he does not have a motive to learn. Motives are an essential condition for training, therefore we have to explain to the worker the importance of training for his career and promotion. This will eventually lead to increase in productivity, and more concentration at work.

B. The Trainee should know his progress

Several experiences have proved that performing work without knowing the results does not lead to education. The trainee's knowledge of his work's results helps him to learn better and increases his productivity as he will be trying to maintain a certain level and improve it. Otherwise, he may imagine that he has reached perfection and not make any effort to improve.

C. Reward and Punishment:

Experiments prove that reward and punishment assist the learning process. Reward encourages the trainee to repeat what he was rewarded for, and reasonable punishment makes him careful not to repeat faults and mistakes. The type of punishment should not hurt the worker's pride or his self respect, or he may lose self-confidence and any interest in learning.

D. The effect of competition on training:

Some institutions use competition as a motive for learning by offering privileges to the trainees who show improvement in their work, such as writing their names in the board of honour and giving special privileges. However, if a trainee feels he is unsuccessful, this can undermine his motivation to learn. Therefore competition should be reasonable and between equals, or else it should be individualized by comparing the work of single trainees over different periods and stages.

E. Learning by Doing

As swimming can not be learned without practice, neither can good thinking. The trainer's effort, explanation, and guidance are not useful, or helpful, unless they motivate personal activity on the trainee's part. Some trainers have vast experience but are considered less than average because they do not give the trainees a chance to practice and exercise their personal creativity. Actually, a successful trainer can not teach trainees; all he can do is to show them the right ways and assist them to teach themselves.

F. Understanding Principles Taught

Experiments showed that whenever the subject material is understandable, it is easier and faster to learn and harder to forget. Many experiments have been made to compare learning based on understanding and mechanical learning. One of them was about training workers to install electric lamp hangers. One group installed the lamps by repetition and mechanical practice, while the trainer explained to the other group the general principles of what they were doing. The productivity of the second group was higher than the first one. Therefore the trainer must explain what is going to be learned and why. He should also ask the trainees to repeat to him what they are going to do and how. This helps to identify and correct misunderstandings. In other words, the trainee should have a clear picture of what he is going to learn before starting the training.

G. Guidance:

Experiments prove that training with guidance is more effective than training without it. If the trainee is not guided he may use inefficient methods. Also positive and detailed guidelines and instructions are better than negative and general ones. Positive instruction means directing the trainee to the correct methods and not just identifying the wrong ones.

H. Total Method and Partial Method:

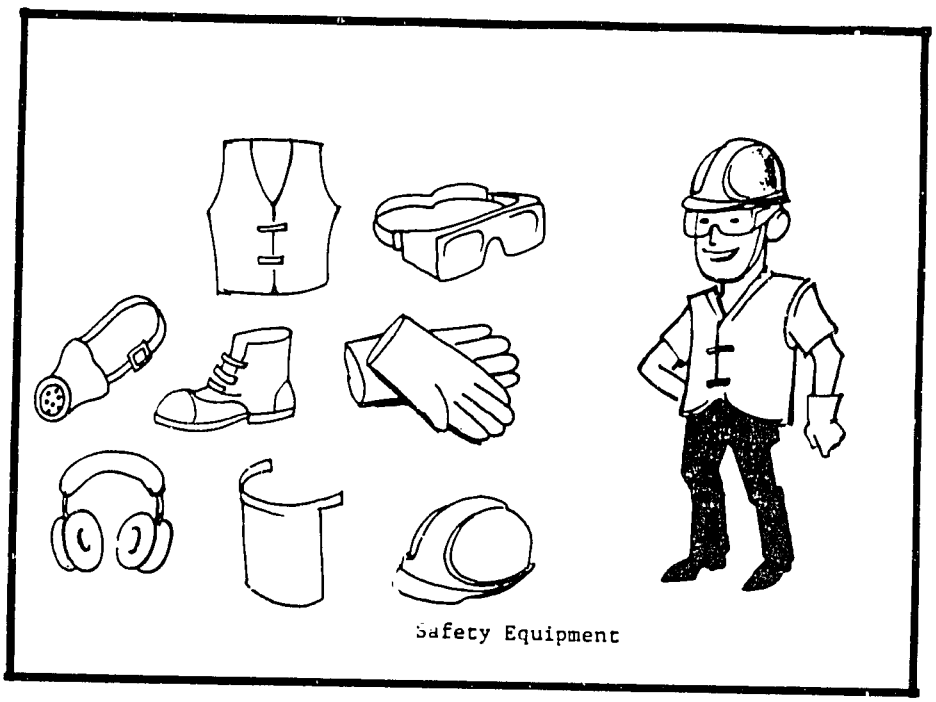
Is it better to divide the materials to be learned into parts and sections and learn each separately, then combine them together, or to learn the material as a whole without division? Each method has its advantages, disadvantages and applications. Experiments have proved that the holistic method is better when the material is neither difficult nor long. When studying a chapter from a book this method would allow the trainee to understand the relations between its parts and understand some parts which could not be explained separately. This method is also better for learning movement skills. Yet, each type of work has its conditions and suitable methods, for example most industrial work is too complicated for average worker to perform without mistakes. The trainer in this case should divide the work into separate units and train the workers on a unit until they master it, then move to the next unit, and so on. Whatever method is used, the trainer should start by giving a general idea about the work as a whole, then move from this to the details.

I. Dispersed Training and Concentrated Training:

Experiments have showed that training in learning and acquiring movement skills distributed among courses or sessions is better that concentrated training in one course.

Hence, it can be realized that the process of training is a comprehensive one based on interaction between the different elements of training: the trainer, the trainee and the training method. The trainer's understanding of the psychological basics and the person he is training is one of the most important factors helping to achieve the required level of training.

Industrial Safety



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## 5.8 Industrial Safety*:

To ensure industrial safety and prevention of accidents at work there are rules that should studied and mastered by workers and technicians, otherwise workers may be exposed to accidents and danger while working.

In the following section the best safety rules that workers have to follow to accomplish their work efficiently and avoid accidents are indicated.

All the instructions mentioned in this section must be placarded or posted in a visible place in the workshop.

### 5.8.1. Working on Engines and Machines:

Work accidents usually occur during moments of low attention. A conscientious and keen worker should be able to do his job without endangering himself or others. The following instructions are addressed to workers in this field:

- Use only the machines and tools to which you were assigned and have to use. In workshops do not start or try to operate any engine or machine before having sufficient information about its operation.

- Check that the preventive partitions and the protective devices fitted to the machines' running parts are in good shape before starting the machine.

- Do not remove the preventive partitions or suspend the security devices on the grounds that this will save time or increase production.

- Do not relax in safety observance when changing speed by shifting the belt to the pullies matching the required speed.

- Be sure that the machine (or engine) has come to a complete stop before adjusting or oiling it.

- If you wish to stop a machine or engine to repair or adjust it, you should first disconnect it and close the operating switch box and keep the key with you, if you are responsible for it. If this is not possible, hang a sign on the operating switch indicating that it is under repair so no one will try to run it.

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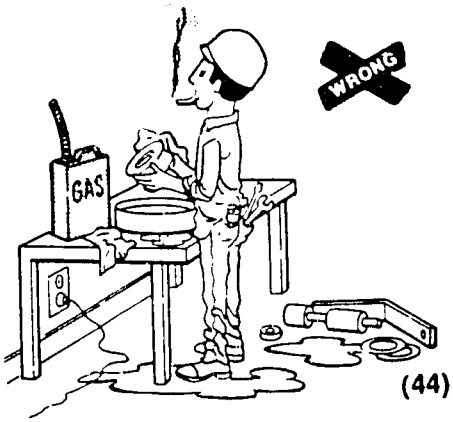
* This item has been written to be read by workers themselves, as well as managers.

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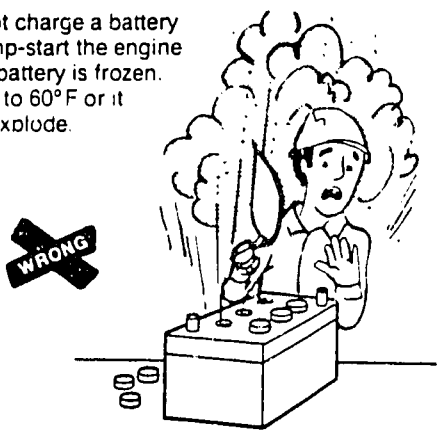
Do not charge a battery or jump-start the engine if the battery is frozen. Warm to 60°F or it may explode.



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- Report immediately any defects or shortcomings in the machine or engine so that they can be repaired.

- Do not overload the machine or engine.

- Always keep your engine or machine clean. Do not place tools or clothes, etc. on it.

- Keep your fingers away from the operating parts or any other running parts of the machine.

- When operating a machine do not wear gloves, rings, ties, scarves or long, loose sleeves.

- Keep the floor around your machine clean, dry and free of any substance that could cause someone to fall or slip.

- Operate the engine or machine according to received instructions.

- When operating a diesel engine or fuel injector set, do not expose the skin of your arms or face to the fuel spray.

- Disconnect the battery cable while repairing an engine unless it is essential for work.

- Avoid work accidents resulting from running starters which do not operate properly.

- Do not smoke with gasoline on your hands and do not expose petroleum materials to uncovered electric wires.

- Fresh air circulation into and out of the engine repair workshop is very important, since gases like carbon monoxide are released when running engines that have been recently repaired.

- When you finish your work, clean the machine after stopping it completely.

5.8.2. <u>On Using Hand Tools</u>:

- A conscientious skilled technical worker should know how to avoid problems and dangers resulting from use of inappropriate hand tools or inappropriate use of tools.

- Do not carry any instruments or hand tools in your pockets, especially sharp ones. Always keep them in their cases and boxes.

- Always return hand tools and instruments to their places after finishing work and do not place them on the machines, or anywhere near them, as this may cause accidents or loss.

- Wipe oil and grease off instruments and hand tools, as this damages them and may cause accidents.

- Inspect hand tools and instruments before using them. Do not use damaged tools and instruments and always use ones suitable in size or type. There are different kinds of keys, hammers and saws; always choose the right one to ensure work quality and avoid accidents.

- If you notice that one of the hand tools needs more pressure or power this may mean that is not the right tool. If you are performing work that can create sparks or splinters, put on suitable preventive glasses and place partitions to protect yourself and others against harm.

- Do not use hand tools with flattened heads or sharp ends or cracked handles as these may cause accidents. If you are scratched, apply first aid immediately.

5.8.3. <u>On Working with Electrical Devices</u>

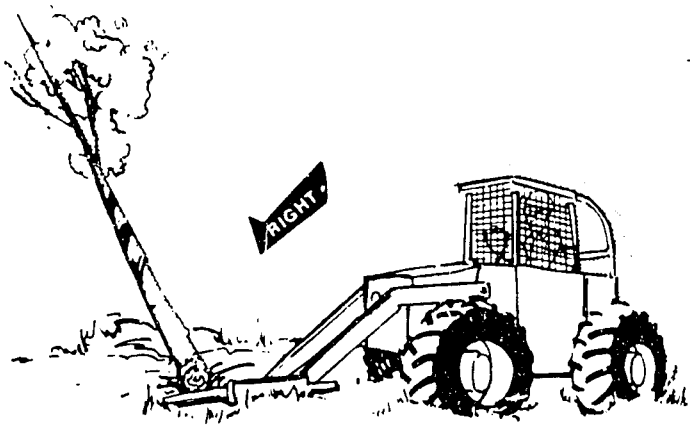
The effects of electric shock differ according to the type of electricity (static or current), current (direct or alternating), and the voltage and the period of time to which a person is exposed to it.

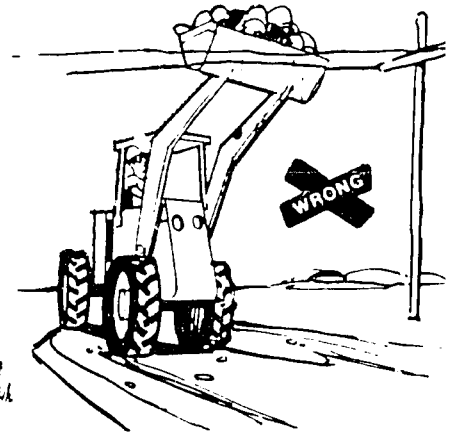
Individuals themselves vary in their sensitivity towards electricity, depending on the dryness or moisture of the skin.

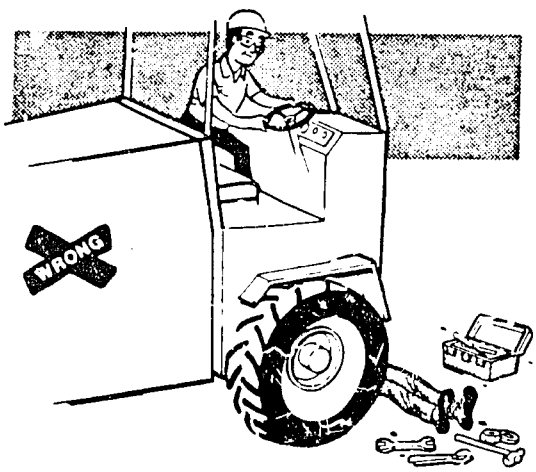
Generally speaking, direct current is more dangerous than alternating current. The danger of alternating current decreases with its frequency. The longer the duration of the shock, the more dangerous are its effects; similarly, danger increases with voltage.

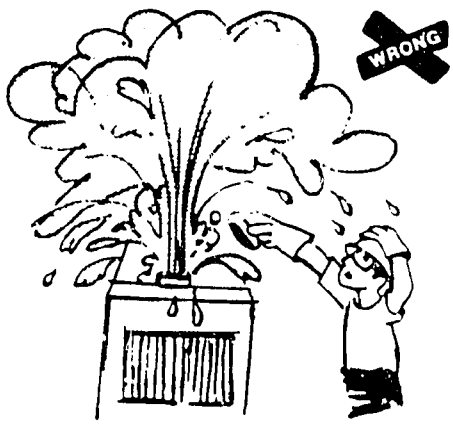
Some precautions that should be followed when using electrical devices are:

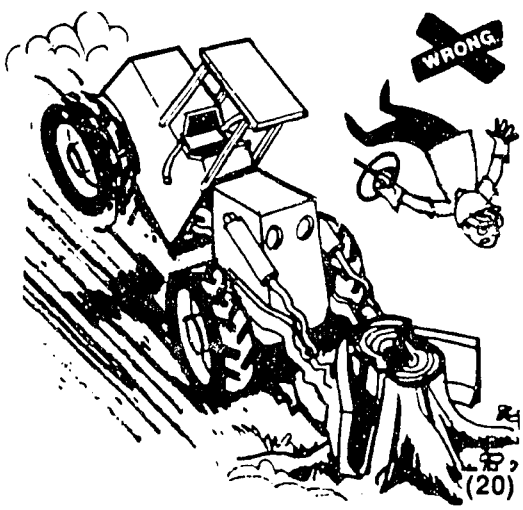
- Disconnect electricity before starting any repair or maintenance.



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- If you notice any increase in the heat of electric generators or engines, or that instruments are giving off sparks or smoke, disconnect them immediately.

- Before approaching electric equipment be sure that the equipment and the ground around them are dry.

- Check that all electric devices and equipment are grounded with ground cables.

- Avoid touching conducting circuits or running parts.

- To avoid sudden injuries warn unauthorized persons they are not allowed to approach the machines.

5.8.4. On Operating Cranes

- Each crane has a maximum load. The cargo to be lifted should be less than this maximum.
- Use chains and ropes that are adequate for both lifting and loading requirements.
- Assign a person who is well acquainted with unloading and discharge techniques to direct the crane driver.
- Before starting to load, make sure that the crane is completely fixed using brake and tire supports to ensure that it does not move forward or backward. The crane should be on level ground whenever possible.
- Stretch the crane boom to keep it away from the cabin so that no damage is done to the cabin.
- No one should be permitted in the loading area, especially under the freight or cargo, or within the radius of the crane boom.
- Use the horn while moving the boom and the cargo.
- When loading on trailers, load with the rear first, not the front.
- During and before loading, check that the ropes are well-fitted in the reels. Perform maintenance constantly according to instructions.

ANNEXES

# Annex I

Technical Specification
of an Agricultural Tractor

I. Engine:

1. Four stroke diesel engine
2. Four cylinders
3. Air or water cooling
4. Producing 60-65 horsepower at the wheels.
5. Includes an air cleaner certified to work in dusty weather and has a changeable element.
6. Equipped with primary and secondary oil filter; the primary is metallic and self-cleaning with outside sleeve, the secondary has a changeable element.
7. Two stage fuel filter is to be furnished.

II. Transmission:

1. 6 forward speeds and 2 reverse
2. Double acting dry clutch.
3. Power transmision shaft could work directly with the engine or parallel with tractor's speed.

III. Brakes

Power assisted hydraulic activated service brake. Parking and emergency brakes capable of controlling and holding the loaded tractor on 25% grade.

IV. Tires:

Equipped with four inflated tube tires.

V. Electrical System:

Electrical system works on a potential of 12 volt by means of one acid battery to be placed in a suitable place for easy maintenance.

VI. Chassis:

Tractor must be multi-purpose to do all agricultural and transportation operations and should at least be equipped with the following:

1. An hydraulic device to operate the agricultural instruments and the special standard equipment.

2. Drawbar to pull the agricultural trailers (Capable of pulling trailers from 4 to 8 tons).

3. Air compressor needed to operate trailers working with air brakes.

4. Adjustable operator seat, horizontal and vertical (front - rear - up - down)

5. Sun visor, textile or steel made

6. 6 Rear wheels to be covered with fenders to protect the driver against dust.

7. All tractor parts (engine - transmission - hydraulic ...) easy to operate and maintain.

VII. Spare parts:

A list must be enclosed with the offer that includes the fast moving parts equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...), and should cover the maintenance requirements for at least two years.

VIII. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with tire wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).



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Technical Specifications
of Articulated Double Drum Vibrating Roller

I. Engine:

1. Diesel engine
2. Four stroke
3. Water cooling
4. Produce not less than 70 net flywheel horsepower
5. Includes an air cleaner qualified to work in dusty weather and has a changeable element.
6. Fuel tank capacity must be enough for min. 10 hours working
7. Equipped with a primary and secondary oil filter; the primary is metallic and self cleaning with outside sleeve, the secondary has a changeable element.
8. Fuel filter with two following stages to be furnished.

II. Propulsion:

1. Both drums should be hydraulically or hydrostatically propelled.
2. Fluid power hydraulic pump should be capable of propelling roller at full operating load and maximum vibration.
3. Gradability is not less than 30%
4. Speed range should be from 0 to 10 km/hr

III. Steering

1. The steering should be by 2 hydraulic cylinders.
2. Turning angle at the articulated joint is not less than 35 degrees right or left.
3. Oscillation is vertical and not less than 10 degrees up or down.
4. Outside turning radius is not more than 5.25 m.

IV. Chassis:

1. Roller is articulated with double drum which must be operated with extra care. These drums must be machined and with a finished surface.
2. The roller shall be suitable for operation on dirt, gravel and asphalt roads (base and sub-base materials).
3. Roller weight 8-10 ton
4. Operator should be able to see all directions specially front and rear drum.
5. ROPS with sun canopy.
6. Instrument panel to include:

   A. A-meter/voltmeter.
   B. Hour meter

C. Engine water temperature indicator
D. Engine oil pressure gauge
E. Fuel level gauge
F. Hydraulic oil level indicator
G. Hydraulic oil temperature indicator
H. Switch for outer lights, front and rear
K. Horn button
L. Frequency meter
M. Sprinkler system, water level indicator and low level alarm

7. Adjustable seat with backrest and seat belt.
8. Cab is equipped with exterior night lights (4 spot lights, front and rear) traffic lights and stop lights.

V. Drums:

1. Width is not less than 1.40 meter
2. Diameter is not less than 1.00 meter
3. Drum shell thickness is not less than 14mm
4. Roller must be equipped with a drum wetting system to keep the asphalt from sticking to the drums
5. Eccentric should be oil bath lubricated by means of oil in special tanks.
6. The sprinkler system water tank(s) should be anti-rust treated and should have a capacity of not less than 600 liters. The filling openings should be fitted with proper screens to prevent entrance of dirt. Drums should be fitted with double wipers for both the two moving directions.

VI. Electrical System

Electrical system works with 24 volts by means of 2 acid batteries, each 12 volts, which should be placed in a suitable place for easy maintenance.

VII. Brakes:

- Hydrostatic drive chain
- Parking brakes to be to manufacturer's standard and should be capable of holding roller at a gradient of 25%

VIII. Training:

The supplier must provide a training course for the operator or the technicians for at least 1 week. The supplier is responsible for salaries, expenses and transportation of the trainees during the training period.

IX. Transportation:

The supplier is responsible to transport the roller to any markaz of the governorates at his expense.

X. Spare Parts

A list must be enclosed with the offer including the fast moving parts equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic, ...). This list should cover at least the maintenance requirements for two years.

XI. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).



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Technical Specifications
for Sewer Cleaner - Truck Mounted Type

General:

1. Truck and equipment is of a modern type ... models and later.

2. The units will be used for cleaning blockage in sanitary and combined sewer pipes and conduits of various shapes-6" diameter and above, using high velocity water jet.

3. Truck is to be supplied with all connections, appendages and hoses required.

I. Engine

1. 4-Stroke diesel engine working with direct injection.
2. Water or air cooling suitable for tropical conditions.
3. Horsepower not less than 160 S.A.E. at the flywheel at the rated R.P.M for this type of production.
4. Equiped with an air filter qualified to work in dusty conditions and has a changeable dual element.
5. Equiped with a primary and secondary oil filter; the primary metallic and self cleaning with outside sleeve, the secondary has a changeable element.
6. Following two stages fuel filter is to be furnished.

II. Wheels:

Driving Wheels are to be 4 x 2. The rear axle may be equipped with double wheels, taking into considerations that truck will work in dirt, mud and off roads. It will work in dusty conditions.

III. Transmission

1. Transmission is to be manual by means of one shift
2. The gear box is to provide 4 forward speeds and one reverse.
3. Outside control panel is to be equipped with all the gauges and switches to operate all the equipment needed for cleaning and clearing blockages.
4. The control panel has a switch to control the power produced from the high quality truck engine which must have more power than that required to operate the water pump and the hose drums by 35%.
5. Water pump is to work by an hydraulic system from a hydraulic pump connected to the power source.

IV. Brakes:

Brakes work by air pressure from an air compressor run by the engine. Emergency and parking brakes capable of holding the truck when fully loaded on a grade of 25%.

V. Suspension:

Truck is to be equipped with heavy duty front and rear springs and heavy duty shock absorbers for the front axle.

VI. Tires:

Truck is equipped with 5 or 7 tube type tires with rims. One of them is to be used as a spare mounted in a suitable location and easy to change.

Tire size is to be the local production size, and the tread is to be from (specify size).

VII. Cab:

A. Modern type steel cab having 2 doors with safety glass manually opened. Front wipers are to be furnished. Equipped with 3 person (including driver) bench seat.
B. Dash board lighted at night automatically with driving lights and should include:

1. Speedo-meter by kilometers with tachometer.
2. Charging indicator
3. Oil pressure gauge
4. Engine temperature indicator
5. Fuel level indicator
6. Lighting control switches inside, outside, front and rear lighting.
7. Turning signal switch (right and left)
8. Windshield wiper controls which work with an electric motor
9. Two sun visors easy to move and to fix in any direction.
10. Air brake indicator with a warning device for low air pressure.

C. Left and right outside rear view mirrors.

VIII. Electrical System:

Electrical system shall be 12 or 24 volts with one or two acid batteries placed in a suitable place for easy maintenance.

IX. Body and Chassis:

1. Truck is to be equipped with front and rear heavy duty steel bumpers, minimum 8" "C" channel. Bumpers are both bolted to the chassis frame.

2. Equipped with two front tow-loops, hooks, eyes or shades capable of pulling the full loaded truck. Also one rear tow-hook mounted on the chassis.

3. Equipped with one or two fuel tanks, not less than 200 liter capacity, each furnished with lockable type cover.

4. Paint: Before painting, all metal surfaces shall be thoroughly primed, cleaned and phosphated. The finish paint will be highly resistant to scratching and fading, and have long lasting shiny appearance.

5. Pump: The pump shall be manufacturer's standard positive displacement, heavy and continuous duty capable for satisfactory operation with wastewater. Pump minimum capacity is 230 liter/min at 125-140 kg/cm2 pressure. Running speed is 500 R.P.M. maximum.

   The pump construction shall include an enclosed oil bath crankcase. Shafts and gears shall be hardened or tuftrided. The pumps shall have inspection ports and covers to permit easy inspection and servicing of the valves.

   Suction line shall include heavy duty "Y" type filter/strainer or equivalent to protect the pump from contamination in the water.

   Pressure relief valve, adjustable from 70-140kg/cm2.

   The valves shall be stainless steel repairable type.

   All wetted parts of the pump shall be of materials highly resistant to corrosion.

6 Hose Reel. The hose reel shall be constructed to withstand the maximum working pressure.

   Two high pressure hoses of 1" inside diameter suitable for sewer application, not less than "1/4" steel thickness and 120-180 m. long. Operating nominal pressure approx. 140kg/cm2 and burst pressure 345 kg/cm2 min.

   It shall be mounted at the front or rear of the truck, hydraulically driven through payout and retrieve control. The hydraulic drive shall have sufficient power to retract the hose when fully extended into the sewer when the unit is in operation.

   The reel flanges will be constructed to avoid any damage while winding the hoses which will be hand guided

7. Water Tank:

   o Tank capacity shall be at least 6000 liters

- It shall be constructed from welded steel sheets with sufficient stiffeners and have a minimum of three internal baffles to reduce sloshing.
- The fill connection shall be 2.5", suitable for filling from fire hydrant fitting located at accessible position. It shall include a 2.5" coupling cover, all brass.
- The tank shall be constructed to permit complete draining thru 2.5" opening with brass value and handle located at a convenient position to the operator.
- The tank shall also be provided with a manhole of 50 cm. diameter covered by quick-locking cover and hinged on one side.
- The tank should be coated inside with at least triple Epoxy coatings to protect it against corrosion and outside with at least double rust coatings.

8. All piping subjected to high pressure should be of seamless high quality pipe with forged fittings.

   Return piping and low pressure piping may be ordinary standard type.

9. Cleaning system: The cleaning system shall include 7.5 m, long 0.5" inside diameter hose and hand gun with stream adjustment from straight stream to fine fog. Low pressure hand clean up shall be limited to 55 kg/cm2 at full throttle R.P.M. Pressure relief valve shall be provided.

10. All sewer cleaning components and the instrument panel should be completely enclosed with an easy open and close cover latchable with locks and keys.

11. The body should be constructed so as to have suitable storage areas for tool box, nozzles, hoses,.... and all equipment required to operate the unit.

12. The body, chassis and tank are to be painted inside and out with enough layers by anti-corrosive and anti-rust painting to prevent corrosion.

13. Mudflaps are to be furnished at the rear wheels.

14. Control panel:

Control panel should be located outside the vehicle so that one can easily control the whole cleaning operation. It should include at least the following:

A. Auxiliary engine start switch.
B. Engine oil pressure gauge.
C. Engine temperature gauge.
D. Charging indicator.
E. Fuel tank(s) level indicator.

F. Water tank level indicator.
G. Water pressure gauge.
H. Control lever for engine speed.
I. Control lever for speed, and direction of rotation of hose reel.
J. Water pressure control handle for setting pressure between 0-140 kg/cm2.
K. Failure warning indicator.
L. Control panel should have night working light.

15. A spotlight with 15 m long retractable cord should be supplied.

X. Spare Parts

1. A list must be enclosed with the offer which includes the fast moving spare parts and equal to 10% of the truck's value. This list should include filters (oil, air, fuel, hydraulic,...) belts, hoses and gaskets ..... This list should cover the maintenance requirements for at least two years.

2. Accessories and attachments to be supplied with the truck:

Each unit shall be supplied with the following (or equivalent):

a. One 15 degree radial nozzle with high forward thrust for light accumulations of sand and grit. Five or six rearward jets.
b. One 35 degree radial nozzle with low forward thrust for heavy accumulations of sand and grit. Five or six rearward jets.
c. One 15-35 degree radial penetrator nozzle with low forward thrust for use where complete blockage exists. Five rearward jets and one forward penetrating jet.
d. One 35 degree radial grease nozzle for heavy buildups of grease and detergent. Eight rearward jets.
e. Lower man hole roller assembly with three extension handles to provide a smooth surface for the hose as it is extended or retracted in the sewer.
f. One hand gun with 7.5m (25 ft.) of 12.5mm (1/2 inch) I.D rubber or plastic hose for manhole cleaning. Handgun hose shall have connection at rear of machine and shut-off at operator station.
g. A 25 ft. section of 21/5 inch filter hose.
h. two sewage end fittings for 1" hose.
i. One sewage splicer kit for 1" hose.
j. Six intermediate splicer connections and any special tools required for splicing hose.

XI. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have manual hydraulic jack and tire wrench. All is to be put in a metallic box fixed in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service.)

Technical Specifications
of Cesspit Emptiers-Truck Mounted Type

- Truck mounted sewage vacuum human waste truck model (specify) or later.
- Driving wheels are to be 4 x 2 and the rear axle is to be equipped with double wheels.
- Taking into consideration that truck will work some times off the road and on dirt roads in the Egyptian villages, it should work in dusty conditions.

I. Engine:

1. Four stroke diesel engine
2. [illegible] cooling
3. [illegible] is not less than 100 HP net at the wheels.
4. Equipped with an air filter with pre-cleaner suitable for operation in dusty conditions (or oil bath air filter).
5. Equipped with a primary and secondary oil filter, the first is metallic and self-cleaning with outside sleeve, the secondary with changeable element.
6. Fuel filter with two following stages is to be furnished.

II. Transmission:

Manual transmission, with one shift drive, of 3-4 forward speeds and one reverse shall be furnished.

III. Brakes:

Power assisted hydraulic activated service brake. Manual parking brakes capable of controlling and holding the full loaded vehicle on 20% grade should be furnished.

IV. Suspension:

Heavy duty front and rear springs and heavy duty shock absorbers for the front axle shall be furnished.

V. Tires:

Truck is equipped with 7 tube type tires with rims. One of them will be used as a spare and is mounted in a suitable place where easy to change. Tires should be suitable to the truck weight at full load and must be radial.

VI. Cab:

Coventional steel (modern type) cab, includes gauge panel which can be lighted at night and includes:

1. Speedmeter in kilometers and a tachometer

2. Charging indicator

3. Engine pressure oil gauge

4. Engine temperature indicator

5. Fuel level indicator

6. Lighting control switches inside, outside, front and rear lighting.

7. Turning signal switch (right and left).

8. Windshield wiper controls which work with an electric motor.

9. Left, right and inside rear view mirrors

VII. Electrical System:

Electrical system shall be 12 volt by means of one acid battery placed in a suitable place for easy maintenance.

VIII. Body and Chassis:

1. Truck is equipped with a front steel heavy duty bumper.

2. Truck is equipped with one or two fuel tank(s).

3. Mudflaps are to be furnished behind the rear wheels to protect from the sprayed water and much while moving.

4. Truck is to be equipped with high quality types of all equipment, hoses, couplings and covers needed for cesspit and discharge.

IX. Sewage Tank Body:

1. Cylindrical or spherical tank with capacity of 3-4 cubic meters made from at least 5mm steel thickness in any part of the tank. Tank should be furnished with dished steel heads and anti-surge baffles, also with top ventilation holes and a top hole with 35-50 cm diameter, with suitable light buffed and with a tight seating cover. Tank is to be furnished with one stay from the middle of the tank leading to this opening. One 50cm diameter quick opening manhole should be loaded at the bottom of the tank for cleaning.

2. Body should be insulated with a minimum of 8cm slope from front to rear to unload the charge easy. Body shall be bolted down to the chassis by means of brackets. Insulating rubber must be placed in the intersection points between tank and chassis.

3. The tank should be interior coated with Epoxy coating, two exterior antirust coatings and lastly, blue color layer painting

4. Two hand-operated heavy duty 4 inch brass valves with brass quick couplers and brass cabs to be furnished on the suction and discharge openings. The valves shall permit solids of up to 5 cm to pass through.

5. Tank should be equipped with a sight glass allowing the operator to see the fluid inside the tank. One external level indicator actuated by slainless steel float ball and arm. The level indicator shall be calibrated in cubic meters.

X. Pump

Pump is to be heavy duty self priming capable of operating at pressures of at least 1.2 atmospheres and capable of creating a high volume (minimum 90%). Pressure indicator and vacuum indicator are to be furnished and each of them is to be graded in kilograms/$cm^3$.

XI. Spare Parts

A list must be enclosed with the offer including the fast moving parts equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,....). This list should cover the maintenance requirements for at least two years.

Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

XIII. General

1. Truck must be (specify) mode' or latest.

2. Local production is preferable.

3. If local production are not available, item must be American or Western made.

4. Must enclose with the offer the warrantee for each of the truck parts if these parts are not original.

Technical Specification of
The Articulated Frame Motorgrader

Motorgrader must be from the modern type (specify)

I. Engine:

A. Diesel engine
B. Four stroke
C. Water or air cooling
D. Produces at least 125 flywheel horsepower and according to the R.P.M. for this type of production.
E. Includes an air cleaner qualified to work in the dusty weather and has a changeable element.
F. Includes muffler
G. Incudes exhaust stack, with rain cap.
H. Equiped with primary and secondary oil filter; the primary metallic and self-cleaning with outside sleeve, the second with a changeable element.
I. Fuel filter with two following stages is to be furnished

II. Operator's Cab:

A. Modern type
B. Steel manufactured
C. Includes ventilating windows
D. Covered with saftey glass throughout with wipers and water injector to clean the glass.
E. Adjustable driver's seat.
F. The instrument panel can be lighted at night and should include:

1. Hour meter gauge
2. Charging indicator
3. Engine oil pressure gauge
4. Engine temperature indicator
5. Fuel level gauge
6. Hydraulic oil level gauge
7. Light switches for inside, outside, front and rear lighting.
8. Turn signal switch
9. Wiper switch and water injector
10. Lever for operating blade
11. Torque convertor oil temperature indicator (if found)

G. Includes rear view mirrors needed for driving and working
H. The cab is equipped with external night work lights (4 big spot lights, front and rear), traffic lights, stop lights and turn signal flasher.

III. Frame

1. Heavy duty articulated frame, modern production (specify) models and later, also having all the standard accessories for this type of product.

2. Frame shall be all-welded and shall be stress-relieved before precision bored for precise shaft alignment for minimum wear and longer life.

3. Articulation action of frame shall be by hydraulic cylinder(s) of single or double acting type depending on manufacturer's design.

4. Blade is to be from the standard type and equipped with a changeable cutting edge made from steel. Fixing bolts are to be immersed to ensure no corrosion.

5. Articulation angle should not be less than 35 degrees to both sides.

IV. Transmission:

Manual power shift transmission with or without torque convertor, with at least 6 forward speeds.

V. Steering:

Full hydraulic power steering and by using articulation, turning radius equals 75 cm or less.

VI. Wheels and Tires:

1. Motor grader is equipped with 7 tube tires and rims, one of them is used as a spare.

2. Standard production tires with min. 12 ply rating. All traction type tread.

VII. Brakes:

1. Full power hydraulic brakes on all drive wheels (4 wheels in this case).

2. Motor grader is equipped with parking and emergency brakes.

VIII. Electrical System:

1. Electrical system work of 12 volts with 2 acid batteries which should be put in suitable place to be easy to maintained.

2. Motorgrader is equipped with a horn to be used while driving and a rear buzzer to be used during work.

IX. Spare Parts

A list must be enclosed with the offer including the fast moving parts and equals to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...). This list should cover the maintenance requirements for at least two years.

X. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenanace and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

Technical Specifications
for Rubber - Tired Tractor Dozer

The tractor dozer must a modern type (specify) and later.

I. Engine:

A. Diesel engine
B. Four Stroke
C. Water or air cooling
D. Produce at least 210 flywheel horsepower and according to the R.P.M. for this type of production.
E. Include an air cleaner qualified to work in a dusty climate and has a changeable element.
F. Includes muffler.
G. Includes exhaust stack, with rain cap.
H. Equipped with primary and secondary oil filter; primary is metallic and self cleaning with outside sleeve, the secondary has a changeable element.
I. Fuel filter with two following stages to be furnished.

II. Operator's Cab

A. Modern type
B. Steel manufactured
C. Includes ventilating windows
D. Covered with saftey glass throughout with wipers and water injector to clean the glass.
E. Adjustable driver's seat
F. The instrument panel can be lit at night and should include:

1. Hour meter gauge
2. Charging indicator
3. Engine oil pressure gauge
4. Engine temperature indicator
5. Fuel level gauge
6. Hydraulic oil level gauge
7. Switches for inside and outside lights
8. Turn signal switch (left and right)
9. Wiper switch and water injector.
10. Controls for operating the dozer blade

G. Includes rear view mirrors needed for driving and working.
H. Equipped with external night work lights, traffic lights, stop lights and turn signal flsher.

III. Frame

1. Heavy duty articulated frame, latest modern production (specify) models and later.

2. The body works on two axles, the front axle is fixed and the rear axle is oscillating.

3. Frame shall be all-welded and shall be stress-relieved as necessary according to normal practice before precision line-boring for precise shaft alignment for minimum wear and longer life.

4. All rotating and turning componenets shall be enclosed for mechanical protection. All such enclosures must have large accesses which are easily opened and removed. Also radiators shall have extra protection against dust.

5. Articulation shall be minimum 35 degrees to both sides.

6. Dozer blade is to be from the standard type and equipped with a changeable cutting edge made from steel. Fixing bolts are to be immersed to ensure non corrosion.

7. The dozer blade operates hydraulically (up and down, tilting and tipping).

8 Blade width is not less than 3.50 meter. Blade height is not less than 1.00 meter. Up and down tilting is not less than 70 cm. Blade tipping is not less than 18 degrees.

IV. Transmission:

1. Torque converter type with full power shift having at least 4 speeds both forward and reverse.

2. Tractor dozer should be 4 wheel drive.

V. Steering:

Hydraulic power steering and by using articulation the turning radius should not be more than 7.50 m (from edge to edge).

VI. Wheels and Tires:

1. Tractor dozer is equipped with 5 tube tires and rims one of them used as a spare tyre.

2. Standard production tyres with min 20 ply rating. All traction type tread in front and rear.

VII. Brakes:

1. Full power hydraulic brakes on all drive wheels (4 wheels drive in this case).

2. Tractor dozer is equipped with manual parking/emergency brakes.

VIII. Electrical System:

1. Electrical system works on potential equal to 12 or 24 volt by acid batteries which should be placed in suitable place to be easy to maintain.

2. Tractor dozer is equipped with a horn for driving use and rear buzzer to be used during work.

IX. Spare Parts:

A list must be enclosed with the offer including the fast moving parts equals to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...). This list should cover the maintenance requirements for at least two years.

X. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with type wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

Technical Specifications
Of Small Water Spray Truck, Rear Spraying

I. Engine:

1. Four stroke diesel engine
2. Water cooling
3. Producing not less than 100 horsepower on the wheels
4. Equipped with an air filter with pre-cleaner suitable for operation in dusty conditions.
5. Equipped with primary and secondary oil filter, the primary is metallic and self cleaning with outside sleeve. The secondary has a changeable element.
6. Fuel filter with two following stages shall be furnished.

II. Driving Wheel:

Driving wheel shall be (specify) due to working conditions. The rear axle shall be equipped for double wheels.

III. Chassis:

1. Spherical or elliptic tank, 3-4 cubic meter capacity with all necessary pipes, valves, and hoses for filling the tank with water from the rivers and canals by the pump and for the spraying.

2. The tank shall be constucted of minimum 5mm high strength steel flanged heads, surge steel plates baffles not more than 1 meter apart so as to provide additional tank strength. One along the middle of the tank length.

3. Tank shall be equipped with a down opening to clean the tank. Must be 2 openings. One with 3 inches diameter for discharging the water and one to indicate the water level.

4. A manhole of minimum 50cm diameter and with suitable height should be furnished on top of the tank and should have a tight sealing cover. One staires shall be furnished at the middle of the tank.

5. Suction hose shall be furnished with a strainer ensure clean water when filling the tank. This hose should not be less than 22 meter long.

6. Tank shall be back inclined at an angle equalsto 3-5 degree to ensure complete discharge.

7. The tank should be suitably protected against corrosion from both from inside and outside by a minimum of 5 coats of anti-corrosive paint.

8. The unit should be provided with a single or multi-stage

centrifugal self priming water pump. The pump should be capable of filling the tank within 5 minutes minimum at a level 3 meters lower than the truck level by means of a 22 meter suction hose.

9. The pump should have a bronze impeller and shaft sleeves with wearing rings.

10. Spraying:

Rear spray bar the width of the truck shall be furnished to operate by gravity or under pressure from pump. Control of discharge from spray bar shall be a switch on the control panel within easy reach of operator/driver.

11. Control Panel:
Control panel shall include a switch for the spray bar, discharge pressure selection valve, operating water pressure gauge and all other gauges and warning lights necessary for the safe and efficient operation of the unit including an indicator to indicate the level of water in the tank. Awarning buzzer shall also be provided for low water level. As an extra precaution a sight glass for the water level shall be furnished.

12. The truck shall be equipped with a front steel heavy duty bumper.

13. The truck shall be equipped with one or two fuel tanks with a total capacity not less than 150 litres fuel.

14. Mudflaps shall be furnished behind the rear wheels.

IV. Cab:

Modern type produced from steel, equipped with a control panel that can be lighted at night and should include:

A. Speedometer/tachometer calibrated in kilometers.
B. Charging indicator
C. Engine temperature indicator
D. Fuel level gauge
E. Switch for outside and inside lights, front and rear
F. wipers switch.
G. Turn signals switch.
H. Cab shall be paint with colour (specify).

V. Electrical system:

Electrical system shall be 12 volt with one acid battery which should be put in suitable place for easy maintenance.

VI. Transmission:

A. Transmission shall be one manual shift.

B. At least 3 forward speeds and one reverse should take into consideration that the truck will work on narrow dirt roads and not paved in the Egyptian villages.

VII. Brakes:

Power assisted hydraulic activated service brakes. Emergency and parking brakes capable of controlling and holding the loaded vehicle on 20% grade should be furnished.

IIX. Suspension:

Heavy duty front and rear springs, heavy duty shock absorbers for the front axle and assistant springs for the rear springs.

IX. Tyres:

Truck is equipped with tube tyres and rims. One of them shall be used as a spare and is mounted in a suitable place where it is easy to change. Tyres shall be radial type and shall be of proper capacity for gross Vehicle weight rating and weight distribution.

IX. Spare Parts:

A list must be enclosed with the offer that includes the fast moving parts and equals to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...). This list should cover at least the maintenance requirements for two years.

X. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repairing and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

Technical Specifications
of Truck Mounted Hydraulic Articulating Aerial Beams

Truck shall be from the modern type (  ) and later.

I. Engine

A. Diesel engine
B. Four stroke direct injection
C. Producing not less than 125 net flywheel horsepower at manufacturer's rated R.P.M.
D. Water or air cooling
E. Includes an air cleaner qualified to work in the dusty weather and with changeable element.
F. Equipped with primary and secondary oil filter; the primary is metallic and self-cleaning with outside sleeve, the secondary has a changeable element.
G. Two following stage fuel filters shall be furnished.

II. Driving Wheel:

Driving Wheel shall be (specify). The rear axle equipped with double wheels. Taking into consideration that the truck will work sometimes on the narrow dirt roads and not paved in the Egyptian villages and cities, it should work in dusty areas.

III. Transmission:

1. Transmission shall be one manual shift.

2. 3-4 forward speeds and 1 reverse.

3. Controls for the aerial beam shall be located at both the truck and at the bucket.

IV. Brakes:

Power assisted hydraulic activated four wheel service brakes. Parking emergency brakes capable of controlling and holding loaded vehicle on a 20% grade should be furnished.

V. Suspension:

Heavy duty front and rear springs and heavy duty shock absorbers for the front axle.

VI. Tires:

Truck shall be equipped with 7 tube tyres and rims. One of them will be used as a spare and mounted in a suitable place where it is easy to change. Size of the tyres must be from those which are produced locally. The tread shall be suitable for the dirt and unpaved roads.

VII. Cab:

1. Modern type steel production, has 2 doors with manual open safety glass - wipers - adjustable drivers' seat or bench.

2. Dash panel which can be lit at night and should inlude:

   A. Speedometer in kilometers which has tachometer.
   B. Charging indicator
   C. Engine temperature indicator
   D. Fuel level gauge
   E. Switches for outside and inside lights, front and rear.
   F. Turn signal switch
   G. Switch for the wiper which works by electric motor.
   H. 2 sun visors easy to move and fix in any direction.

3. Includes 3 rear view mirrors right, left, inside the cab.

VIII. Electrical System:

Electrical system working on potential equal to 12 volts by one or 2 acid batteries which can be placed in a suitable place to be easy to maintain.

IV. Chassis

1. Truck shall be equipped with front and rear heavy duty steel bumbers.

2. Truck shall be equipped with one or two fuel tank(s) enough for at least 2 working days.

3. All-steel rear heavy duty box with storage compartments on each side, non-skid tread-plate steel to rear surface.

4. Unit shall include one man bucket capable of raising a minimum of 160 kg at least (1 man plus needed tools) to the height of 100 meter minimum.

5. Bucket shall be equipped with safety features like belts,... and manufactured of, or insulated with, material to provide safety working around live wires up to 10,000 volts.

6. Independently operated hydraulic out-riggers and/or stabilizer bars shall be provided as necessary for stabilizing vehicle for work on slopes up to 5 degrees.

7. The hydraulic pump shall be operated by a heavy duty P.T.O. to be mounted on the transmission. An emergency hydraulic system shall be provided to enable personnel to be brought down in case of hydraulic main line failure.

8. A mean should be provided to ensure that beams and outriggers do not collapse in the event of hydraulic line failure.

9. Rotation of the aerial beam should be 360 degrees continuous or to a positive stop. Personnel bucket should be self-leveling.

10. There are 2 controlling panels to move aerial beams, one in the bucket and the other in the truck. Controls shall be deadman type, only operating during positive action by the operator. The controls at the truck shall be equipped with an override to enable a disabled worker in the bucket to be brought down. Means shall be provided to prevent unauthorized use of the unit.

IX. Spare Parts:

A list must be enclosed with the offer including the fast moving parts and equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...). This list should cover the maintenance requirements for at least two years.

X. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repairing and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).



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Technical Specifications
For Small Refuse Trucks

I. Engine

1. Four stroke diesel engine

2. Water cooling

3. Producing at least 100 net horsepowe.

4. Equipped with an air filter with pre-cleaner suitable for operation in dusty conditions (or an air filter that works in an oil bath).

5. Equipped with a primary and seocndary oil filter, the primary is metallic and self cleaning with ouside sleave, the secondary has a changeable stuff.

6. Fuel filter with two folwoing stages.

II. Wheel driving:

Wheels driving are 4 x 2. The rear axle is equipped with double wheels.

III. Chassis:

1. Refuse packer body shall be minimum 4 cubic meters (GVWR) and not more than 6 cubic meters. Gross vehicle weight rating shall not be less than 5 tons. Front axle should carry 25% minimum weight distribution of the rated GVW of the units bid. The centre of gravity of the fully loaded body should be located between the cab and the centre of the rear axle.

2. The body should be produced from high strength steel with thickness not less than 2mm and should have heavy reinforcment at the bottom, sides and top. The reinforcement should be welded to the body with continous welding. Body shall be painted with two coats of anti-rust paint.

3. Refuse body shall be equipped with a cover and slide side doors which must be low enough for the operator. The rear door shall be easy to open to unload the refuse (utilizing hyraulic cylinders)

4. An hydraulic dump shall be furnished which can be operated from the cab.

5. Truck shall be equipped with a front steel heavy duty bumper.

6. Truck shall be equipped with one or two fuel tank(s)

7. Mudflaps shall be provided behind the rear wheels.

IV. Cab:

1. Modern type production from steel, equipped with gauge panel can be lit at night and should include:

   A. Speedometer in kilometers which has tachometer.
   B. Charging indicator
   C. Engine oil pressure gauge
   D. Engine temperature indicator
   E. Fuel level gauge
   F. Switch for outside and inside lights, front and rear.
   G. Turn signal switch
   H. Wiper operating switch

2. Includes 3 rear view mirrors, right, left and inside the cab. Cab shall also be equipped with sun visors, easy to move and fix in any direction. Cab shall be (specify) colour.

V. Electrical System:

Electrical system works on potential equal to 12 volts by means of one acid battery which can be placed in suitable place to be easy to maintain.

VI. Transmission:

A. Transmission shall be one manual shift.

B. 3-4 forward speeds and one reverse. Must take into considration that the truck will work in narrow dirt and unpaved roads in the Egyptian villages.

VII. Brakes

1. Service brakes shall be hydraulic power brakes, dual system.

2. A parking/emergency brake shall be furnished and shall be capable of holding the vehicle in either direction, forward or reverse, loaded to its gross vehicle weight rating on a 20 % grade.

VIII. Suspension:

Heavy duty front and rear springs heavy duty shock absorbers for the front axle.

IX. Tyres:

Truck shall be equipped with 7 tube tyres and rims, one to be used as a spare and shall be mounted in a suitable place where it is easy to change. Tires shall be radial type and shall be of proper capacity for gross vehicle weight rating and weight distrtibution.

X. Spare Parts:

A list must be enclose ith the offer include the fast moving parts equals to 10% of the tru value. This t should include filters (oil, air, fuel, hydraulic,... This list should cover the maintenance requirements for at least two years.

XI. Tools:

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with type wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

XII. General

1. Truck must be (specify) models or and later

2. Preferably locally made.

3. If the local ones are not available, those purchased must be American or from Western production.

4. Enclose with the offer the warantee certificate for each part of the truck if these parts are not produced in the orignal factory.

Technical Specifications
For Articulated Loader on Wheels
with $1m^3$ Bucket Capacity

I. Engine:

A. Diesel engine
B. Four stroke
C. Water or air cooling
D. Producing minimum 80 flywheel horse power (net) at manufacturer's rated RPM.
E. Includes an air cleaner qualified to work in the dusty weather and has a changeable element.
F. Equipped with a primary and secondary oil filter. The primary is metalic and self cleaning with outside sleeve. The secondary has a changeable element.
G. Fuel filter with two following stages to be furnished.

II. Driving Wheels

Driving wheels are (specify) (due to working condition)

III. Frame and Chassis:

1. The frame is heavy-duty articulated type, appropriately jointed, with front axle fixed and rear oscillating axle.

2. Frame should be all-welded and should be stress relieved as necessary according to normal practice before precision line-boring for precise shaft alignment for minimum wear and longer life.

3. Articulation should be minimum 35 degrees to both sides and oscillation should be not less than 20 degrees.

4. All the hydraulic and electrical wires should be fully protected.

5. The bucket should be general purpose type and should be made from hardened steel with replacable wear plates.

6. Bucket operation should include hydraulic lift and tip (drump), and should include hydraulic lines , guards and controls inside cabin.

IV. Performance and operation:

1. Tipping load: (4) tons minimum

2. Operating weight: (7) tons minimum

3. Bucket roll back: 35 degree minimum.

4. Break out force: (5.5) tons minimum

5. Loader turning radius outside bucket should not be more than 5.5 meters.

V. Cab:

A. Modern type, steel manufactured, fully enclosed with front and rear glass, includes front and rear wipers and equiped with adjustable operator's seat.

B. The instrument panel can be lighted at night and should include:

1. Hour meter
2. Charging indicator
3. Engine oil pressure gauge
4. Engine temperature indicator
5. Fuel level gauge
6. Hydraulic oil level gauge
7. Switches for outside and inside light, front and rear
8. Turn signal switches
9. Wipers switch front and rear
10. Switch for operating the dump

C. The cab is equipped with three rear view mirrors, the right , left sides and inside the cab.

D. Cab shall be painted with (specify)

E. Cab shall be equipped with outer lights needed for night work (4 big spot lights, front and rear), travel lights, stop lights and turn signals flasher.

VI. Electrical system:

The electrical system works on a potential equal to 12 volts using 2 acid batteries (12 volt each), which should be placed in suitable place to be easy to maintain.

VII. Transmission and axles:

A. The transmission should be torque converter type with full power shift and having at least (3) forward speeds and (2) reverse speeds.

B. Steering should be hydraulic.

C. 4 wheel drive.

IIx. Brakes

A. Power assisted hydraulic activated service brakes

B. Loader should be equipped with parking and emergency brakes.

IX. Tyres:

Tyres size should be manufacturers standard size with ply rating not less than twelve (12). Tread should be traction type.

X. Spare Parts

A list enclosed with the offer must include the fast moving parts equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...), this list should cover at least the maintenance requirements for two years.

XI. Tools

1. The offer should include a list of the ordinary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

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General Technical Specifications
Of Truck Workshop
To Repair And Maintain Equipment

I. Engine:

- 4 stroke - 4 cylinder - water cooling - producing not less than 60 net horsepower at the wheels.

- Equipped with an air cleaner qualified to work in dusty conditions and having a changeable element.

- Oil filter should have a changeab element.

II. Driving Wheel:

Driving Wheel should be 4 x 4.

III. Cab:

Modern type steel manufactured and having a dashboard panel that can be lit at night and should include:

1. Speedometer in kilometers which has tachometer.

2. Charging indicator

3. Engine oil pressure gauge

4. Engine temperature indicator

5. Fuel level gauge

6. Switch for outside and inside lights, front and rear.

7. Turn signal switch

8. Wi per switch which works by an electric motor.

9. Cab is to be painted with (specify)

IV. Electrical System:

Electrical system works on potential equal to 12 volts by means of one acid battery which should be placed in a suitable place for easy maintenance.

V. Transmission:

Transmission should be one ground manual shift. The gear box should have at least 3 forward speed and one reverse, also shall be equipped with transfer case works with ground cabin shift.

VI. Brakes

Power assisted hydraulic activated service brake. Manual parking and emergency brake capable of stopping the full loaded truck on 20% grade should be furnished.

VII. Suspension:

Truck should be equipped by front and rear heavy duty springs, also heavy duty snock absorbers for front axle and assisted springs for the rear axle.

VIII. Tyres:

Truck shall be equipped with 5 tube tyeres with rims. One of them to be used as a spare when needed. Tires should be suitable to the truck weight at full load, and should be radial type.

IX. Body and Chassis (If the vehicle is a pick-up)

1. Back loading shall be closed box with a rear door, front window, two side windows and roof ventilating fan.

2. Back loading closed box shall be manufactured from 1.5 inch steel angle, speed at least 50 cm at both sides and ceiling. Box height should not be less than 220 cm.

3. Box should be built of two insulated layers (7 cm. minimum) of steel sheets one mm. thickness minimum.

4. Windows should be of slide glass type, and can be opened easily for ventilation. All can be closed from inside for safty and not to open from outside.

5. The door has a glass window (not to be open) used for lighting inside the box.

6. Glass should be security type of 6 mm. thickness and should have ratchet with locks.

7. Ground of the truck shall be covered with black, not smooth rubber carpet.

8. Box should be internally lighted by means of ceiling spot lights and should be spaced by 50 cm. Lamps used are to be one pole 70 watt, 12 volts and its electric source is truck's battery. Every 2 spot lights are to be connected to on/off botton.

9. Box is equipped with a bench each side 80 cm high, 1.50 m long and 50 cm wide. Each bench should be equipped with drawers to keep the hand tools. Each drawer shall be 40cm long, 40 cm wide and 15 cm high. Each drawer has a handle for opening and closing. Sweden wood of two cms. thickness shall be used for bench and drawers.

10. Each bench should be furnished with 8 inch chisel (Western production.)

11. Each bench drawer should be equipped with buffles to put the hand tools required for diesel mechanic, motor electriction, plumber and matallic fi . Each set should be Western manufactured. Contents of each set is shown in enclosed lists.

12. Truck should be equipped by an injection adjustment device mounted on any bench which should be Western produced.

13. Truck should be equipped with two fire extinguishers, one using carbon monoxide and the other, powder.

14. Truck should be equipped with one or two fuel tank(s) with capacity not less than 100 liters of fuel.

15. Mudflaps should be furnished at the rear tires.

In case of van-vehicle:

All the above are workable exept items 1.2 and 3 concerning the pick up only.

X. Spare Parts

A list must be enclosed with the offer including the fast moving parts and equal to 10% of the truck value. This list should include filters (oil, air, fuel, hydraulic,...) . This list should cover the maintenance requirements for at least two years.

XI. Tools

1. The offer should include a list of the ordianary and special hand tools needed for repair and maintenance and should have a manual hydraulic jack with tyre wrench. All are to be placed in a metallic box, mounted in a suitable place on the truck.

2. The list should include catalogues for repair, maintenance and spare parts.

3. Should have two years service contract for truck and equipment (after sale service).

Mechanic's Tool Kit

| No. | Description | Quantity | Unit Price |
|---|---|---|---|
| 1. | 0.5 kg ball peen hammer | 1 | |
| 2. | Open end wrench set (12 pcs) (6mm - 32 mm) | 1 | |
| 3. | Deeps off set box wrench set (9pcs) (6mm - 23mm) | 1 | |
| 4. | Adjustable wrench (8 inch) | 1 | |
| 5. | 8" pliers | 1 | |
| 6. | Flat, Phillips screwdriver set (6 pcs) 3 sizes each, 5,8,12 inches long | 1 | |
| 7. | Set of chisels (3 pcs) flat, rollpin and pin | 1 | |
| 8. | Files set with handles (4 pcs) 6" square, 8 mill, 8" round, 8" half round | 1 | |
| 9. | General use feeler gauge (13 x 82 mm blades) 13 blades in sizes (0.01, 0.02, 0.04, 0.07, 0.1, 0.13, 0.15, 0.18, 0.19, 0.2, 0.26, 0.3 and 0.4) | 1<br>1 | |
| 10. | Grease gun 0.5 kg cap length 35 cm | 1 | |
| 11. | Small pressure oiler with screw on tip bronze finish 1/4 kg, 5 cm diameter | 1 | |
| 12. | Metric torque wrench, flex - ratchet, range min. 5kg.m., max. 34 kg. m | 1 | |

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Electrician Tool Kit

| No. | Description | Quantity | Unit Price |
|---|---|---|---|
| 1. | 8" isolated pliers | 1 | |
| 2. | Combination set of screw drivers (8 pcs) includes flat tip (5 pcs), Phillips tip (3 pcs) different sizes from 5,8, 12 inch | 1 | |
| 3. | Electric test screw driver, 6 inch | 1 | |
| 4. | Steel cutter with steel protective coating | 1 | |
| 5. | Deep offset box wrench set (9 pcs) 6 mm - 23 mm | 1 | |
| 6. | Open end wrench set ends one set at 15" angle (12 pcs) (6 mm - 32 mm) | 1 | |
| 7. | Adjustable wrench 8 inch | 1 | |
| 8. | Steel cutter with clear protective coating, vaw length is 15 mm | 1 | |

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Plumber's Tool Kit

| No. | Description | Quantity | Unit Price |
|---|---|---|---|
| 1. | Open ends wrench set (9 pcs) from 15 - 32 mm | 1 | |
| 2. | Punch 6" length, hex - size 1/4 inch | 1 | |
| 3. | Chisel 8 inch length, edge 7/8" flat | 1 | |
| 4. | Ball peen hammer (hickory handle) with head of 1kg | 2 | |
| 5. | Ball peen hammer (hickory handle) with head of 2 kg | 1 | |
| 6. | Hack saw, frame designed for 10, 12 inch blades adjustable to 4 different positions | 1 | |
| 7. | Adjustable wrench 18" | 1 | |
| 8. | External pipe wrench 24" | 1 | |
| 9. | Chain wrench 15" handle length, 19" chain length, and 5" diameter capacity | 1 | |
| 10. | Spirit level with two bubbles, one for vertical direction and one for longitudinal direction. | 1 | |
| 11. | Measuring meter with 3m long wrapped inside metallic frame<br>o. One for vertical direction and one for longitudinal direction. | 1 | |

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Fitter's Tool Kit:

| No. | Description | Quantity | Unit Price |
|---|---|---|---|
| 1. | Tap & die set from 6 - 12 mm tap wrench and stocks in a compartmented storage case | 1 | |
| 2. | Tap and die set from 13-25 mm tap wrench and die stocks in a compartmented storage case | 1 | |
| 3. | Vernier caliper, handles inside, outside or depth measurements. Includes both U.S. and metric graduations (0" - 6" and 0 - 150 mm). Metric increments are 0.05 mm and U.S. increments are 0.01". Caliper features a thumb lock slide. Press, and it releases for easy sliding; release, and locks into position. | 1 | |
| 4. | Variable speed reversible drills 220 volts, 4.5 amperes, speed from 0-1200 RPM, 8 ft cable, 1/2" chuck size, chuck key and chuck key holder. Also includes 360 degree mounting auxialiary handle | 1 | |

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Welding Machine:

| No. | Description | Quantity | Unit Price |
|---|---|---|---|
| 1 | Electric are weldig machine specified as: | 1 | |
| | o High electric insulation, with strong cooling fan | | |
| | o On/off switch & warning light when it is switched on | 1 | |
| | o Smooth, continuous and progressive adjustment by means of a long cranking arm | | |
| | o High open circuit voltages awarding on easy starting a stable arc | | |
| | o Connection of cables by universal plugs | | |
| | o Quick operation on sites and including a safety device adjusts instantaneously the windings to the mains voltage 220 or 380 volts | | |
| | o Primary cable 5 m long, 3 x 6 mm2 and earthing cable 3 m long, and 25 mm2 with earth clamp | | |
| | o Electrodes diameter from 2 - 5 mm | | |
| | o Welding current from 40 - 300 A | | |
| 2. | Chipping hammer | 1 | |
| 3. | Wire brush | 1 | |
| 4. | Pair of leather gloves | 1 | |
| 5. | Hand scarce with filter lens and coverlens | 1 | |
| 6. | Welding clamp | 1 | |

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## ANNEX II

### Tightening Torque:

The equipment manufacturers' guidelines call for the necessity for obiding by the technical instructions in carrying out preventive maintenance and repair of this equipment. One of the most important items of those instructions is the tightening torque of parts. This torque is related to bolt's type, size, location, number and the marks on each bolt's head.

To present those marks, we should clarify how to identify the type of thread of each bolt. There are two main systems for identifying types of threads:

### Metric System:

If the bolt's name is (M8 x 125 - 25), so:

| | | |
|---|---|---|
| M8 | = | The maximum thread diameter in mm |
| X125 | = | The effective length of bolt |
| -25 | = | Thread length in mm |

### US System:

If the bolt's name is (5/16-18-1 1/2), so:

| | | |
|---|---|---|
| 5/16 | = | The maximum diameter in inches |
| -18 | = | No. of thread teeth in inches |
| -1 1/2 | = | the bolt's length in inches |

To identify the meanings of the marks and numbers written on the bolt's head, there are two main systems;

### Metric System

The numbers are written on the bolt's head as shown in figure (1). The tighting torques of this type of bolt are shown in table (1) which includes the value of tightening torques of the bolts shown in figure (1)

### US System

This system was established by the American Vehicles Engineers Society (SAE). In this system there are radial lines on the bolt's head as shown in figure (2). The tightening torques of this type are shown in table (2) according to the existing mark.

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FIGURE (1)

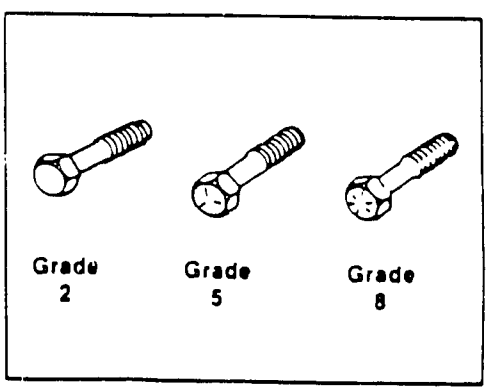



FIGURE (2)

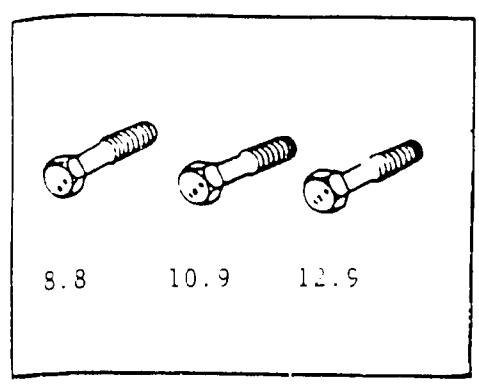


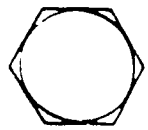
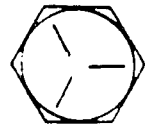
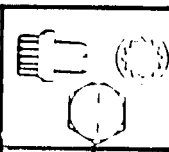
TABLE (1)

TIGHTENING TORQUE OF BOLTS ( METRIC SYSTEM )

| TORQUE / THREAD DIAMETER | TORQUE OF TYPE 8.8 | | TORQUE OF TYPE 10.9 | | TORQUE OF TYPE 12.9 | |
|---|---|---|---|---|---|---|
| | Kg.m | lb.ft | Kg.m | lb.ft | Kg.m | lb.ft |
| 6 | 1.0 | 5 | 1.5 | 10 | 1.5 | 10 |
| 7 | 1.5 | 10 | 2.0 | 15 | 2.5 | 20 |
| 8 | 2.5 | 20 | 3.5 | 25 | 4.0 | 30 |
| 10 | 4.5 | 35 | 6.5 | 50 | 7.5 | 55 |
| 12 | 8.0 | 60 | 11.5 | 85 | 14.0 | 105 |
| 14 | 13.0 | 95 | 18.0 | 135 | 21.5 | 160 |
| 16 | 19.5 | 145 | 26.5 | 195 | 32.0 | 235 |
| 18 | 26.0 | 190 | 36.0 | 265 | 44.0 | 325 |

TABLE (2)

Tightening Torque of Bolts, US System (SAE)

| Thread Diameter inch | No of Thread Teeth | Kg.m | lb.ft | kg.m | lb.ft | kg.m | lb.ft | Kg.m | lb.ft |
|---|---|---|---|---|---|---|---|---|---|
| | |  | |  | | | |  | |
| ¼ | 20 | 0.7 | 5 | 1.1 | 8 | 1.4 | 10 | 1.6 | 12 |
| | 28 | 0.8 | 6 | 1.4 | 10 | 1.4 | 10 | 1.9 | 14 |
| 5/16 | 18 | 1.5 | 11 | 2.3 | 17 | 2.6 | 19 | 3.3 | 24 |
| | 24 | 1.8 | 13 | 2.6 | 19 | 2.6 | 19 | 3.7 | 27 |
| 3/8 | 16 | 2.4 | 18 | 4.2 | 31 | 4.6 | 34 | 6.0 | 44 |
| | 24 | 2.7 | 20 | 4.7 | 35 | 4.6 | 34 | 6.6 | 49 |
| 7/16 | 14 | 3.8 | 28 | 6.6 | 49 | 7.5 | 55 | 9.5 | 70 |
| | 20 | 4.1 | 30 | 7.5 | 55 | 7.5 | 55 | 10.6 | 78 |
| ½ | 13 | 5.3 | 39 | 10.2 | 75 | 11.5 | 85 | 14.2 | 105 |
| | 20 | 5.6 | 41 | 11.5 | 85 | 11.5 | 85 | 16.3 | 120 |
| 9/16 | 12 | 6.9 | 51 | 14.9 | 110 | 16.3 | 120 | 21.0 | 155 |
| | 18 | 7.5 | 55 | 16.3 | 120 | 16.3 | 120 | 23.1 | 170 |
| 5/8 | 11 | 11.3 | 83 | 20.3 | 150 | 22.6 | 167 | 28.5 | 210 |
| | 18 | 12.9 | 95 | 23.1 | 170 | 22.6 | 167 | 32.5 | 240 |
| 3/4 | 10 | 14.2 | 105 | 36.6 | 270 | 38.1 | 280 | 50.8 | 375 |
| | 16 | 15.6 | 115 | 40.0 | 295 | 38.1 | 280 | 56.9 | 420 |
| 7/8 | 9 | 21.7 | 160 | 53.6 | 395 | 59.7 | 440 | 82.8 | 605 |
| | 14 | 23.7 | 175 | 59,0 | 435 | 59.7 | 440 | 91.5 | 675 |
| 1 | 8 | 31.9 | 235 | 80.0 | 590 | 89.5 | 660 | 123.4 | 910 |
| | 14 | 33.9 | 250 | 89.5 | 660 | 89.5 | 660 | 134.2 | 990 |

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It would be useful to mention that reducing the tightening torque will result in troubles which are not easy toestimate, or will cause inadequate equipment operation. Increasing the tightening torque will cause damage to the bolt's thread, shearing the bolt itself, or damage of the thread of the relevant hole.

A damaged bolt should be replaced with one of the same size, type, marks and number.

Finally when tightening engine cylinder heads, certain steps should be followed according to engine type and manufacturer's instructions. Normally tightening starts from the middle and then rmoves symetrically in both directions to the edges. (Figure 3).

The torque wrench should be used to ensure having the tightening torque mentioned in the manufacturers' guidelines. In the case of disassembling tightening should start from edges towards the middle.

FIGURE (3)

tightening of Engine Cylinder Head.

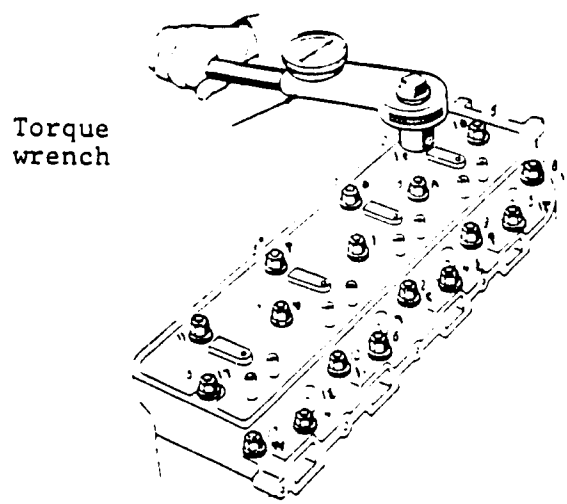


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TABLE 35. AMERICAN STANDARD STEEL PIPE DATA

(All dimensions in inches. Weights in pounds.)

| Nominal Size | Actual Outside Diameter | Standard Weight (40) * | | | Extra-Strong (80) † | | | Double-Extra Strong ‡ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Inside Diameter | Wall Thickness | Weight per Foot § | Inside Diameter | Wall Thickness | Weight per Foot | Inside Diameter | Wall Thickness | Weight per Foot |
| 1/8 | 0.405 | 0.269 | 0.068 | 0.244 | 0.215 | 0.095 | 0.314 | | | |
| 1/4 | 0.540 | 0.364 | .088 | 0.424 | 0.302 | .119 | 0.535 | | | |
| 1/8 | 0.675 | 0.493 | .091 | 0.567 | 0.423 | .126 | 0.738 | | | |
| 1/2 | 0.840 | 0.622 | .109 | 0.850 | 0.546 | .147 | 1.087 | 0.252 | 0.294 | 1.714 |
| 3/4 | 1.050 | 0.824 | .113 | 1.130 | 0.742 | .154 | 1.473 | 0.434 | .308 | 2.440 |
| 1 | 1.315 | 1.049 | .133 | 1.678 | 0.957 | .179 | 2.171 | 0.599 | .358 | 3.659 |
| 1 1/4 | 1.660 | 1.380 | .140 | 2.272 | 1.278 | .191 | 2.996 | 0.896 | .382 | 5.214 |
| 1 1/2 | 1.900 | 1.610 | .145 | 2.717 | 1.500 | .200 | 3.631 | 1.100 | .400 | 6.408 |
| 2 | 2.375 | 2.067 | .154 | 3.652 | 1.939 | .218 | 5.022 | 1.503 | .436 | 9.029 |
| 2 1/2 | 2.875 | 2.469 | .203 | 5.79 | 2.323 | .276 | 7.66 | 1.771 | .552 | 13.70 |
| 3 | 3.500 | 3.068 | .216 | 7.58 | 2.900 | .300 | 10.25 | 2.300 | .600 | 18.58 |
| 3 1/2 | 4.000 | 3.548 | .226 | 9.11 | 3.364 | .318 | 12.51 | ..... | ..... | ..... |
| 4 | 4.500 | 4.026 | .237 | 10.79 | 3.826 | .337 | 14.98 | 3.152 | .674 | 27.54 |
| 5 | 5.563 | 5.047 | .258 | 14.62 | 4.813 | .375 | 20.78 | 4.063 | .750 | 38.55 |
| 6 | 6.625 | 6.065 | .280 | 18.97 | 5.761 | .432 | 28.57 | 4.897 | .864 | 53.16 |
| 8 | 8.625 | 7.981 | .322 | 28.55 | 7.625 | .500 | 43.39 | 6.875 | .875 | 72.42 |
| 10 | 10.750 | 10.020 | .365 | 40.48 | 9.750 | .500 | 54.74 | ..... | ..... | ..... |
| 12 | 12.750 | 12.000 | .375 | 49.56 | 11.750 | .500 | 65.42 | ..... | ..... | ..... |

* Same as ASA B36.10—"Schedule 40" except 12-inch diameter.
† Same as ASA B36.10—"Schedule 80" except 10- and 12-inch diameter.
‡ Not identified with ASA Schedule number, but available as indicated.
§ Plain ends.

TABLE 36. AGA STANDARD CAST-IRON BELL-AND-SPIGOT PIPE DATA

(All dimensions in inches. Approx. weights in pounds.)

| Nominal Size Inside Diameter | Outside Diameter of Pipe | Pipe Wall Thickness | Inside Diameter of Socket | Depth of Socket | Thickness of joint | Weight per Foot, 12-Foot Lengths * |
|---|---|---|---|---|---|---|
| 4 | 4.80 | 0.40 | 5.80 | 4.00 | 0.50 | 19.5 |
| 6 | 6.90 | 0.43 | 7.90 | 4.00 | .50 | 30.58 |
| 8 | 9.05 | 0.45 | 10.05 | 4.00 | .50 | 42.42 |
| 10 | 11.10 | 0.49 | 12.10 | 4.00 | .50 | 55.91 |
| 12 | 13.20 | 0.54 | 14.20 | 4.50 | .50 | 73.83 |
| 16 | 17.40 | 0.62 | 18.40 | 4.50 | .50 | 112.58 |
| 20 | 21.60 | 0.68 | 22.85 | 4.50 | .63 | 153.83 |
| 24 | 25.80 | 0.76 | 27.05 | 5.00 | .63 | 206.41 |
| 30 | 31.74 | 0.85 | 32.90 | 5.00 | .63 | 284.00 |
| 36 | 37.96 | 0.95 | 39.21 | 5.00 | .63 | 370.25 |
| 42 | 44.20 | 1.07 | 45.45 | 5.00 | .63 | 497.66 |
| 48 | 50.50 | 1.26 | 51.75 | 5.00 | .63 | 663.50 |

* Including bell-and-spigot bend.



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**TABLE 37. ASTM Standard Brass and Copper Pipe Data**

(All dimensions in inches. Weights in pounds.)

| Nominal Size | Outside Diameter | Regular | | | Extra-Strong | | |
|---|---|---|---|---|---|---|---|
| | | Wall Thickness | Weight per Foot | | Wall Thickness | Weight per Foot | |
| | | | Red Brass | Copper | | Red Brass | Copper |
| 1/8 | 0.405 | 0.062 | 0.253 | 0.259 | [illegible] | 0.368 | 0.371 |
| 1/4 | 0.540 | 0.082 | 0.447 | 0.457 | [illegible] | 0.611 | 0.625 |
| 3/8 | 0.675 | 0.090 | 0.627 | 0.641 | [illegible] | 0.829 | 0.847 |
| 1/2 | 0.840 | 0.107 | 0.934 | 0.955 | [illegible] | 1.23 | 1.25 |
| 3/4 | 1.050 | 0.114 | 1.27 | 1.30 | [illegible] | 1.67 | 1.71 |
| 1 | 1.315 | 0.126 | 1.78 | 1.82 | [illegible] | 2.46 | 2.51 |
| 1 1/4 | 1.660 | 0.146 | 2.63 | 2.69 | [illegible] | 3.39 | 3.46 |
| 1 1/2 | 1.900 | 0.150 | 3.13 | 3.20 | [illegible] | 4.10 | 4.19 |
| 2 | 2.375 | 0.156 | 4.12 | 4.22 | [illegible] | 5.67 | 5.80 |
| 2 1/2 | 2.875 | 0.187 | 5.99 | 6.12 | [illegible] | 8.66 | 8.85 |
| 3 | 3.500 | 0.219 | 8.56 | 8.75 | [illegible] | 11.6 | 11.8 |
| 3 1/2 | 4.000 | 0.250 | 11.2 | 11.4 | [illegible] | 14.1 | 14.4 |
| 4 | 4.500 | 0.250 | 12.7 | 12.9 | [illegible] | 16.9 | 17.3 |
| 5 | 5.562 | 0.250 | 15.6 | 16.2 | [illegible] | 23.2 | 23.7 |
| 6 | 6.625 | 0.250 | 19.0 | 19.4 | [illegible] | 32.2 | 32.9 |
| 8 | 8.625 | 0.312 | 30.9 | 31.6 | [illegible] | 48.4 | 49.5 |
| 10 | 10.750 | 9.365 | 45.2 | 46.2 | [illegible] | 61.1 | 62.4 |
| 12 | 12.750 | 0.375 | 55.3 | 56.5 | | | |

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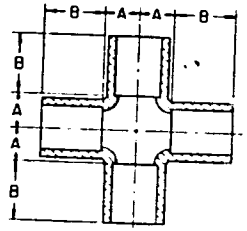


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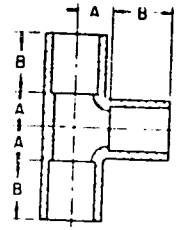
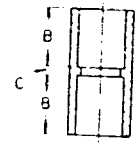
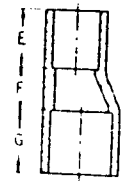


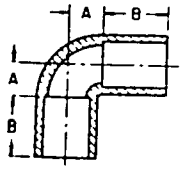

TEE



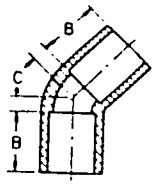

COUPLING




ECCENTRIC COUPLING




90° ELL




45° ELL

**American Standard Brass Solder-joint Fittings***

| Tubing size | *A* | *B* | *C* | *D* | Reducing size | *F* | *E* | *G* |
|---|---|---|---|---|---|---|---|---|
| ⅜ | 9/16 | 13/16 | 5/16 | ⅛ | ¾ × ½ | ½ | 1 | 13/16 |
| ½ | 7/8 | 15/16 | 3/16 | ⅛ | 1 × ¾ | 15/16 | 15/16 | 1 |
| ¾ | 9/16 | 1 | ¼ | ⅛ | 1 × ½ | ½ | 15/16 | 13/16 |
| 1 | ¾ | 1 1/16 | 3/16 | ⅛ | 2 × 1½ | 1 1/8 | 1⅜ | 1 3/16 |
| 1½ | 1 | 1 3/16 | ½ | ⅛ | 2½ × 2 | 1 3/16 | 1⅜ | 1⅜ |
| 2 | 1¼ | 1⅜ | 5/16 | 3/16 | 2½ × 1½ | 1 5/16 | 1⅜ | 1 5/16 |
| 2½ | 1½ | 1⅜ | ⅜ | 3/16 | 3 × 2½ | 1¼ | 1⅞ | 1⅜ |
| 3 | 1¾ | 1⅞ | ¾ | 3/16 | 3½ × 3 | 1⅜ | 2 5/16 | 1⅞ |
| 3½ | 2 | 2 1/16 | ⅞ | 3/16 | 3½ × 2½ | 1 3/16 | 2 5/16 | 1⅜ |
| 4 | 2¼ | 2¼ | 1 3/16 | ¼ | 4 × 3½ | 1 3/16 | 2¼ | 2 1/16 |

* Adapted from ASA B16.18—1950.

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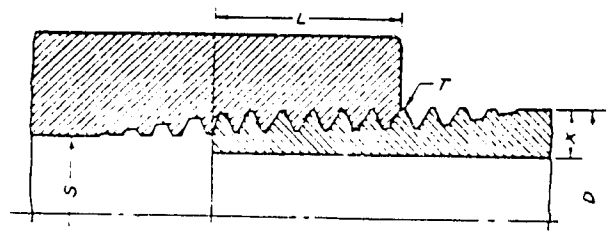
## American Standard Pipe[a, b]

*Welded wrought iron*




| Nominal pipe size | Actual outside diam. $D$ | Tap-drill size $S$ | Thd. in. $T$ | Distance pipe enters fittings $L$ | Wall thickness $X$ | | | Weight, lb/ft[f] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Standard 40[c] | Extra strong 80[d] | Double extra strong[e] | Standard 40[c] | Extra strong 80[d] | Double extra strong[e] |
| 1/8 | 0.405 | 11 1/32 | 27 | 3/16 | 0.070 | 0.098 | ... | 0.25 | 0.32 | |
| 1/4 | 0.540 | 7/16 | 18 | 9/32 | 0.090 | 0.122 | ... | 0.43 | 0.54 | |
| 3/8 | 0.675 | 37/64 | 18 | 19/64 | 0.093 | 0.129 | .... | 0.57 | 0.74 | |
| 1/2 | 0.840 | 23/32 | 14 | 3/8 | 0.111 | 0.151 | 0.307 | 0.86 | 1.09 | 1.714 |
| 3/4 | 1.050 | 39/64 | 14 | 13/32 | 0.115 | 0.157 | 0.318 | 1.14 | 1.48 | 2.440 |
| 1 | 1.315 | 1 5/32 | 11 1/2 | 1/2 | 0.136 | 0.183 | 0.369 | 1.68 | 2.18 | 3.659 |
| 1 1/4 | 1.660 | 1 1/2 | 11 1/2 | 33/64 | 0.143 | 0.195 | 0.393 | 2.28 | 3.00 | 5.214 |
| 1 1/2 | 1.900 | 1 47/64 | 11 1/2 | 9/16 | 0.148 | 0.204 | 0.411 | 2.72 | 3.64 | 6.408 |
| 2 | 2.375 | 2 7/32 | 11 1/2 | 37/64 | 0.153 | 0.223 | 0.447 | 3.66 | 5.03 | 9.029 |
| 2 1/2 | 2.875 | 2 5/8 | 8 | 7/8 | 0.208 | 0.282 | 0.565 | 5.80 | 7.67 | 13.695 |
| 3 | 3.5 | 3 1/4 | 8 | 15/16 | 0.221 | 0.306 | 0.615 | 7.58 | 10.3 | 18.583 |
| 3 1/2 | 4.0 | 3 3/4 | 8 | 1 | 0.231 | 0.325 | .... | 9.11 | 12.5 | |
| 4 | 4.5 | 4 1/4 | 8 | 1 1/16 | 0.242 | 0.344 | 0.690 | 10.8 | 15.0 | 27.451 |
| 5 | 5.563 | 5 5/16 | 8 | 1 5/32 | 0.263 | 0.383 | 0.768 | 14.7 | 20.8 | 38.552 |
| 6 | 6.625 | 6 5/16 | 8 | 1 1/4 | 0.286 | 0.441 | 0.884 | 19.0 | 28.6 | 53.160 |
| 8 | 8.625 | ..... | 8 | 1 13/32 | 0.329 | 0.510 | 0.895 | 28.6 | 43.4 | 72.424 |
| 10 | 10.75 | ..... | 8 | 1 43/64 | 0.372 | 0.606 | .... | [illegible] | 64.4 | |
| 12 | 12.75 | ..... | 8 | 1 7/8 | 0.414 | 0.702 | .... | [illegible] | 88.6 | |
| 14 OD | 14.0 | ..... | 8 | 2 | 0.437 | 0.750 | .... | 62.2 | 104. | |
| 16 OD | 16.0 | ..... | 8 | 2 13/64 | 0.500 | ... | ... | 82.2 | | |
| 18 OD | 18.0 | ..... | 8 | 2 13/32 | 0.562 | ... | .... | 103. | | |
| 20 OD | 20.0 | ..... | 8 | 2 19/32 | 0.562 | ... | ... | 115. | | |
| 24 OD | 24.0 | ..... | 8 | 3 | | | | | | |

[a] For welded and seamless steel pipe. See ASA B36.10—1939. Dimensions in inches.

[b] A pipe size may be designated by giving the nominal pipe size and wall thickness or by giving the nominal pipe size and weight per linear foot.

[c] Refers to American Standard schedule numbers, approximate values for the expression 1,000 × $P/S$. Schedule 40—standard weight.

[d] Schedule 80—extra strong.

[e] Not American Standard, but commercially available in both wrought iron and steel.

[f] Plain ends.

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TABLE 38. ASTM STANDARD COPPER WATER TUBE DATA

(All dimensions in inches. Weights in pounds.)

| Nominal Size | Outside Diameter | Type K | | Type L | | Type M | |
|---|---|---|---|---|---|---|---|
| | | Wall Thickness | Weight per Foot | Wall Thickness | Weight per Foot | Wall Thickness | Weight per Foot |
| 1/8 | 0.250 | 0.032 | 0.085 | 0.025 | 0.068 | 0.025 | 0.068 |
| 1/4 | 0.375 | 0.032 | 0.134 | 0.030 | 0.126 | 0.025 | 0.10[illegible] |
| 3/8 | 0.500 | 0.049 | 0.269 | 0.035 | 0.198 | 0.025 | 0.1[illegible]5 |
| 1/2 | 0.625 | 0.049 | 0.344 | 0.040 | 0.285 | 0.028 | 0.204 |
| 5/8 | 0.750 | 0.049 | 0.418 | 0.042 | 0.362 | 0.030 | 0.263 |
| 3/4 | 0.875 | 0.065 | 0.641 | 0.045 | 0.455 | 0.032 | 0.328 |
| 1 | 1.125 | 0.065 | 0.839 | 0.050 | 0.655 | 0.035 | 0.465 |
| 1 1/4 | 1.375 | 0.065 | 1.04 | 0.055 | 0.884 | 0.042 | 0.682 |
| 1 1/2 | 1.625 | 0.072 | 1.36 | 0.060 | 1.14 | 0.049 | 0.940 |
| 2 | 2.125 | 0.083 | 2.06 | 0.070 | 1.75 | 0.058 | 1.46 |
| 2 1/2 | 2.625 | 0.095 | 2.93 | 0.080 | 2.48 | 0.065 | 2.03 |
| 3 | 3.125 | 0.109 | 4.00 | 0.090 | 3.33 | 0.072 | 2.68 |
| 3 1/2 | 3.625 | 0.120 | 5.12 | 0.100 | 4.29 | 0.083 | 3.58 |
| 4 | 4.125 | 0.134 | 6.51 | 0.110 | 5.38 | 0.095 | 4.66 |
| 5 | 5.125 | 0.160 | 9.67 | 0.125 | 7.61 | 0.109 | 6.66 |
| 6 | 6.125 | 0.192 | 13.9 | 0.140 | 10.2 | 0.122 | 8.92 |
| 8 | 8.125 | 0.271 | 25.9 | 0.200 | 19.3 | 0.170 | 16.5 |
| 10 | 10.125 | 0.338 | 40.3 | 0.250 | 30.1 | 0.212 | 25.6 |
| 12 | 12.125 | 0.405 | 57.8 | 0.280 | 40.4 | 0.254 | 36.7 |

TABLE 39. AMERICAN STANDARD TAPER PIPE THREAD DATA

(All dimensions in inches. Weights in pounds.)

| Nominal Size | Outside Diameter | Inside Diameter | Threads per Inch | Tap Drill | Weight per Foot Thds. and Couplings | Normal Engagement by Hand |
|---|---|---|---|---|---|---|
| 1/8 | 0.405 | 0.269 | 27 | 11/32 | 0.245 | 0.180 |
| 1/4 | 0.540 | 0.364 | 18 | 7/16 | 0.425 | 0.200 |
| 3/8 | 0.675 | 0.493 | 18 | 37/64 | 0.568 | 0.240 |
| 1/2 | 0.840 | 0.622 | 14 | 23/32 | 0.852 | 0.320 |
| 3/4 | 1.050 | 0.824 | 14 | 59/64 | 1.134 | 0.339 |
| 1 | 1.315 | 1.049 | 11 1/2 | 1 5/32 | 1.684 | 0.400 |
| 1 1/4 | 1.660 | 1.380 | 11 1/2 | 1 1/2 | 2.281 | 0.420 |
| 1 1/2 | 1.900 | 1.610 | 11 1/2 | 1 47/64 | 2.731 | 0.420 |
| 2 | 2.375 | 2.067 | 11 1/2 | 2 7/32 | 3.678 | 0.436 |
| 2 1/2 | 2.875 | 2.469 | 8 | 2 5/8 | 5.82 | 0.682 |
| 3 | 3.500 | 3.068 | 8 | 3 1/4 | 7.62 | 0.766 |
| 3 1/2 | 4.000 | 3.548 | 8 | 3 3/4 | 9.20 | 0.821 |
| 4 | 4.500 | 4.026 | 8 | 4 1/4 | 10.89 | 0.844 |
| 5 | 5.563 | 5.047 | 8 | 5 3/16 | 14.81 | 0.937 |
| 6 | 6.625 | 6.065 | 8 | 6 3/16 | 19.18 | 0.958 |
| 8 | 8.625 | 7.981 | 8 | | 29.35 | 1.063 |
| 10 | 10.750 | 10.020 | 8 | | 41.85 | 1.210 |
| 12 | 12.750 | 12.000 | 8 | | 51.15 | 1.360 |



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## Lengths of Malleable-iron Unions*

*Ground joint*

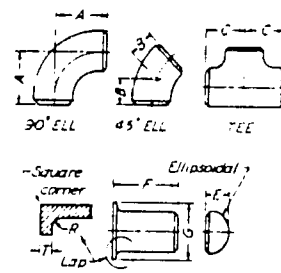
| Nominal size | 1/8 | 1/4 | 3/8 | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| End to end | 1 1/2 | 1 9/16 | 1 5/8 | 1 13/16 | 2 1/16 | 2 1/4 | 2 1/2 | 2 5/8 | 3 | 3 9/16 | 3 15/16 |

* Compiled from manufacturers' catalogues. Dimensions in inches.

## American Standard Steel Butt-welding Fittings* †

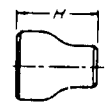
*Elbows, tees, caps, and stub ends*

| Nominal pipe size | Outside diam. at bevel | Center to end: 90° welding elbow A | Center to end: 45° welding elbow B | Center to end: Of run, welding tee C | Welding caps E | Lapped-joint stub ends: Lengths F | Lapped-joint stub ends: Radius of fillet R | Lapped-joint stub ends: Diameter of lap G |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.310 | 1 1/2 | 7/8 | 1 1/2 | 1 1/2 | 4 | 1/8 | 2 |
| 1 1/4 | 1.660 | 1 7/8 | 1 | 1 7/8 | 1 1/2 | 4 | 3/16 | 2 1/2 |
| 1 1/2 | 1.900 | 2 1/4 | 1 1/8 | 2 1/4 | 1 1/2 | 4 | 1/4 | 2 7/8 |
| 2 | 2.375 | 3 | 1 3/8 | 2 1/2 | 1 1/2 | 6 | 5/16 | 3 5/8 |
| 2 1/2 | 2.875 | 3 3/4 | 1 3/4 | 3 | 1 1/2 | 6 | 5/16 | 4 1/8 |
| 3 | 3.500 | 4 1/2 | 2 | 3 3/8 | 2 | 6 | 3/8 | 5 |
| 3 1/2 | 4.000 | 5 1/4 | 2 1/4 | 3 3/4 | 2 1/2 | 6 | 3/8 | 5 1/2 |
| 4 | 4.500 | 6 | 2 1/2 | 4 1/8 | 2 1/2 | 6 | 7/16 | 6 3/16 |

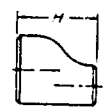



*Butt-welding reducers*

| Nominal pipe size | Outside diam. at bevel: Large end | Outside diam. at bevel: Small end | End to end H |
|---|---|---|---|
| 1 × 3/4 | 1.315 | 1.050 | 2 |
| 1 × 1/2 | | 0.840 | |
| 1 × 3/8 | | 0.675 | |
| 1 1/4 × 1 | 1.660 | 1.315 | 2 |
| 1 1/4 × 3/4 | | 1.050 | |
| 1 1/4 × 1/2 | | 0.840 | |
| 1 1/2 × 1 1/4 | 1.900 | 1.660 | 2 1/2 |
| 1 1/2 × 1 | | 1.315 | |
| 1 1/2 × 3/4 | | 1.050 | |
| 1 1/2 × 1/2 | | 0.840 | |
| 2 × 1 1/2 | 2.375 | 1.900 | 3 |
| 2 × 1 1/4 | | 1.660 | |
| 2 × 1 | | 1.315 | |
| 2 × 3/4 | | 1.050 | |
| 2 1/2 × 2 | 2.875 | 2.375 | 3 1/2 |
| 2 1/2 × 1 1/2 | | 1.900 | |
| 2 1/2 × 1 1/4 | | 1.660 | |
| 2 1/2 × 1 | | 1.315 | |
| 3 × 2 1/2 | 3.500 | 2.875 | 3 1/2 |
| 3 × 2 | | 2.375 | |
| 3 × 1 1/2 | | 1.900 | |
| 3 × 1 1/4 | | 1.660 | |
| 3 1/2 × 3 | 4.000 | 3.500 | 4 |
| 3 1/2 × 2 1/2 | | 2.875 | |
| 3 1/2 × 2 | | 2.375 | |
| 3 1/2 × 1 1/2 | | 1.900 | |
| 3 1/2 × 1 1/4 | | 1.660 | |
| 4 × 3 1/2 | 4.500 | 4.000 | 4 |
| 4 × 3 | | 3.500 | |
| 4 × 2 1/2 | | 2.875 | |
| 4 × 2 | | 2.375 | |
| 4 × 1 1/2 | | 1.900 | |
| 5 × 4 | 5.563 | 4.500 | 5 |
| 5 × 3 1/2 | | 4.000 | |
| 5 × 3 | | 3.500 | |
| 5 × 2 1/2 | | 2.875 | |




CONCENTRIC REDUCER




ECCENTRIC REDUCER

* For larger sizes, see ASA B16.

† ASA B16.9—1940. Dimensions in inches.

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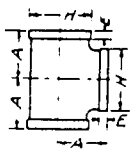
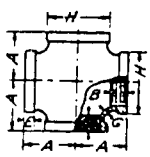
## American Standard 150-lb Malleable-iron Screwed Fittings[a]

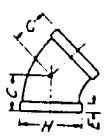
90° ELBOW



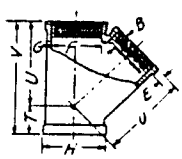

TEE



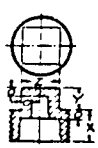

CROSS




45° ELL




Y BRANCH




PLUG

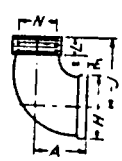
| Nominal pipe size | A | B | C | E | F | G | H | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/8 | 0.69 | 0.25 | .... | 0.200 | 0.405 | 0.090 | 0.693 | 1.00[b] | .... | 0.264 | |
| 1/4 | 0.81 | 0.32 | 0.73 | 0.215 | 0.540 | 0.095 | 0.844 | 1.19 | 0.94 | 0.402 | 1.00 |
| 3/8 | 0.95 | 0.36 | 0.80 | 0.230 | 0.675 | 0.100 | 1.015 | 1.44 | 1.03 | 0.408 | 1.13 |
| 1/2 | 1.12 | 0.43 | 0.88 | 0.249 | 0.840 | 0.105 | 1.197 | 1.63 | 1.15 | 0.534 | 1.25 |
| 3/4 | 1.31 | 0.50 | 0.98 | 0.273 | 1.050 | 0.120 | 1.458 | 1.89 | 1.29 | 0.546 | 1.44 |
| 1 | 1.50 | 0.58 | 1.12 | 0.302 | 1.315 | 0.134 | 1.771 | 2.14 | 1.47 | 0.683 | 1.69 |
| 1 1/4 | 1.75 | 0.67 | 1.29 | 0.341 | 1.660 | 0.145 | 2.153 | 2.45 | 1.71 | 0.707 | 2.06 |
| 1 1/2 | 1.94 | 0.70 | 1.43 | 0.368 | 1.900 | 0.155 | 2.427 | 2.69 | 1.88 | 0.724 | 2.31 |
| 2 | 2.25 | 0.75 | 1.68 | 0.422 | 2.375 | 0.173 | 2.963 | 3.26 | 2.22 | 0.757 | 2.81 |
| 2 1/2 | 2.70 | 0.92 | 1.95 | 0.478 | 2.875 | 0.210 | 3.589 | 3.86 | 2.57 | 1.138 | 3.25 |
| 3 | 3.08 | 0.98 | 2.17 | 0.548 | 3.500 | 0.231 | 4.285 | 4.5 | 3.00 | 1.200 | 3.69 |
| 3 1/2 | 3.42 | 1.03 | 2.39 | 0.604 | 4.000 | 0.248 | 4.843 | 5.0[illegible] | .... | 1.250 | 4.00 |
| 4 | 3.79 | 1.08 | 2.61 | 0.661 | 4.500 | 0.265 | 5.401 | 5.69 | 3.70 | 1.300 | 4.38 |
| 5 | 4.50 | 1.18 | 3.05 | 0.780 | 5.563 | 0.300 | 6.583 | 6.86[b] | .... | 1.406 | 5.12 |
| 6 | 5.13 | 1.28 | 3.46 | 0.900 | 6.625 | 0.336 | 7.767 | 8.03[b] | .... | 1.513 | 5.86 |

| Nominal pipe size | N | P | T | U | V | W | X | Y | Z[c] | O[d] | Thickness of ribs on caps, couplings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/8 | 0.20 | .... | .... | .... | .... | 0.96 | 0.37 | 0.24 | 9/32 | .... | 0.090 |
| 1/4 | 0.26 | .... | .... | .... | .... | 1.06 | 0.44 | 0.28 | 3/8 | .... | 0.095 |
| 3/8 | 0.37 | .... | 0.50 | 1.43 | 1.93 | 1.16 | 0.48 | 0.31 | 7/16 | .... | 0.100 |
| 1/2 | 0.51 | 0.87 | 0.61 | 1.71 | 2.32 | 1.34 | 0.56 | 0.38 | 9/16 | 0.16 | 0.105 |
| 3/4 | 0.69 | 0.97 | 0.72 | 2.05 | 2.77 | 1.52 | 0.63 | 0.44 | 5/8 | 0.18 | 0.120 |
| 1 | 0.91 | 1.16 | 0.85 | 2.43 | 3.28 | 1.67 | 0.75 | 0.50 | 13/16 | 0.20 | 0.134 |
| 1 1/4 | 1.19 | 1.28 | 1.02 | 2.92 | 3.94 | 1.93 | 0.80 | 0.56 | 15/16 | 0.22 | 0.145 |
| 1 1/2 | 1.39 | 1.33 | 1.10 | 3.28 | 4.38 | 2.15 | 0.83 | 0.62 | 1 1/8 | 0.24 | 0.155 |
| 2 | 1.79 | 1.45 | 1.24 | 3.93 | 5.17 | 2.53 | 0.88 | 0.68 | 1 3/16 | 0.26 | 0.173 |
| 2 1/2 | 2.20 | 1.70 | 1.52 | 4.73 | 6.25 | 2.88 | 1.07 | 0.74 | 1 1/2 | 0.29 | 0.210 |
| 3 | 2.78 | 1.80 | 1.71 | 5.55 | 7.26 | 3.18 | 1.13 | 0.80 | 1 11/16 | 0.31 | 0.231 |
| 3 1/2 | 3.24 | 1.90 | .... | .... | .... | 3.43 | 1.18 | 0.86 | 1 7/8 | 0.34 | 0.248 |
| 4 | 3.70 | 2.08 | 2.01 | 6.97 | 8.98 | 3.69 | 1.22 | 1.00 | 2 1/8 | 0.37 | 0.265 |
| 5 | 4.69 | 2.32 | .... | .... | .... | .... | 1.31 | 1.00 | 2 3/16 | 0.46 | 0.300 |
| 6 | 5.67 | 2.55 | .... | .... | .... | .... | 1.40 | 1.25 | 2 1/2 | 0.52 | 0.336 |

[a] ASA B16c—1939. Street tee not made in 1/8-in. size. Dimensions in inches. Left-hand couplings have four or more ribs. Right-hand couplings have two ribs. [b] Street ell only.

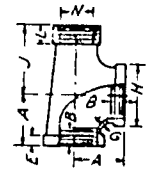
[c] These dimensions are the nominal size of wrench (ASA B18.2—1941). Square-head plugs are designed to fit these wrenches.

[d] Solid plugs are provided in sizes 1/8 to 3 1/2 in. inclusive; cored plugs 1 1/2 to 3 1/2 in. inclusive. Cored plugs have min. metal thickness at all points equal to dimension O except at the end of thread.

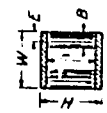



90° STREET ELBOW

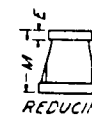
45° STREET ELBOW



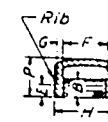

STREET TEE




COUPLING




REDUCING COUPLING

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## American Standard 150-lb Malleable-iron Screwed Fittings: Dimensions of Close-, Medium-, and Open-pattern Return Bends*†

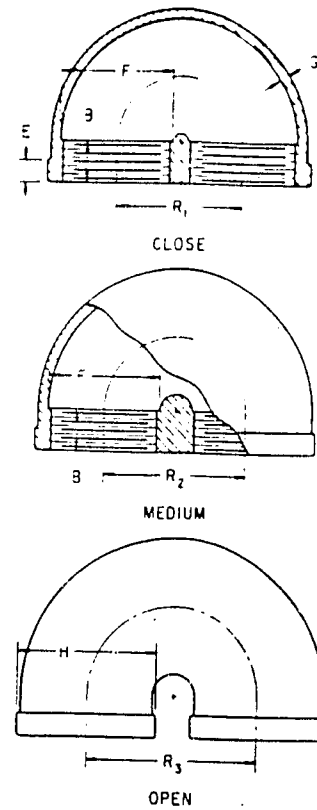
| Nominal pipe size | Length of thread, min. B | Width of band, min. E | Inside diam. of fittings F Max. | Inside diam. of fittings F Min. | Metal thickness ‡ G | Outside diam. of band, min. H | Center to center (close pattern) $R_1$ | Center to center (medium pattern) $R_2$ | Center to center (open pattern) $R_3$ |
|---|---|---|---|---|---|---|---|---|---|
| ½ | 0.43 | 0.249 | 0.840 | 0.897 | 0.116 | 1.197 | 1.000 | 1.250 | 1.50 |
| ¾ | 0.50 | 0.273 | 1.050 | 1.107 | 0.133 | 1.458 | 1.250 | 1.500 | 2.00 |
| 1 | 0.58 | 0.302 | 1.315 | 1.385 | 0.150 | 1.771 | 1.500 | 1.875 | 2.50 |
| 1¼ | 0.67 | 0.341 | 1.660 | 1.730 | 0.165 | 2.153 | 1.750 | 2.250 | 3.00 |
| 1½ | 0.70 | 0.368 | 1.900 | 1.970 | 0.178 | 2.427 | 2.188 | 2.500 | 3.50 |
| 2 | 0.75 | 0.422 | 2.375 | 2.445 | 0.201 | 2.963 | 2.625 | 3.000 | 4.00 |
| 2½ | 0.92 | 0.478 | 2.875 | 2.975 | 0.244 | 3.589 | ... | ... | 4.50 |
| 3 | 0.98 | 0.548 | 3.500 | 3.600 | 0.272 | 4.285 | ... | ... | 5.00 |
| 4 | 1.08 | 0.661 | 4.500 | 4.600 | 0.315 | 5.401 | ... | ... | 6.00 |

All dimensions given in inches.

* Adapted from ASA B16.3—1951.

† It is permissible to furnish close-pattern return bends not banded. Close-pattern return bends will not make up parallel coils, as the distance center to center of two adjacent bends is greater than the center to center of openings of a single bend.

‡ Patterns shall be designed to produce castings of metal thicknesses given in the table. Metal thickness at no point shall be less than 90 per cent of the thickness given in the table.

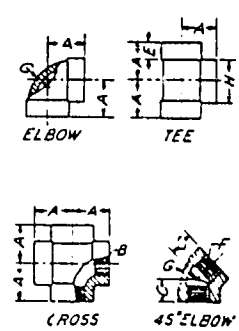



## American Standard Cast-iron Screwed Fittings*

*For maximum working saturated steam pressure of 125 and 250 lb per sq in.*

| Nominal pipe size | A | B min. | C | E min. | F Min. | F Max. | G min. | H min. |
|---|---|---|---|---|---|---|---|---|
| ⅛ | 0.81 | 0.32 | 0.73 | 0.38 | 0.540 | 0.584 | 0.110 | 0.93 |
| ¼ | 0.95 | 0.36 | 0.80 | 0.44 | 0.675 | 0.719 | 0.120 | 1.12 |
| ½ | 1.12 | 0.43 | 0.88 | 0.50 | 0.840 | 0.897 | 0.130 | 1.34 |
| ¾ | 1.31 | 0.50 | 0.98 | 0.56 | 1.050 | 1.107 | 0.155 | 1.63 |
| 1 | 1.50 | 0.58 | 1.12 | 0.62 | 1.315 | 1.385 | 0.170 | 1.95 |
| 1¼ | 1.75 | 0.67 | 1.29 | 0.69 | 1.660 | 1.730 | 0.185 | 2.39 |
| 1½ | 1.94 | 0.70 | 1.43 | 0.75 | 1.900 | 1.970 | 0.200 | 2.68 |
| 2 | 2.25 | 0.75 | 1.68 | 0.84 | 2.375 | 2.445 | 0.220 | 3.28 |
| 2½ | 2.70 | 0.92 | 1.95 | 0.94 | 2.875 | 2.975 | 0.240 | 3.86 |
| 3 | 3.08 | 0.98 | 2.17 | 1.00 | 3.500 | 3.600 | 0.260 | 4.62 |
| 3½ | 3.42 | 1.03 | 2.39 | 1.06 | 4.000 | 4.100 | 0.280 | 5.20 |
| 4 | 3.79 | 1.08 | 2.61 | 1.12 | 4.500 | 4.600 | 0.310 | 5.79 |
| 5 | 4.50 | 1.18 | 3.05 | 1.18 | 5.563 | 5.663 | 0.380 | 7.05 |
| 6 | 5.13 | 1.28 | 3.46 | 1.28 | 6.625 | 6.725 | 0.430 | 8.28 |
| 8 | 6.56 | 1.47 | 4.28 | 1.47 | 8.625 | 8.725 | 0.550 | 10.63 |
| 10 | 8.08 | 1.68 | 5.16 | 1.68 | 10.750 | 10.850 | 0.690 | 13.12 |
| 12 | 9.50 | 1.88 | 5.97 | 1.88 | 12.750 | 12.850 | 0.800 | 15.47 |

* ASA B16d—1941. Dimensions in inches.



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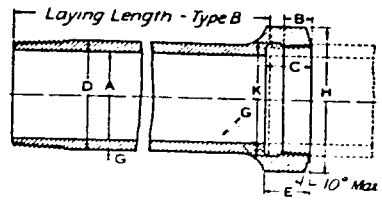


## Threaded Cast-iron Pipe*

*Dimension of pipe and drainage hubs*

| Pipe size | Pipe: Nominal diam. Outside D | Pipe: Nominal diam. Inside A | Pipe: Wall thickness, min., G | Drainage hubs: Thread length* B | Drainage hubs: Diam. of groove, max., K | Drainage hubs: End to shoulder † C | Drainage hubs: Min. band Diam. H | Drainage hubs: Min. band Length E | Nominal weights: Type A and barrel of type B per foot | Nominal weights: Additional weight of hubs for type B |
|---|---|---|---|---|---|---|---|---|---|---|
| 1¼ | 1.66 | 1.23 | 0.187 | 0.42 | 1.73 | 0.71 | 2.39 | 0.71 | 3.033 | 0.60 |
| 1½ | 1.90 | 1.45 | 0.195 | 0.42 | 1.97 | 0.72 | 2.68 | 0.72 | 3.666 | 0.90 |
| 2 | 2.38 | 1.89 | 0.211 | 0.43 | 2.44 | 0.76 | 3.28 | 0.76 | 5.041 | 1.00 |
| 2½ | 2.88 | 2.32 | 0.241 | 0.68 | 2.97 | 1.14 | 3.86 | 1.14 | 7.032 | 1.35 |
| 3 | 3.50 | 2.90 | 0.263 | 0.76 | 3.60 | 1.20 | 4.62 | 1.20 | 9.410 | 2.80 |
| 4 | 4.50 | 3.83 | 0.294 | 0.84 | 4.60 | 1.30 | 5.79 | 1.30 | 13.751 | 3.48 |
| 5 | 5.56 | 4.81 | 0.328 | 0.93 | 5.66 | 1.41 | 7.05 | 1.41 | 19.069 | 5.00 |
| 6 | 6.63 | 5.76 | 0.378 | 0.95 | 6.72 | 1.51 | 8.28 | 1.51 | 26.223 | 6.60 |
| 8 | 8.63 | 7.63 | 0.438 | 1.06 | 8.72 | 1.71 | 10.63 | 1.71 | 39.820 | 10.00 |
| 10 | 10.75 | 9.75 | 0.438 | 1.21 | 10.85 | 1.92 | 13.12 | 1.93 | 50.234 | |
| 12 | 12.75 | 11.75 | 0.438 | 1.36 | 12.85 | 2.12 | 15.47 | 2.13 | 60.036 | |

* ASA A40.5—1943. All dimensions are given in inches, except where otherwise stated. Type *A* has external threads both ends. Type *B* as shown.

† The length of thread *B* and the end to shoulder *C* shall not vary from the dimensions shown by more than plus or minus the equivalent of the pitch of one thread.

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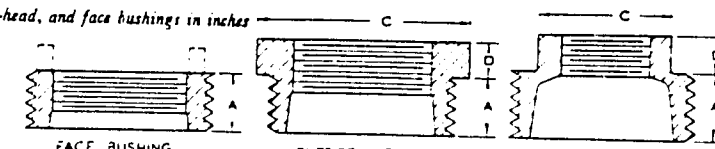
## Pipe Bushings*

*Dimensions of outside-head, inside-head, and face bushings in inches*




| Size | Length of external thread,† min., A | Height of head, min., D | Width of head,‡ min., C | |
|---|---|---|---|---|
| | | | Outside | Inside |
| 1/4 × 1/8 | 0.44 | 0.14 | 0.64 | |
| 3/8 × 1/4 | 0.48 | 0.16 | 0.68 | |
| 3/8 × 1/8 | 0.48 | 0.16 | 0.68 | |
| 1/2 × 3/8 | 0.56 | 0.19 | 0.87 | |
| 1/2 × 1/4 | 0.56 | 0.19 | 0.87 | |
| 1/2 × 1/8 | 0.56 | 0.19 | 0.87 | |
| 3/4 × 1/2 | 0.63 | 0.22 | 1.15 | |
| 3/4 × 3/8 | 0.63 | 0.22 | 1.15 | |
| 3/4 × 1/4 | 0.63 | 0.22 | 1.15 | |
| 3/4 × 1/8 | 0.63 | 0.22 | 1.15 | |
| 1 × 3/4 | 0.75 | 0.25 | 1.42 | |
| 1 × 1/2 | 0.75 | 0.25 | 1.42 | |
| 1 × 3/8 | 0.75 | 0.30 | .... | 1.12 |
| 1 × 1/4 | 0.75 | 0.30 | .... | 1.12 |
| 1 × 1/8 | 0.75 | 0.30 | .... | 1.12 |
| 1 1/4 × 1 | 0.80 | 0.28 | 1.76 | |
| 1 1/4 × 3/4 | 0.80 | 0.28 | 1.76 | |
| 1 1/4 × 1/2 | 0.80 | 0.34 | .... | 1.34 |
| 1 1/4 × 3/8 | 0.80 | 0.34 | .... | 1.12 |
| 1 1/4 × 1/4 | 0.80 | 0.34 | .... | 1.12 |
| 1 1/2 × 1 1/4 | 0.83 | 0.31 | 2.00 | |
| 1 1/2 × 1 | 0.83 | 0.31 | 2.00 | |
| 1 1/2 × 3/4 | 0.83 | 0.37 | .... | 1.63 |
| 1 1/2 × 1/2 | 0.83 | 0.37 | .... | 1.34 |
| 1 1/2 × 3/8 | 0.83 | 0.37 | .... | 1.12 |

| Size | Length of external thread,‡ min., A | Height of head, min., D | Width of head,† min., C | |
|---|---|---|---|---|
| | | | Outside | Inside |
| 1 1/2 × 1/4 | 0.83 | 0.37 | .... | 1.12 |
| 2 × 1 1/2 | 0.88 | 0.34 | 2.48 | |
| 2 × 1 1/4 | 0.88 | 0.34 | 2.48 | |
| 2 × 1 | 0.88 | 0.41 | .... | 1.95 |
| 2 × 3/4 | 0.88 | 0.41 | .... | 1.63 |
| 2 × 1/2 | 0.88 | 0.41 | .... | 1.34 |
| 2 × 3/8 | 0.88 | 0.41 | .... | 1.12 |
| 2 × 1/4 | 0.88 | 0.41 | .... | 1.12 |
| 2 1/2 × 2 | 1.07 | 0.37 | 2.98 | |
| 2 1/2 × 1 1/2 | 1.07 | 0.44 | 2.68 | |
| 2 1/2 × 1 1/4 | 1.07 | 0.44 | .... | 2.39 |
| 2 1/2 × 1 | 1.07 | 0.44 | .... | 1.95 |
| 2 1/2 × 3/4 | 1.07 | 0.44 | .... | 1.63 |
| 2 1/2 × 1/2 | 1.07 | 0.44 | .... | 1.34 |
| 3 × 2 1/2 | 1.13 | 0.40 | 3.86 | |
| 3 × 2 | 1.13 | 0.48 | 3.28 | |
| 3 × 1 1/2 | 1.13 | 0.48 | .... | 2.68 |
| 3 × 1 1/4 | 1.13 | 0.48 | .... | 2.39 |
| 3 × 1 | 1.13 | 0.48 | .... | 1.95 |
| 3 × 3/4 | 1.13 | 0.48 | .... | 1.63 |
| 3 × 1/2 | 1.13 | 0.48 | .... | 1.34 |

* ASA B16.14—1949.

† In the case of outside-head bushings, length A includes provisions for imperfect threads.

‡ Heads of bushings shall be hexagonal or octagonal, except that on the larger sizes of outside-head bushings the heads may be made round with lugs instead of hexagonal or octagonal.

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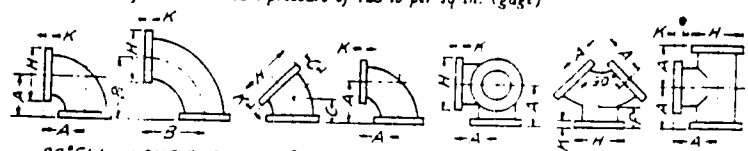
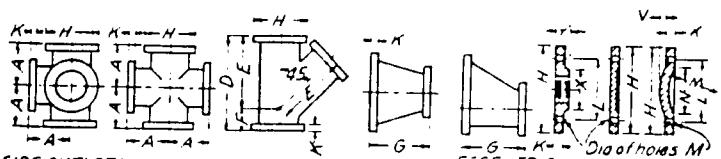
## American Standard Cast-iron Pipe Flanges and Flanged Fittings*

*For maximum working saturated steam pressure of 125 lb per sq in. (gage)*




| Nominal pipe size N | A | B | C | D | E | F | G | H | K min. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3½ | 5 | 1¾ | 7½ | 5¾ | 1¾ | .... | 4¼ | 7/16 |
| 1¼ | 3¾ | 5½ | 2 | 8 | 6¼ | 1¾ | .... | 4⅜ | ½ |
| 1½ | 4 | 6 | 2¼ | 9 | 7 | 2 | .... | 5 | 9/16 |
| 2 | 4½ | 6½ | 2½ | 10½ | 8 | 2½ | 5 | 6 | ⅝ |
| 2½ | 5 | 7 | 3 | 12 | 9½ | 2½ | 5½ | 7 | 11/16 |
| 3 | 5½ | 7¾ | 3 | 13 | 10 | 3 | 6 | 7½ | ¾ |
| 3½ | 6 | 8½ | 3½ | 14½ | 11½ | 3 | 6½ | 8½ | 13/16 |
| 4 | 6½ | 9 | 4 | 15 | 12 | 3 | 7 | 9 | 15/16 |
| 5 | 7½ | 10¼ | 4½ | 17 | 13½ | 3½ | 8 | 10 | 15/16 |
| 6 | 8 | 11½ | 5 | 18 | 14½ | 3½ | 9 | 11 | 1 |
| 8 | 9 | 14 | 5½ | 22 | 17½ | 4½ | 11 | 13½ | 1⅛ |
| 10 | 11 | 16½ | 6½ | 25½ | 20½ | 5 | 12 | 16 | 1 3/16 |
| 12 | 12 | 19 | 7½ | 30 | 24½ | 5½ | 14 | 19 | 1¼ |

| Nominal pipe size N | L | M | No. of bolts | Diam. of bolts | Length of bolts | X min. | Y min. | Wall thickness | V |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3⅛ | ⅝ | 4 | ½ | 1¾ | 1 15/16 | 1 1/16 | 5/16 | ⅜ |
| 1¼ | 3½ | ⅝ | 4 | ½ | 2 | 2 5/16 | 1 3/16 | 5/16 | 7/16 |
| 1½ | 3⅞ | ⅝ | 4 | ½ | 2 | 2 9/16 | ⅞ | 5/16 | ½ |
| 2 | 4¾ | ¾ | 4 | ⅝ | 2¼ | 3 1/16 | 1 | 5/16 | 9/16 |
| 2½ | 5½ | ¾ | 4 | ⅝ | 2½ | 3 9/16 | 1 1/8 | 5/16 | ⅝ |
| 3 | 6 | ¾ | 4 | ⅝ | 2½ | 4 1/4 | 1 3/16 | ¾ | 11/16 |
| 3½ | 7 | ¾ | 8 | ⅝ | 2¾ | 4 13/16 | 1 1/4 | 7/16 | ¾ |
| 4 | 7½ | ¾ | 8 | ⅝ | 3 | 5 5/16 | 1 5/16 | ½ | ¾ |
| 5 | 8½ | ⅞ | 8 | ¾ | 3 | 6 7/16 | 1 7/16 | ½ | ¾ |
| 6 | 9½ | ⅞ | 8 | ¾ | 3¼ | 7 9/16 | 1 9/16 | 9/16 | 15/16 |
| 8 | 11¾ | ⅞ | 8 | ¾ | 3½ | 9 11/16 | 1 ¾ | ¾ | 1 1/16 |
| 10 | 14¼ | 1 | 12 | ⅞ | 3¾ | 11 15/16 | 1 13/16 | ¾ | 1 1/8 |
| 12 | 17 | 1 | 12 | ⅞ | 3¾ | 14 1/16 | 2 3/16 | 13/16 | |

* ASA B16a—1939. Dimensions in inches.

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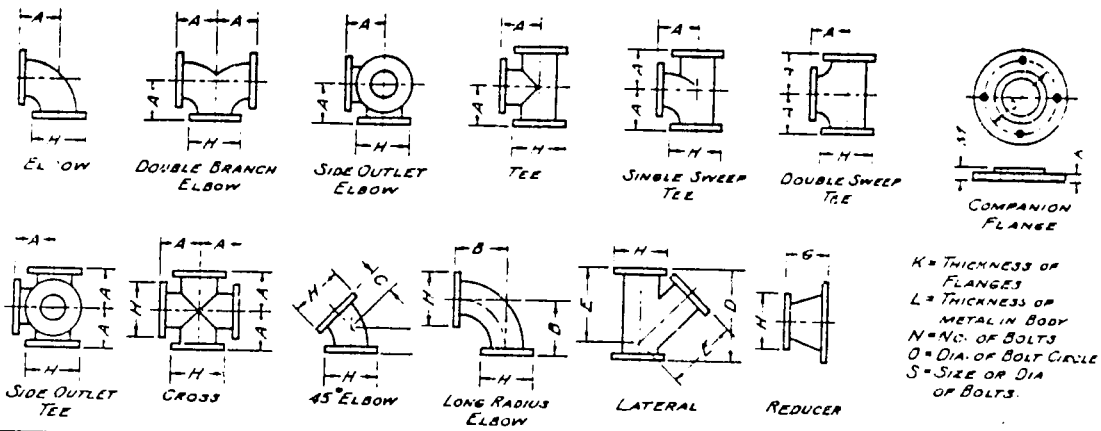
## TABLE 40. Standard Flanged Fittings

(125 lb per sq in. pressure.)




| Size | A | B | C | D | E | G | H | K | L | M | N | O | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3½ | 5 | 1¾ | 7½ | 5¾ | .... | 4 | 7/16 | 7/16 | 11/16 | 4 | 3⅛ | ½ |
| 1¼ | 3¾ | 5½ | 2 | 8 | 6¼ | .... | 4½ | ½ | 7/16 | ¾ | 4 | 3½ | ½ |
| 1½ | 4 | 6 | 2¼ | 9 | 7 | .... | 5 | 9/16 | 7/16 | ⅞ | 4 | 3⅞ | ½ |
| 2 | 4½ | 6½ | 2½ | 10½ | 8 | .... | 6 | ⅝ | 7/16 | 1 | 4 | 4¾ | ⅝ |
| 2½ | 5 | 7 | 3 | 12 | 9½ | .... | 7 | 11/16 | 7/16 | 11/16 | 4 | 5½ | ⅝ |
| 3 | 5½ | 7¾ | 3 | 13 | 10 | 6 | 7½ | ¾ | 7/16 | 1⅛ | 4 | 6 | ⅝ |
| 3½ | 6 | 8½ | 3½ | 14½ | 11½ | 6½ | 8½ | 13/16 | 7/16 | 13/16 | 8 | 7 | ⅝ |
| 4 | 6½ | 9 | 4 | 15 | 12 | 7 | 9 | 15/16 | ½ | 13/16 | 8 | 7½ | ⅝ |
| 5 | 7½ | 10¼ | 4½ | 17 | 13½ | 8 | 10 | 15/16 | ½ | 15/16 | 8 | 8½ | ¾ |
| 6 | 8 | 11½ | 5 | 18 | 14½ | 9 | 11 | 1 | 9/16 | 17/16 | 8 | 9½ | ¾ |
| 8 | 9 | 14 | 5½ | 22 | 17½ | 11 | 13½ | 1⅛ | ⅝ | 1⅝ | 8 | 11¾ | ¾ |
| 10 | 11 | 16½ | 5½ | 25½ | 20½ | 12 | 16 | 1 3/16 | ¾ | 1⅞ | 12 | 14¼ | ⅞ |
| 12 | 12 | 19 | 7½ | 30 | 24½ | 14 | 19 | 1¼ | 13/16 | 2 1/16 | 12 | 17 | ⅞ |

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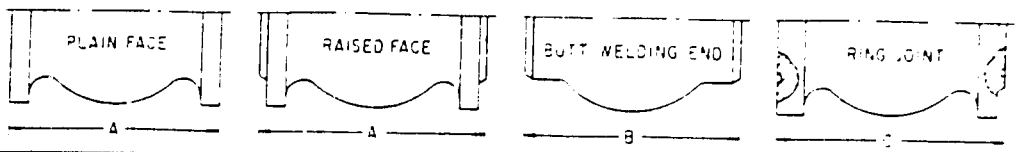
**American Standard Class-125 Cast-iron and 150-lb Steel Valves: Valves with Class-125 or 150-lb End Flanges, or with Welding Ends—Face-to-face and End-to-end Dimensions[a]**




| Nominal valve size | Class-125 cast iron | | | | | | | | 150-lb steel | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanged end—plain face | | | | | | | | Flanged end[a] (1/16 in. raised face) and welding end | | | | | | | |
| | Gate | | Plug | | | Globe and lift check | Swing check[b] | Control[c] | Gate[d] | | | | Plug | | | |
| | Solid wedge | Double disc | Short pattern | Regular | Venturi | | | | Solid wedge | Double disc | Solid wedge | Double disc | Short pattern | Regular | Venturi | Round port full bore |
| | A | A | A | A | A | A | A | A | A | A | B | B | A | A | A | A |
| ¼ | | | | | | | | | 4 | 4 | 4 | 4 | | | | |
| ⅜ | | | | | | | | | 4 | 4 | 4 | 4 | | | | |
| ½ | | | | | | | | | 4¼ | 4¼ | 4¼ | 4¼ | | | | |
| ¾ | | | | | | | | | 4⅜ | 4⅜ | 4⅜ | 4⅜ | | | | |
| 1 | | | 5½ | 5½ | | | | 7¼ | 5 | 5 | 5 | 5 | 5½ | | | 7 |
| 1¼ | | | | 6½ | | | | | 5½ | 5½ | 5½ | 5½ | | | | |
| 1½ | | | 6½ | 6½ | | | | 8⅜ | 6½ | 6½ | 6½ | 6½ | 6½ | | | 8⅜ |
| 2 | 7 | 7 | 7 | 7½ | | 8 | 8 | 10 | 7 | 7 | 8¼ | 8¼ | 7 | | | 10½ |
| 2½ | 7¼ | 7¼ | 7¼ | 8½ | | 8½ | 8½ | 10⅞ | 7½ | 7½ | 9½ | 9½ | 7½ | | | 11⅞ |
| 3 | 8 | 8 | 8 | 9 | | 9½ | 9½ | 11⅝ | 8 | 8 | 11⅛ | 11⅛ | 8 | | | 13½ |
| 3½ | 8½ | 8½ | | | | | | | | | | | | | | |
| 4 | 9 | 9 | 9 | 9 | | 11½ | 11½ | 13⅞ | 9 | 9 | 12 | 12 | 9 | | | 17 |
| 5 | 10 | 10 | 10 | 14 | | 13 | 13 | | 10 | 10 | 15 | 15 | | | | |
| 6 | 10½ | 10½ | 10½ | 15½ | 15¼ | 14 | 14 | 17⅝ | 10½ | 10½ | 15⅞ | 15⅞ | 10½ | 15¼ | | 21 |
| 8 | 11½ | 11½ | 11½ | 18 | 18 | 19½ | 19½ | 21⅝ | 11½ | 11½ | 16½ | 16½ | 11½ | 18 | | 25 |

| Nominal valve size | 150-lb steel | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flanged end[a] (1/16 in. raised face) and welding end | | | | Flanged end (ring joint) | | | | | | | |
| | Globe and lift check | Swing check | "Y" pattern globe | Control[c] | Gate[d] | | Plug | | | Round port full bore | Globe and lift check | Swing check |
| | | | | | Solid wedge | Double disc | Short pattern | Regular | Venturi | | | |
| | A & B | A & B | A & B | A | C | C | C | C | C | C | C | C |
| ¼ | 4 | 4 | | | | | | | | | | |
| ⅜ | 4 | 4 | | | | | | | | | | |
| ½ | 4¼ | 4¼ | 5¼ | | 4 11/16 | 4 11/16 | | | | | 4 11/16 | 4 11/16 |
| ¾ | 4⅜ | 4⅜ | 6 | | 5⅛ | 5⅛ | | | | | 5⅛ | 5⅛ |
| 1 | 5 | 5 | 6½ | 7¼ | 5½ | 5½ | 6 | | | 7½ | 5½ | 5½ |
| 1¼ | 5½ | 5½ | 7¼ | | 6 | 6 | | | | | 6 | 6 |
| 1½ | 6½ | 6½ | 8 | 8⅜ | 7 | 7 | 7 | | | | 7 | 7 |
| 2 | 8 | 8 | 9 | 10 | 7½ | 7½ | 7½ | | | 9¼ | 8½ | 8½ |
| 2½ | 8½ | 8½ | 11 | 10⅞ | 8 | 8 | 8 | | | 11 | 9 | 9 |
| 3 | 9½ | 9½ | 12½ | 11⅞ | 8½ | 8½ | 8½ | | | 12⅞ | | |
| 3½ | | | | | | | | | | 14 | | 10 |
| 4 | 11½ | 11½ | 14½ | 13⅞ | 9½ | 9½ | 9½ | | | 17½ | 12 | 12 |
| 5 | 13 | 13 | | | 10½ | 10½ | | | | | 14½ | 13½ |
| 6 | 16 | 14 | 18½ | 17⅞ | 11 | 11 | 11 | 16 | | 21½ | 16½ | 14½ |
| 8 | 17½ | 19½ | 23½ | 21⅝ | 12 | 12 | 12 | 18½ | | 25½ | 20 | 20 |

[a] Adapted from ASA B16.10—1957. API Standards 6D and 600 conform to the dimensions shown for corresponding sizes, valve type and flange class or welding end.

[b] These dimensions are not intended to cover the type of check valve having the seat angle at approximately 45 deg to the run of the valve or the "Underwriter Pattern" or other patterns where large clearances are required.

[c] Instrument Society of America Tentative Standard ISA RP41 face-to-face conforms to dimensions shown in column 10 and column 23.

[d] 150-lb corrosion-resistant valves covered by MSS SP-42 have *plain faces*.

[e] 150-lb Steel conduit-type gate valves are not standardized.

[f] These valves are flanged end only.

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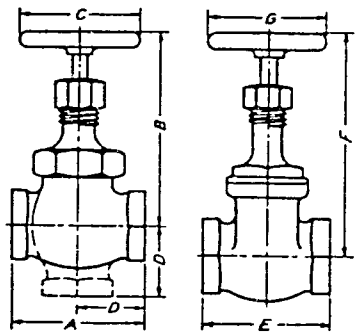


## Globe, Angle-globe, and Gate Valves*

| Size | A (globe only) | B (open) | C | D (angle only) | E | F (open) | G |
|---|---|---|---|---|---|---|---|
| 1/8 | 2 | 4 | 1 3/4 | 1 | | | |
| 1/4 | 2 | 4 | 1 3/4 | 1 | 1 7/8 | 5 1/8 | 1 3/4 |
| 3/8 | 2 1/4 | 4 1/2 | 2 | 1 1/8 | 2 | 5 1/8 | 1 3/4 |
| 1/2 | 2 3/4 | 5 1/4 | 2 1/2 | 1 1/4 | 2 1/8 | 5 1/2 | 2 |
| 3/4 | 3 3/16 | 6 | 2 3/4 | 1 1/2 | 2 3/8 | 6 3/8 | 2 1/2 |
| 1 | 3 3/4 | 6 3/4 | 3 | 1 3/4 | 2 7/8 | 7 7/8 | 2 3/4 |
| 1 1/4 | 4 1/4 | 7 1/4 | 3 5/8 | 2 | 3 1/4 | 9 1/2 | 3 |
| 1 1/2 | 4 3/4 | 8 1/4 | 4 | 2 1/4 | 3 1/2 | 10 7/8 | 3 5/8 |
| 2 | 5 3/4 | 9 1/2 | 4 3/4 | 2 3/4 | 3 7/8 | 13 1/8 | 4 |
| 2 1/2 | 6 3/4 | 11 | 6 | 3 1/4 | 4 1/2 | 15 3/8 | 4 3/4 |
| 3 | 8 | 12 1/4 | 7 | 3 3/4 | 5 | 17 7/8 | 5 3/8 |

* Dimensions in inches and compiled from manufacturers' catalogues for drawing purposes.

## Lengths of Pipe Nipples*

| Size | Length | | Size | Length | | Size | Length | | Size | Length | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Close | Short | | Close | Short | | Close | Short | | Close | Short |
| 1/8 | 3/4 | 1 1/2 | 1/2 | 1 1/8 | 1 1/2 | 1 1/4 | 1 5/8 | 2 1/2 | 2 1/2 | 2 1/2 | 3 |
| 1/4 | 7/8 | 1 1/2 | 3/4 | 1 3/8 | 2 | 1 1/2 | 1 3/4 | 2 1/2 | 3 | 2 5/8 | 3 |
| 3/8 | 1 | 1 1/2 | 1 | 1 1/2 | 2 | 2 | 2 | 2 1/2 | | | |

* Compiled from manufacturers' catalogues. Dimensions in inches.

Long-nipple lengths: from short-nipple lengths to 6 in. in 1/2 in. increments; from 6 in. nipple lengths to 12 in. in 1 in. increments; from 12 in. nipple lengths to 24 in. in 2 in. increments.



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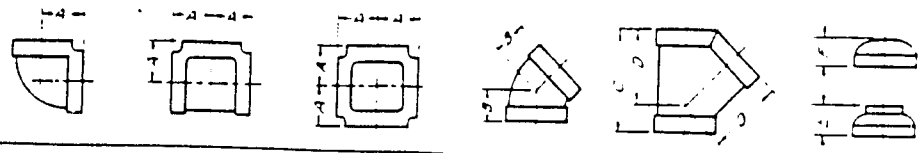
TABLE 41. STANDARD CAST-IRON SCREW FITTINGS

(125 lb per sq in. pressure.)

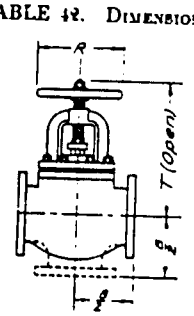


| Size Inches | Dimensions in Inches | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| ¼ | 13/16 | ¾ | | | | |
| ⅜ | 15/16 | 13/16 | | | | |
| ½ | 1⅛ | ⅞ | 2½ | 1⅞ | | |
| ¾ | 1 5/16 | 1 | 3 | 2¼ | | |
| 1 | 1 7/16 | 1⅛ | 3½ | 2¾ | | |
| 1¼ | 1¾ | 1 5/16 | 4¼ | 3¼ | 2⅛ | |
| 1½ | 1 13/16 | 1 7/16 | 4⅞ | 3 13/16 | 2¼ | |
| 2 | 2¼ | 1 11/16 | 5¾ | 4¼ | 2 7/16 | |
| 2½ | 2 11/16 | 1 15/16 | 6¾ | 5 3/16 | 2 11/16 | |
| 3 | 3⅛ | 2 3/16 | 7⅞ | 6⅛ | 2 15/16 | |
| 3½ | 3 7/16 | 2⅜ | 8⅞ | 6⅞ | 3⅛ | |
| 4 | 3¾ | 2⅝ | 9¾ | 7⅝ | 3⅜ | 2 1/16 |
| 5 | 4 7/16 | 3 1/16 | 11⅜ | 9¼ | 3⅞ | 2⅜ |
| 6 | 5⅛ | 3 7/16 | 13 7/16 | 10¾ | 4⅜ | 2⅝ |
| 8 | 6½ | 4¼ | 16 13/16 | 13⅜ | 5¼ | 3⅛ |
| 10 | 8 1/16 | 5 3/16 | 20 11/16 | 16¾ | 6 3/16 | 3⅝ |
| 12 | 9½ | 6 | 24⅛ | 19⅝ | 7⅛ | 4¼ |

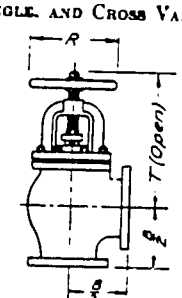
Fractional dimensions are nominal. See ASA Bulletin for decimal dimensions.

TABLE 42. DIMENSIONS OF STANDARD GLOBE, ANGLE, AND CROSS VALVES

(All dimensions in inches.)




GLOBE OR CROSS VALVE




ANGLE VALVE

| Size | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 6½ | 7 | 8 | 9 | 10 | 11¼ | 13 | 18½ | | |
| B | 8 | 8½ | 9½ | 10½ | 11½ | 13 | 14 | 19½ | 24½ | 27½ |
| T | 11⅓ | 11½ | 13⅓ | 13⅓ | 15½ | 17⅓ | 19½ | 24⅓ | 30¼ | 33½ |
| R | 8 | 8 | 9 | 9 | 10 | 10 | 12 | 16 | 18 | 20 |

Substitute A for B for screw fittings.



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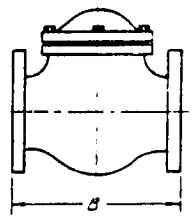
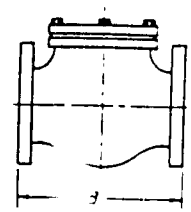
## TABLE 43. Dimensions of Standard Lift and Swing Valves

(All dimensions in inches.)




Lift Check Valve



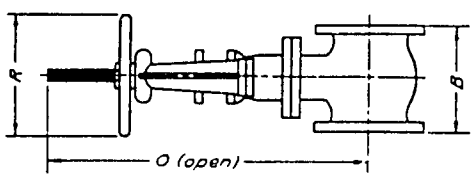

Swing Check Valve

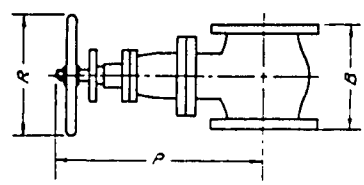
| Size | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| *A* | 6½ | 7 | 8 | 9 | 10 | 11¼ | 12½ | 18½ | | |
| *B* | 8 | 8½ | 9½ | 10½ | 11½ | 13 | 14 | 19½ | 24½ | 27½ |

Substitute *A* for *B* for screw fittings.

## TABLE 44. Dimensions of Standard Gate Valves

(All dimensions in inches.)




| Size | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|
| *A* | 6⅛ | 6½ | 6¼ | 7⅜ | 7⅝ | 8½ | 8⅞ | 10¼ | | |
| *B* | 7 | 7½ | 8 | 8½ | 9 | 10½ | 11 | 11½ | 13 | 14 |
| *O* | 14¾ | 17 | 19½ | 21¼ | 23¾ | 28¾ | 32⅜ | 41⅞ | 50¼ | 38 |
| *P* | 12¾ | 13⅜ | 15½ | 16½ | 18½ | 21¼ | 23⅜ | 27⅜ | 33 | 36¼ |
| *R* | 8 | 8 | 9 | 9 | 10 | 12 | 12 | 16 | 20 | 20 |

Substitute *A* for *B* for screw fittings.

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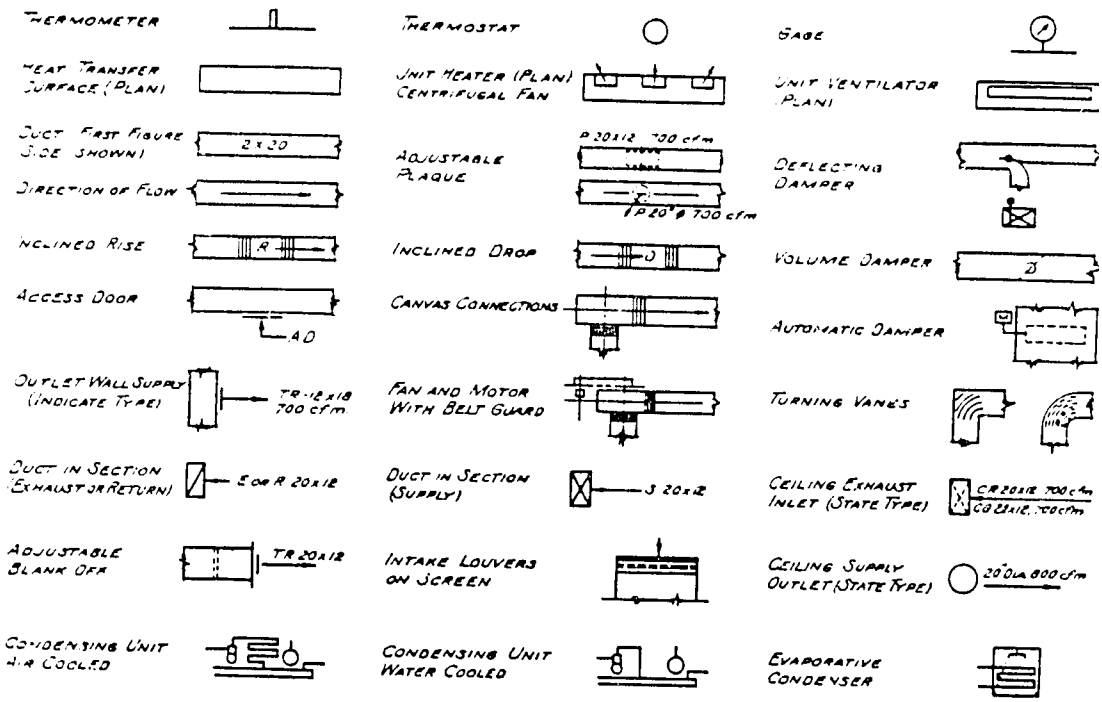
TABLE 45. ASA SYMBOLS FOR HEATING, VENTILATING, AND AIR CONDITIONING

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## TABLE 46. ASA Graphic Symbols for Piping

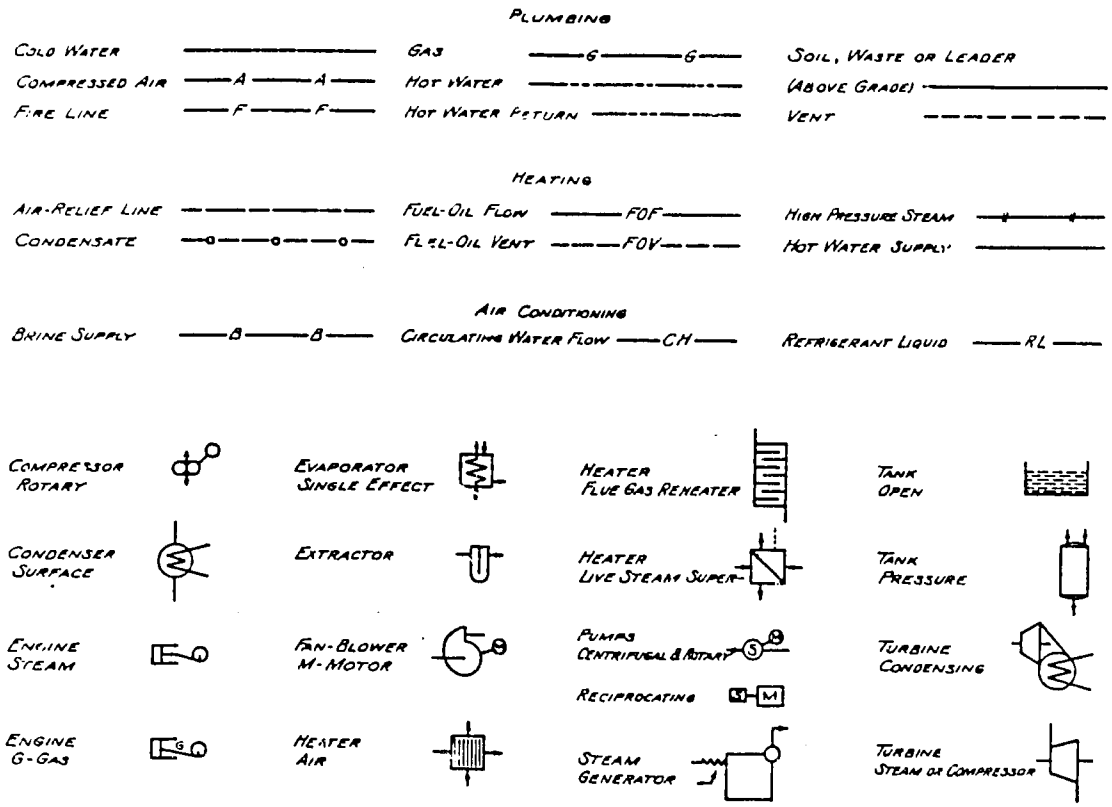


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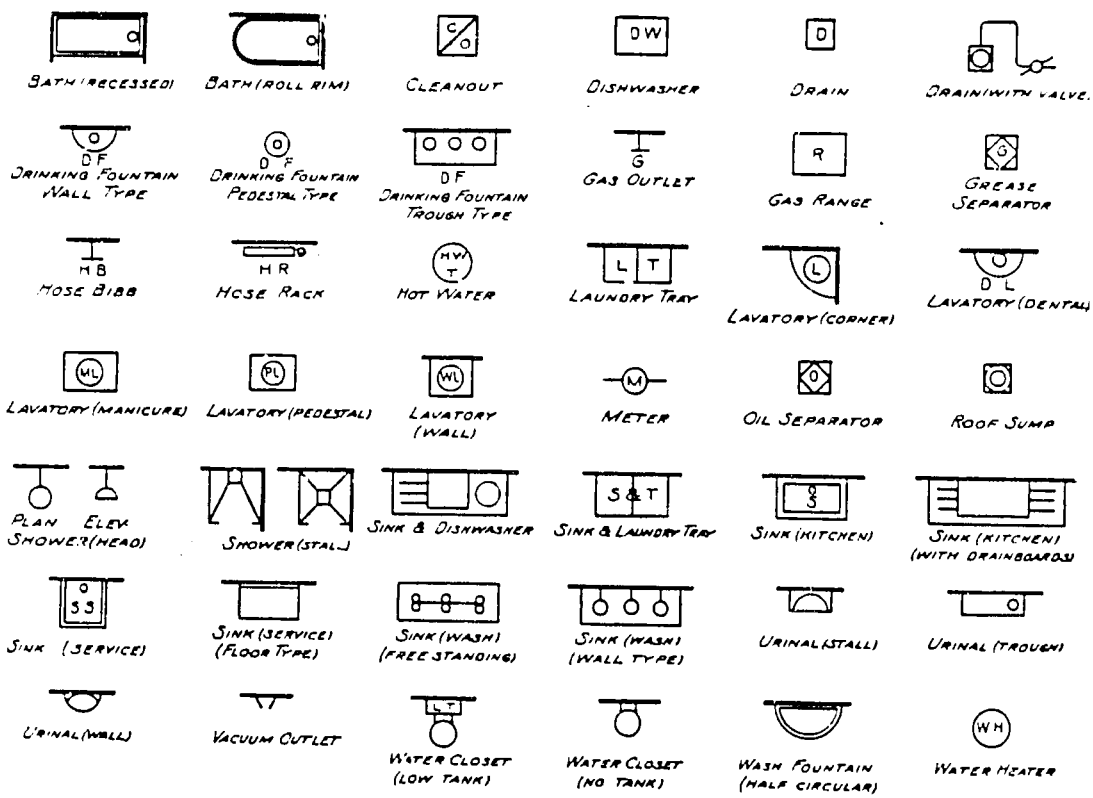
TABLE 47. ASA PLUMBING SYMBOLS

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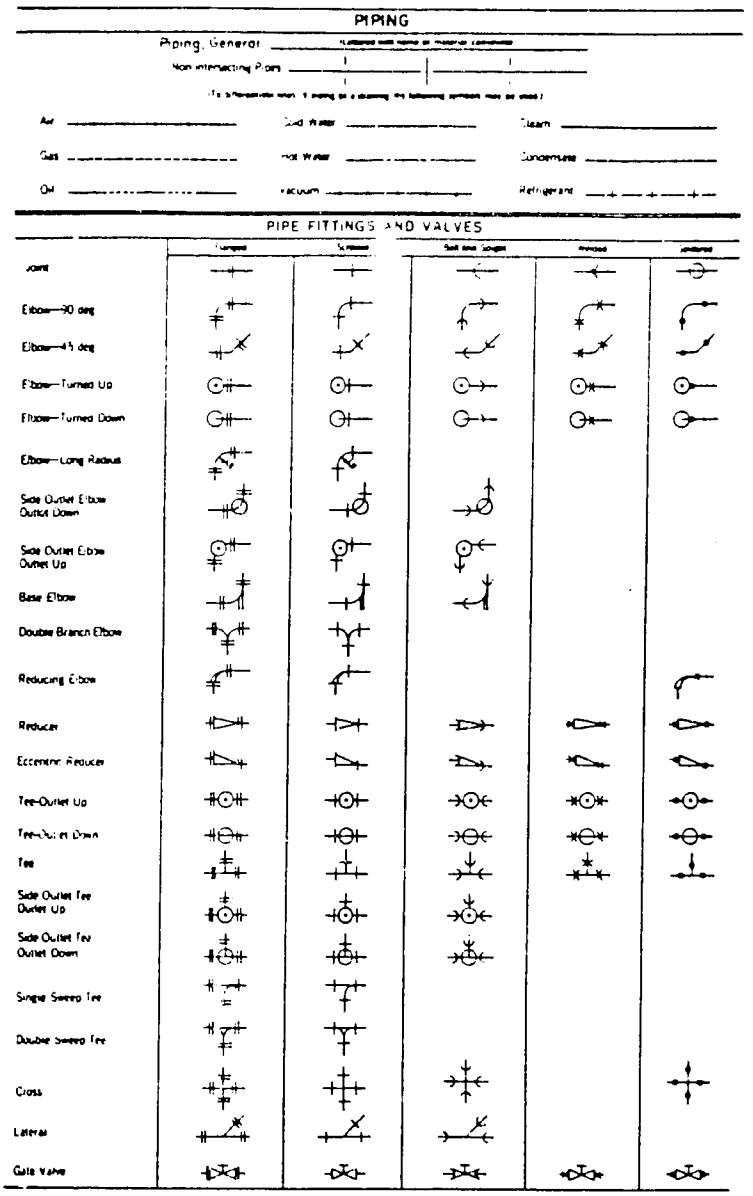
## American Standard Graphic Symbols for Piping and Heating*




* ASA Z14.2—1935.

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## Symbols for Piping and Heating (Cont.)

### PIPING

| | Flanged | Screwed | Bell and Spigot | Welded | Soldered |
|---|---|---|---|---|---|
| Globe Valve | | | | | |
| Angle Globe Valve | | | | | |
| Angle Gate Valve | | | | | |
| Check Valve | | | | | |
| Angle Check Valve | | | | | |
| Stop Cock | | | | | |
| Safety Valve | | | | | |
| Quick Opening Valve | | | | | |
| Float Operating Valve | | | | | |
| Motor Operated Gate Valve | | | | | |
| Motor Operated Globe Valve | | | | | |
| Expansion Joint Flanged | | | | | |
| Reducing Flange | | | | | |
| Union | Gas Joint | | | | |
| Sleeve | | | | | |
| Bushing | | | | | |

### HEATING AND VENTILATING

Lock and Shield Valve

Reducing Valve

Diaphragm Valve

Thermostat

Radiator Trap (Plan) (Elev.)

Tube Radiator (Plan) (Elev.)

Wall Radiator (Plan) (Elev.)

Pipe Coil (Plan) (E)

Indirect Radiator (Plan) (Elev.)

Supply Duct Section

Exhaust Duct Section

Butterfly Damper (Plan or Elev.) (Elev. or Plan)

Deflecting Damper Rectangular Pipe

Vanes

Air Supply Outlet

Exhaust Inlet

### HEAT-POWER APPARATUS

Flue Gas Reheater (Economizer, Superheater)

Steam Generator (Boiler)

Low Steam Superheater

Feed Heater With Air Outlet

Surface Condenser

Steam Turbine

Condensing Turbine

Open Tank

Closed Tank

Automatic Reducing Valve

Automatic Bypass Valve

Automatic Valve Operated by Governor

Pumps
Air
Service
Boiler Feed
Condensate
Circulating Water
Reciprocating

Dynamic Pump (Air Ejector)

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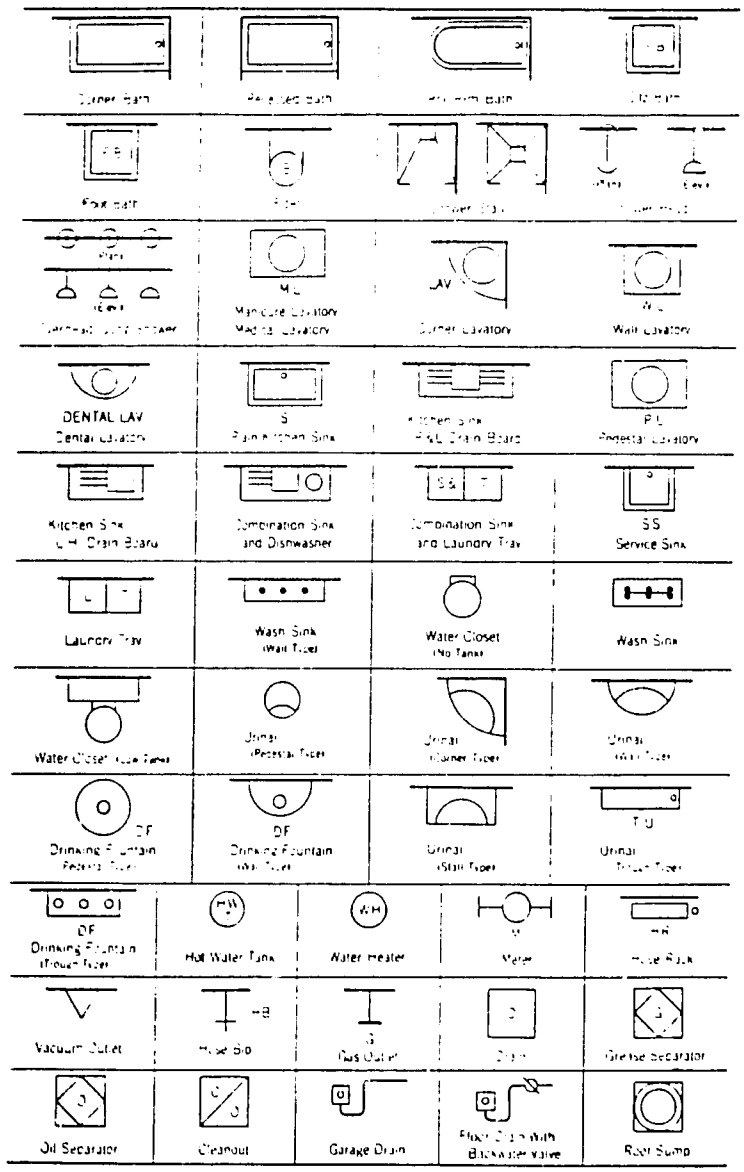
**American Standard Plumbing Symbols***




*A Z14.2—1935.

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