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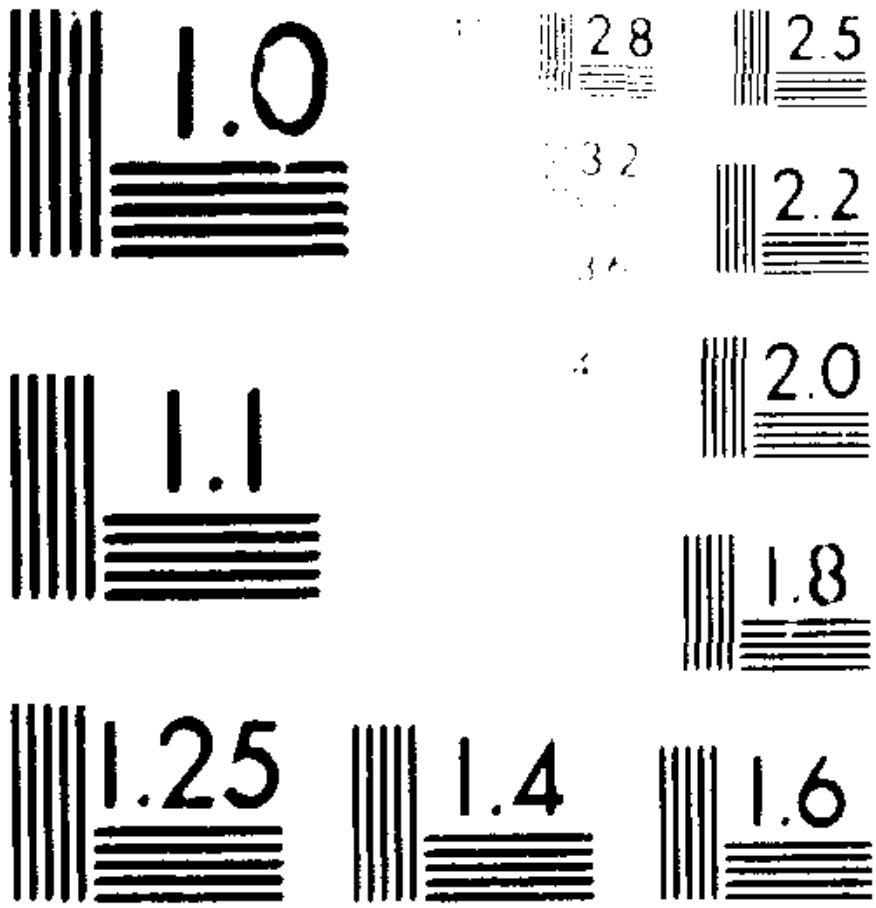
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DP/ID/SER.A/336
28 May 1981
English

RESTRICTED

SPECIALIZED INSTITUTE FOR ENGINEERING

INDUSTRIES, BAGHDAD

DP/IRQ/77/003

IRAQ

Technical report: Establishment of a preventive maintenance system

Prepared for the Government of Iraq by the
United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Jurgen Steffens, expert
in preventive maintenance

United Nations Industrial Development Organization
Vienna

V.81-25940

Explanatory notes

A full stop (.) is used to indicate decimals.

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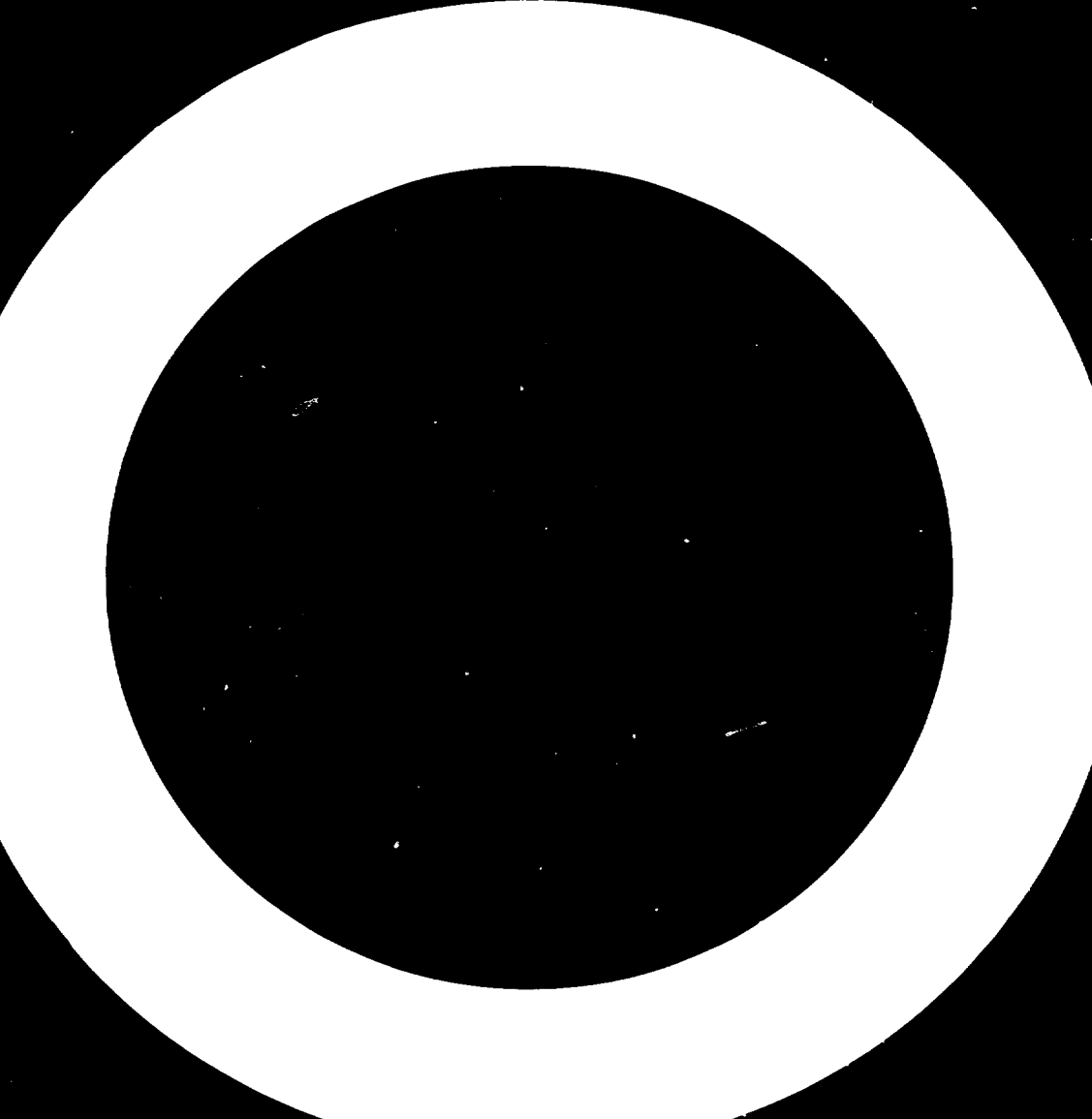
ABSTRACT

As part of the ongoing project "Specialized Institute for Engineering Industries, Baghdad" (DP/IRQ/77/003), approved by the United Nations Industrial Development Organization (UNIDO) on 20 April 1978, a UNIDO consultant worked from 25 April to 19 May 1981 on the establishment of a preventive maintenance system for the Institute. He drew up operators' check-lists and preventive maintenance guides for the existing machinery and equipment and worked out a timetable for the implementation of the system. He also provided his counterparts with detailed examples of check-lists, maintenance guides and timetables and instructed them in the use of preventive maintenance techniques.

The expert recommended that the preventive maintenance system should be implemented in steps by a maintenance engineer, under the supervision of the Director of the Production Engineering Department. The maintenance engineer should also train the personnel in the techniques of preventive maintenance.

It was agreed that the consultant should make a follow-up visit in order to help in the implementation of the project. The final decision about the visit is to be made by the management of the Institute.



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INTRODUCTION

As part of an ongoing project, "Specialized Institute for Engineering Industries, Baghdad" (DP/IRQ/77/003), approved by the United Nations Industrial Development Organization (UNIDO) on 20 April 1978, work was carried out from 25 April to 19 May 1981 on the establishment of a preventive maintenance system in the Institute. The UNIDO consultant assigned to the project was Mr. J. Steffens, working in collaboration with Mr. Batool N. Turki and Mr. Mounir F. Youssif, both of the Institute. Discussions were also held with the Acting Director of Production of the Institute, Mr. Adnan Al-Khozaee.

The object was to set up a preventive maintenance system for machines and equipment, which might later be introduced into other workshops by the Institute, and to train the counterparts in the techniques of preventive maintenance.

I. DESCRIPTION OF THE WORK CARRIED OUT

The following work was carried out in the course of the assignment:

(a) Discussions were held with counterparts on:

(i) Preventive maintenance in general;

(ii) The need for operators' check-lists and how to draw them up;

(iii) The headings to be included in the preventive maintenance system;

(iv) The layout of forms for preventive maintenance guides;

(v) How to fill in preventive maintenance guides;

(vi) How to plan the various types of preventive action to be taken;

(vii) Routines for the preventive maintenance system;

(b) Operators' check-lists and preventive maintenance guides were drawn up for the machines and equipment listed in annex I below;

(c) A full description of the preventive maintenance system was furnished, including the routines shown in annex II below;

(d) A visit was paid to the workshop of the State Enterprise for Mechanical Industries in Iskanderiyah in order to find out whether the system could be introduced there and to discuss the maintenance problems in that workshop;

(e) A schedule was worked out for the implementation of the system and the various steps were described in detail (see annex III below).

II. RECOMMENDATIONS

1. The system should be implemented one step at a time, making sure that each step is completed before the next one is started.

2. The system should be implemented by an engineer in charge of maintenance, under the supervision of the Director of the Production Engineering Department.

3. The staff carrying out the work should be trained in the techniques of preventive maintenance by the maintenance engineer.

4. In the course of discussions with the Acting Director of Production and with the counterparts, it was agreed that the consultant should make a follow-up visit in order to help in the implementation of the project. The final decision about the follow-up visit is left to the management of the Institute.

Annex I

MACHINES COVERED BY THE PREVENTIVE MAINTENANCE SYSTEM

The machines listed in the table below were included in the preventive maintenance system for the Specialized Institute for Engineering Industries at Baghdad during the period 25 April - 19 May 1981. The table indicates with a cross whether operators' check-lists, maintenance guides or instructions were provided.

Type of machine	Machine number	Operators' check-lists	Maintenance guides	Instructions
Surface-grinding machine	13	x	x	
Universal grinding machine	30	x	x	
Internal grinding machine	31	x	x	
Surface-grinding machine	29	x	x	
Surface-grinding machine	28	x	x	
Tool-grinding machine	35	x	x	
Tool-grinding machine	36	x	x	
Optical grinding machine		x	x	
Universal lathe	14	x	x	
Universal lathe	16	x	x	
Planing machine	50	x	x	
Combined planing machine	57	x	x	
Milling machine	17	x	x	
Milling machine	19	x	x	
Universal lathe	15 A and B	x	x	
Jig-boring machine	24	x	x	
Lapping machine	37	x	x	
Hydraulic press	42	x	x	
Universal milling machine		x	x	
Column-drilling machine	26	x	x	
Tool-room milling machine	20	x	x	
Furnace	56	-	x	
Compartment furnace	48	-	x	

Type of machine	Machine number	Operators' check-lists	Maintenance guides	Instructions
Shaft furnace	54	-	x	
Plate-bending machine	10	x	x	
Electro-spark erosion machine	55		x	
Salt furnace	53	-	x	
Shaper	11	x	x	
Milling and boring machine	18	x	x	
Saw sharpener	59	x	x	
Bandsaw	2	x	x	
Spot welder	5	x	x	
Bending machine	9	x	x	
Punching and shearing machine	7	x	x	
Engraving machine	40	x	x	
Press brake	8	x	x	
Hacksaw	1	x	x	
Vertical copying machine	21	x	x	
Radial drilling machine	25	x	x	
Eccentric press	41	x	x	
Pneumatic hammer	52	x	x	
Wood saw	51	x	x	
Oxy-acetylene welding set	3	-	x	
Bandsaw	39	x	x	
Slotting machine	22	x	x	
Drilling machine	27	x	x	

Annex II

DESCRIPTION OF THE SYSTEM

CONTENTS

Appendices

Figures

I. PREVENTIVE MAINTENANCE SYSTEMS IN GENERAL

Preventive maintenance is a term for all programmed maintenance designed to prevent failures or to discover them before they result in further problems or,damage to machines and products.

Typical preventive maintenance jobs include:

Lubrication
Cleaning, housekeeping
Inspections, condition monitoring
Calibrations, adjustments
Programmed repairs
Programmed overhauls
Programmed replacements

The object of a preventive maintenance system is to plan and control all preventive maintenance activities so that they will be carried out at the right time, using the right methods and the right personnel. This will result in a substantial increase in the number of planned maintenance jobs, while the total amount of maintenance will decrease.

Some form of system is essential because even in a small company it is impossible, without a system, to ask anyone to remember when, where and how lubrication or inspection should be carried out. The system should be able to plan the jobs that can be done when the machine is running, for example, inspections, measurements of temperatures, leakage checks, lubrication etc. Also the system should be able to allow for jobs that need special planning because the machine will need to be shut down, for example, change of oil, accuracy tests etc.

In addition to the above activities, the system should consist of guidelines for operators, in which daily checks, lubrication and cleaning operations are described.

The system also should be supplemented by brief instructions for staff with some experience and more detailed instructions for less experienced employees.

As the preventive maintenance system is closely aligned with the production equipment, it must be changed when the production equipment is modified, added to or discarded. The system should also allow for changes to be made on the basis of actual experience such as more suitable methods, change of intervals between jobs etc.

II. DESCRIPTION OF THE PREVENTIVE MAINTENANCE SYSTEM AT THE SPECIALIZED INSTITUTE FOR ENGINEERING INDUSTRIES

Taking into account the type and size of the plant and its production equipment, the following preventive maintenance system has been worked out for the Specialized Institute for Engineering Industries.

A. Operators' check-lists

The operators' check-lists contain descriptions of the jobs that need to be done daily in order to make sure that the machine is operated in accordance with guide-lines provided by the manufacturer and in order to keep the machine in good working order. The lists are intended to provide the operators with guide-lines for the daily care of their machines, for example:

Lubrication
Checking of the oil level
Cleaning
Checking for abnormal function.

The check-lists are organzied under the following headings:

Jobs to be done before starting the machine
Jobs to be done after starting the machine
Jobs to be done while the machine is in operation
Jobs to be done at the end of the shift

If necessary, the check-lists should also consist of a sketch showing where to check, lubricate etc.

They should have a plastic cover and should be attached to the machine and the operators should be taught how to do the various jobs. An example of an operator's check-list is given in appendix I below.

B. Preventive maintenance guides

The form containing the preventive maintenance guide is the main document of the preventive maintenance system. It covers all the jobs to be done by maintenance personnel, that is, by the mechanical inspectors, electrical

inspectors and lubricators. The form is used in the planning of all preventive maintenance work and a copy is also used as a guide-line for carrying out preventive maintenance activities.

The preventive maintenance guide is filled in as follows (see also figure I):

1. Name of the machine or piece of equipment
2. Number of the machine or piece of equipment
3. Page number for each preventive maintenance guide per machine (if the description of the preventive maintenance jobs for one machine covers three pages, the first page is numbered "Page 1 of 3" etc.)
4. The subject of the preventive maintenance work can be indicated either by giving the name of the component or machine part on which the work is to be done, (for example 6, tailstock, motor etc., or by indicating the type of work required, for example overhaul, condition measurement etc.)
5. A brief description of the steps to be taken, consisting of:

   A description of the job
   A note of the clearance and temperature limits etc.
   Methods
   Names of instruments and aids to be used
   Quantity of oil, grease etc. needed

6. The number of the detailed instruction - if the job is not described in sufficient detail in the preventive maintenance guide, a fuller description must be provided in a separate numbered instruction (the contents of the instructions, how to write them and the numbering system will be described later).
7. The category of personnel to be entrusted with the work; the category is indicated by an abbreviation, as shown below:

   M - mechanical inspector, repairman or fitter
   E - electrical inspector or technician
   L - lubricator, oiler etc.

   If necessary, more categories could be added, for example:

   V - inspector responsible for measuring vibrations
   H - inspector responsible for condition monitoring, inspection and adjustment of hydraulic systems

Figure I. How to fill in a preventive maintenance guide

Name:

Page 3 of

Machine No:

Job No.	Category	Stage	Interval (weeks)	Subject	Description	Instruction
(10)	(7)	(8)	(9)	(4)	(5)	(6)

8. The stage at which the job has to be done, abbreviated as follows:

O - "Operation", meaning that the work can be done while the machine is in operation

S - "Stop", which means that the machine has to be stopped while the work is being done

9. The interval between jobs expressed in weeks - to facilitate the planning of preventive maintenance work, all intervals should be multiples of each other, as follows:

1	one week
2	two weeks
4	one month
12	three months
24	half a year
48	one year
96	two years
144	three years
192	four years

... .

10. A serial number for each job, to be filled in when all the maintenance guides have been prepared and sorted (see also section D.1 below)

An example of a completed maintenance guide is given in appendix II below.

C. Instructions

As already indicated, additional specifications have to be provided if the job is not fully described in the preventive maintenance guide. There are no general rules for determining when this is necessary or how detailed the instructions should be, since the difficulty of the work and the competence of the personnel vary from case to case. The following types of instruction may be needed:

(a) Commonly occurring components: instructions for monitoring these should be drawn up once only for each component and referred to when filling in the maintenance guides; they should contain:

(i) A description of the check-points;

(ii) A note of the clearance and temperature limits etc.;

(iii) A description of methods - if, for example, it is discovered at a later stage that a change of methods is needed, the new method is entered in the instruction and thereby automatically applies to all components of this type, since the instruction number is always the same;

(b) Special instructions should be drawn up when sketches, photos or drawings are needed to show the whole machine and the areas where the jobs have to be carried out; this type of instruction should contain the same descriptions as those listed under (a) above;

(c) Detailed instructions should be drawn up when required, containing:

(i) A description of the spare parts that are needed;

(ii) A description of the tools and other aids needed;

(iii) Sketches showing where the task, or part of it, has to be carried out;

(iv) A description of each sequence of the job;

There are no general rules for determining when this is necessary or how detailed the instructions should be, since the difficulty of the work and the competence of the personnel vary from case to case;

(d) Instructions for accuracy tests should be drawn up when the job involves measurements that have to be recorded; the instruction should contain:

(i) Sketches, showing where and how to carry out the measurement;

(ii) If necessary, a description of the measurement;

(iii) Records where the results of the measurement can be noted.

Examples of the instructions described under (a)-(d) above are given in appendices III-VI respectively.

To prevent instructions for the various categories (that is, mechanical, electrical, lubricator) and the various types of jobs (that is, jobs to be done while the machine is in operation and for jobs to be done during a stop) from getting mixed up, the following numbering system has been established:

Series MO	Instructions for mechanical inspections etc. to be done while the machine is running
Series MS	Instructions for mechanical jobs to be done during a stop period
Series EO	Instructions for electrical inspections to be done while the machine is running

Series ES	Instructions for electrical jobs to be done during a stop period
Series LO	Instructions for lubrication to be done while the machine is running
Series LS	Instructions for lubrication to be done during a stop period

The instructions should be filed according to the above numbering system, that is, in one file for each series. It is also advisable to have the originals filed in the maintenance office, while a copy is used by the maintenance personnel performing the jobs. To protect these copies from oil, dirt etc., a plastic cover should be used.

D. Planning of preventive maintenance work

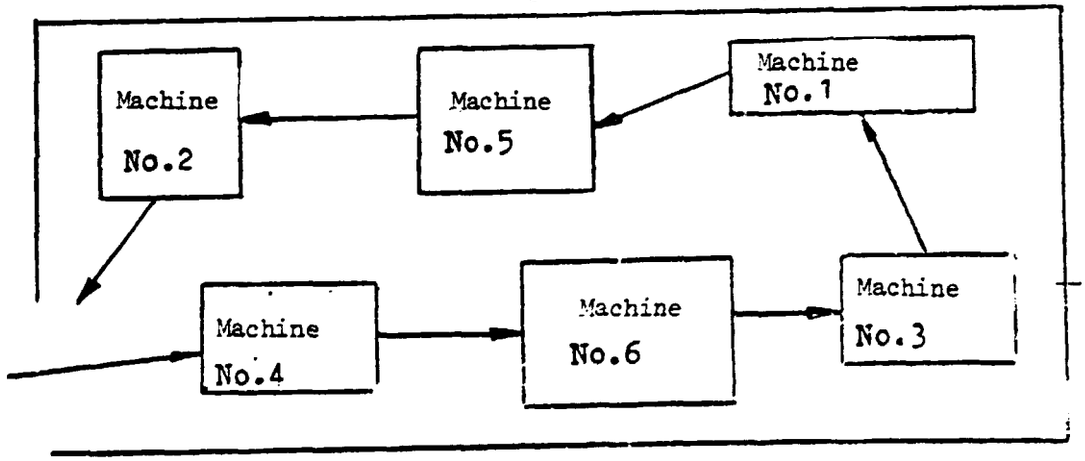
1. Planning of jobs to be done while the machine is in operation

The planning of these jobs must take into account the fact that the jobs fall into different categories and must be carried out in a logical order, and approximately the same number of jobs should be done each week.

(a) Logical planning

When all the preventive maintenance guides for one plant or preventive maintenance area [a/] have been drawn up, they have to be sorted and filed in a certain way, as described below for the simplified plant layout shown in figure II.

Figure II. Simplified plant layout



Preventive maintenance work on the various machines should be carried out in a logical order, that is to say, all the jobs on machine No. 4 should be done first, followed by all the jobs on machine No. 6, and so on as indicated by the arrows. This only applies to jobs to be done while the machines are running. Jobs to be done during a stop period are planned in conjunction with the

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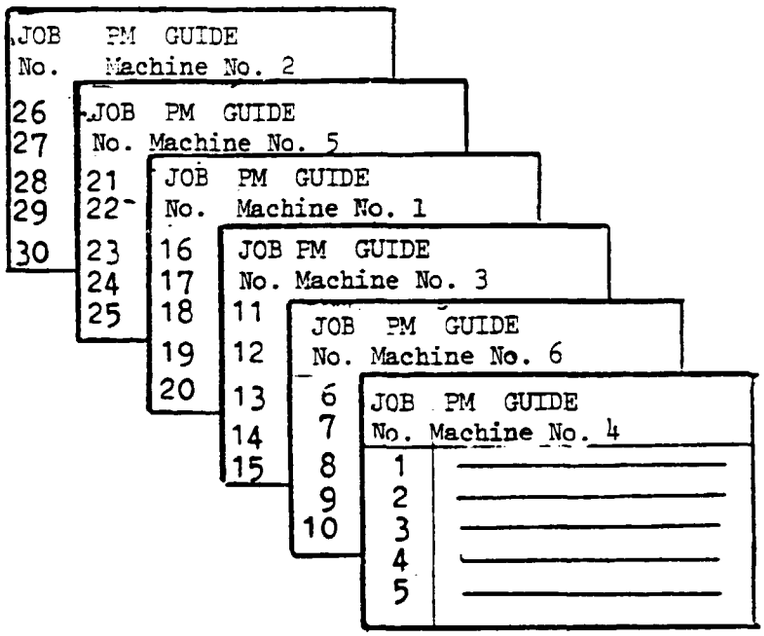
a/ The whole plant can be divided into a number of preventive maintenance areas, each served by a preventive maintenance group, maintenance workshop etc.

production planning process (see section B.2 below). To achieve this, all the preventive maintenance guides have to be sorted and filed in the above order.

When this has been done, all the jobs in the file are to be given a serial job number, as shown in figure III below (see also item 10 of the preventive maintenance guide, described in section B above).

Figure III. Sorting order for preventive maintenance guides of job



(b) Planning according to the category of job and the intervals between jobs

Each category has to be planned separately with the aid of a planning list. For instance, in the case of mechanical (M) jobs, the planner simply has to go through the preventive maintenance guide file from the beginning, pick out the numbers for all the mechanical jobs and enter them on the planning list as shown in figure IV.

The procedure is as follows. First, all the mechanical jobs extracted from the file are set out as shown in the table below.

Figure IV. Planning list for the mechanical inspector (M-0)

1981

Weeks	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
Job numbers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	7	3	17	3	7	3	17	3	7	3	17	3	7	3	17	3	7	3	17	3	7	3	17	3	7
	4	8	11	18	4	8	11	18	4	8	11	18	4	8	11	18	4	8	11	18	4	8	11	18	4	8
	5	9	13	19	21	21	13	19	21	21	13	19	5	9	13	19	21	21	13	19	21	21	13	19	5	9
	21	21	15	21	23	21	21	21	23	21	21	21	21	21	15	21	23	21	21	21	23	21	21	21	21	21
	23		21		25				25				23		21		25				25				23	
	25												25												25	
	etc.																									

Job Number	Machine No.	Interval between jobs
1	4	1
3	4	2
4	4	4
5	4	12
7	6	4
8	6	4
9	6	12
11	3	4
13	3	4
15	3	12
17	1	4
18	1	4
20	1	4
21	5	1
23	5	4
25	5	4
etc.		

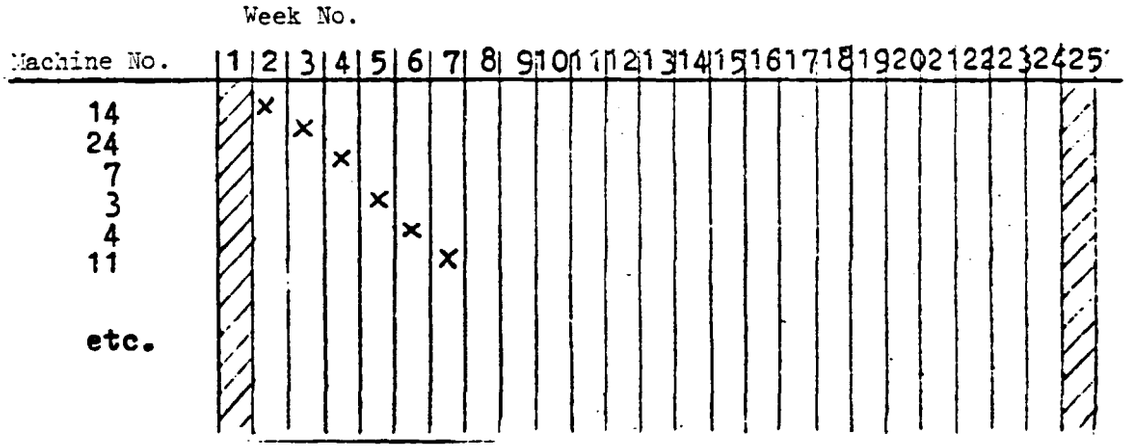
From these figures the planning list is then drawn up. All the jobs on the same machine should be done together, although at different intervals. For instance, jobs 1, 3, 4 and 5 all refer to machine No. 4: job 1 must be done once a week and should be entered under the heading for each week, job 2 is to be done every other week and should be entered under weeks 1, 3, 5, 7, 9 etc., job 4 falls due every four weeks and should be entered under weeks 1, 5, 9, 13 etc. and job 5 has to be done at 12-weekly intervals and should be entered under weeks 1, 13, 25 etc. Jobs 7-9 belong to machine No. 6; jobs 7 and 8 are to be done at four-weekly intervals and should be entered under weeks 2, 6, 10, 14, 18 etc.; job 9 is a 12-weekly job and should be entered under weeks 2, 14 and 26; and so on for all the other jobs. It will be noticed that the various machines are given different starting weeks in order to balance the number of jobs done each week.

2. Planning of jobs to be done during a stop period

These jobs are planned in a similar way, except that all categories are dealt with at one time, so that the number of stop-periods can be held to a minimum.

The first thing to do is to establish, in co-operation with the production planning department, a main "stop-list" for all the machines (see figure V).

Figure V. Stop-list



The stop-list will indicate the most suitable time for the machines to be stopped, the idea being to ensure that not too may are serviced in the same week. In the sample stop-list, weeks 1 and 25 are shaded, since they are weeks in which holidays fall, which makes them unsuitable for a stop-period. Although not shown as such in the figure, weeks 31 and 41 are also holiday periods, and therefore unsuitable.

The next step is the detailed planning, for which the maintenance guides provide the necessary information. The following table shows the stop (S) jobs indicated in the maintenance guides for machines 14, 24 and 1.

Machine No.	Job No.	Interval between jobs
14	15	12
	18	48
	19	12
	20	4
	21	96
24	52	4
	53	12
	59	48
	60	24
	61	12
1	2	12
	3	12
	6	48

Since a stop has already been planned for week 2 (see main stop-list), the job numbers are entered on the planning list (see figure VI), as follows:

Job 15 to be done in weeks 2, 14, 27 (25 is not counted) and 40 (31 is not counted)

Job 18 to be done in week 2

Job 19 to be done in weeks 2, 14, 27 and 40

Job 20 to be done in weeks 2, 6, 10, 14, 18, 22, 27, 32, 36, 40, 45 and 49

Job 21 to be done in week 2

When all the jobs to be carried out on machine No. 14 have been noted in the planning list, a line should be drawn below the last job. This means that all the jobs above that line belong to one machine, which gives a better overview. Work then starts on machine No. 24 (pre-planned for week 3 in the main stop-list). Starting with week 3, all the job numbers should be filled in as described above. Work then continues on the next machine, and so on.

Figure VI demonstrates how the planning list for machines Nos. 14, 24 and 1 will look.

E. Preventive maintenance routines

When filling in preventive maintenance guides, each category should be given a separate page, to keep down the number of copies needed. When the file has been sorted and job numbers assigned, the whole file should be copied.

Copies of all the pages for each category of job should be given to the section that will be carrying out the work. In addition, each section should also be given a copy of the relevant instructions. The above documents should be protected by plastic covers.

1. Routines for jobs to be done while the machine is running

A number of jobs are planned for each week, and the job numbers given to the section involved. The job numbers and the copies of the maintenance guides constitute a complete "work package". In addition, detailed descriptions are given in the maintenance instructions.

Figure VI. Planning list for stop-jobs for machines Nos. 14, 24 and 1

Week No.

Job No.	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
		15	52	2		20	52			20	52			15	52	2		20	52			20	52			
		18	53	3										19	53	3										
		19	59	6										20	61											
		20	60																							
		21	61																							

Week No.

Job No.	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	15	52	2			20	52			20	52			15		52	2		20	52			20	52		
	19	53	3											19		53	3									
	20	60												20		61										
		61																								

In carrying out the work, the following routines should be followed:

(a) Any faults that are detected and can be repaired without stopping the machine (other than during a change of tools or work-pieces etc.) should be seen to immediately if the job is not supposed to take longer than about 30 minutes;

(b) Any other faults that are detected should be reported to the maintenance engineer and recorded on a work-order so that they can be repaired later. The routines are set out in figure VII.

2. Routines for job to be done during a stop period

In this case, too, a number of jobs are to be done each week. The planning list will show which machine has to be stopped. The length of the "stop time" should then be estimated and the information passed on to production planning from two to three weeks ahead of time, so that a date can be set for the work to be done.

The job numbers for each category should be recorded on a work order, which, together with the maintenance guides and the instructions, constitutes a complete "work-package".

When the work has been completed, a work report containing a description of detected faults and repairs should be given to the maintenance engineer. The work report should be analysed in order to find out if and how the faults etc. could have been avoided. If the cause of the faults is found, appropriate preventive methods should be indicated in the preventive maintenance guides.

Figure VIII illustrates the above procedure.

Figure VII. Routines for jobs to be done while the machine is running

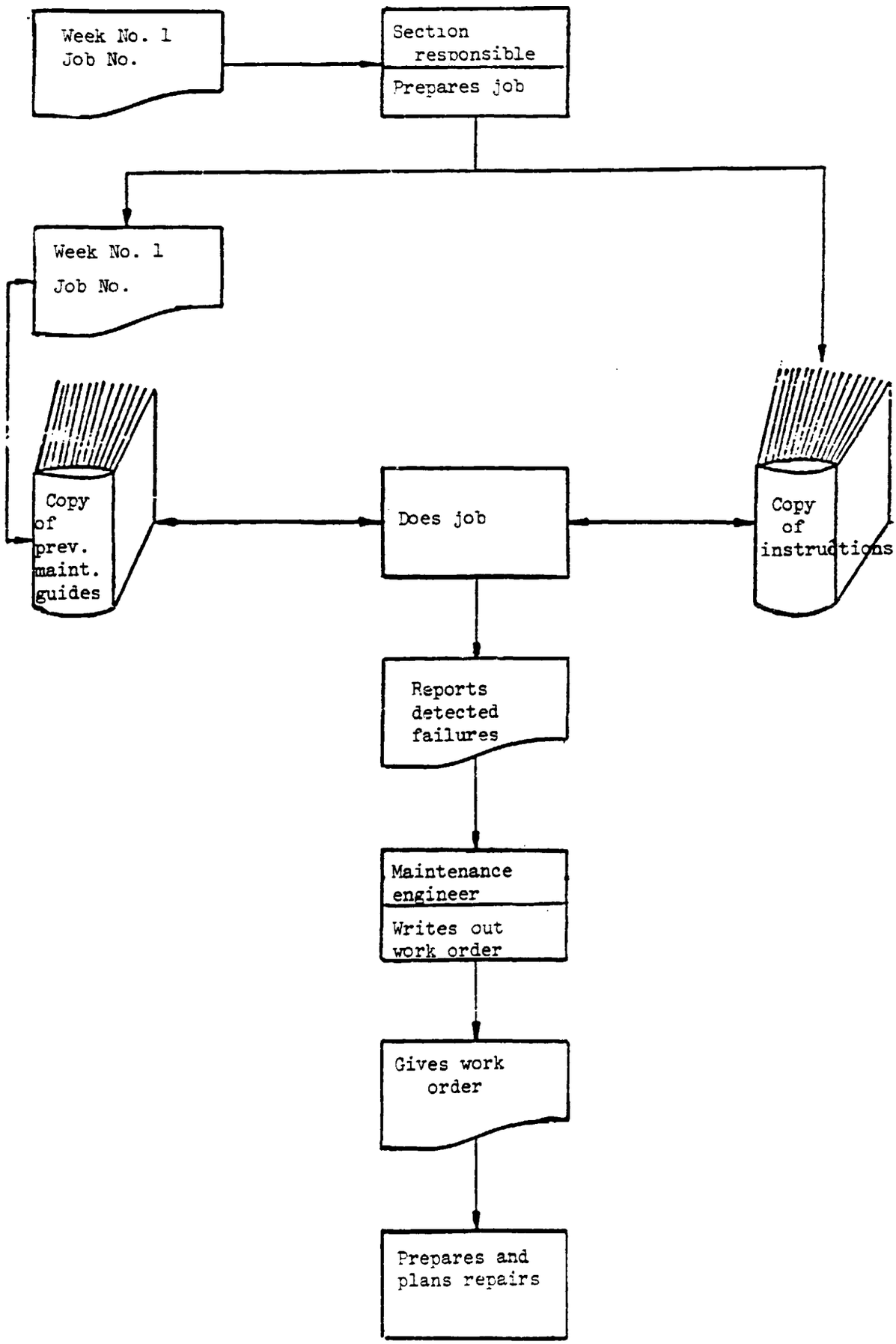
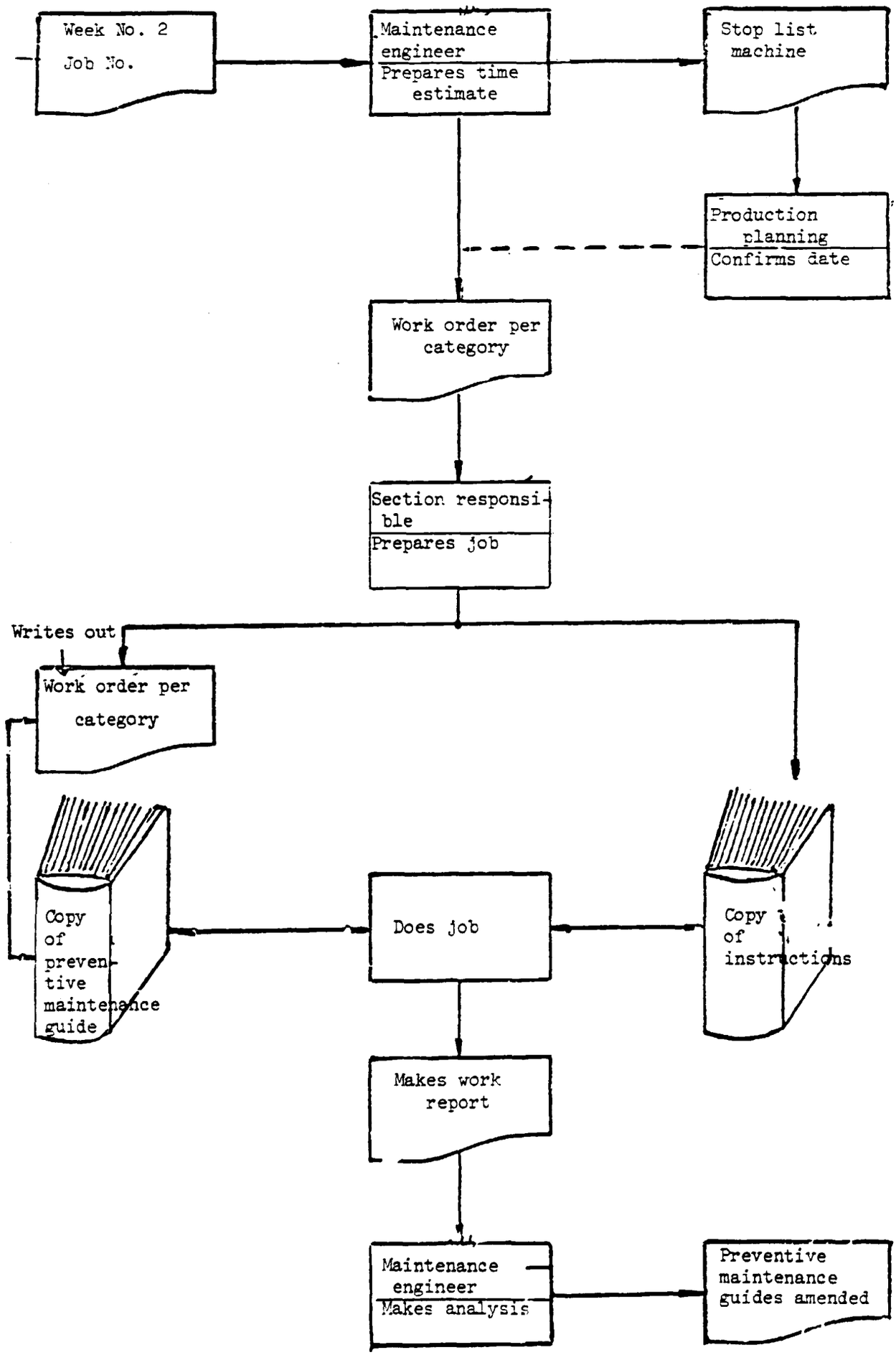


Figure VIII. Routines for jobs to be done during a stop-period



Appendix I

EXAMPLE OF AN OPERATOR'S CHECK-LIST

Universal lathe
(Machine No. 14)

Before starting

Lubricate marked points (see plan below).
Check oil level.

During operation

Observe spyhole on top of the headstock.
Oil must flow continuously; stop machine immediately if there is no oil flow.
Listen for abnormal noise in gear box, main spindle, cooling system.
Inform maintenance if there is any malfunction while operating the machine.

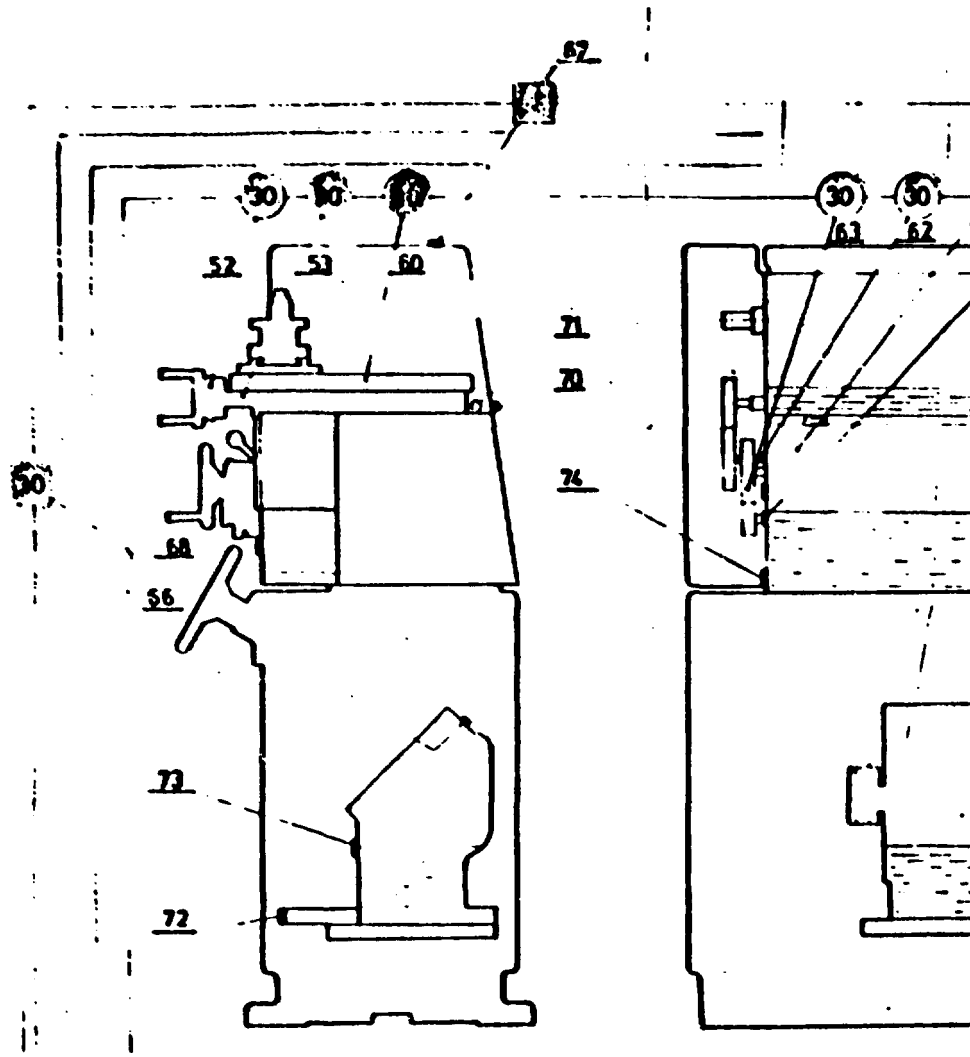
End of shift

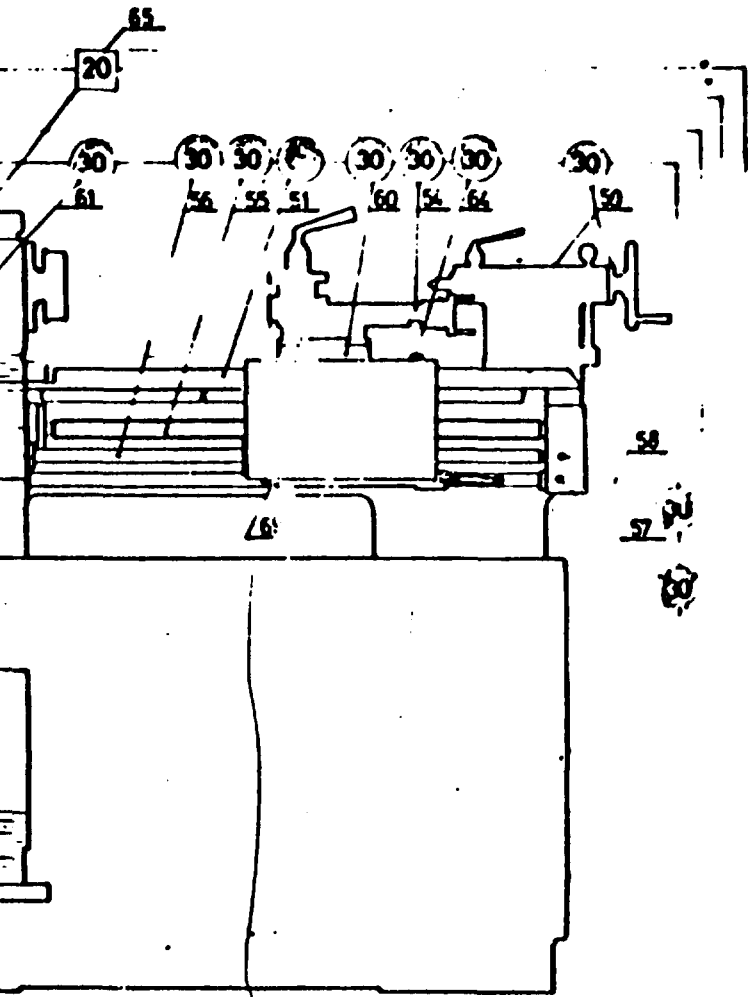
Carefully clean and oil:

- Chuck
- Top slide
- Cross slide
- Bed
- Tailstock
- Leadscrew

Clean tray below bed.

Machine No. 14

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Appendix II

EXAMPLE OF A PREVENTIVE MAINTENANCE GUIDE

Name: Universal lathe

Machine No. 14

Job No.	Category	Operation status	Interval	Subject	Description	Instruction
	L	O	1	Top slide	Grease surface between tool-holder and top slide	
	L	S	4	Head stock lubrication	Check oil level Clean oil filter	SL4
	L	S	4	Clutch on motor	Grease with grease gun	SL4
	L	O	4	Saddle-box lubrication	Lubricate through hole on top of saddle	
	L	S	24	Headstock lubrication	Change oil, approximately 4 litres	SL4
	L	S	24	Lead screw/ headstock	Remove lock and lubricate	
	L	S	48	Saddle-box lubrication	Change oil, approximately 0.75 litre	
	M	O	4	Machine, general	Check all levers for distinct operation Look for damage on switches, lamps oil eyes etc. Look for dirt, corrosion and other damage	
	M	S	12	Cooling system	Clean tank and pump Check pump, pipes and hoses	
	M	S	12	Bed	Clean and check scraper on cross saddle	MS5
	M	S	12	V-belts, main drive	Check V-belts for: Tension Cracks or other damage Check the pulleys for wear	MO1

Job No.	Category	Operation status	Interval	Subject
	M	S	48	Main inspection
	M	S	96	Condition of machine
	E	O	4	Cables, switches
	E	S	12	Main motor
	E	S	48	Main motor

Description	Instruction
Check alignment Measure axial and radial play in main bearings Check centrifugal clutch Check bed and slides for wear or damage Measure axial movement in lead screw	MS4
Measurement according to "test form"	MS6
Look for damage on cables, cable connections, switches and other electrical equipment	
Check motor for: Temperature (max. 55°C) Abnormal noise Vibrations	E01
Attention: when doing the above checks, the motor has to be running.	
Check that assembly bolts are tightened Make sure that the motor is clean and not subject to moisture	
Measure insulation with Megger Lubricate motor bearings	

Appendix III

EXAMPLE OF AN INSTRUCTION FOR MONITORING COMMONLY OCCURRING COMPONENTS*

ELECTRIC MOTOR

Feel motor with your hand. If scorching, it is probably too hot. The check:

- that inlet and outlet of cooling fan are not clogged. If there are separate cooling air ducts, these should have well perceptible temperature differences.
- that cooling fan is working
- that there is no insulating cover on the motor
- that motor is not overloaded. Read amperemeter, if any. Max. amperes (rated current) may be found on motor type plate.

TEMPERATURE
MAX. 65°C

Check temperature with your hand. Too high temperature may depend on:

- too much lubrication
- bearing damage
- overload (too much strain of V-belts etc.)

If necessary, listen to the bearings with a stethoscope etc.
For journal bearings, max. 60°C.

BEARING TEMPERATURE
MAX. 75°C
MAX. 60°C

Vibrations may depend on unbalance, defective lining-up of coupling, uneven load or electrical trouble. In case of electrical trouble, vibrations cease at once upon switch-off of current.

VIBRATIONS

Electric motors should not be subjected to dripping water, sludge etc.

MOISTURE

* Not formally edited.

Appendix IV

EXAMPLE OF A SPECIAL INSTRUCTION *

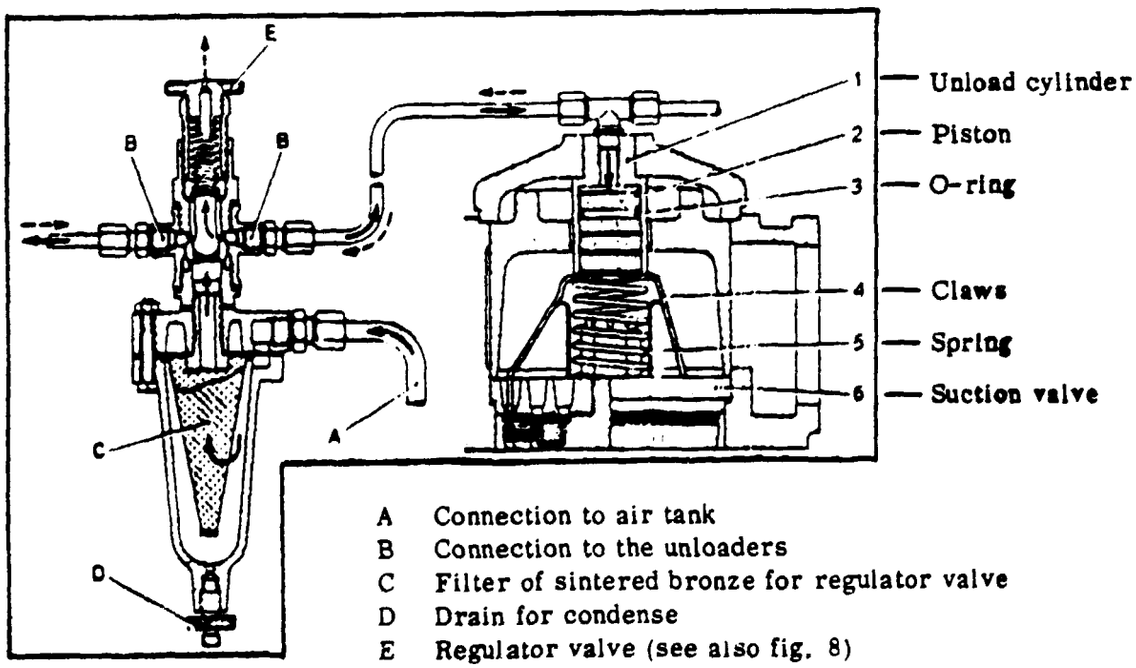
COMPRESSOR

Atlas Copco CR4, CR6, CT4, CT6

Inspect the cooler of CT-types for dirt on the air side of the cooler.	COOLER
The play of the gear train is correct if the movement is 0,5 - 2 mm at the outer	FAN GEAR
Check the air inlet pipe inside after removal of the air filter. Dirt indicates leaking filter or pipe. Must be repaired soonest possible.	SUCTION PIPE
Check and test the safety valves. Correct opening pressures are for :	SAFETY VALVES

Pressure tank:	0,6 kp/cm^2	above work pressure
Pressure pipe:	0,7 kp/cm^2	above work pressure
Cooler:	0,6 kp/cm^2	above work pressure

Fig. 7 Unloading system



A Connection to air tank
B Connection to the unloaders
C Filter of sintered bronze for regulator valve
D Drain for condense
E Regulator valve (see also fig. 8)

* Not formally edited.

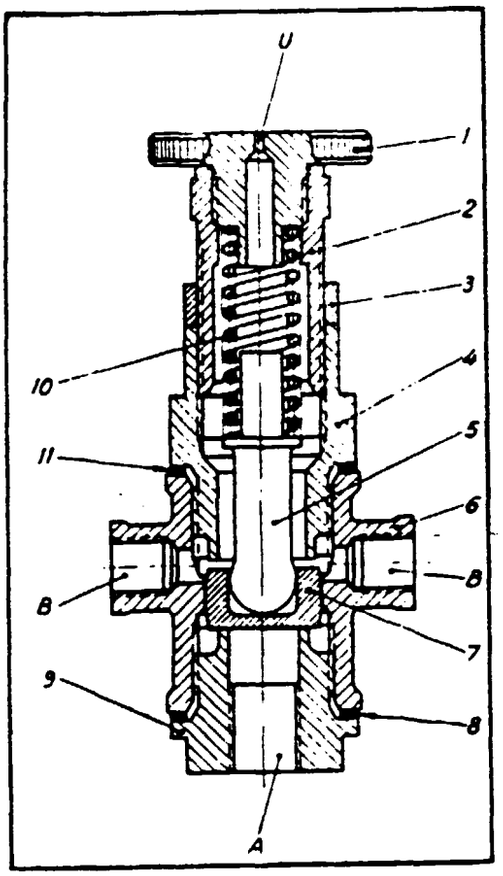


Fig. 8 Regulating valve

A Connection from air tank
B Connection to relief mechanisms
U Air escape hole

1 Unloading screw
2 Adjusting screw
3 Locking nut
4 Upper valve seat
5 Spring guide
6 Valve body
7 Valve
8 Copper sealing
9 Lower valve seat
10 Spring
11 Shims

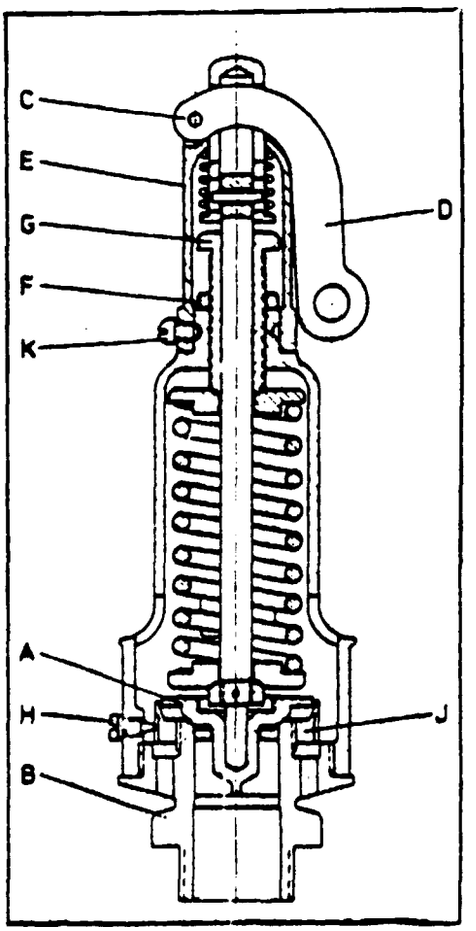


Fig. 9 Safety valve

A Valve
B Valve seat
C Locking pin
D Lever
E Case
F Locking nut
G Opening pressure adjusting screw
H Locking screw
J Pressure drop adjusting ring
K Locking screw

Trouble-Shooting

Fault	Cause	Action
Air tank pressure too low	Air consumption exceeds compressor capacity	Check compressed air system for consumption and leaks
	Regulating valve setting incorrect	Check unloading pressure, see "Adjustment of Regulating Valve"
	Faulty valve	See "Valve Faults"
Compressor does not unload	Dummy piston O-rings worn or defective	Replace O-rings
	Regulating valve setting incorrect	Check unloading pressure, see "Adjustment of Regulating Valve"
Pressure gradient too low (should be appr. 0.4 atm)	Excessive valve lift in regulating valve	Reduce valve lift by removing one or more shims, see "Adjustment of Regulating Valve"
Oil pressure falls below 0.8 kg/cm^2	Motor wrongly connected, resulting in wrong direction of rotation	Reconnect motor. Direction of rotation = clockwise looking from pump side.
	Out of oil	Clean crankcase, fill up with oil
	Oil pressure gauge faulty or gauge tube clogged	Change pressure gauge or clean tube
	Oil screen clogged	Clean oil screen
	By-pass valve stuck	Dismantle and clean valve
	Crank bearing play too great for pump to maintain pressure	Check bearings, play should be appr. 0.05 mm. Recondition if necessary
Compressor using too much oil	Oil level too high in crankcase	Draw off oil until level is between marks on dipstick
	Leaking packings	Locate oil leak and replace packings
	Air escape valve clogged	Dismantle and clean valve. Change if necessary.

Appendix V

EXAMPLE OF A DETAILED INSTRUCTION*

CYLINDER HEAD

ACTIVITY: Dismantling

RECOMMENDED INTERVAL: 8000 h (In connection with piston withdrawal)

MAIN INSTRUCTION MANUAL: 12.2
SPARE PART CATALOGUE: 120-1

TECHNICAL DATA:

Opening pressure for cylinder head nuts: 395 bar (400 kp/cm^2)
Tightening pressure for cylinder head nuts: 375 bar (380 kp/cm^2)
Weight of cylinder head: 95 kg

SPARE PARTS AND MATERIAL:

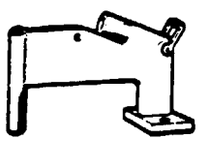
- Seal ring between cylinder head and liner
- O-rings for cooling water discharge pipe

TOOLS:

Hydraulic tool for cylinder head nuts

Pos. 1

Lifting tool for cylinder head



Pos. 2

Extension tube for turning device

Pos. 16

*Not formally edited.

27 mm special open end wrench for injection pipe

Pos. 26

Ratchet handle

Pos. 40

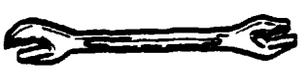
Ratchet handle for turning device

Pos. 41

Extension bar for ratchet wrench for exhaust pipe (applies to in-line engine)

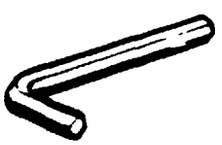
Pos. 42

14 mm and 19 mm open end wrenches



Pos. 46

6 mm and 10 mm hex. socket screw keys

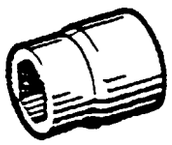


Pos. 47

10 mm hex. socket screw bit for exhaust pipe, lower screws (applies to in-line engine)

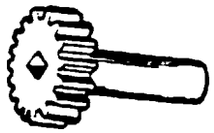
Pos. 48

19 mm socket wrench for rocker arm bracket and open end wrench



Pos. 49

Turning device

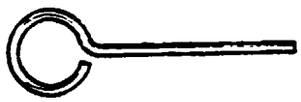


Pos. 55

Guiding lever for lifting tool (necessary only for V-engine)

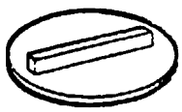
Pos. 57

Pin for cylinder head nuts

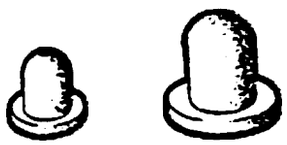


Pos. 65

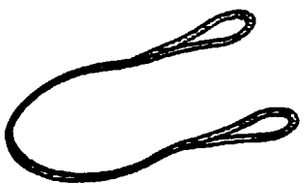
Disc for covering cylinder opening



Plastic caps for injection pipe socket and push rod pipe



Nylon rope for lifting tool



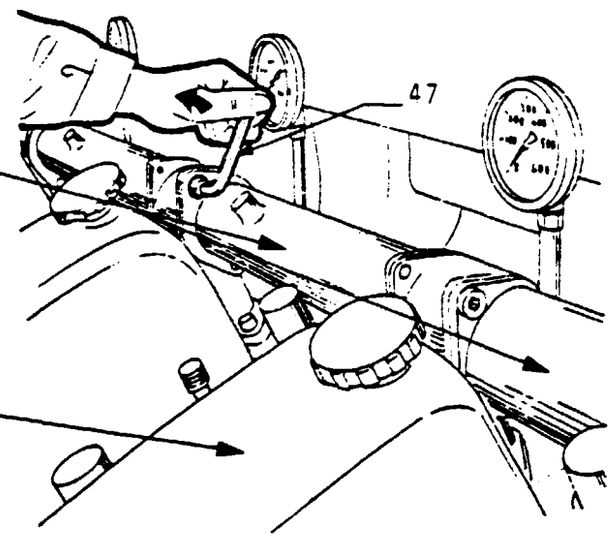
TO OBSERVE BEFORE EXECUTION:

Drain the cooling water so that no water runs out when lifting off the head. If the cooling water has been treated with additives, collect if for reuse, if possible.

The operation to be carried out by two men.

DISMANTLING:

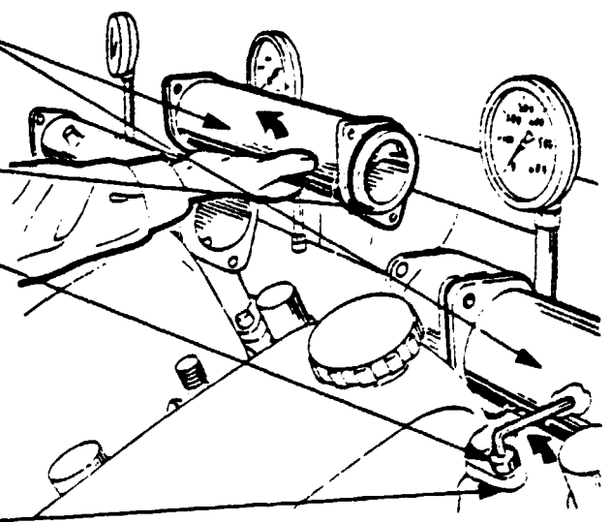
Loosen the eight hex. socket screws and push back the flanges holding the pipe parts on both sides of the T-pipe. Use 6 mm hex. socket screw key.



NOTE!

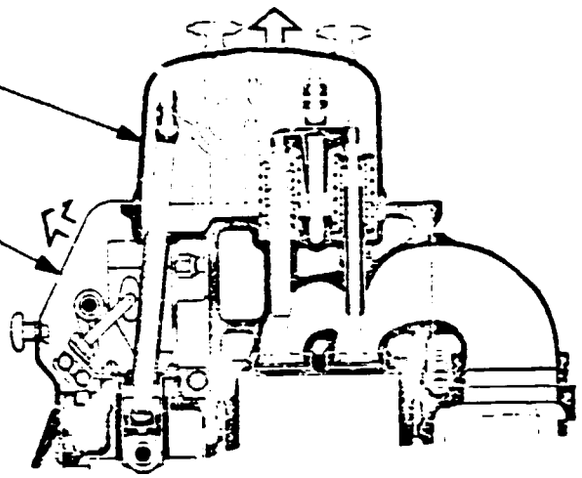
Do not remove the cylinder head cover before the cooling water discharge pipe is removed to prevent residual water from entering the lubricating system.

Lift off both pipe parts. If necessary, knock lightly with a wooden or plastic hammer. The O-rings can be left if they are intact. Loosen the two hex. socket screws holding the flange of the T-pipe against the cylinder head. Use 10 mm hex. socket screw key. Extend the key with a tube if the screws do not move. Remove the T-pipe and take care of the O-ring.

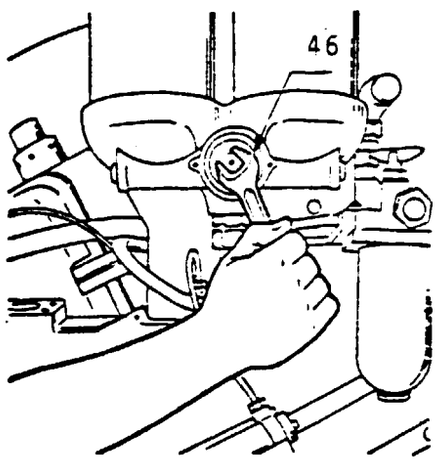


Remove the cylinder head cover.

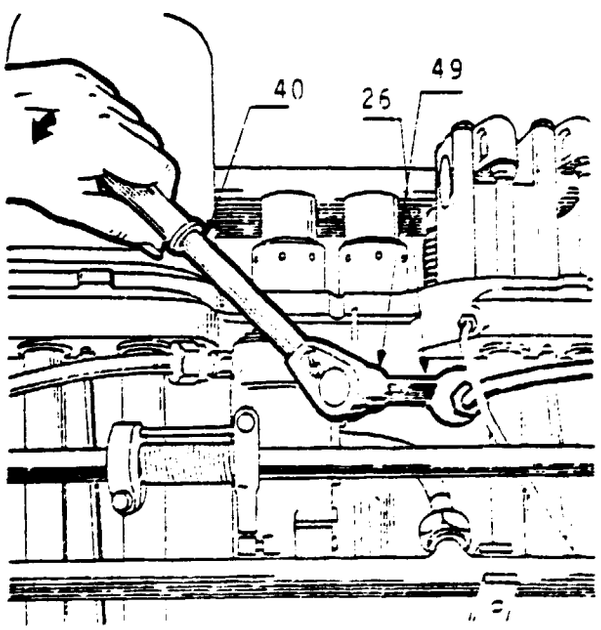
Remove the side cover.



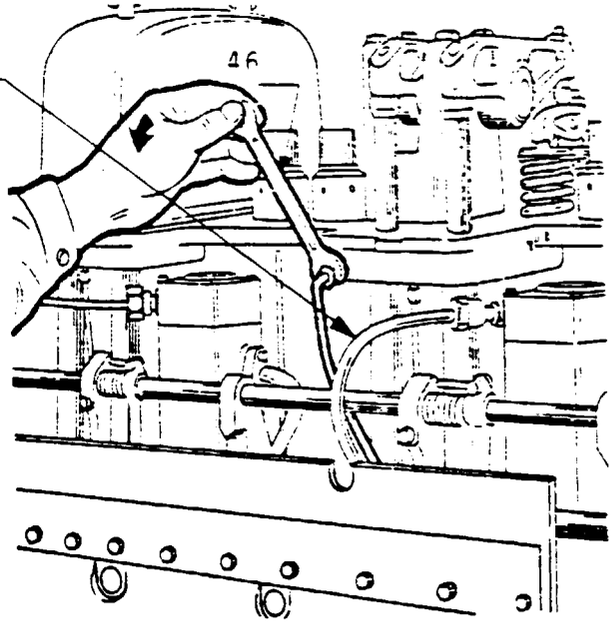
Shut off the fuel supply to the engine on the main fuel filter with a 19 mm open end wrench.



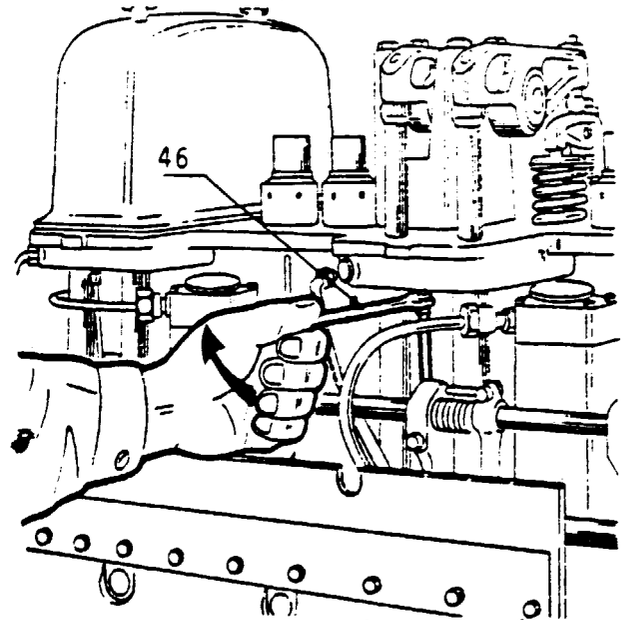
Loosen both connections for the injection pipe. Use 27 mm open end wrench.



Put back the injection pipe on the pump side as the figure shows. Cover the unprotected connection in the head. Loosen the upper connection on the supply pipe for the rocker arm lubrication. Use 14 mm open end wrench.



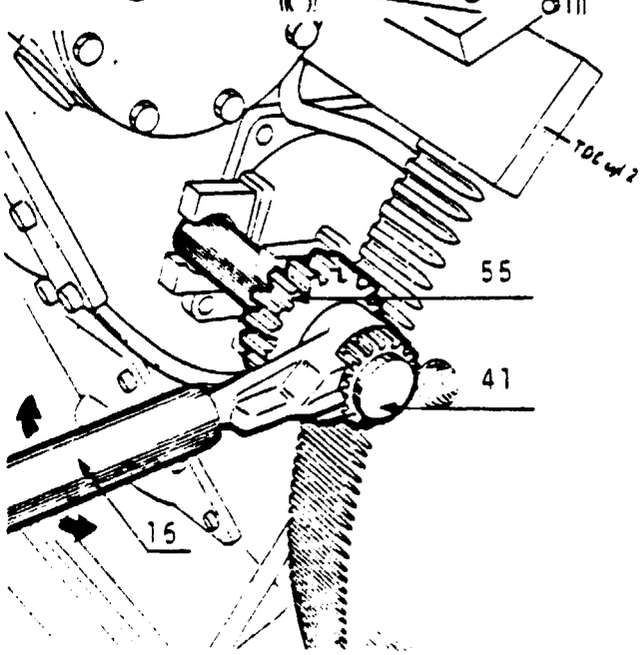
Loosen the upper connection of the control air pipe. Use 14 mm open end wrench.



NOTE!

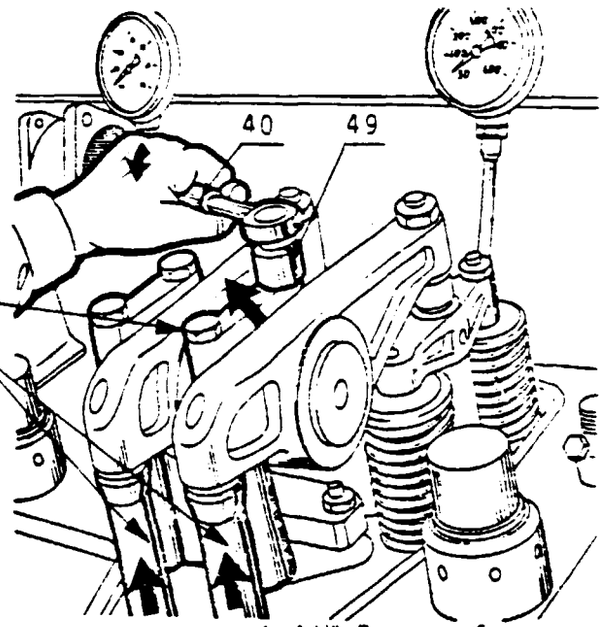
The leak fuel oil pipe from the injection valve need not be loosened.

The operation is facilitated if the engine is turned so that the springs of the inlet and exhaust valves are completely unloaded, i.e. when the push rods are not jammed between cam and rocker arm but are loose, or at TDC at ignition for the cylinder in question.



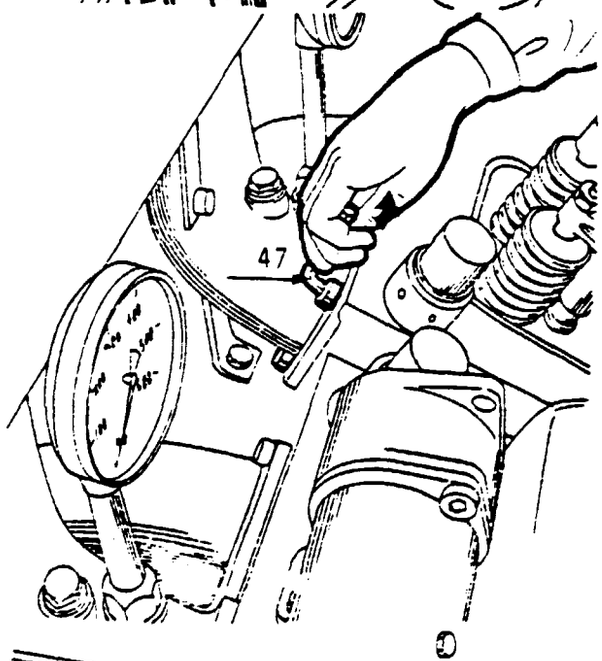
Loosen the four screws of the rocker arm bracket crosswise in steps. Use 19 mm socket wrench.

Lift off the rocker arm bracket.
Lift out the push rods.



Loosen the two upper screws for the exhaust pipe. Use 10 mm hex. socket screw key. Extend the key with a tube, when necessary.

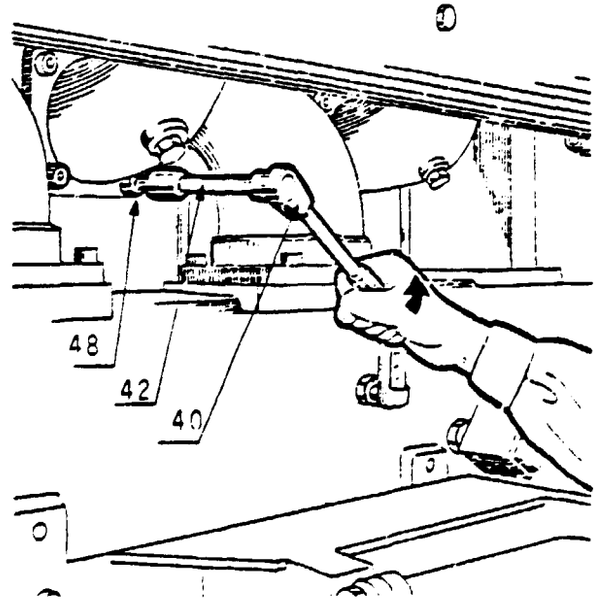
V-engine
Loosen also the two lower screws.



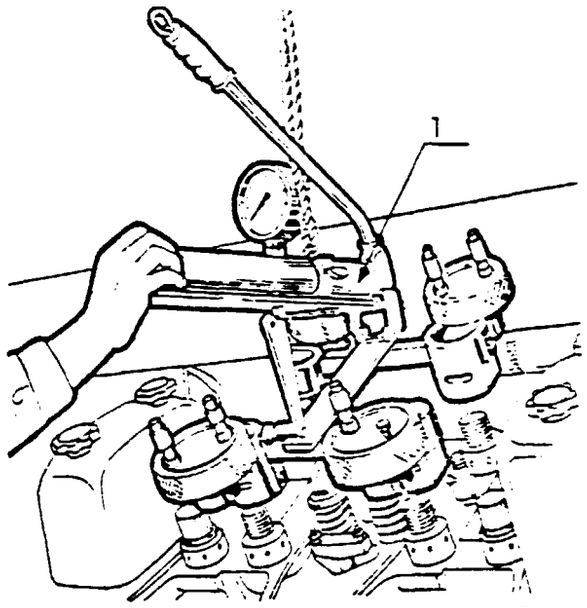
In-line engine
Loosen the two lower screws for the exhaust pipe from the rear side of the engine. Use 10 mm hex. socket screw bit.

NOTE!

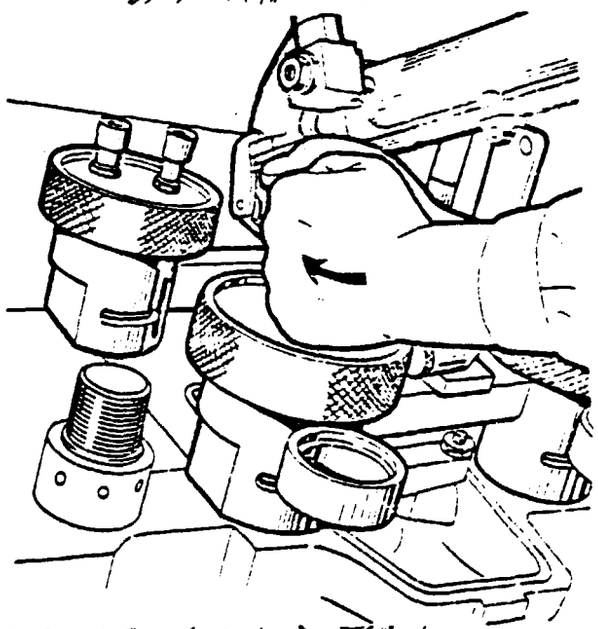
The charge air bend need not be loosened. It accompanies the cylinder head.



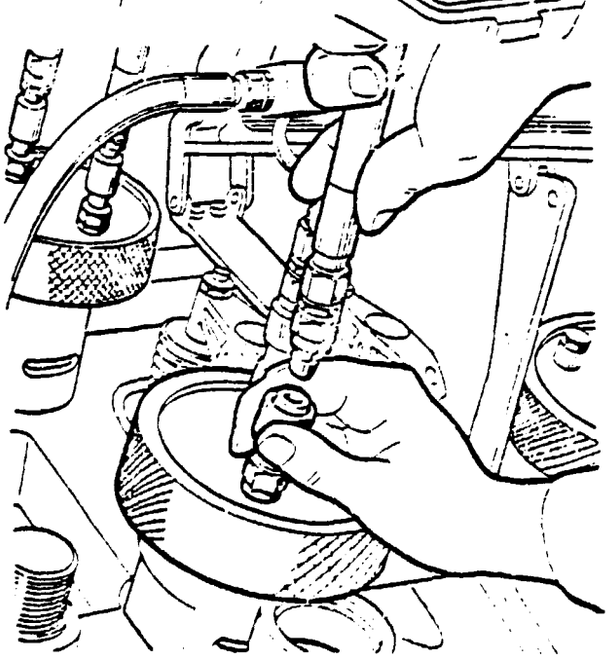
Remove the protecting caps from the cylinder head screws. Lift the hydraulic tool for the cylinder head bolts in position by means of a lifting tackle.



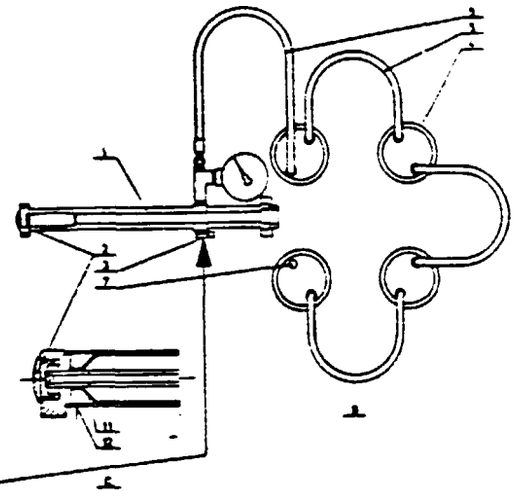
Screw the hydraulic cylinders on the cylinder head screws as far as possible.



Connect the hoses to pump and cylinder according to the scheme on the next page.



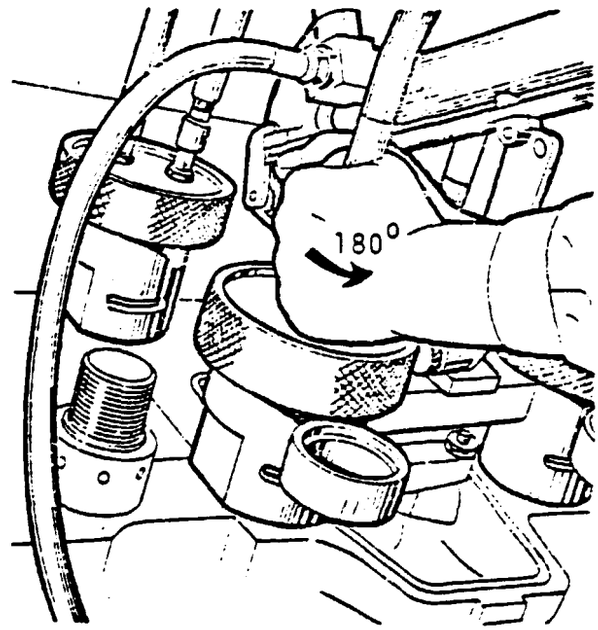
1. Pump
2. Plastic plug (oil filling)
3. Relief valve
4. Cylinders
5. Hose
6. Hose
7. Air vent screw
11. Rubber hose
12. Oil indicating hole



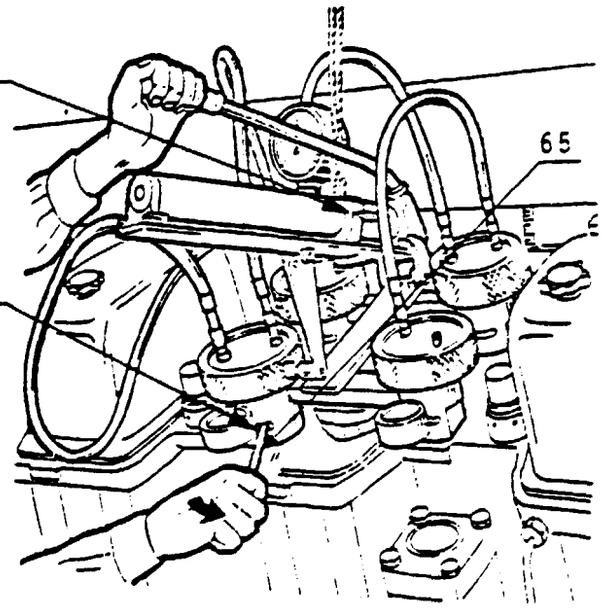
Check that the relief valve of the pump is open and keep on screwing the cylinders clockwise to expel possible oil out of the cylinders.

NOTE!

Loosen the cylinders half a revolution (180^{o}).



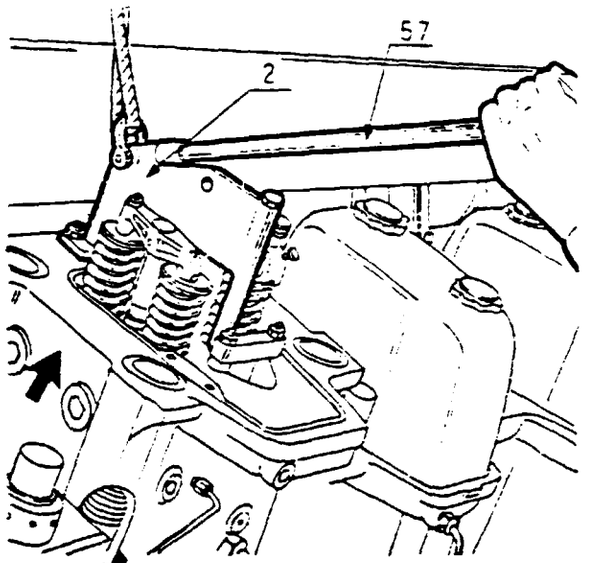
Shut the relief valve.
Pretension the screws by pumping the hydraulic pressure to 375 bar (380 kp/cm^2). Then loosen the nuts about one revolution by means of the pin.
Open the relief valve. Disconnect the hoses. Screw off the hydraulic cylinders. Lift off the hydraulic tool. Remove the four cylinder head nuts.



Mount the lifting tool for the cylinder head. Use 10 mm hex. socket screw key and 19 mm socket wrench. Lift off the cylinder head.

V-engine

Guide with the lever inserted into the lifting tool.



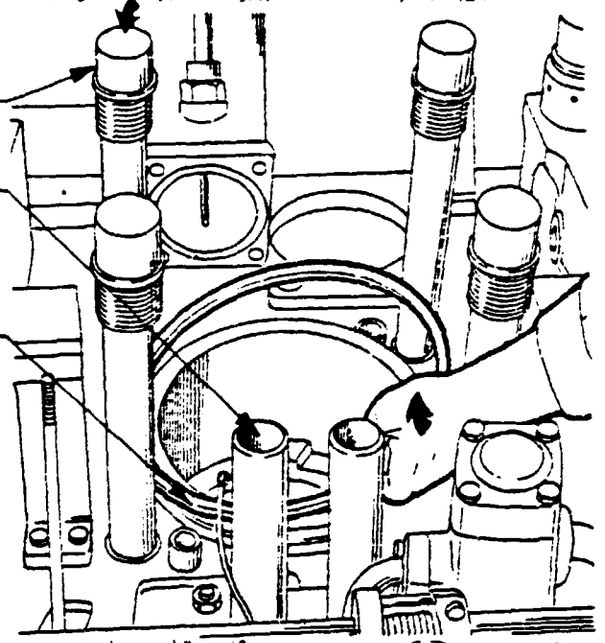
NOTE!

Place the nead on a plane base and dismount the lifting tool.

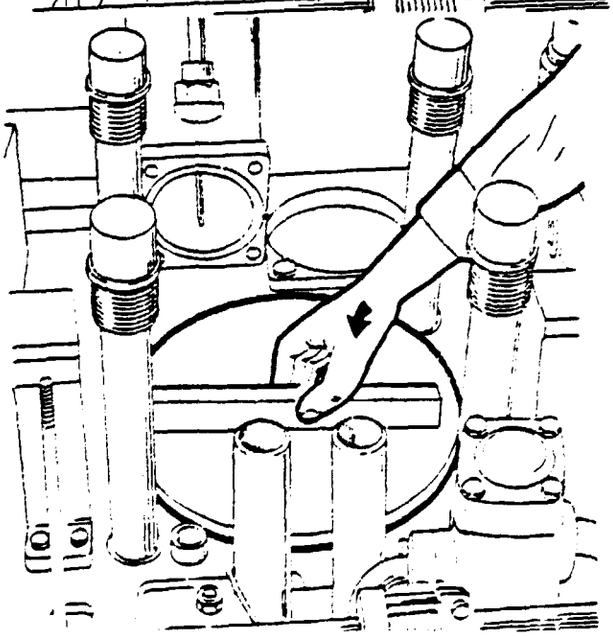
Apply the protecting caps on the cylinder head screws.

Cover the protecting pipes of the push rods to protect from dirt.

Remove the seal ring.



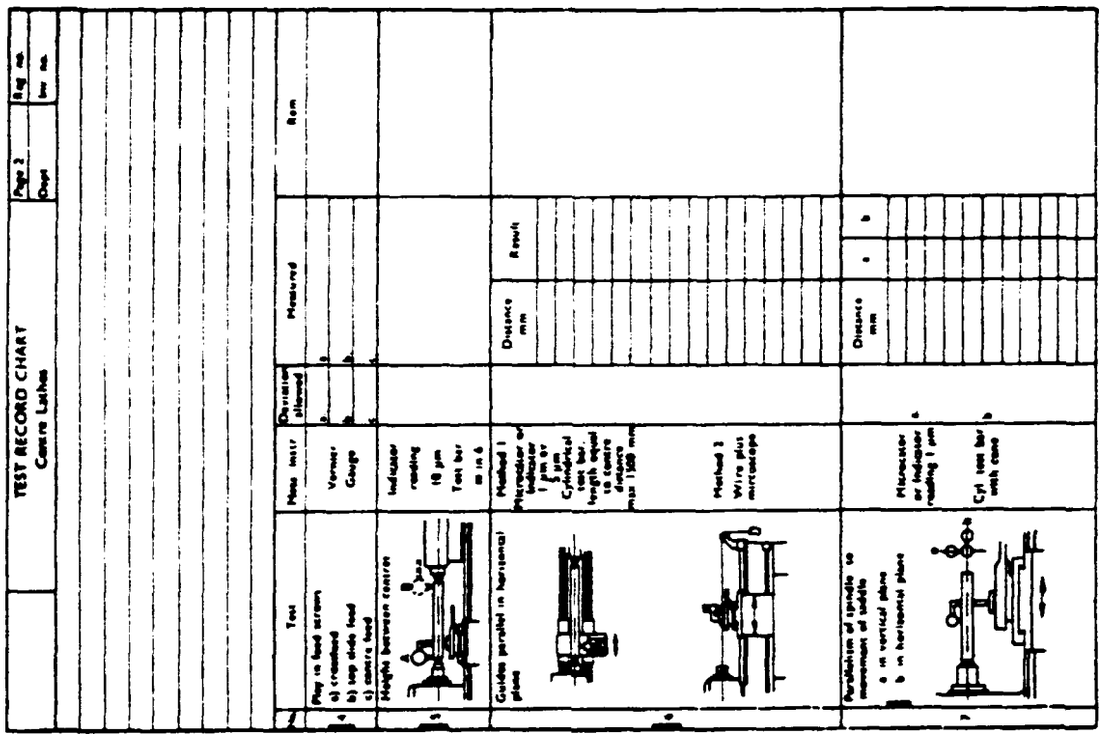
Cover the cylinder opening with a plywood disc or similar.



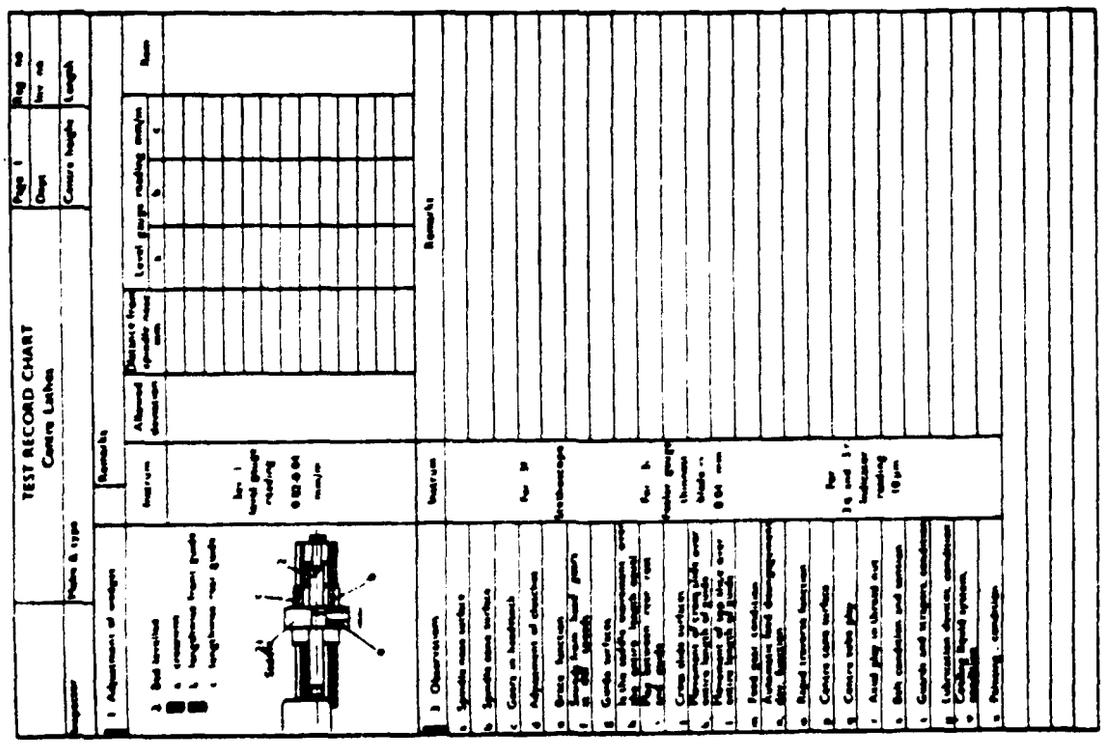
See instruction No 2 regarding cleaning, inspection and reconditioning of cylinder head.

Appendix VI

EXAMPLE OF AN INSTRUCTION FOR CARRYING OUT ACCURACY TESTS*



Test Record Chart—2



Test Record Chart—1

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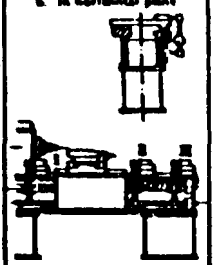
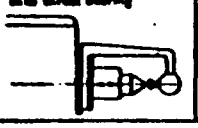
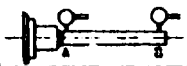
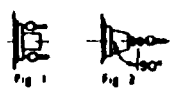
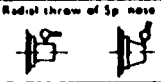
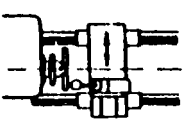
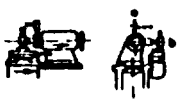
* Not formally edited.

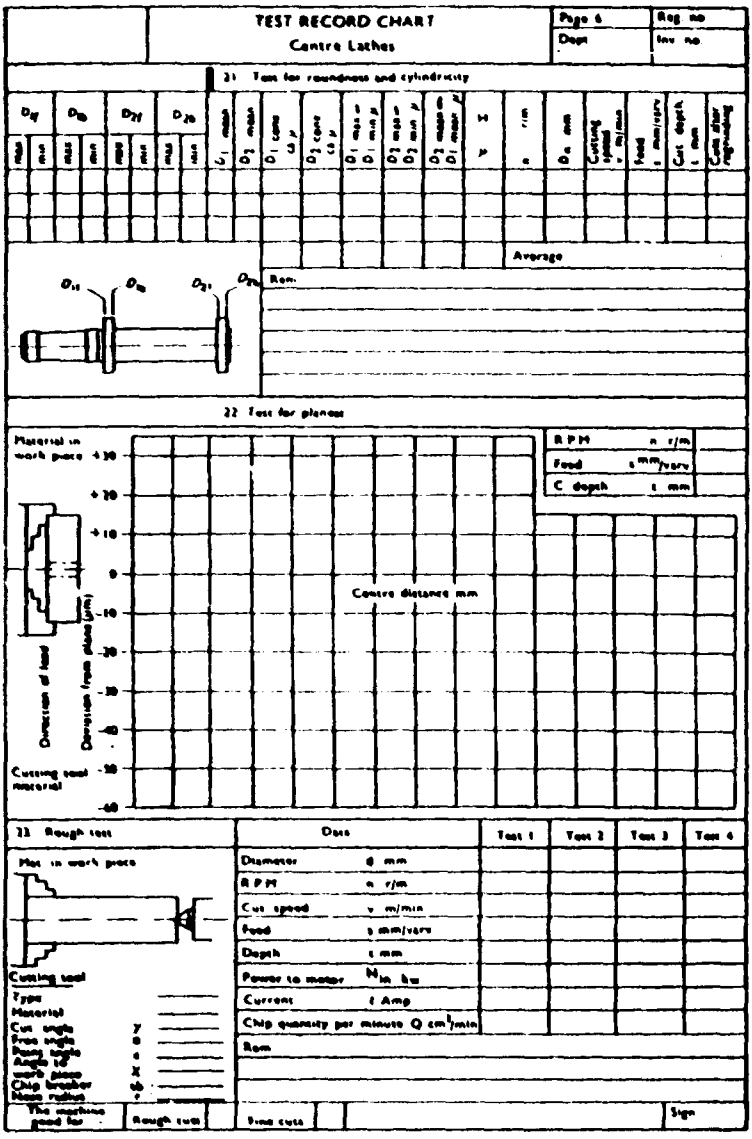
	TEST RECORD CHART Centre Lathes			Page 4	Reg. no
				Dept.	Inv. no
	Test	Instrum.	Deviation allowed	Result	Rem.
13	Parallelism of spindle to movement of carriage a. in vertical plane b. in horizontal plane 	Indicator reading 1 µm	a.	a.	
			b.	b.	
14	Spindle parallelism to movement of carriage a. in vertical plane b. in horizontal plane 	Indicator reading 1 µm Cylindrical test bar, with cone	a.	a.	
			b.	b.	
17	17.1 Axial thrust of lead screw 17.2 Axial play of lead screw 	Indicator reading 1 µm plan parm Steel ball	17.1	17.1	
			17.2	17.2	
18	18.1. Parallelism of lead screw to saddle guides a. in vertical plane b. in horizontal plane 18.2. Concentricity of lead nut to screw a. in vertical plane b. in horizontal plane 	Indicator reading 10 µm Bridge with arms	18.1.a.	18.1.a.	
			18.1.b.	18.1.b.	
			18.2.a.	18.2.a. II - I II - III	
			18.2.b.	18.2.b. II - I II - III	
19	Axial play in spindle axial thrust bearing 	Indicator reading 1 µm plan parm			

Test Record Chart—4

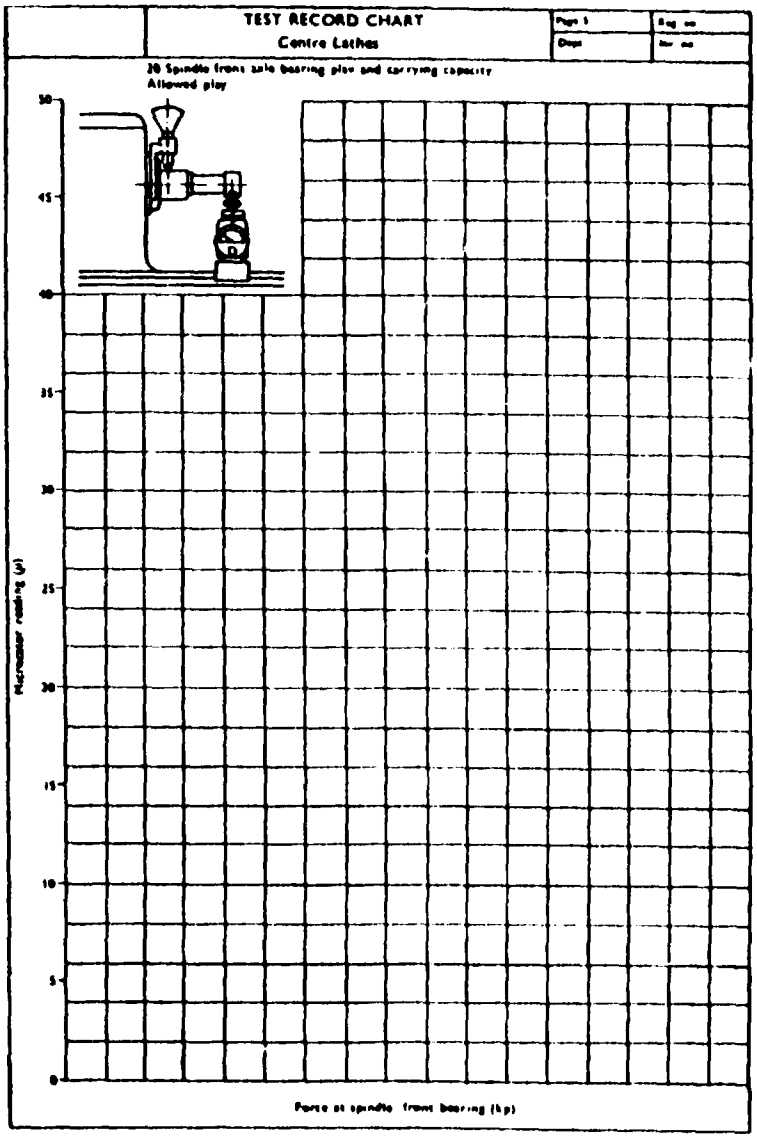
	TEST RECORD CHART Centre Lathes			Page 1	Reg no
				Date	Inv no

No	Test	Meas. instr.	Deviation allowed	Measured	Rem
8	Parallel movement of top slide to spindle in vertical plane 	Micrometer or indicator reading 1 µm Cylindrical test bar with cone			
9	Radial throw of spindle cone A At the spindle nose B mm from A 	Micrometer or indicator reading 1 µm Cylindrical test bar with cone	A B	1 2 3 4 Mean value A B	
10	Axial throw of spindle  Fig 1 Fig 2	Micrometer or indicator reading 1 µm Convex point at method fig 1 plan at method fig 2			
11	Radial throw of Sp. nose 	Indicator reading 1 µm			
12	Centre throw 	Indicator reading 1 µm		1 2 3 4 Mean value	
13	Straightness of cross slide movement and angularity to spindle 	Indicator reading 10 µm Rule with fastener		Distance from centre mm / Result	
14	Parallelism of tailstock guides to movement of saddle a in vertical plane b in horizontal plane 	Indicator reading 1 µm or 5 µm possibly indicator reading 10 µm		Distance from tailstock right-hand position mm / a / b	

Test Record Chart—1



Test Record Chart—6



Test Record Chart—5

Annex III

IMPLEMENTATION OF THE PREVENTIVE MAINTENANCE SYSTEM

I. GENERAL

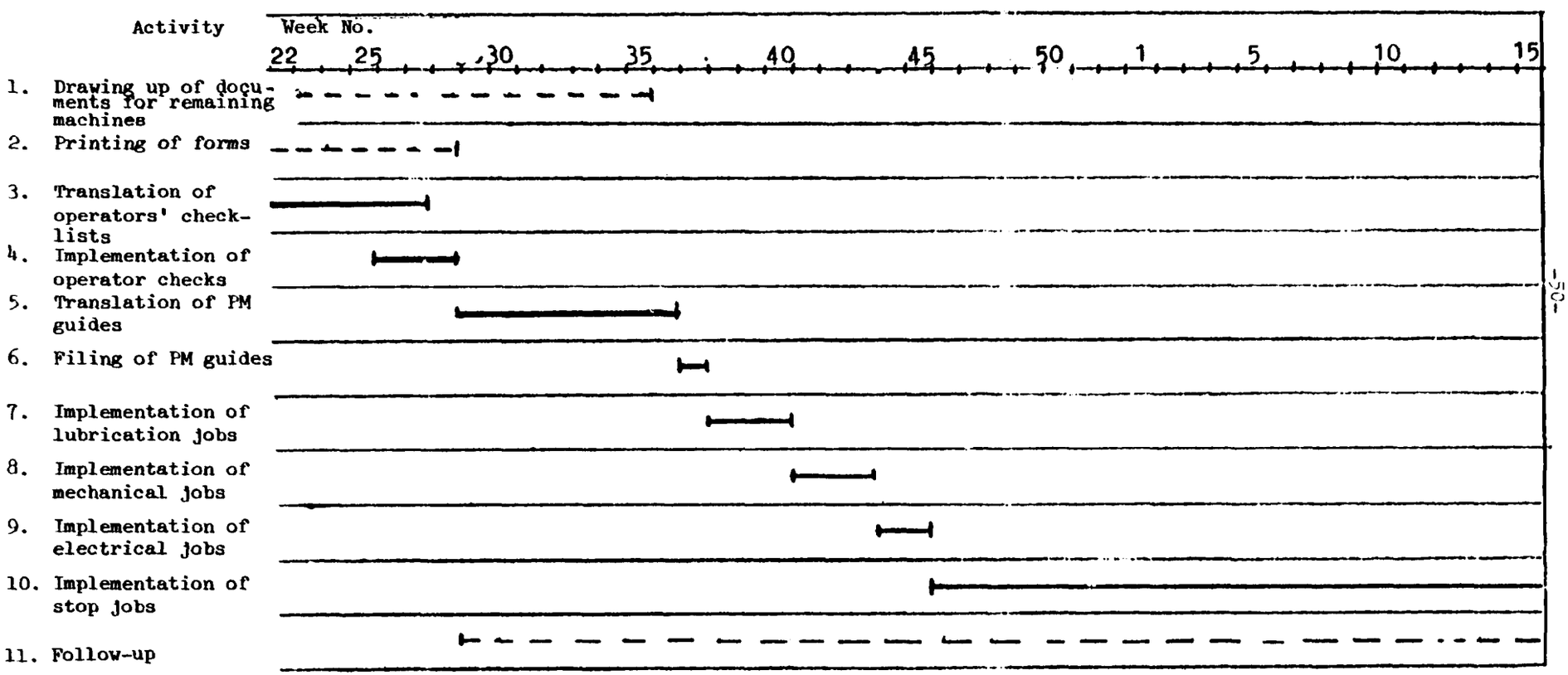
In any preventive maintenance system, numerous activities have to be carried out by both maintenance engineers and the personnel actually doing the work, in addition to their normal work-loads. The maintenance engineers are responsible for drawing up the various documents, planning activities, training and instructing the personnel concerned, drawing up instructions etc.

The personnel responsible for doing the work have to carry out their normal duties, that is, repairs etc., as well as the inspections and condition monitoring specified in the preventive maintenance system. Furthermore, in the course of the inspections, numerous faults will be discovered and have to be repaired or adjusted.

In view of the above it is advisable to introduce preventive maintenance a step at a time, and to complete each step before starting the next one.

The following schedule of activities has been worked out for the Specialized Institute for Engineering Industries.

SCHEDULE OF PREVENTIVE MAINTENANCE ACTIVITIES



II. DESCRIPTION OF ACTIVITIES

Drawing up of preventive maintenance documents for remaining machines or equipment

Before the system is implemented, documents such as operators' check-lists and preventive maintenance guides must be drawn up for all remaining machines and equipment. This can be done in co-operation with operators and maintenance personnel. Manufacturers manuals should be used as guide-lines.

Printing of forms

The layout of forms for preventive maintenance guides and instructions should be established, translated into Arabic and printed. Approximately 500 preventive maintenance guides and 1,000 instructions sheets are needed.

Translation and preparation of operators' check-lists

Most of the operators' check-lists have to be translated into Arabic and sketches copied or drawn.

Implementation of operators' check-lists

To ensure that the most basic maintenance requirements are fulfilled, the operators' check-lists should be introduced as a first step. The check-lists are given to the operators, the stated activities must be explained and the operator should be motivated to do the jobs. In order to find out whether there are any mistakes in the descriptions, the jobs should be done together with the operator and any faults corrected immediately.

Translation of preventive maintenance guides

All job descriptions in the preventive maintenance guides must be translated into Arabic and typed on the printed forms provided.

Filing of preventive maintenance guides

A logical sequence should be established for the various inspection jobs, in consultation with the staff responsible for carrying out the work, and the preventive maintenance guides should be filed in that order. The job numbers should be filled in and the preventive maintenance guides copied.

Lubrication jobs

A file containing copies of the preventive maintenance guides for lubricators should be handed over to the staff responsible for carrying out the work. All lubrication work to be done while the machine is in operation (L-O jobs) should be gone over in detail on the machine and each one discussed with the lubricator. Any faults should be corrected immediately. Any instructions that are missing should be filled in in co-operation with the lubricator the first time that the job is done. The jobs should then be planned and the routine lubrication activities should begin.

Mechanical jobs

The routine is the same as for the lubrication jobs.

Electrical jobs

The same routine should be followed.

Stop jobs

When carrying out work after the machine has been stopped, the first thing to do is to draw up a main stop list, in co-operation with the Production Planning Department. All the stop jobs should then be planned in detail and the necessary information given to the staff responsible for the work.

The first time the job is done on a machine, the maintenance engineer should be present to give explanations and instructions. This could be done by using a camera and photographing each job sequence.

Follow-up

There should be a continuous follow-up of each stage in order to check routines, results etc. Any change in methods or additional jobs etc. should be discussed and incorporated in the system.