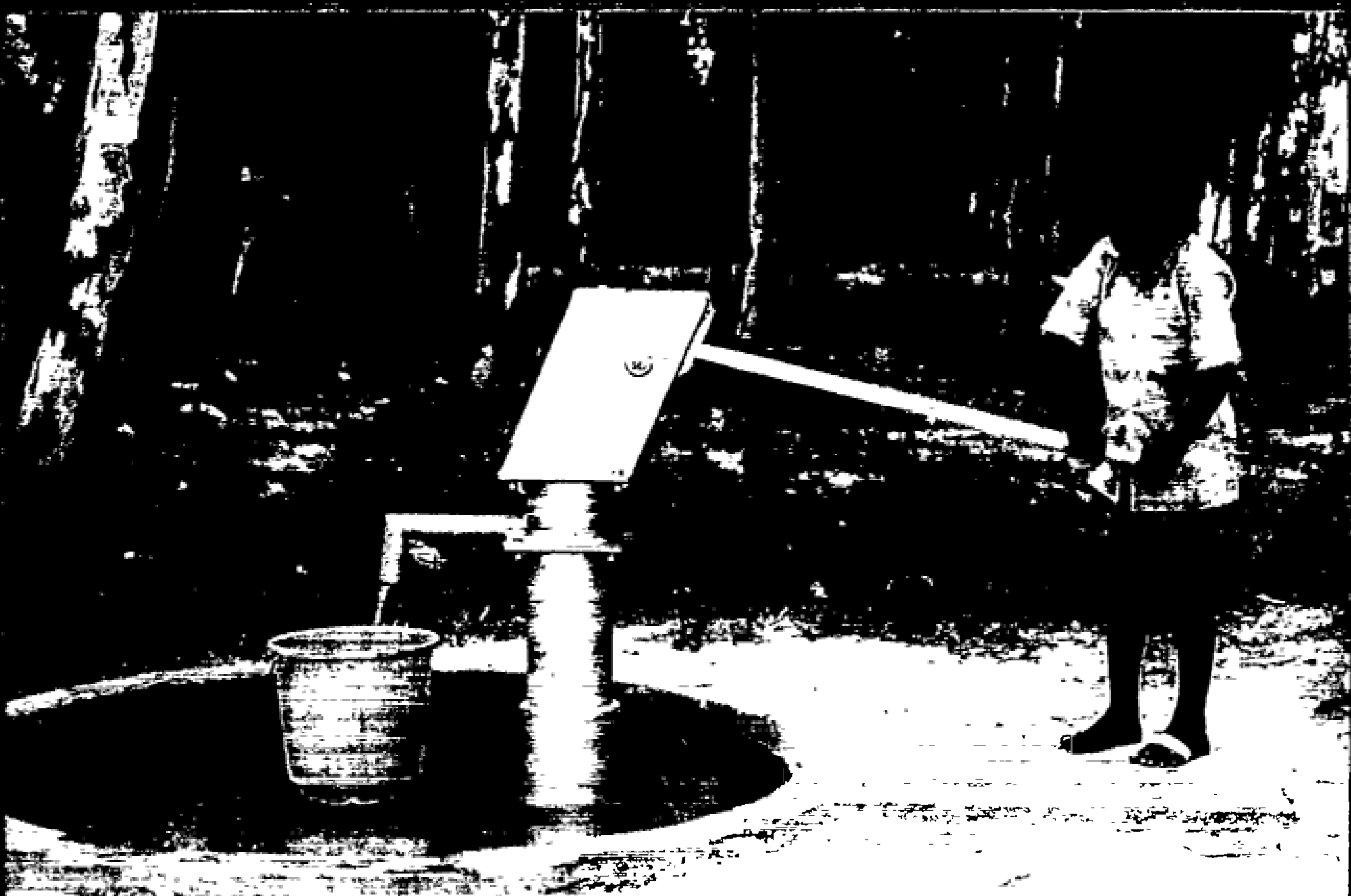
REPORT ON TESTING IN COIMBATORE OF THE NDARD INDIA MARK II AND OPEN TOP CYLINDER INDIA MARK III PUMPS



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REPORT ON

FIELD TESTING IN COIMBATORE OF THE STANDARD INDIA MARK II AND OPEN TOP CYLINDER INDIA MARK III PUMPS

DEPARTMENT OF RURAL DEVELOPMENT
MINISTRY OF AGRICULTURE

IN COOPERATION WITH

UNDP/WORLD BANK WATER & SANITATION PROGRAM

AND

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ABBREVIATIONS USED

B	Bearings
BM	Block Mechanic
C	Caretaker
CH	Chain Assembly
EI	Essential Intervention
EIBD	Essential Intervention Break Down
EIPP	Essential Intervention Poor Performance
FV	Foot Valve
HA	Handle Assembly
ID	Internal Diameter
INTV	Intervention
LB	Lubrications
LB & TN	Lubrication and Tightening of Nuts
MTBF	Mean Time Before Failure
MT	Mobile Team
NB	Nominal Bore
OT	Others
PE	Piston Elements
PM	Preventive Maintenance
PPM	Parts Per Million
PR	Pump Rod
PS	Piston Seal
uPVC	Unplasticized Poly Vinyl Chloride
RM	Rising Main (Galvanized Iron)
SWL	Static Water Level
UNICEF	United Nations Children's Fund
UNDP	United Nations Development Program
VLOM	Village Level Operation and Maintenance

PREFACE

The International Drinking Water Supply and Sanitation Decade has focussed attention on the needs of the rural and ru-urban population for safe water and adequate sanitation. The UNDP, World Bank, UNICEF and a number of major donors have collaborated with member countries in projects to develop and promote low cost water supply and sanitation technologies which communities could afford and maintain with their own resources.

Successful community water supply projects need to be planned as a package of measures designed to make the best use of available resources and to ensure that maximum benefits are achieved from completed projects. The most important elements of an "integrated" strategy for community water supply programs are outlined as follows in the UNDP/World Bank publication entitled Community Water Supply: The Handpump Option.

* Effective involvement of communities in the design, implementation, maintenance and financing of planned improvements, with promoting agencies providing technical assistance and support services as needed. Communities' needs and wishes have to be reconciled with their capacity and willingness to pay for the level of service planned.

* Provision for full recurrent cost recovery, with support of capital (construction) costs for poorer communities, offset by full recovery where higher service levels are provided.

* Maximum involvement of in-country industry in the supply of services and materials for project construction and maintenance (e.g. supply of pumps and spare parts, servicing and repairs) with the important proviso that quality control and reliability should be assured and that costs are competitive.

* Technology chosen to match the resources available to sustain it.

* Institutional and manpower development programs matching the needs of the planned water supply system.

* Parallel programs in health education and sanitation improvements.

The report that follows documents the improvements in the standard India Mark II deepwell handpump and its implications on the reliability, serviceability, maintenance structure and maintenance costs of the deepwell handpumps in India.

EXECUTIVE SUMMARY

Background

India Mark II deepwell handpumps benefit an estimated 360 million people in Asian, African, and Latin American countries. India, with the largest national rural water supply program in the world, has over 1.3 million India Mark II deepwell handpumps installed in rural and peri-urban areas to provide safe water to over 260 million people. Though extensive field and laboratory tests have demonstrated that the India Mark II deepwell handpump is very durable, it is not easy to maintain because of the high skills, special tools and a motorized van needed to service the below-ground components of the pump. This report describes how the potential improvements made to the India Mark II in the Coimbatore handpump testing project make the handpump more reliable and easily serviceable, which has an impact on downtime, maintenance structure and costs.

> The need to carry out potential improvements to the India Mark II handpump used by over 260 million people in India arose because, though durable, it is not easy to repair the below-ground components.

The Coimbatore Handpump Project

The project was taken up in late 1983 by the Tamil Nadu Water Supply and Drainage Board in collaboration with the UNDP/World Bank Handpump Testing and Development Project, UNICEF and Richardson & Cruddas (1972) Limited, a major manufacturer of handpumps. The National Drinking Water Mission, Department of Rural Development, Government of India, coordinated the intensive development and testing project at the national level.

The dominant issues in the rural water supply being maintenance costs and difficulties in maintenance, the project aimed at :

(a) Verification of actual costs of operation of the India Mark II deepwell handpumps and ;

(b) Identification and testing of potential improvements to the standard India Mark II handpump design to make maintenance easier and less expensive.

Methodology for data collection

Approximately 80 handpumps were tested near Coimbatore over a period of 4-1/2 years under conditions of heavy use and deep static water level. A sample of about 50 standard India Mark II handpumps provided the baseline information with which the performance of the experimental variations were compared. Each pump assigned with an identification number, was visited by project staff on a regular basis and repaired whenever necessary. The data collected on performance, maintenance and repair were entered into a database for analysis.

Pump development work

Two types of design were tested: first, the design improvement that would increase the Mean Time Before Failure (MTBF); second, the design improvements that would make the pump easier to take apart and reassemble, using fewer tools and less manpower. Radical design changes were avoided to ensure a high degree of compatibility with the existing India Mark II deepwell handpump.

Analysis of field data

Analysis of field data shows the following distinct improvements in the reliability and serviceability of the experimental pumps - India Mark II (modified) deepwell handpump and India Mark III deepwell handpump - over the standard version India Mark II deepwell handpump. In the India Mark III deepwell handpump, the average frequency of service required (from a mobile maintenance team) was reduced by 89% per year and the mean annual active repair time was reduced by 67%. In fact, 90% of the total repairs for the India Mark III deepwell handpump can be carried out by a bicycle-mobile mechanic using few tools and with the assistance of the handpump caretaker/users.

In the India Mark II (modified) deepwell handpump, minor design changes like a nitrile cup seal instead of a leather cup seal, and a two piece upper valve instead of a three piece upper valve and a modified spacer increase the MTBF by 100%.

Summary and conclusions

The implications of these design improvements are as follows.

1. Minor modifications costing Rs.250 - which will be fully offset in less than two years - to the existing 1.3 million India Mark II deepwell handpumps will, due to increased MTBF, result in a substantial decrease in the maintenance cost and effort. This will increase the quality of service as mobile teams will be required to make fewer visits.

2. Adoption of the India Mark III deepwell handpump will substantially reduce the dependence on a mobile team for most of the repairs. It will be possible for a village-based mechanic to move about on a two-wheeler and carry out 90% of the repairs with the help of a handpump caretaker/user. This will substantially reduce the downtime and also the maintenance cost.

3. The additional capital cost of Rs.1320 in the case of the India Mark III deepwell handpump will be fully offset by the lower maintenance cost in less than three years time.

4. There is need for further improvement in the handpump design to make the maintenance of the handpumps simpler and easier so that the handpump caretakers are able to carry out most of the repairs at the village-level itself.

Recommendations

(1) Design improvements to the India Mark II deepwell handpump be incorporated into the national standard specifications.

(2) The existing 1.3 million India Mark II deepwell handpumps be modified to substantially increase the MTBF.

(3) The India Mark III deepwell handpump be installed on a large scale in all the states presently using the India Mark II deepwell handpumps and a village-based maintenance system be developed which needs minimal support from a mobile team.

(4) A national standard be prepared for the India Mark III deepwell handpump.

(5) A study on a national level be conducted to evaluate the strengths and weaknesses of the various existing maintenance systems and to suggest ways to create village-level capacity and capability to repair deepwell handpumps.

(6) Further research and development should be undertaken to simplify maintenance requirements which will encourage the users themselves to carry out maintenance.

INTRODUCTION

Reciprocating handpumps, for drawing water from below-ground, have been in use for centuries. During the early 1960s reciprocating type handpump designs meant for small user groups were introduced in India to pump water from deeper borewells with substantially large user groups. These pumps failed too frequently and were unable to provide a constant source of drinking water. Then, in the early 1970s, the Government of India (GOI), concerned about the poor performance of the then deepwell handpumps available for community use and its failure to provide sustained drinking water, initiated action in cooperation with the State Governments, World Health Organization (WHO), United Nations Children's Fund (UNICEF), Mechanical Engineering Research & Development Organization (MERADO) and Richardson & Cruddas (1972) Ltd., (a GOI undertaking), for the development of a dependable deepwell handpump. The reliable and sturdy deepwell handpump developed in the late 1970s was the India Mark II handpump. In a decade, the India Mark II handpump became a household name in villages in India. By 1988, over 1.3 million India Mark II handpumps were in operation in India alone.

The development of the India Mark II was a major breakthrough in terms of reliability and ease of operation. The number of handpumps operating at any point of time rose from a dismal 25% to an impressive 85%. However, this pump relies heavily on centralized maintenance. A mobile team, consisting of a van with special tools and a team of 4 or 5 semi-skilled workers is needed to provide specialized maintenance. This system is expensive and difficult to sustain. Alternative models of decentralized maintenance systems have been tried out with limited success.

The "Village-level Operation and Maintenance" (VLOM) concept has been promoted by various agencies, including UNICEF and the UNDP/World Bank Water and Sanitation Program since the early 1980s. The VLOM concept promotes the maintenance of a handpump by the users themselves with minimal outside support. It demonstrates that it is possible for pumps to be maintained by users themselves with minimum downtime and lowest financial and economic cost, provided it is technically easy and spare parts are made available.

To encourage the maintenance of handpumps by the users themselves and to reduce dependence on centralized maintenance, it was necessary to introduce design changes in the existing India Mark II handpump. These changes simplified the maintenance procedures substantially i.e. the changes make it easier to take apart and carry out repairs with simple standard tools that are locally available.

To achieve the objective of the International Drinking Water Supply & Sanitation Decade, the UNDP/World Bank Water & Sanitation Program, in association with multilateral and bilateral agencies, initiated a global project for laboratory and field testing and technological development for community water supply handpumps. Laboratory tests were carried out by the Consumer Research Laboratory in the United Kingdom and field trials were carried out in 17 countries, involving some 2,700 handpumps of 70 different models to assess the individual performance of different handpumps. The Coimbatore Handpump Field Testing Project in India formed part of the Global Handpump Testing Project. In the Coimbatore project, efforts were largely concentrated on the further development of the world's most popular deepwell handpump, the India Mark II, to improve its maintainability, reliability and serviceability.

DESCRIPTION OF THE COIMBATORE PROJECT

In late 1983, GOI, with the Tamil Nadu Water Supply & Drainage Board (TWAD Board), undertook and executed a Handpump Field Testing Project in Coimbatore, in partnership with the UNDP/World Bank Water & Sanitation Program, UNICEF and Richardson & Cruddas, a major manufacturer of the India Mark II. At the national level, the Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Works & Housing, and later, the National Drinking Water Mission, Department of Rural Development (DRD) supported the successful implementation of the project. The National Drinking Water Mission has attached national priority to improvements in rural water supply technology, community-based maintenance systems and implementation of the VLOM concept.

For testing deepwell handpumps, it was necessary to select an area which had a deep static water level (SWL) and "high usage" of pumps. In the late 1970s, the GOI, TWAD Board and UNICEF selected Coimbatore and its adjoining area for testing the prototypes of India Mark II Deepwell Handpumps, as it fulfilled the criteria.

> Government organisations, international agencies, manufacturers and individual experts, all contributed to make the project successful. Coimbatore was chosen for the project because handpumps are used extensively and it has a deep water table.

For the same reason, Coimbatore was again selected for field testing of the standard India Mark II and various modifications under the global/ interregional project of the UNDP/World Bank Water & Sanitation Program for laboratory and field testing the technological developments in community water supply handpumps. The project was located within a radius of 60 km from Coimbatore city, in the state of Tamil Nadu. (See Annex I, Figure I-1 for a map showing the location of test pumps).

Test pumps' sample size

A test sample of 48 standard India Mark II handpumps, 18 experimental pumps with galvanized iron (GI) rising main pipe and 15 experimental pumps with PVC rising main pipe were installed on existing borewells. Figure 1 shows the actual size of samples for the two types of handpumps over the test period of 4-1/2 years.

Geohydrological conditions

The test area is a hard rock area comprising high grade metamorphic rocks of the peninsular gneissic complex, extensively weathered and overlain by recent valley-fill material at some places. The main rock types are horn blendebiotite gneiss, garnet sillimanite gneiss, charnockite and granite. All the borewells drilled were 6" (150mm NB) dia with depth ranging from 60 mts to 100 mts and mostly drilled by DTH drilling rigs. In most of the cases a 6mts long casing pipe was used to encase the overburden. The SWL varied from relatively shallow to more than 50 mts deep in some of the installations. (Figure 2 shows the SWL in the test borewells from 1984 to 1987). The average SWL was 21.6 m, 21.8 m,27 m and 29.2 m during 1984, 1985, 1986 and 1987 respectively. The seasonal variation in the SWL was quite substantial. As much as a 20m variation was noticed in the year 1987 when rainfall in the test area was scanty.

Pump usage

The usage of handpumps varied considerably from one hour to 15 hours per day. On an average, therefore, handpumps in the test sample worked for 7 hours a day discharging 5.46 m^3 of water.

Water quality

Many of the borewells were found to have a high percentage of dissolved solids. Important parameters are summarized here.

(a) pH value - 6.9 to 8.0

(b) Total dissolved solids - 362 to 5220 PPM

(c) Total iron content - 0.05 to 2.00 PPM

(d) Total chlorides - 16 to 1560 PPM

(e) Electrical conductivity - 450 to 7000 μmoh/cm

The details of water analysis in respect of bore wells are given in Annex II.

Age of test pumps

The monitored period of the test pump varies. Standard India Mark II handpumps had been monitored for 32 months to 53 months. India Mark III handpumps had been monitored for 10 months to 48 months. The average monitored age for the standard India Mark II handpump tested is 3.83 years and for the India Mark III handpump tested is 2.26 years.

Types of pump tested

Initially, all test handpumps were fitted with the standard India Mark II pump head and leather cup seals. However, as the field testing and monitoring progressed, refinements were carried out in the standard India Mark II handpump as well as the experimental handpumps with open top cylinder and 2-1/2" (65mm NB) galvanized iron riser pipe. The refined standard India Mark II pumps and experimental open top cylinder pumps have been referred to in the report as the India Mark II handpumps and the India Mark III handpumps respectively. The extensive field testing and monitoring was mainly confined to the following two types of handpumps.

> The Coimbatore handpump project aims at improving the serviceability and reliability of the widely-used India Mark II handpump. The India Mark III handpump design facilitates the withdrawal of the piston and foot valve without having to remove the rising main.

(a) India Mark II: In this pump the above ground mechanism was modified slightly to facilitate easier and quicker removal for access to the below-ground parts. The detailed specifications are given in Annex III.

(b) India Mark III: This pump uses a 2-1/2" G.I. pipe for the rising main to facilitate withdrawal of the extractable piston and foot valve without having to remove the rising main. The pump's above-ground mechanism was modified slightly to facilitate its easier and quicker removal for access to the below-ground parts. The detailed specifications are given in Annex IV.

Apart from the preceding, the following variations of pump components were also tested in the field.

(a) Different types of piston seals
(b) Connecting rods with different type of coatings/material
(c) PVC rising main pipe with different type of connectors

(d) PVC cylinder
(e) Bottom intake pipe
(f) Sand trap
(g) Plastic bush bearings
(h) 50 mm ID brass lined cast iron cylinder - VLOM type
(i) Pump rod centralizers
(j) Rising main pipe centralizers
(k) Special tools
(l) Different platform designs

OBJECTIVES

By 1983, more than 0.8 million India Mark II deepwell handpumps were already in operation in India and 1,50,000 pumps were being added every year. In view of the high reliability of the India Mark II, its standardization and adoption on a national scale and the large number of pumps already in the field, development work to improve serviceability had to be carried out without adversely affecting the interchangeability of the components. This restricted the evolution of an altogether new handpump design. The objectives of the Coimbatore Handpump Field Testing Project were as follows:

(a) To document the working life of the standard India Mark II deepwell handpump components, its maintenance cost and spare parts requirement for two years of normal operation.

(b) To identify and test potential improvements to the standard India Mark II to reduce maintenance costs.

(c) To test experimental variations of certain handpump components to identify and evolve improvements to a basically sound design.

(d) To recommend a field-proven design for adoption on a national scale.

(e) To develop special tools for easy maintenance of the handpump.

METHODOLOGY FOR DATA COLLECTION

The following methodology was adopted to collect field data for the test pumps. It consisted of three types of formats.

(i) Pump installation and borewell details form

(ii) Inspection and repair report form

(iii) Water quality data form.

An inspection-cum-maintenance team with a mobile van was attached to the project to install and carry out repairs on the test pumps. The crew consisted of four semi-skilled workers and was supervised by a monitoring engineer, who recorded the nature of the service call, the type of intervention, the spare parts replaced, reason/s for failure and the elapsed time of servicing.

Installation and borewell details

Each test pump was identified by a code number which was painted on the pedestal. Information regarding location, SWL, depth of borewell, yield of borewell, date of installation, depth of installation and number of users were entered in a form (as per attached Annex VI).

The measurement of pump yield is essential to compare the performance of different pump components in an equitable way. For this purpose discharge from each pump was measured with the help of standard turbine type water meter. Twelve special water tank assemblies, each fitted with a 25mm NB water meter were used and rotated among the test pumps.

Inspection and repair report form

The inspection and repair report form is discussed in detail in Annex VII. The interventions i.e. "what was done to the pump" were classified as follows.

(a) Essential interventions: When something had to be repaired to restore the pump to normal service. This was of two types: (1) breakdown coded with the abbreviations "EIBD" and (2) poor performance coded with the abbreviations "EIPP";

(b) Other interventions, coded "OT", were repairs or replacements made during an essential intervention which were not the primary cause of the intervention, or were design changes to the experimental pumps;

(c) Preventive maintenance was coded "PM" and consisted of minor adjustments to pump parts, like tightening fasteners, lubricating chains or cleaning parts.

The SWL below-ground level in each borewell was measured on a monthly basis and recorded in the inspection and repair report form. The conventional method of using a rope was used to measure the SWL, since the electrical instruments did not function properly. Data is reported in Figure 2.

Quarterly reports were prepared by M/s Crown Agents based on the data collected by the monitoring engineer which included status of the project, design details of components under trial, field observations and conclusions.

Water quality data form

The chemical analysis of borewell water was carried out in the government laboratory. The results are summarized in Annex II. Only data relevant to pump performance were collected. Consequently, microbiological and physical quality data, although important to user acceptance, were not collected.

Analysis of data

The data were analyzed on a modified spread sheet program (Lotus 123 Release 2) using a microcomputer. This helped in comparing various parameters and to arrive at conclusions.

To document and compare the life of the pump components in a fair manner M^4 was adopted as the unit of measurement of work done. This unit is the product of water pumped in cubic meters and the head of water in meters. The head of water was computed as follows:

$$\text{Head of Water} = \frac{\text{Average static water in mts.} + \text{Depth of cylinder in mts.}}{2}$$

The usage of a pump in hours was computed by dividing the pump yield in liters/day by a factor 780 (derived by multiplying actual discharge in litres per minute x 60)

PUMP DEVELOPMENT WORK

During the course of field testing, the design of the India Mark III pump was developed. Some potential improvements were also made in the standard India Mark II pump. Special installation tools were developed for the erection and maintenance of India Mark III pumps.

India Mark III

This pump was developed to enable extraction of the piston and foot valve without having to remove the rising main pipes. Figure 3 shows the India Mark III pump installation details and figure 4 gives details of cylinder assembly of the India Mark III pump. Annex IV gives detailed specifications. The following are the important features.

(a) The piston and foot valve can be extracted without lifting the rising main.

(b) The push rod in the foot valve assembly lifts the upper valve guide when the piston assembly is screwed onto the foot valve body. This helps in dumping the column of water soon after the foot valve is lifted up by a few millimeters. This makes the lifting of the foot valve, piston assembly and pump rods much easier.

(c) The foot valve is placed in a conical receiver and sealing is provided by a nitrile rubber O-ring.

(d) Nitrile rubber piston seals, with longer life than leather seals, have been used. Cylinder brass liner does not get scored as easily as well. For details of nitrile rubber seals, please see Figure 5.

(e) Modified spacer is used. For details of modified spacer please see Figure 6.

(f) A two-piece upper valve to eliminate failures due to disconnection of threaded joint.

(g) An additional flange known as the intermediate plate is placed between the head flange and the water tank top flange. This facilitates removal of the head assembly without the removal of the handle assembly. Access to the chain assembly is improved and the maintenance of the above-ground mechanism simplified.

(h) A square bearing housing instead of a round bearing housing ensures higher rigidity and less distortion of the housing due to welding. This improves the quality of bearing housing and will enhance the life of bearings and handle assembly.

(i) Increased window opening to reduce hitting (banging) of handle on the bracket bottom stop.

(j) The height of the water tank assembly was increased by 25mm to eliminate water splashing during fast pumping. The overall height of the stand assembly was decreased by 75mm to bring the operating end of the handle close to the platform foot rest to reduce the frequency of handle banging on the bracket bottom stop.

India Mark II

The improvements listed in items (d) to (j) were made to the standard India Mark II pump.

Special tools

The following special tools were developed for the installation and maintenance of the India Mark III pump.

(a) Self-locking clamp

(b) Rod-holding vice

(c) Pipe lifters

<u>Self-locking clamp</u>

The pipe clamp was developed to facilitate the installation and dismantling of the 2-1/2" (65mm NB) galvanized iron rising main. It consists of a base with pillar welded and two hardened steel jaws which move simultaneously through a link block. In an incline of 5 degree to 10 degree sloping downwards from a horizontal position, these jaws hold the pipe firmly. The riser pipe can be lifted by using four pipe lifters. The self-locking clamp jaws need not be operated while pulling out the rising main. While lowering the rising main, the jaws are to be opened. This can be done by one person. The use of this tool significantly reduces repair time. For proper functioning, however this tool has to be manufactured under strict quality control. For details see Figure 7.

<u>Rod-holding vice</u>

The rod holding vice was specially developed for the maintenance of the India Mark III pump. The special feature of this vice is that for disengaging a rod connection the hexagonal half coupler is placed in a socket provided on the vice. One person can disengage the threaded connection with an open ended spanner. There is also a safety device which prevents the connecting rod from falling into the rising main. For details see Figure 8.

Pipe lifters

The pipe lifter was developed to lift the 2 1/2" (65mm NB) galvanized iron rising main. Four pipe lifters in conjunction with a self-locking clamp are required to lift the riser pipe. This eliminates the need of a tripod while installing and dismantling the rising main. For more details see Figure 9.

Coatings on the connecting rod

Different types of coated connecting rods were tested in the same borewell containing water with high total solids. The natural rubber coating on mild steel rods was found intact after two years of operation except at the coupler surface where the rubber coating was damaged due to abrasion with the rising main. The hot dip galvanized mild steel rods were also rust-free after two years of operation. However, further development and field testing is needed. For more details please refer to Annex V.

PVC rising main pipe and joints

The 75mm outer diameter and 5mm wall thickness uPVC pipe with different types of joints was used as the rising main and tested in 15 borewells. The riser main failed mainly due to external and internal abrasion. It is evident that the uPVC rising main is not suitable for installation in unlined borewells. Further development work is needed to develop uPVC joints and pipe centralizers suitable for unlined borewells. For more details please refer to Annex V.

Rubber compression fittings

The rubber compression fitting was developed and field tested to hold the suspended uPVC rising main in 15 borewells. This compression fitting worked exceptionally well and no failure was noticed during two years of field testing. This method is recommended for holding the suspended uPVC rising main in the water tank assembly. For further details please refer to Annex V.

50mm ID cylinder assembly

Two pumps with 50mm ID cylinder assembly with extractable plunger and foot valve, 50mm NB GI riser main, a modified water tank and an India Mark II head assembly with 10:1 mechanical advantage handle were tested with a 60 meter cylinder setting. These pumps worked well without any problem for over two years. This design offers the following advantages.

(a) Ideal for low-yielding wells

(b) Reduced operational effort; and

(c) Relatively easy to install.

Platform

Different designs of platforms were constructed and tested to overcome the problems faced in the existing India Mark II platforms. The rectangular platform as per the details given in Figure 14 was found to be most suitable and acceptable design as it reduces splashing and provides a broad foot rest area for the operator. For more details please refer to paragraph 20 in Annex V.

ANALYSIS OF FIELD DATA

Improved serviceability and its effect on maintainability

The India Mark III pump is easier to service than the Mark II version, particularly in repairing the below-ground components, except for the rising main pipes and the cylinder body. For routine maintenance of India Mark III pumps, a set of fewer and lighter tools, and less labour and time are needed to replace the parts most frequently needing replacement - piston seals, valves, valve seats and above-ground parts and occasionally pump rods. This conclusion is supported by lower average values observed over the test period for "active repair time" (the amount of time spent from beginning the repair until the pump is again in working order). Comparing the active repair time for two similar pieces of equipment is a good indicator of the relative ease or difficulty involved in repairing the equipment. Table 1 compares the mean values for active repair time spent per pump per year to replace various parts. Figure 10 displays the information graphically.

TABLE 1
COMPARISON OF MEAN ANNUAL ACTIVE REPAIR TIME BY COMPONENT
INDIA MARK II VERSUS INDIA MARK III

Component	Repair time (minutes/pump/year)			
	Mark II	Serviced by	Mark III	Serviced by
ABOVE-GROUND				
Handle assembly	3.1	BM	2.7	BM
Bearings	1.5	BM	1.5	BM
Chain	2.4	BM	1.3	BM
Lubrication	6.4	C	5.2	C
Sub-total	13.4	--	10.7	--
BELOW-GROUND				
Pump rods	7.7	MT	0.7	C & BM
Piston seals	154.7	MT	45.2	C & BM
Foot valve	11.7	MT	3.9	C & BM
Rising main	71.4	MT	15.7	MT
Cylinder	4.8	MT	9.6	MT
Others	1.0	MT	0.7	MT
Sub-total	250.8	--	75.8	--
Total	264.2		86.5	

Note: Average depth of cylinder setting for both type of handpumps is 36M.

Average repairs on the India Mark III pumps took 67 % less time to carry out than similar repairs on the India Mark II pumps. Above-ground components account for approximately 5 and 12.4 percent of total active repair time for the India Mark II and India Mark III pumps respectively.

Access to the below-ground components in the standard India Mark II pumps is cumbersome with conventional tools. A team of four semi-skilled workers with a mobile van and special tools is necessary in most cases to lift and disassemble the rising main pipes and the pump rods to repair any of the below-ground components.

> Repairs on the India Mark III pump take 67% less time than the India Mark II pump. Moreover, tools required for 90% of the repairs can be easily transported on a two-wheeler, unlike the tools required for repairing a Mark II, which weigh at least 60 kgs.

In the India Mark III pumps, the piston and foot valve assemblies and the pump rods can be extracted through the bigger rising main pipe. Therefore, they are easy to remove by a mechanic with the help of a handpump caretaker or a user and require only a two-wheeler to move and carry fewer and lighter tools. Only the infrequent repair or replacement of the rising main pipes and cylinder body of the India Mark III pumps will require a mobile van with a team of four or five skilled persons and special tools.

Table 2 gives the details of assistance required from a mobile team, a block mechanic and a caretaker for the maintenance of an India Mark II and an India Mark III pump. This is also illustrated graphically in Figure 11.

TABLE 2
COMPARISON OF MEAN ANNUAL ACTIVE REPAIR TIME AND TYPE OF ASSISTANCE REQUIRED
INDIA MARK II VERSUS INDIA MARK III

Type of pump	Active repair time (minutes/pump/year)		
	Mobile team with van	Block Mechanic	Caretaker
India Mark II	250.8	7.0	6.4
India Mark III	26.0	55.3	60.5

As is evident from the above table, the assistance of a mobile team, required for the India Mark III pump is reduced by 89.6% compared to the assistance required for the India Mark II pump. Therefore the cost of the maintenance structure will be substantially less for the India Mark III pumps when compared with the India Mark II pumps.

The weight of tools required for the majority of repairs of the India Mark III pumps is approximately 7 kgs and therefore tools can be easily carried by the mechanic on a two-wheeler. In the case of the India Mark II pumps, at least 60 kgs of special tools and standard tools, and frequent replacements like pipes and connecting rods need to be transported in a mobile van to attend to the majority of below-ground repairs. If the tools and spare parts are made available at village-level, it is possible to substantially reduce the dependence on the central mobile team.

Reliability

Reliability of a pump can be measured by the number of occasions a pump breaks down or needs major repairs to keep it in working condition. Table 3 gives the mean annual frequency of visits required per pump for maintaining both types of pumps. It can be seen from the table that the essential visits required were 32 % less in the case of India Mark III pumps than for the India Mark II pumps. It is evident that the India Mark III pumps are more reliable than the India Mark II pumps. Annex VIII discusses in more detail improvements in the reliability of the India Mark III pumps.

TABLE 3
MEAN ANNUAL FREQUENCY OF VISITS BY TYPE
INDIA MARK II VERSUS INDIA MARK III

Type of visits	Visits/pump/year	
	Mark II	Mark III
Essential, breakdown	0.81	0.42
Essential, poor performance	0.75	0.64
Essential, all	1.56	1.06
Preventive maintenance (LB&TN)	1.14	1.11
Preventive maintenance (bearings & chain)	0.25	0.22
Preventive maintenance, all	1.39	1.33
Others	0.03	0.07
Total	2.98	2.46

Note: Preventive maintenance was carried out during scheduled visits.

Table 4 gives details of the numbers of visits required per pump per year by a caretaker, a block mechanic and a mobile team. These are based on data given in Table 3 and the types of repairs actually carried out during each visit. For instance, to work out the need for a mobile team for servicing an India Mark III pump, all the visits during the test period where riser pipes, cylinder body and cylinder caps were replaced were added and divided by the product of number of test pumps and average age. Similarly, in the case of the India Mark II pump, all visits during the test period where mobile team intervention was a must were added and then divided by the product of number of test pumps and average age of pumps.

TABLE 4
MEAN ANNUAL FREQUENCY OF VISITS
_NDIA MARK II VERSUS INDIA MARK III

Visits by	Visits/pump/year	
	Mark II	Mark III
Caretaker (LB & TN)	1.14	1.11
Block mechanic	0.40	1.19
Mobile team	1.44	0.16
Total	2.98	2.46

The India Mark III pump uses a 65mm NB GI pipe as against a 32mm NB GI pipe used in the India Mark II pump. The cylinder design facilitates the replacement of piston seals, plunger assembly, and foot valve components without lifting the riser main. This simplifies the maintenance procedure for over 90% of the repairs.

In the case of the India Mark III pumps, block mechanic/caretaker attendance which is available within 10 kilometers is needed for 93.5 % of the repairs as compared to a mobile team as far as 50km away from the pump installation. Repairs to the India Mark III pumps can thus be carried out in a much shorter time. Based on four years experience it is estimated that on an average the major repairs that need a mobile team's attendance will perhaps be once in 6 years, and therefore the downtime for the India Mark III pumps will be much lower than for the Mark II pumps. Table 4 clearly illustrates that the India Mark III pumps need very little mobile team attendance.

Average frequency of replacement of parts

The design features of the India Mark III pump have substantially reduced the need for replacement parts. The overall frequency of replacement parts is 9.15 per pump per year for the India Mark II to 4.79 for the India Mark III pump. Below-ground component replacements have been reduced from 6.55 to 2.9 per pump per year.

The total number of replacements of parts per year per pump was 4.79 in the India Mark III handpump as against 9.15 in the India Mark II handpump. Cost of replacement therefore is also 46% less.

The average frequency of replacement of parts is discussed in detail in Annex IX. Table 5 lists the mean annual frequency of parts replacement for both the pumps. The data is presented graphically in Figure 12. Annexes XI and XII give details of spare parts recommended for normal maintenance for two years of the India Mark II pump and the India Mark III.

TABLE 5
MEAN ANNUAL FREQUENCY OF PARTS REPLACEMENT
INDIA MARK II VERSUS INDIA MARK III

Part type	Parts replaced/pump/year	
	Mark II	Mark III
Handle assembly	0.24	0.16
Bearing (single)	0.15	0.14
Chain	0.18	0.09
Pump rod	0.74	0.22
Rising main (pipe)	1.71	0.37
Rising main (coupler)	2.36	0.62
Piston seal (set)	1.06	1.11
Piston valve	0.20	0.21
Foot valve/assembly	0.20	0.17
Cylinder body	0.10	0.00
Cylinder cap	0.17	0.00
Cylinder assembly	0.02	0.20
Bolts	0.46	0.11
Nuts	1.46	1.00
Others	0.10	0.39
Total	9.15	4.79

Rising Main

The frequency of rising main pipe replacement (the major cost) reduced by 78 percent for the India Mark III pump when compared to the India Mark II pump. A major factor in this case is less abrasion between pump rod and rising main. The higher annular space available in the case of the India Mark III helps in keeping the galvanized protective inner surface intact, which in turn increases the life of the rising main. Further, the rising main pipes in the case of the India Mark III pump are not taken out for the replacement of piston seals and valves as in the case of the India Mark II pump. Therefore, the damage to the pipes due to the use of pipe wrenches and clamps is minimized. It is projected that the rising main for the India Mark III pump will have double the life than that of the India Mark II pump.

Piston Seal

The piston seal is the component which is replaced most frequently. Piston seals made of various types of leather and nitrile rubber were tested. Nitrile rubber piston seals have the highest average life as is evident from Table 6. For further details please refer to Annex IX. The average life of a nitrile rubber piston seal is estimated to be over two years.

Development of a nitrile piston seal, which will reduce frequency of breakdown in the deepwell handpumps by at least 50%, is one of the major developments of the project. The average life of a nitrile seal is atleast twice that of a conventional leather piston seal, presently being used in the India Mark II handpumps.

TABLE 6
AVERAGE PISTON SEAL LIFE BY TYPE

Type of piston seal	Seal life						Quantity
	Average		Minimum		Maximum		Sets
	M4 x100	days	M4 x100	days	M4 x100	days	
Chrome tanned leather	256	188	26	19	1082	793	122
Vegetable tanned leather	734	538	60	44	2515	1843	35
Vegetable tanned leather (in operation)	509	373	148	109	1641	1203	6
Nitrile rubber	861	631	210	154	1898	1391	36
Nitrile rubber (in operation)	975	715	259	190	2539	1861	46

Note: Piston seal life in days is based on an average usage of 7 hrs per day and average SWL of 25 meters i.e. 498 M4 x 100 is equivalent to one year of pump operation.

The frequency of EIBD/EIPP for both types of pumps were reduced when nitrile rubber piston seals were used as compared to the leather piston seals. Unlike leather, the quality of nitrile rubber is more uniform and reliable. To use the nitrile rubber piston seals in standard India Mark II pumps, it will be necessary to use the modified spacer shown in Figure 6.

Pump rod

It is evident from Table 5 and the graph shown in Figure 12 that the frequency of annual replacement of pump rods is 70 % less for the India Mark III pumps as compared to the India Mark II pumps. This is due to the larger annular space between the pump rod and the riser main pipe which reduces the failure of the connecting rod due to abrasion between the pump rod and the rising main.

Handle assembly and bearings

The annual frequency of replacement of the handle assembly is 0.24 and 0.16 pump/year for the India Mark II and the India Mark III pumps respectively. It was noticed that the fit between the bearing housing and the bearing outer race was loose and therefore the handle assemblies themselves were replaced, instead of changing the bearings alone. The average life of a bearing is 2.8 years.

Although frequency of replacement for the handle assembly is lower in the case of India Mark III pumps, the average life of bearings is expected to be more or less the same for both types of pumps. The life of a bearing can be increased by improving the fit of the bearing, increasing the diameter of the bearing housing and increasing the bracket opening in the pump head. For more details please refer to Annex IX.

Two-piece upper valve

This development has solved the problems in the three piece upper valve due to unscrewing and breakage of the stem at the end of the thread. In the new design the thread connection has been done away with and the rubber seating is slipped on to a recess. This has eliminated the type of failure described here and reduced the frequency of replacement of the upper valve.

OPERATING COST ANALYSIS

The country has adopted the India Mark II deepwell handpump on a national scale and adoption of the India Mark III pump can be recommended only if it offers distinct advantages over the present India Mark II design. While technical issues have been discussed in the foregoing pages, this chapter compares the economic and social advantages of both the designs. As the sample size was very small, the data collected during the project, were not considered adequate. To obtain realistic estimates of downtime and number of breakdowns etc. data available from the ORG report* have been used to supplement the data collected by the project.

The analysis includes the following.

(a) Comparison of capital costs
(b) Comparison of maintenance/recurring costs
(c) Breakeven cost for India Mark III pump

Capital cost

The capital costs of the India Mark II and India Mark III pump are given below. For detailed cost estimates please refer to Annex XIII.

> The capital cost of a complete India Mark III handpump installation is Rs 1300 more than the India Mark II pump. The increase, largely due to the use of a bigger riser main, will be completely offset by lower maintenance costs in less than three years.

* This report entitled "Survey on the Performance of India Mark II Deepwell Handpumps Maintenance, Repair System and Cost" was prepared by the Operations Research Group (ORG) on behalf of UNICEF in 1988.

TABLE 7
COMPARISON OF CAPITAL COSTS OF INDIA MARK II AND INDIA MARK III PUMP INSTALLATION

Item	Mark II Rs.	Mark III Rs.	Difference Rs
Borewell (100 mts)	20,000	20,000	--
Pump	2,250	2,420	170
24 mts rising main	1,040	2,064	1,024
Installation	160	280	120
Platform	1,500	1,500	--
Total	24,950	26,264	1,314

Note: Pump and rising main price as prevailing in 1988.

The capital cost of a complete India Mark III installation is Rs.1,314/- (5.3%) more than the India Mark II installation. A comparison of the costs of the pumps, excluding the cost of borewell and platform, indicates that the cost of the India Mark III pump is 36.3% higher than that of the India Mark II pump. Only 7.6% of the increase is because of increase in the cost of the pump itself. The remaining 28.7% is attributed to the bigger sized rising main (from 1-1/4" to 2-1/2") which is necessary to facilitate the easy removal of the plunger assembly, check valve and pump rods. Invariably, the initial cost is an important consideration in the selection of equipment. Higher capital expenditure can be justified only if it can be offset by lower recurring maintenance costs and other advantages.

Maintenance cost

The maintenance cost depends on the type of maintenance structure, the number of pumps a maintenance structure can look after, the number of interventions per year, and the cost of parts replaced. The maintenance cost can be categorized as:

(a) Fixed expenses; and
(b) Variable expenses.

The maintenance structure presently available with minor variations in many states in India is as follows.

(a) A mobile team of three or four semi-skilled workers with a mobile van, tools and spares, capable of handling all repairs;

(b) Block level mechanics capable of handling essentially above-ground repairs. The pump design will decide the scope of repairs that can be carried out by a block level mechanic.

(c) A caretaker who is a volunteer from the village who motivates users and informs the appropriate authorities about the breakdown of the pump, tightens nuts and bolts, lubricates the chain and helps in keeping pump surroundings clean.

Capacity of a maintenance system

Travel time, active repair time, mode of transport and number of pumps per square kilometer have a significant influence on the cost and maintenance and the number of pumps that can be serviced by each crew. While active repair time per pump per year for each level of maintenance is given in Table 2, travel time is discussed in the next section.

Travel time

Travel time depends mainly on the density of handpumps and the mode of transport. It is assumed that mobile teams and block mechanics will be provided with a 1.5 ton four-wheel motorized van and a motorcycle respectively. The average distance that these modes of transport can cover has been assumed as 40 kilometers per hour. The density of pumps has been taken as 0.238 per square kilometer, i.e. 300 handpumps in an area with a radius of 20 kilometers. The distance travelled per visit has been assumed as twice the radius. The travel time worked out on the basis of these assumptions is given in Annex XIV. These assumptions may not be applicable in many regions as field conditions vary substantially from region to region and therefore the travel time arrived at is an indicative value only.

The number of pumps that can be serviced by a mobile van are given in Table 8. It is estimated that a mobile van can provide a desired level of service to a maximum of 410 India Mark II pumps or 2765 India Mark III pumps. However, it is not feasible to work a system with 100 per cent efficiency. The capacity has therefore been de-rated by 30 per cent taking into account vehicle breakdown and repairs; non-reporting of a crew member, especially the driver; and non-availability of spare parts or tools.

TABLE 8
TRAVEL TIME AND NUMBER OF PUMPS THAT CAN BE SERVICED BY A MOBILE TEAM

Item	Mark II	Mark III
1. Interventions needing mobile team per year	1.44	0.16
2. Travel time per trip	60 minutes	150 minutes
3. Estimated travel time per pump per year (1x2)	86.4 minutes	24.0 minutes
4. Active repair time per pump per year (Table 2)	250.8 minute	26.0 minutes
5. Total time mobile van is engaged per pump/year (3+4)	337.2 minutes	50.0 minutes
6. Total time van available per year (288 days x 8 hours)	2304 hours	2304 hours
7. Pumps that can be serviced at 100% efficiency (6/5)	410	2765
8. De-rate number of pumps that can be serviced by 30%	290	1940

Table 9 gives details of travel time, mean active repair time and the number of India Mark II and India Mark III pumps that can be serviced by a block mechanic.

TABLE 9
TRAVEL TIME AND NUMBER OF PUMPS THAT CAN BE SERVICED BY A BLOCK MECHANIC

Item	Mark II	Mark III
1. Intervention needing block mechanic/ year	0.4	1.19
2. Travel time per trip	130 minutes	85 minutes
3. Estimated travel time per pump per year (1x2)	52.0 minutes	101.2 minutes
4. Active repair time per pump/year (Table 2)	13.4 minutes	60.5 minutes
5. Total time per pump/year (3+4)	65.4 minutes	161.7 minutes
6. Total time available/year (288 days x 8 hours)	2304 hours	2304 hours
7. Handpumps that can be serviced at 100% efficiency (6/5)	2100	860
8. De-rate number of pumps that can be serviced by 30%	1480	600

From this table, it is estimated that a block mechanic with a motor cycle can service 1480 India Mark II pumps and 600 India Mark III pumps.

Fixed expenses

These costs include expenses incurred in establishing and maintaining a basic maintenance structure. This expense is independent of the level of maintenance effort, the number of breakdowns and the number of pumps repaired. However the fixed expenses per pump will reduce when more pumps are serviced by the same maintenance structure. The fixed expenses of maintaining a mobile maintenance team, a block mechanic with motorcycle and a caretaker are given in Tables 10, 11 and 12.

TABLE 10
ANNUAL FIXED EXPENSES OF MOBILE TEAM WITH VAN

Expenses	Rs.
1. Salaries (5 persons @1000 p.m.) including benefits	60,000.00
2. Tool cost (life assumed - three years)	1,333.00
3. Training expenses (spread over five years)	600.00
4. Interest charges @12% per annum on the cost of van	15,600.00
5. Depreciation (over ten years)	13,000.00
Total	90,533.00

TABLE 11
ANNUAL FIXED EXPENSES OF BLOCK MECHANIC WITH MOTORCYCLE

Expenses		Rs.
1.	Salary (one person)	12,000.00
2.	Tools cost (life assumed-three years)	500.00
3.	Training expenses (spread over five years)	100.00
4.	Interest charges @12% per annum on the cost of motorcycle	2,400.00
5.	Depreciation (over ten years)	2,000.00
Total		17,000.00

TABLE 12
ANNUAL FIXED EXPENSES FOR CARETAKER

Expenses		Rs.
1.	Tools (spread over three years)	15.00
2.	Training (spread over five years)	20.00
Total		35.00

Variable expenses

Unlike fixed expenses, variable expenses are proportionately linked to the level of maintenance and number of interventions. This cost remains consistent over a period of time, unless other extraneous and unforeseen factors influence a change. The variable costs of maintenance for the mobile van, motorcycle and caretaker are given in Table 13. For a detailed working of variable expenses refer to Annex XV.

TABLE 13
ANNUAL VARIABLE EXPENSES OF HANDPUMP MAINTENANCE SYSTEM

Item	Mobile Van Rs.	Block Mechanic Rs.	Caretaker Rs.
INDIA MARK II PUMP			
Running Expenses	17,280	7,920	--
Maintenance Expenses	9,816	3,000	5.00
Total	27,096	10,920	5.00
INDIA MARK III PUMP			
Running Expenses	31,785	6,048	--
Maintenance Expenses	15,465	2,300	5.00
Total	47,250	8,348	5.00

Summary of maintenance expenses

The details of fixed and variable expenses of different types of maintenance systems are given in Tables 14, 15 and 16.

TABLE 14
MOBILE VAN: FIXED AND VARIABLE EXPENSES PER PUMP PER YEAR

Item		Mark II Rs.	Mark III Rs
1.	Fixed expenses	90,533	90,533
2.	Variable expenses	27,096	47,250
3.	Total fixed and variable expenses per mobile van	117,629	137,783
4.	Number of pumps serviced	300 Nos.	1950 Nos.
5.	Total fixed and variable expenses per pump	392.10	70.66

TABLE 15
BLOCK MECHANIC: FIXED AND VARIABLE EXPENSES PER PUMP PER YEAR

Item		Mark II Rs.	Mark III Rs.
1.	Fixed expenses	17,000	17,000
2.	Variable expenses	10,920	8,348
3.	Total fixed and variable expenses per mechanic	27,920	25,348
4.	Number of pumps serviced	1500 Nos.	600 Nos.
5.	Total fixed and variable expenses per pump	18.61	42.25

TABLE 16
CARETAKER: FIXED AND VARIABLE EXPENSES PER PUMP PER YEAR

Item		Mark II Rs.	Mark III Rs.
1.	Fixed expenses	35.0	35.0
2.	Variable expenses (cost of consumables)	5.0	5.0
3.	Total expenses per pump	40.0	40.0

TABLE 17
TOTAL FIXED AND VARIABLE EXPENSES OF HANDPUMP MAINTENANCE SYSTEM

Item		Rupees/Pump/Year	
		Mark II	Mark III
1.	Mobile team with van	392.10	70.66
2.	Block mechanic with motor cycle	18.61	42.25
3.	Caretaker	40.00	40.00
Total		450.71	152.91

From the foregoing tables it can be concluded that the expenses per pump/year in the case of a mobile team maintaining a India Mark II pump are excessively high and are reduced by 66% in the case of the India Mark III. The total fixed and variableexpenditure of the maintenance structure is Rs.450.71 per India Mark II pump per year and Rs.152.91 per India Mark III pump per year.

Cost of parts replaced

> As most repairs on an India Mark III can be shifted from a four-member mobile team to a single mechanic, expenses on labour and transport are reduced from Rs.450 in the India Mark II to Rs.150 for the India Mark III handpump.

The average cost of spare parts used for the maintenance of Mark II and Mark III pumps have been calculated based on the frequency of replacement of parts given in Table 5. Tables 18 and 19 give details of replacement cost of parts replaced per pump/year and also the level of maintenance structure required for replacement of each part. Figure 13 compares the mean annual spare parts cost for both types of pumps. The cost of replacement of parts is discussed in detail in Annex X.

TABLE 18
COST OF PARTS REPLACEMENT PER ANNUM PER PUMP FOR INDIA MARK II PUMP

Component/Maintained by	Cost/Pump Rs.	Percentage of total cost
BLOCK MECHANIC		
Handle assembly	81.70	19.29
Handle bearing	8.10	1.91
Chain	10.80	2.55
Bolt	0.90	0.21
Nut	1.50	0.36
Others	4.40	1.04
Sub-total	107.40	25.36
MOBILE VAN		
Pump rods	29.80	7.04
Rising main pipe	194.70	45.97
Rising main coupler	37.90	8.95
Piston seal	9.60	2.27
Cylinder body	13.90	3.28
Cylinder cap	4.20	0.99
Cylinder assembly	9.40	2.22
Piston valve	4.90	1.16
Foot valve	11.70	2.76
Sub-total	316.10	74.64
Total	423.50	100.00

TABLE 19
COST OF PARTS REPLACEMENT PER ANNUM PER PUMP FOR INDIA MARK III PUMP

Component/Maintained by	Cost/Pump Rs.	Percentage of total cost
BLOCK MECHANIC		
Handle assembly	52.70	16.56
Handle bearing	6.90	2.17
Chain	5.60	1.76
Pump rod	8.80	2.77
Piston seals	10.00	3.14
Piston valve	5.30	1.67
Foot valve	4.20	1.32
Bolt	0.20	0.06
Nut	1.10	0.35
Others	1.80	0.57
Sub-total	96.60	30.36
MOBILE VAN		
Rising main pipe	83.70	26.30
Rising main coupler	18.50	5.81
Cylinder assembly	29.40	37.52
Sub-total	221.60	69.64
Total	228.20	100.00

It may be noted from Tables 18 and 19 that:

(a) The rising main and handle assembly represent major shares in the total cost for the replacement parts for both pumps; and

(b) The cost of parts replaced is 46% less in the case of the India Mark III pump.

Total maintenance cost

The total maintenance cost of a pump will influence the selection of a pump. Table 20 compares the total maintenance cost of both types of handpumps.

TABLE 20
COMPARISON OF MAINTENANCE COSTS PER PUMP PER YEAR

Item		Mark II Rs.	Mark III Rs.
1.	Maintenance Costs		
	(a) Caretaker	40.00	40.00
	(b) Block mechanic	18.61	42.25
	(c) Mobile team	392.10	70.66
	(d) Spare parts	423.50	228.20
	Total	874.21	381.11
2.	Saving/annum in maintenance	--	493.10

From Table 20 it is evident that the requirement of funds for maintenance of the Mark III will be Rs.493.00 less per pump per year.

Break-even point on cash basis

The difference in the capital costs of the India Mark II pump and the India Mark III pump is Rs. 1314.00. This extra expenditure will be fully offset in less than three years by the lower maintenance costs of the India Mark III pump.

Downtime

Downtime is defined as the period of time when the pump is not available for normal use. Downtime consists of:

(a) The time taken to report a breakdown;

(b) The time lag between the receipt of breakdown report and actually reaching the pump to commence repair; and

(c) Active repair time i.e. the time actually taken to carry out repairs.

It is estimated that 85 % of the India Mark II deepwell handpumps remain operational at any point of time. This would mean that the India Mark II handpump remains idle for approximately 50 days in a year. The ORG report notes that reporting breakdown varied from 4 to 13 days while the time taken to put the pump back in operation varied from

Downtime in a handpump causes an indirect financial loss of Rs.15 per day as the investment is not put to use. Apart from this, the community is exposed to health hazards due to use of water from conventional sources like ponds, streams and open dug wells, resulting in high medical expenses and reduced earning capacity.

7 to 44 days after the receipt of the report. This report points out that, on an average, a Mark II pump remains inoperative for 37 days per year. This not only causes hardship to the community but also keeps the investment idle. The inordinate delay in attending to the repair is due to the dependence on the mobile team which has to be notified of the breakdown, travel from a central point and is often not available when required as it is assigned to look after more pumps than it possibly can look after efficiently.

Cost of downtime

When an India Mark II and an India Mark III pump does not work the loss is approximately Rs.15 per day . The detailed calculations are given in Table 21.

TABLE 21
COSTS OF DOWNTIME AND WATER

Item	Mark II Rs.	Mark III Rs.
1. Capital cost	24,950.00	26,264.00
2. Maintenance cost (from Table 20)	874.21	381.11
3. Interest @12% per annum on total cost	2,994.00	3,151.68
4. Depreciation (15 years approx)	1,663.33	1,750.93
5. Total (2+3+4)	5,531.54	5,283.72
6. Maximum number of days pump can work	365	365
7. Cost of operation/day [(5) divide by (6)]	15.16	14.48
8. Water pumped per day (8x60x12)	5,760 ltrs	5,760 ltrs
9. Cost of water per litre [(7) divided by (8)]	0.263 paise	0.251 paise

The table indicates that the cost of water, works out to 0.263 paise per litre and the cost of operating a Mark II pump is Rs.15.16 per day. If a pump is inoperative for 37 days in one year, the loss of benefits to the community in indirect financial terms will be Rs.560.92 per year. Apart from this, the loss of time involved in drawing water from a more distant source and the potential adverse impact on the health of the community is also significant. However, no study has been carried out to quantify the actual impact of these losses in financial terms.

The unusually high downtime of the Mark II in the field is possibly due to the following factors.

(a) Delay in reporting breakdown;
(b) Communication delays;
(c) Delay in taking action on receipt of breakdown report; and
(d) Use of non-standard spares and faulty installations.

These factors could be altogether eliminated if pumps could be repaired by the users themselves. However, this is difficult in the case of the India Mark II pump as maintenance of this pump requires heavy and special tools and tackles and a crew of three or four semi-skilled workers. In the case of the India Mark III pump, however, 93.5% of the repairs can be carried out by a mechanic (who can move about on a motorcycle) with the help of a user. It is also possible to maintain the India Mark III pump through a village mechanic after some training. The shifting of maintenance responsibility from district/block level to village-level will result in a sharp reduction in downtime and maintenance costs.

SOCIAL AND HEALTH BENEFITS

There are many benefits that accrue from a reliable community water supply system. The total impact is often the result of a combination of factors like safe water, good sanitation and health education. Measuring benefits to the community is not only difficult but complex as it involves technical, economic, behavioral, nutritional, public health and many other factors.

Many impact studies have clearly demonstrated the importance of clean drinking water to reduce the frequency of water-borne diseases like diarrhoea, gastro-enteritis, guineaworm etc. A study in Mirzapur in Bangladesh, where an integrated package of handpumps and health education were provided, has shown a 31% reduction in the incidence of diarrhoea in children under 5 years of age over a one-year period.

The loss and suffering caused to the community in indirect financial terms due to the breakdown of a handpump is much more than the downtime cost discussed in the preceding paragraphs. This factor should be given adequate weightage when selecting a pump.

SUMMARY AND CONCLUSIONS

The conclusions and recommendations in this report are based on field data collected over a period of 4 1/2 years covering a relatively small number of India Mark II and India Mark III pumps. Certain assumptions were also made independent of the field data. More extensive data are currently being collected from five demonstration projects being implemented in several states by the State Governments with the approval of and support from the National Drinking Water Mission in cooperation with UNICEF and the UNDP/World Bank Water & Sanitation Program. Pump usage, pump density (number of pumps per square kilometer), quality of tubewells, handpump installation and water varies substantially from place to place. And, these factors have a significant impact on the maintenance costs and system. The estimated maintenance cost should be therefore treated only as indicative of the sensitivity of maintenance cost to the choice of technology.

Technical and economic analysis of field data has led to the following conclusions.

(a) The improvement in the standard India Mark II deepwell handpump, i.e. nitrile cup seals, modified spacer, two piece upper valve, additional plate between the head flange and water tank top flange and square bearing housing made during the project, will substantially improve MTBF. The estimated average life of nitrile cup seal is over two years as compared to less than 12 months for the chrome tanned leather cup seals. This will result in reduced dependence on a mobile van and reduced annual maintenance costs. The additional plate will considerably simplify the maintenance of the above-ground components. The estimated cost of these modifications in the existing standard India Mark II deepwell handpump is Rs.250 per pump (see Annex XVI for details). The estimated annual saving in maintenance due to the above modifications could be Rs.150 per pump per year (see Annex XVI).

(b) The study indicates that the indirect financial costs of downtime per pump per year for the India Mark II deepwell handpump is estimated at Rs.561 approximately. The indirect loss due to this factor alone works out to Rs.729 million approximately per year on a national basis. The loss to the community due to downtime may be much higher than the indirect financial costs indicated. Downtime has to be kept to the minimum by strengthening the maintenance system to improve the service level. At present, in some states, one mobile van is assigned over 1000 handpumps, which makes it impossible for a mobile team to provide prompt and reliable service. Providing an adequate number of mobile vans based on their realistic capacity to service the pumps and inputs from the community will reduce the downtime substantially.

(c) At present, defective handle assemblies and cylinder bodies are replaced and no effort is made to repair them. Reconditioning of the handle assemblies and cylinder bodies will result in substantial savings in the maintenance expense. This can easily be done in the field workshops.

(d) The replacement cycle for spare parts is adequately determined for the India Mark II deepwell handpump after four-and-a-half years of testing. The recommended list of spare parts for two years of normal maintenance is given in Annex XI.

(e) The India Mark III deepwell handpump developed during the project approaches the VLOM concept and can be maintained by an area/village-based mechanic for over 90 % of the repairs required. Backup is needed from a mobile team with special tools and replacements for major repairs i.e. 0.16 times as against 1.44 times per pump per year in the case of the India Mark II deepwell handpump. It has been field tested for over three years and is now ready for introduction on a large scale.

(f) The downtime in the India Mark III deepwell handpump will be substantially less as more than 90 % of the repairs can be carried out by the area mechanic or village-based mechanic with fewer tools weighing just 7 kg.

(g) The India Mark III deepwell handpump is a major advance in facilitating maintenance by the users themselves. Future research and development should be undertaken to further simplify maintenance requirements which will encourage the users to carry out the maintenance, leading to increased self-reliance. The priorities for improvements are:

    (i) Elimination of threaded connections wherever possible;

    (ii) Introduction of tool-less eye and hook joints or similar joints in connecting rods; and

    (iii) Simplified replacement of cup seals and valves.

(h) By introducing the India Mark III deepwell handpump, a reduction in direct maintenance costs in the order of Rs.493 per annum per pump can be realized, primarily as a result of the reduced need for motorized maintenance vans and crews, manpower, replacement parts, interventions and reduced establishment cost as detailed in Table 22. The spare parts requirement for normal maintenance over a two-year period of the India Mark III deepwell handpump is given in Annex XII.

TABLE 22
COMPARISON OF OPERATION REGIMES OF MARK II VERSUS MARK III PUMPS

Mean annual values	Mark II	Mark III	Unit	%Reduction
1. Total visits	2.98	2.46	Visits/year	18
2. Visits by mobile team	1.44	0.16	Visits/year	89
3. Visits by block mechanic	0.40	1.19	Visits/year	66*
4. Visits by caretaker	1.14	1.11	Visits/year	3
5. Active repair time	264	87	Minutes/year	67
6. Parts replacement frequency	9.15	4.79	Parts/year	48
7. Spare parts cost	424	228	Rs/year	46
8. Maintenance cost excluding cost of replacement	450.71	152.91	Rs/year	66 (Rs.297.80)
9. Maintenance cost	874.21	381.11	Rs./year	56.4 (Rs.493.10)

* Number of visits required by the block mechanic are substantially more for the India Mark III deepwell handpump than the India Mark II deepwell handpump.

Note: The above findings are based on 48 India Mark II and 18 India Mark III pumps field tested over four-and-a-half years as part of the Coimbatore Handpump Field Testing Project.

(i) Although the capital costs (excluding the cost of borewell) of the India Mark III deepwell pump is approximately 40 % higher than the India Mark II deepwell handpump, the extra expenditure will be offset fully in many cases in less than three years due to reduced maintenance costs.

(j) The rate of recovery required for maintenance expenses from the users would be about 50 % lower in the case of the India Mark III deepwell handpump. Refer to Table 23 for details.

(k) As the area/village mechanic can easily carry out over 90 % of the repairs with the help of the users/caretakers, the downtime in the case of India Mark III deepwell handpump would be substantially less.

(l) It is estimated that a mobile team can provide a satisfactory level of service for a maximum of 400 India Mark II deepwell handpumps or 2750 India Mark III deepwell pumps if village-level capability to carry out minor repairs is available. As the parameters governing the capacity of a mobile van i.e. SWL, quality of water, density of pumps and depth of cylinder placement differs substantially from district to district, the capacity of a mobile van to service handpumps will also vary significantly. The capacity arrived at should therefore be taken as indicative only.

(m) The platform design as shown in Figure 14 has proved much better than the existing design. It reduces splash of water outside the platform and also the banging of the handle on the bottom stop of the pumphead bracket. Users find it more convenient, as sufficient area is available for the user to stand while operating the pump.

(n) In a borewell where SWL (SWL) is more than 45 meters, greater effort is required to operate the India Mark II deepwell handpump. The use of a 50mm ID cylinder with 2" (50mm N B) galvanized iron rising main with India Mark II head and handle assembly with 10:1 mechanical advantage makes the pump far easier to use.

(o) The special tools developed for the maintenance of the India Mark III deepwell handpump have performed satisfactorily. However, further development of maintenance tools should be given high priority.

(p) The connecting rod with 1.00 mm thick natural rubber coating was found corrosion resistant. It may be a good substitute for stainless steel connecting rods, normally used in wells with corrosive water. Further development and field testing is necessary on this subject.

(q) The use of a pump rod centralizer in pumps with uPVC rising mains is essential. However, its use, even in pumps with a galvanized iron (GI) rising main will reduce damage to the inner surface of GI pipes due to abrasion. Further development work is needed on this problem.

(r) The rubber compression fitting used in experimental pumps to hold the PVC rising main in the water tank assembly performed extremely well. No failure was noticed during three years of field testing.

(s) The uPVC rising main is not found suitable for installation in unlined borewells. The abrasion from outside causes premature failure of the uPVC rising main. The threaded uPVC joint in the uPVC rising main worked satisfactorily for two years. Further development and field testing will be necessary to develop a system compatible with unlined borewells.

RECOMMENDATIONS

1. Adoption of the India Mark III deepwell handpump on a large scale

From the preceding account, it is evident that the India Mark III pump offers distinct technical, economical and social advantages over the India Mark II pump. It is therefore recommended that the India Mark III pump be adopted on a large scale and a national standard be prepared. With the accent on village-based and community managed maintenance approach, a gradual conversion of existing India Mark II deepwell pumps to India Mark III pumps needs to be commenced. However, no existing India Mark II deepwell installation should be replaced by the India Mark III pump unless it is due for major overhaul or replacement.

The adoption of the Mark III pump will require an additional capital investment of Rs.1314 per pump. This additional cost will be fully offset by the lower maintenance cost in less than three years. Moreover, the spin-off in terms of health and socio-economic benefits could easily exceed the savings in maintenance and downtime costs estimated in the report.

2. Adoption of proven developments on a national scale

To improve the MTBF in the standard India Mark II handpump it is recommended that the following modifications be incorporated in the Indian Standard Specifications and made to the existing 1.3 million Mark II pumps.

(a) The existing leather piston seals be replaced by nitrile rubber piston seals.

(b) The existing gun metal spacer be replaced by the modified gun metal spacer.

(c) The cylinder brass liner (wherever it has been in service for more than two years) be replaced with a new brass liner.

(d) The existing piston valve be replaced by the two piece piston valve.

(e) A hole of 75mm dia be provided in the head flange.

(f) An additional flange be inserted in between the head flange and the water tank top flange.

This modification program should be implemented on a mass scale on a priority basis based on a set of operational guidelines. The modifications when effected to the existing 1.3 million India Mark II pumps will need an investment of Rs.325 million. The estimated annual savings on account of reduced maintenance cost will be Rs.195 million per year. The additional investment will be recovered within 20 months through savings in maintenance costs.

Two platform designs as shown in Figure 14 and 15 are recommended for adoption as they offer many advantages over the present design.

3. **Extra deepwell handpump**

It is recommended that a 50mm ID cylinder with 50mm N B galvanized iron medium class rising main pipe and the India Mark II pump head fitted with 10:1 mechanical advantage handle for SWL more than 45 meters should be field tested on a large scale.

4. **Maintenance approach**

The present handpump maintenance system based on a mobile team is in fact a repair-on-demand system. Centralized maintenance which depends on a mobile team has inherent drawbacks which result in long response time, high maintenance costs and extended downtime. To overcome these adverse indicators it is necessary to decentralize the handpump maintenance system to the maximum extent. The ultimate aim must be to create capability at the village-level to carry out maintenance and repairs on the handpumps. It is therefore recommended that a study on a national scale be conducted to:

(i) Prepare a status report on the existing systems for maintenance of handpumps;

(ii) Define the strengths and weaknesses of different systems in operation;

(iii) Suggest modifications in the existing system to improve its efficiency and effectiveness and develop options for a village-based maintenance system; and

(iv) Suggest ways to build capability at the village-level to carry out the maintenance and repairs of the pumps.

It is recommended that adequate mobile teams/block mechanics be provided to reduce the downtime in the existing standard India Mark II handpumps.

5. **Sharing of costs by users**

At present, the handpumps are installed and maintained by the various State Governments. Users do not contribute towards either the capital cost or the maintenance cost. To make the maintenance of the drinking water supply program more efficient and self-sustaining, it is recommended that the users be persuaded to bear at least the maintenance cost. The recovery of maintenance expenses from the users will create a sense of involvement in the community. The approximate rates of recovery at different levels suggested in Table 23 are only indicative. A detailed study is recommended to work out the details of a comprehensive cost recovery system.

TABLE 23
COST RECOVERY FOR INDIA MARK II AND INDIA MARK III

Heads of recovery	Amount to be recovered annually Rs.	Recovery per person annually* Rs.	Total annual recovery per person Rs.
FOR MARK II PUMP			
Annual maintenance	874.21	4.37	4.37
Annual depreciation	1663.33	8.32	12.69
Annual interest cost	2994.00	14.97	27.66
FOR MARK III PUMP			
Annual maintenance	381.11	1.91	1.91
Annual depreciation	1750.93	8.76	10.670
Annual interest cost	3151.68	15.76	26.43

* It is assumed that 200 persons will use one handpump.

6. **Research and development**

Research and development efforts should continue to make such design changes that make the maintenance of the handpump simpler and easier. This is absolutely essential if the users themselves are to maintain the pumps. To reiterate, the following areas need special attention.

(a) Elimination of threaded connections wherever possible.

(b) Hook and eye connectors or similar design to replace threaded joints in connecting rods.

(c) Replacement procedure for piston seal and valves need to be simplified.

(d) Alternatives for corrosion-resistant connecting rods.

(e) Development of connecting rod centralizers.

(f) Development of improved joints for uPVC rising main.

(g) Development of pipe centralizers for uPVC rising main, suitable for installation in unlined borewells.

FIGURE 1

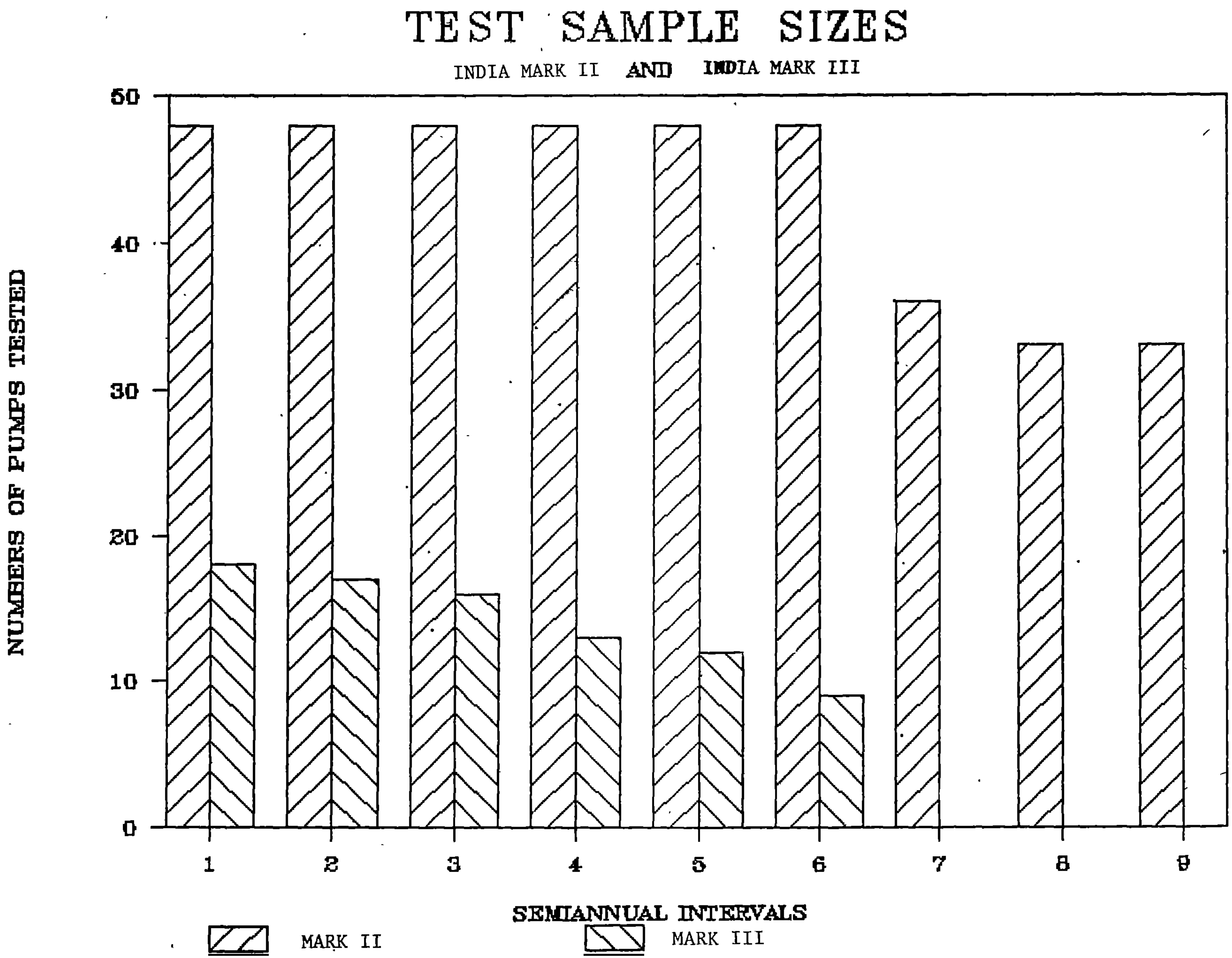

TEST SAMPLE SIZES
INDIA MARK II AND INDIA MARK III
50
40
30
20
10
0
NUMBERS OF PUMPS TESTED
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
MARK II
MARK III

FIGURE 2

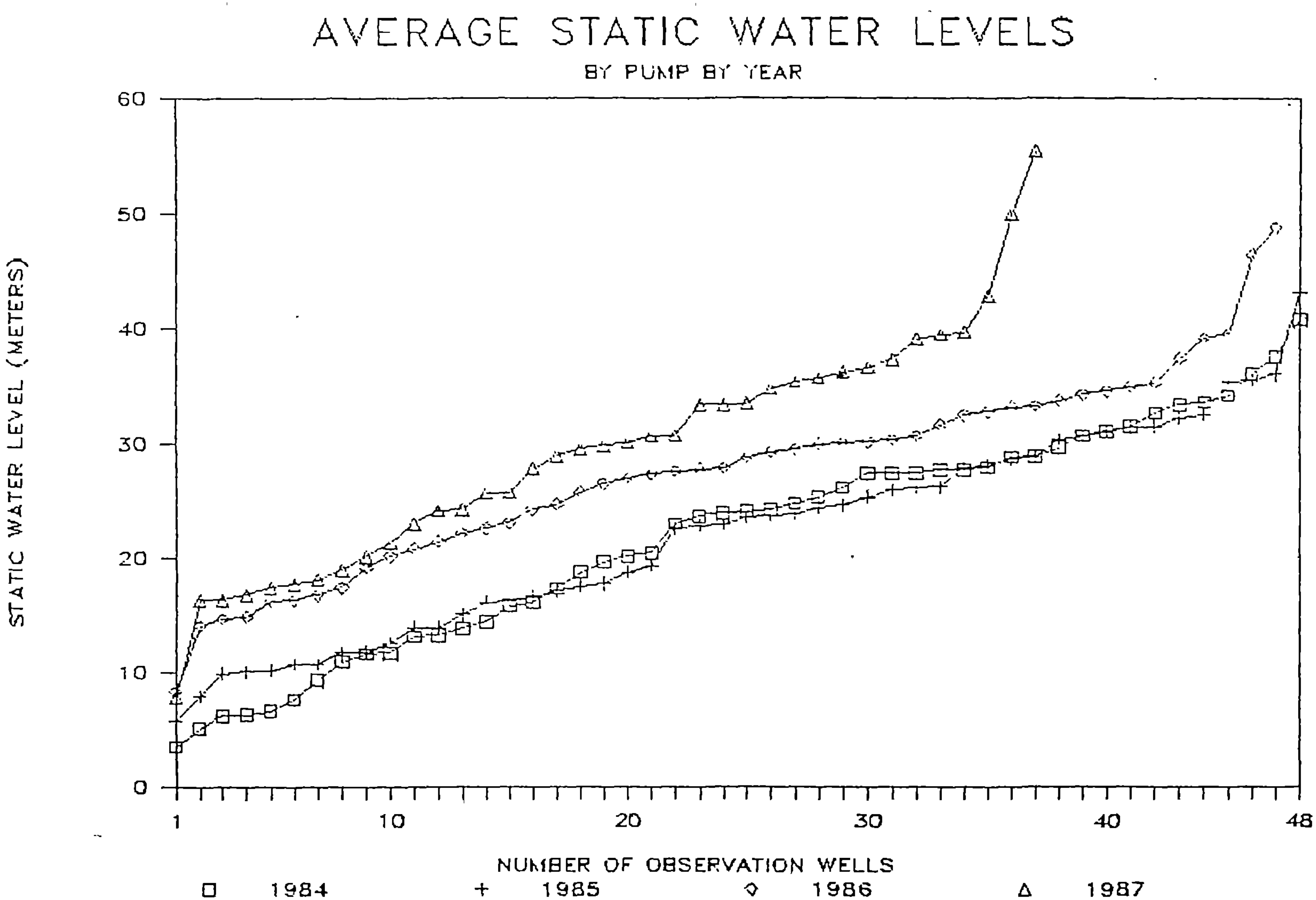
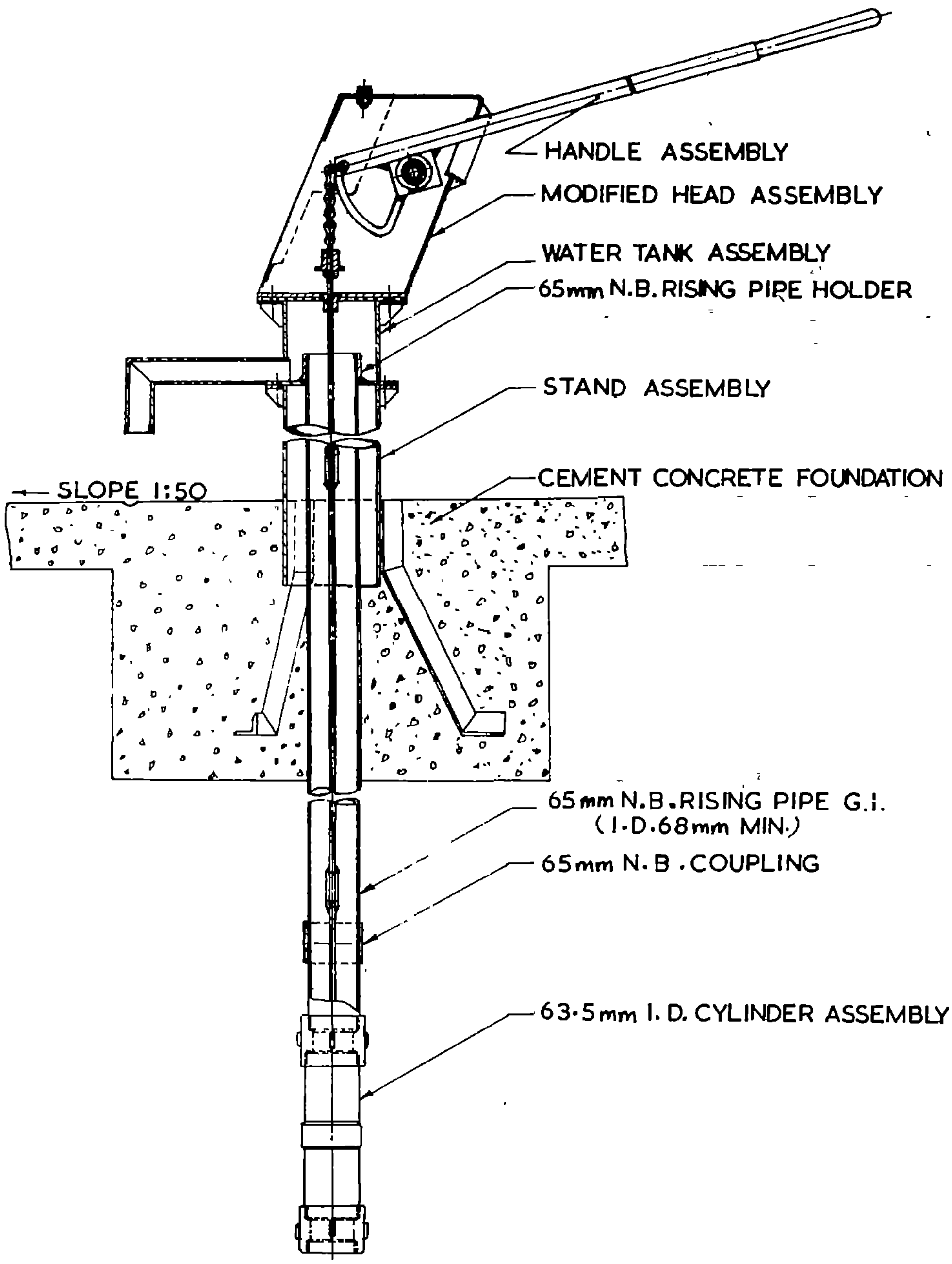
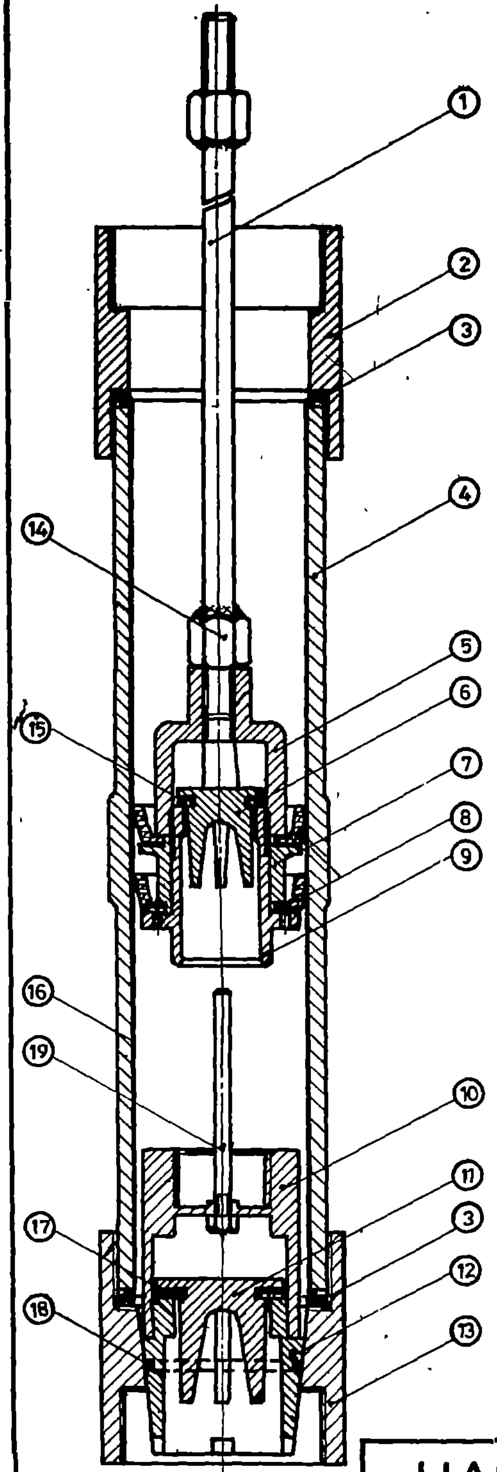

AVERAGE STATIC WATER LEVELS
BY PUMP BY YEAR
STATIC WATER LEVEL (METERS)
60
50
40
30
20
10
0
1
10
20
30
40
48
NUMBER OF OBSERVATION WELLS
□ 1984
+ 1985
◇ 1986
△ 1987

FIGURE 3



HAND PUMP PROJECT INT/087/013	
INSTALLATION DETAILS OF INDIA MARK III DEEP WELL HAND PUMP	SCALE.- N.T.S.
	DRG. No.:-

FIGURE 4



PART NO.	NO. OFF	DESCRIPTION	REMARKS
19	1	PUSH ROD WITH CHECK NUT	—
18	1	'O' RING	—
17	1	RUBBER SEATING FOR 2 PIECE CHECK VALVE GUIDE	—
16	1	BRASS LINER	—
15	1	RUBBER SEATING FOR 2 PIECE UPPER VALVE GUIDE	—
14	2	HEX. COUPLER	—
13	1	BOTTOM COUPLER	—
12	1	FOOT VALVE SEAT	—
11	1	2 PIECE CHECK VALVE GUIDE	—
10	1	FOOT VALVE BODY	—
9	1	FOLLOWER	—
8	2	PUMP BUCKET	—
7	1	SPACER	—
6	1	2PIECE UPPER VALVE GUIDE	—
5	1	PLUNGER YOKE BODY	—
4	1	CYLINDER BODY	—
3	2	SEALING RING	—
2	1	TOP COUPLER	—
1	1	PLUNGER ROD	—

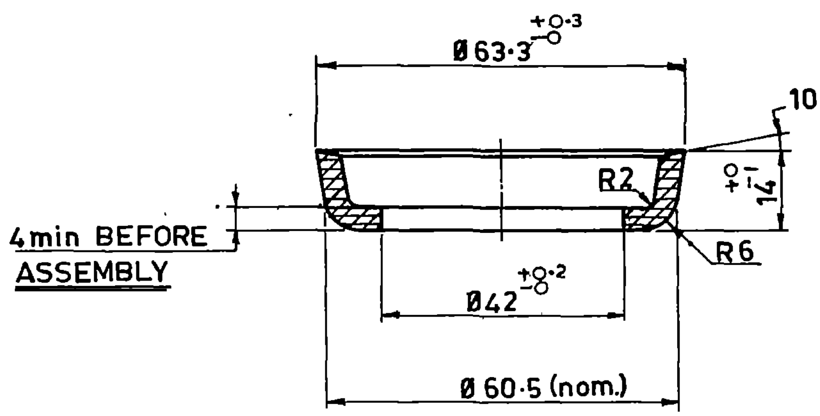
HAND PUMP PROJECT
INT/087/013

INDIA MK III HAND PUMP
CYLINDER ASSEMBLY

SCALE:- N.T.S.

DRG. No.

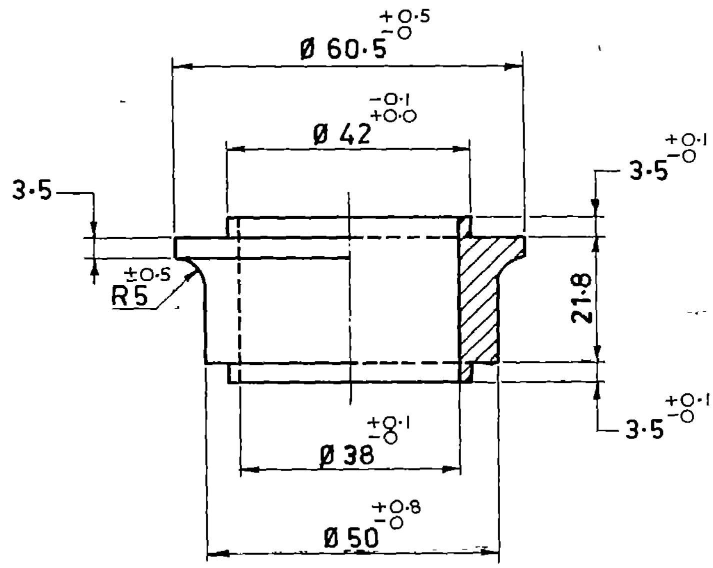
FIGURE 5



MATERIAL:- NITRILE RUBBER (NBR)
SHORE HARDNESS: $80^{\pm 5}$ SCALE 'A'

HAND PUMP PROJECT INT/087/013	
CUP SEAL	SCALE:- 1:1
	DRG. No.:- 2

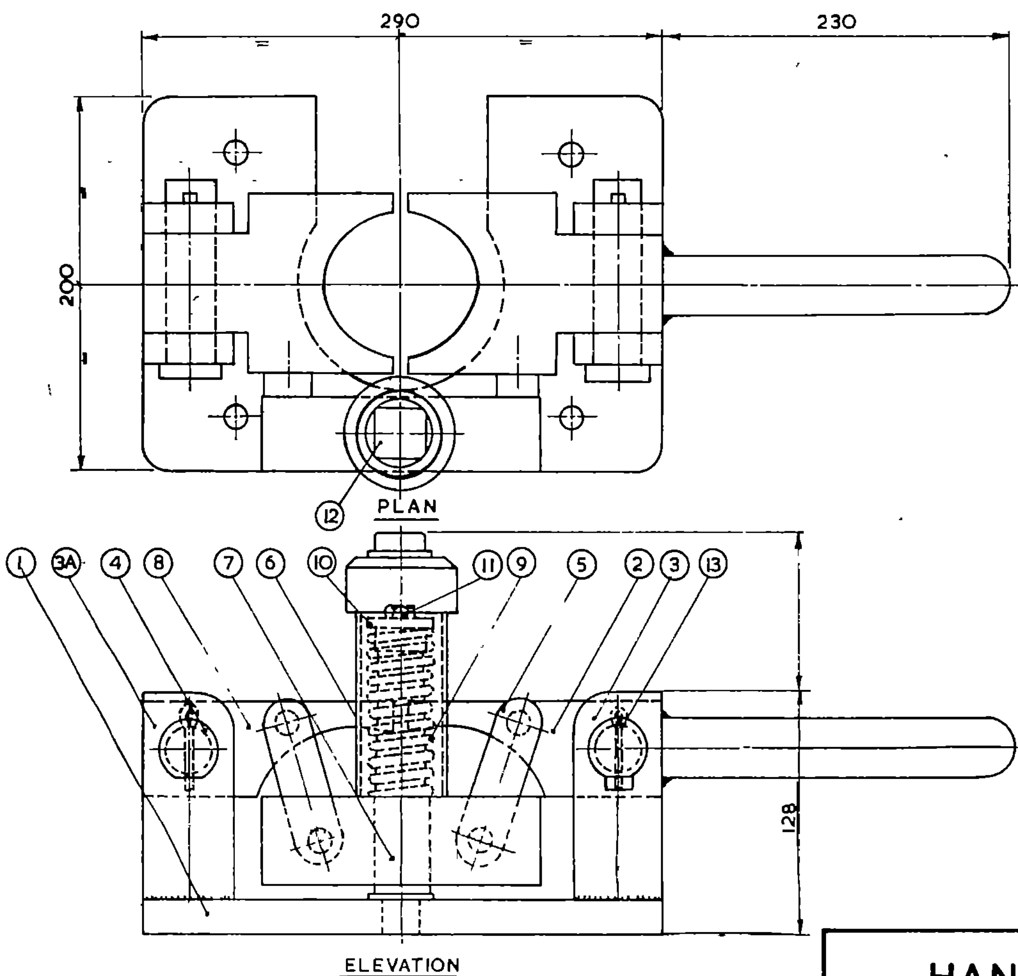
FIGURE 6



MATERIAL :- Gr. LTB 2 OF IS:318-1981 (GUN METAL)

HAND PUMP PROJECT INT/087/013	
MODIFIED SPACER	DRG. No. 1
	SCALE 1:1

FIGURE 7



PART NO.	NO. OFF	DESCRIPTION	MATERIAL
13	2	SPLIT PIN	M S
12	1	PROJECTION COVER	IS. 226 ST 42
11	1	SPRING ANCHOR BOLT	H.T. BOLT 8·8 Gr.
10	1	SPRING RETAINER	IS: 226 ST 42
9	1	SPRING	SPRING STEEL
8	1	LEFT HAND JAW	IS: 226 ST 42
7	1	PILLER GUIDE	IS. 226 ST 42
6	1	LIFTING BLOCK	IS 226 ST 42
5	2	LINK ASSEMBLY	IS· 226 ST 42
4	2	AXLE PIN	EN-8
3A	2	JAW SUPPORTING PILLER	IS: 226 ST 42
3	2	JAW SUPPORTING PILLER	IS: 226 ST 42
2	1	RIGHT HAND JAW	IS: 226 ST 42
1	1	BASE PLATE	IS·226 ST 42

HAND PUMP PROJECT

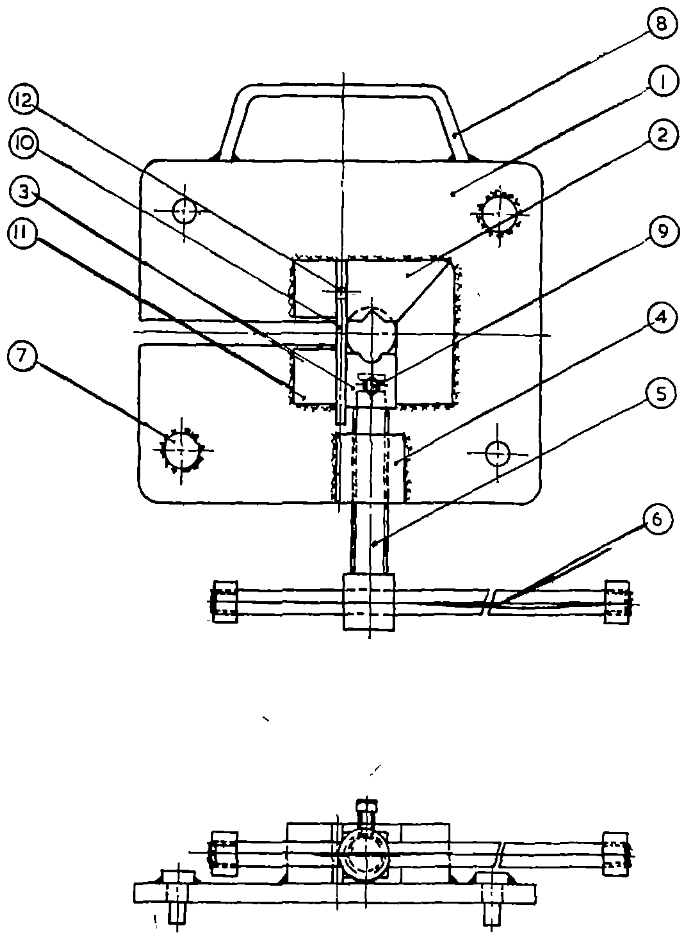
INT / 087 / 013

SELF LOCKING CLAMP FOR INDIA MARK III PUMP

SCALE :- N.T.S.

DRG. No. :-

FIGURE 8



PART NO	NO. OFF	DESCRIPTION	MATERIAL
12	1	FIXED PIN	IS:226-ST 42
11	2	COUPLER HOLDING BLOCK	IS: 226-ST 42
10	1	LATCH	IS. 226-ST 42
9	1	M6 BOLT	—
8	1	CARRYING HANDLE	IS 226-ST 42
7	2	BASE PLATE LOCATION LUGS	IS 226-ST 42
6	1	HANDLE	IS: 226-ST 42
5	1	THREADED SHAFT	IS: 226-ST 42
4	1	FIXED NUT	IS:226-ST 42
3	1	MOVABLE JAW	IS: 226-ST 42
2	1	SUPPORTING BLOCK	IS: 226-ST 42
1	1	BASE PLATE	IS:226-ST 42

NOTE.- TO BE ELECTROGALVANISED 30 MICRONS (MIN) THICK

HAND PUMP PROJECT

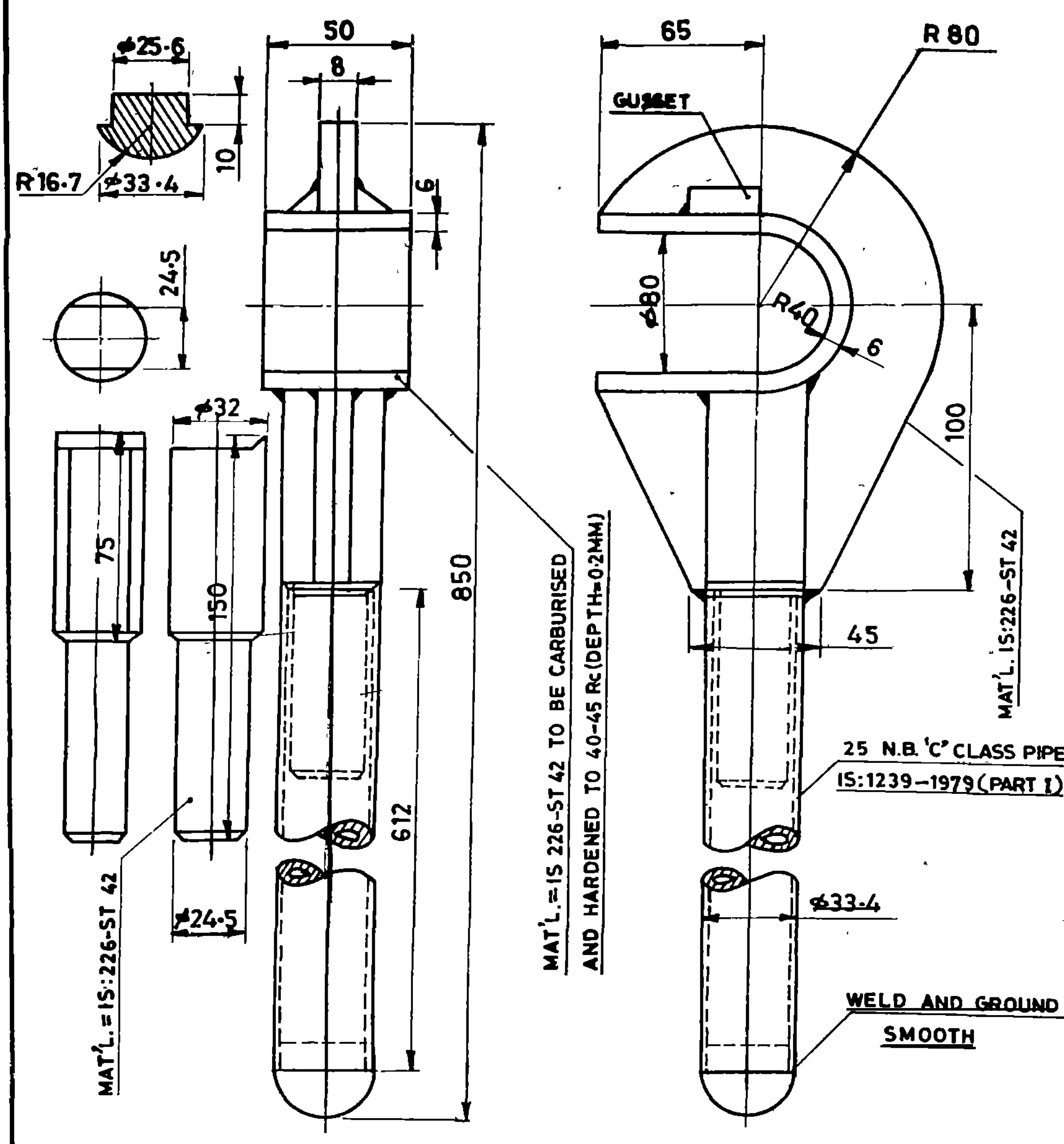
INT / 087 / 013

CONNECTING ROD VICE

SCALE :- N.T.S.

DRG. No.:-

FIGURE 9

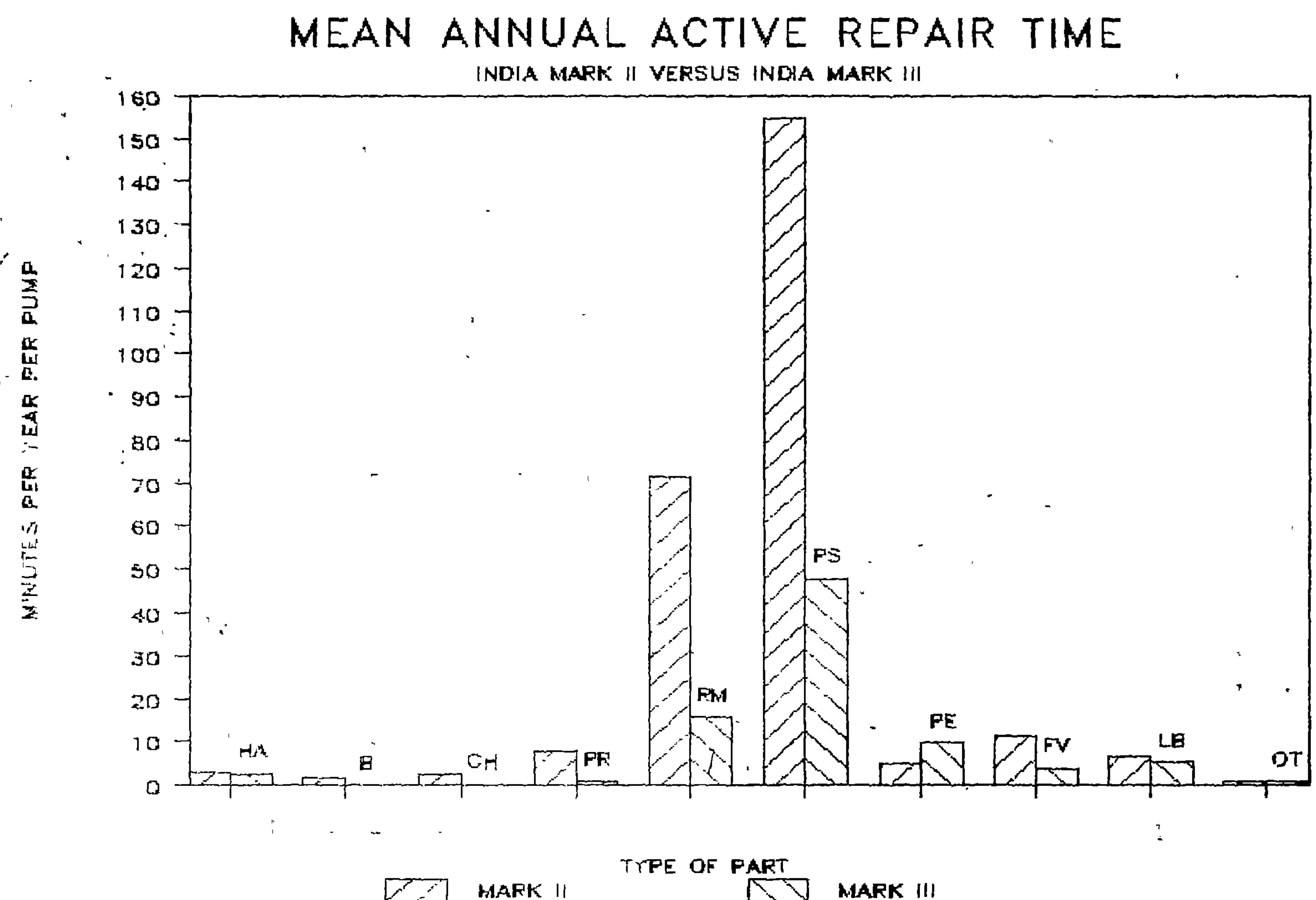


NOTE ① WELDING FILLET 4mm (MIN.)

② GUSSET-SOLID TRIANGULAR 25 TO 30mm LONG-IS:226

HAND PUMP PROJECT INT/087/013	
LIFTING SPANNER	SCALE:- N.T.S. DRG. No.:-

Figure 10



MEAN ANNUAL ACTIVE REPAIR TIME
INDIA MARK II VERSUS INDIA MARK III
MINUTES PER YEAR PER PUMP
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
HA
B
CH
PR
RM
PS
PE
FV
LB
OT
TYPE OF PART
MARK II
MARK III

FIGURE 11

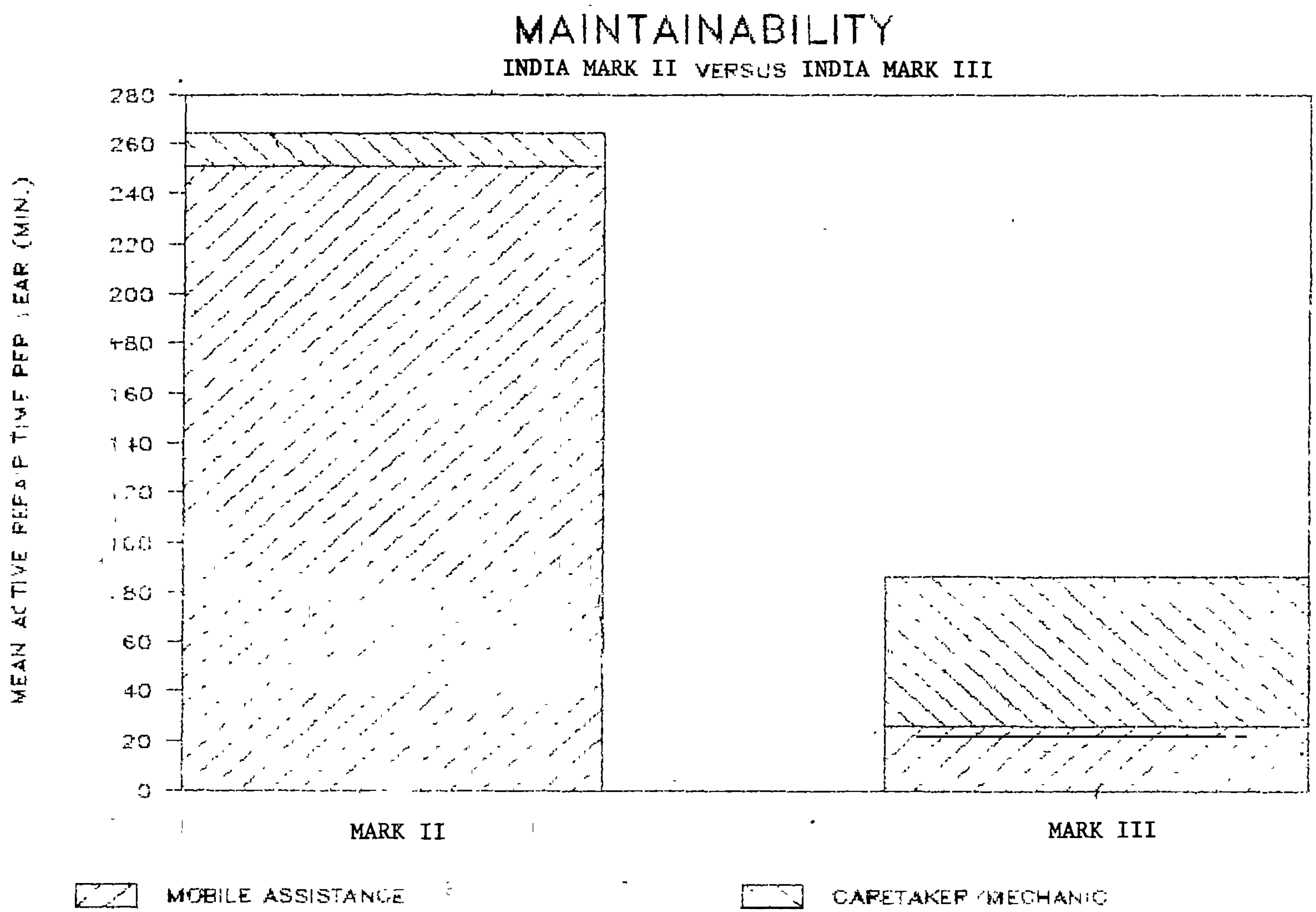

MAINTAINABILITY
INDIA MARK II VERSUS INDIA MARK III
MEAN ACTIVE REPAIR TIME PER YEAR (MIN.)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
MARK II
MARK III
MOBILE ASSISTANCE
CARETAKER/MECHANIC

Figure 12

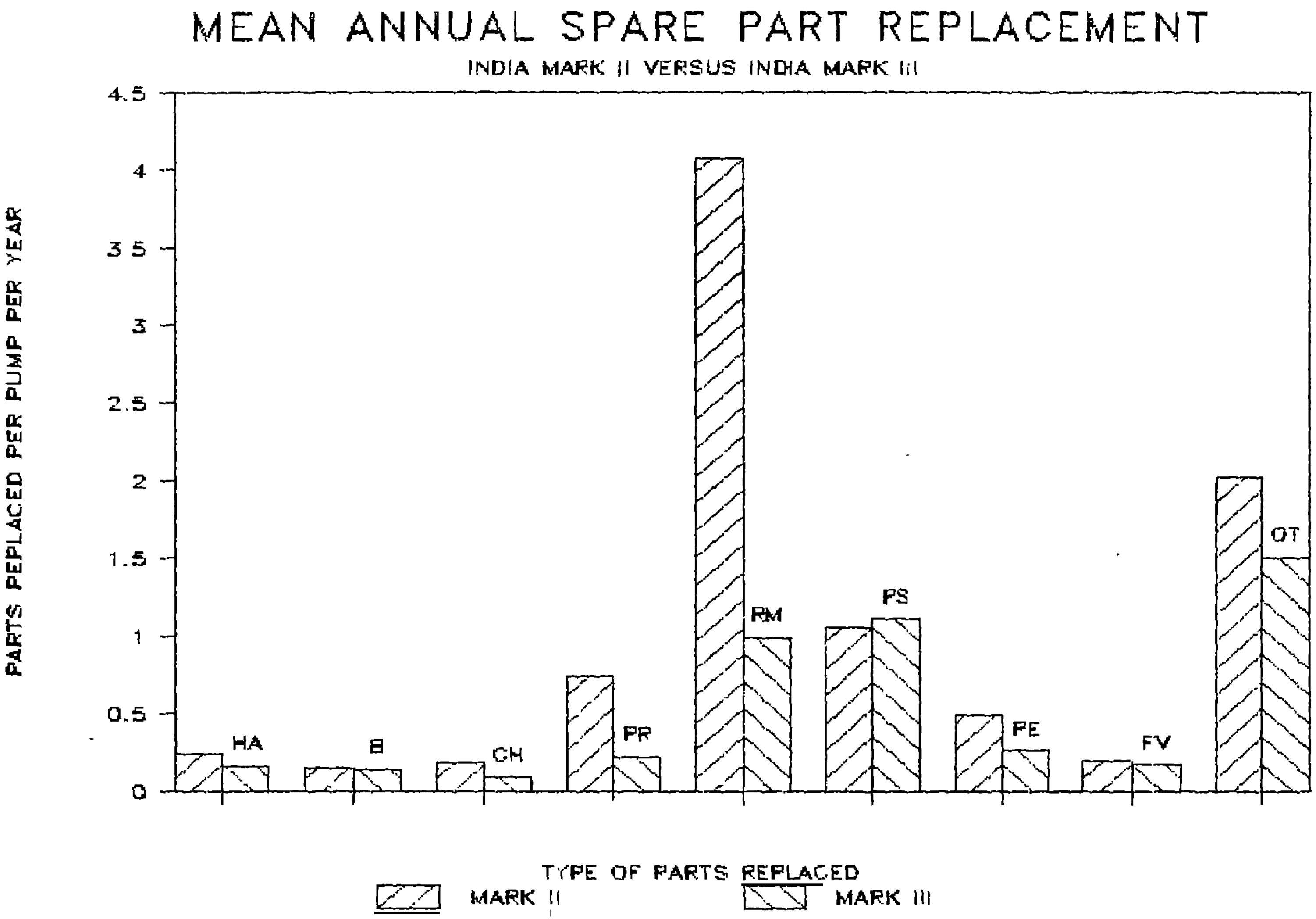

MEAN ANNUAL SPARE PART REPLACEMENT
INDIA MARK II VERSUS INDIA MARK III
PARTS REPLACED PER PUMP PER YEAR
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
HA
B
CH
PR
RM
PS
PE
FV
OT
TYPE OF PARTS REPLACED
MARK II
MARK III

Figure 13

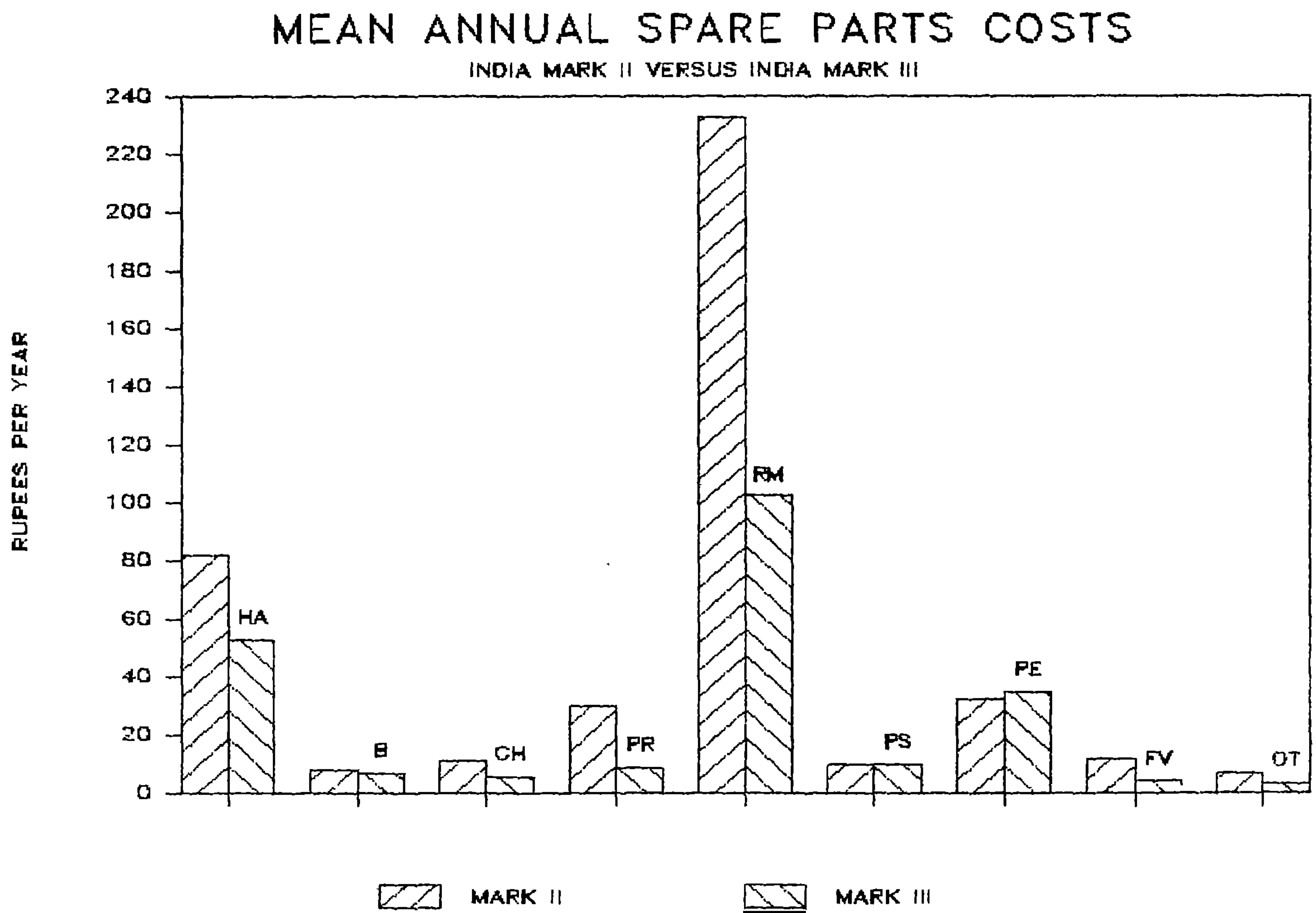
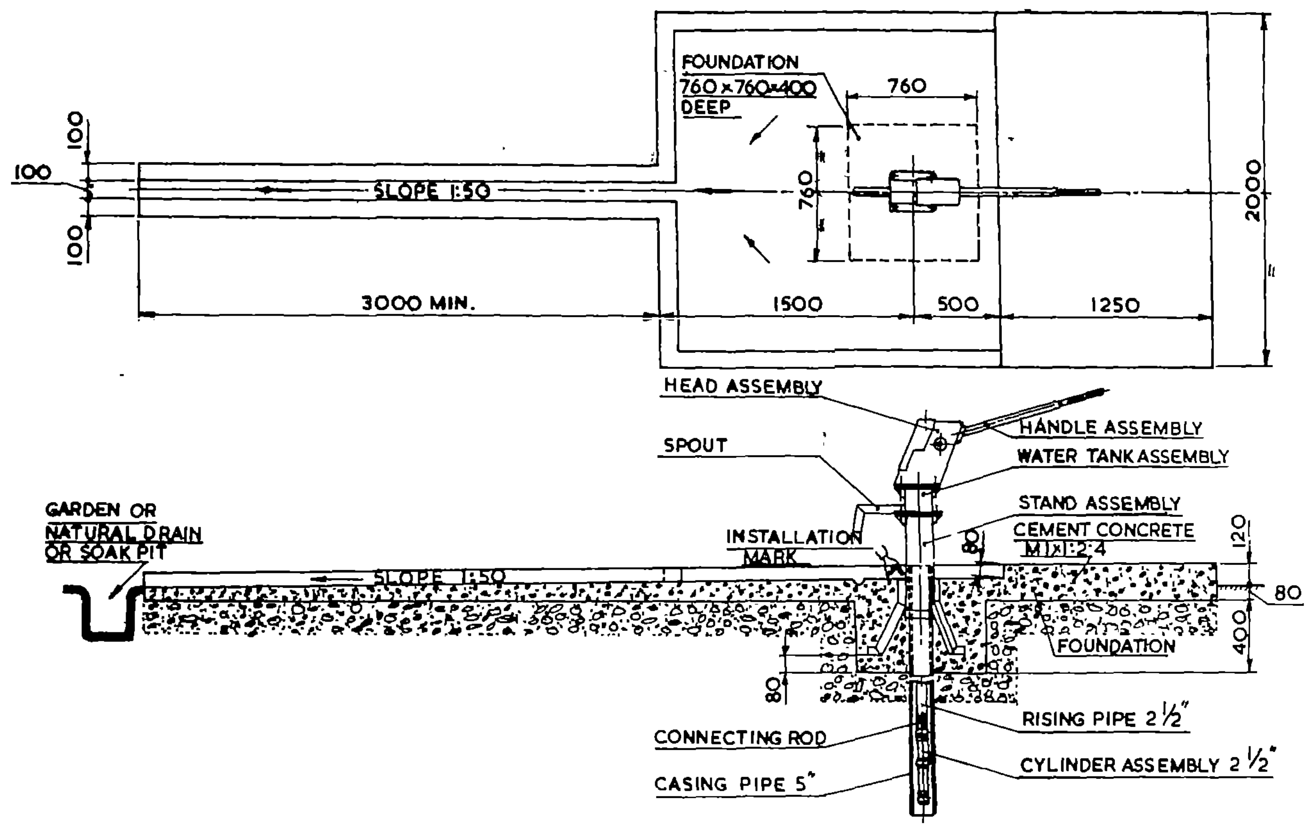

MEAN ANNUAL SPARE PARTS COSTS
INDIA MARK II VERSUS INDIA MARK III
RUPEES PER YEAR
240
220
200
180
160
140
120
100
80
60
40
20
0
HA
B
CH
PR
RM
PS
PE
FV
OT
MARK II
MARK III

FIGURE 14

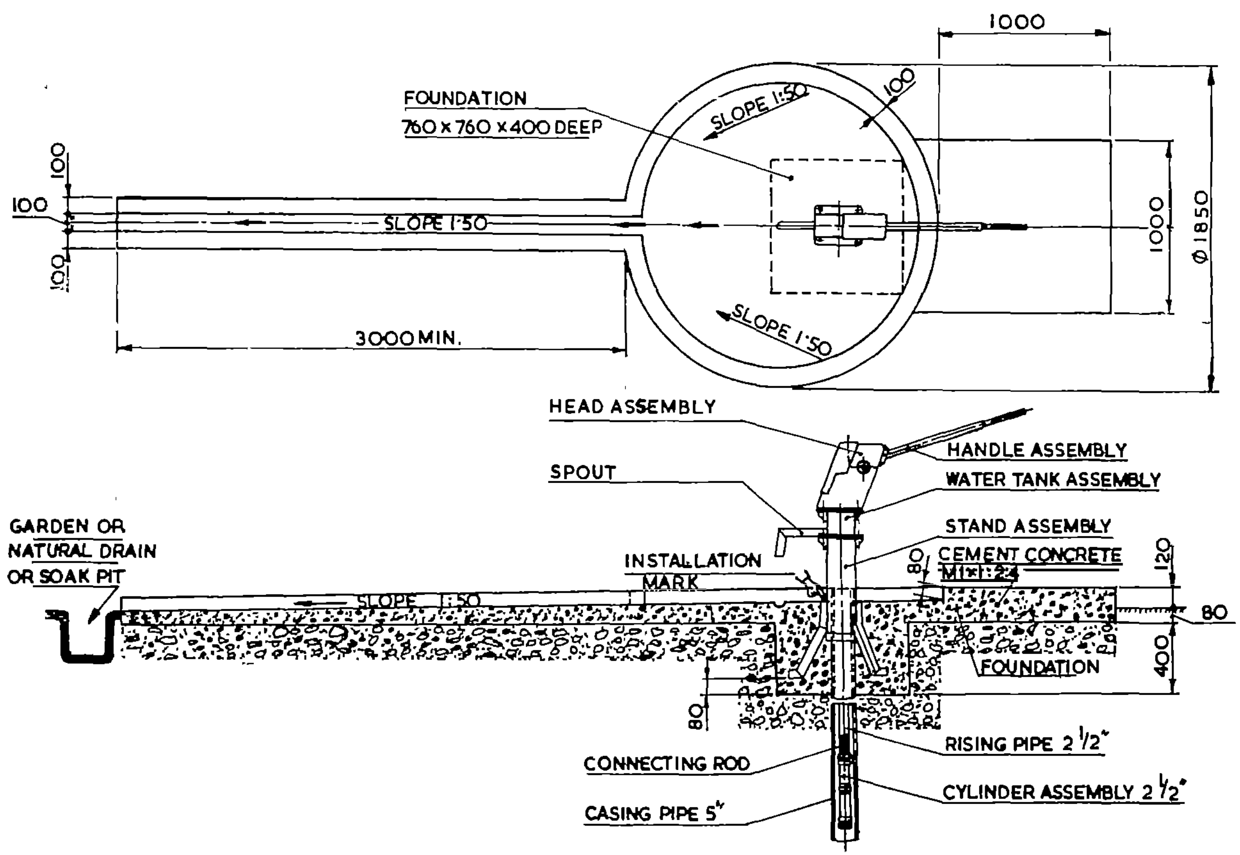


HAND PUMP PROJECT

INT /087/013

PLATFORM DETAILS OF I M II & I M III PUMPS	SCALE :- N.T.S.
	DRG. No. :-

FIGURE 15



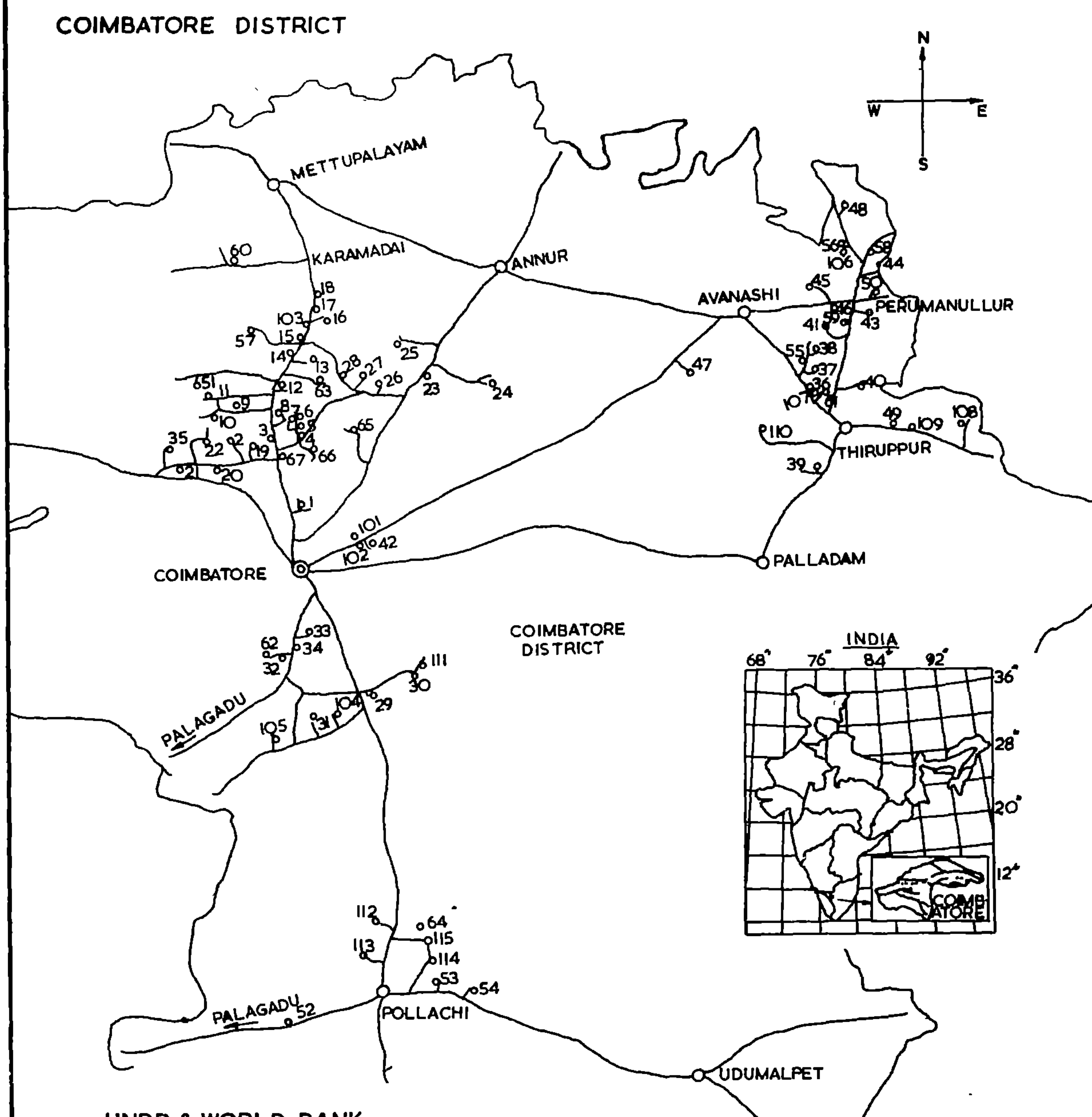
HAND PUMP PROJECT INT / 087/013	
PLATFORM DETAIL OF I M II & I M III PUMPS	SCALE :- N.T.S. DRG. No. :-

List of Test Pump Sites and their Round-Trip Distance

Site No. of HP	Name of habitation	Round trip distance from Coimbatore city in Kms
1.	Manickavasaga Nagar	12
2.	Thippanur	34
3.	Vadamadurai	25
4.	NGGO colony	29
5.	Lakshmi Nagar	31
6.	State Bank colony	30
7.	VKV Nagar -I	28
8.	VKV Nagar -II	28
9.	Sarvodaya colony	30
10.	Jangamanaicken Palayam	31
11.	Nehru colony	33
12.	Vethilaikali Palayam	32
13.	Thullukkanur	46
14.	Nehru Colony	45
15.	Periamatham Palayam	52
16.	Chinnamatham Palayam	57
17.	Thaneerpanthal	58
18.	Bettathapuram	60
19.	Pannimadai-HC	31
20.	Papanaicken Palayam	37
21.	Madathur	35
22.	Varapalayam	42
23.	Kunnathur-HC	46
24.	Manickam Palayam	52
25.	Ellapalayam	56
26.	Kottaipalayam	48
27.	Sengadu	52
28.	Agraharasamakulam	52
29.	Murugan Nagar	36
30.	Chettipalayam	45
31.	Thambagounden Palayam	42
32.	Parvathipuram	26
33.	Narashimapuram-HC	25
34.	Narashimapuram	24
35.	Nanjundapuram	40
36.	Anna Nagar	110
37.	Amma Palayam	107
38.	Pallipalayam	109
39.	Barathi Nagar	134
40.	Boyampalayam	136
41.	Pongupalayam	146
42.	B.R.Puram	20
43.	Perumanullur	146
44.	Athikkadu	155

Site No. of HP	Name of habitation	Round trip distance from Coimbatore city in Kms
45.	Ettiveerampalayam	152
46.	Muttiankinaru	150
47.	Velandipalayam	82
48.	Sokkanur	166
49.	Rakkayapalayam	136
50.	Parasapalayam	154
51.	Palaniswami Nagar	50
52.	Nullur	96
53.	Vijaya Nagar	100
54.	Unjavellampatti	103
55.	Thirumuruganpoondi-HC	108
56.	Vallipuram	160
57.	Mathampalayam	53
58.	Kullanampathi	158
59.	Ayampalayam	142
60.	Pungampalayam	86
61.	Annupparpalayam	115
62.	P.K.V.Pudur	26
63.	Anna Nagar	48
64.	Kullakapalayam	92
65.	Chinnavedampatti	26
66.	Rengammal Colony	32
67.	Vadamadurai	30
101.	Rajagopal Layout	22
102.	B.R.Puram	20
103.	Chinnamatham Palayam	57
104.	P.K.V.Pudur	26
105.	Nachipalayam	50
106.	Vallipuram	160
107.	Annupparpalayam	115
108.	Chennimalaipalayam	152
109.	Rakkayapalayam	136
110.	Kullathupudur	147
111.	Cettipalayam-HC	46
112.	Nanjegoundenpudur	78
113.	Achipatty	80
114.	Kurumbapalayam	97
115.	Kullakapalayam	92

FIGURE I-1



UNDP & WORLD BANK
HAND PUMP FIELD TESTING PROJECT

SERIAL NO. 1 TO 46, 61 & 62 - MARK II PUMPS
SERIAL NO. 47 TO 60, 63 TO 67 - MARK III PUMPS
SERIAL NO. 101 TO 115 - EXPERIMENTAL PUMPS

SCALE = N.T.S

HAND PUMP PROJECT

INT / 087 / 013

TEST PUMPS LOCATION MAP

Water Quality Test Details

Sl. No. of Pump	Name of Habitation	Total dissolved solids PPM	Iron Total PPM	Ferrous PPM	pH	Chlorides as Chlorine PPM	Electrical Conductivity at μmoh/cm
001	Manickavasaga Nagar	1300	0.25	0.10	7.3	350	1900
002	Thippanur	810	0.15	0.05	7.4	140	1300
003	Vadamadurai	1990	0.30	0.15	7.8	600	2600
004	NGGO Colony	1700	0.15	0.10	7.4	500	2400
005	Lakshmi Nagar	708	0.05	0	7.5	100	1100
006	State Bank Colony	469	0.05	0.05	7.9	18	700
007	VKV Nagar I	1010	0.55	0.25	7.2	172	1300
008	VKV Nagar II	1190	0.25	0.10	7.2	268	1800
009	Sarvodaya Colony	1620	0.20	0.10	7.4	456	2200
010	Jangamanaicken Palayam	3080	0.50	0.20	6.9	1048	4000
011	Nehru Colony	744	0.55	0.20	7.4	64	1200
012	Vethilaikali Palayam	886	0.30	0.25	7.7	76	1400
013	Thullukkanur	3050	0.05	0	7.0	528	4000
014	Nehru Nagar	494	0.30	0.20	7.1	46	700
015	Periyanathan Palayam	1280	0.05	0	7.1	280	4000
016	Chinnanathan Palayam	860	0.05	0	7.2	117	1200
017	Thaneerpandal	461	0.05	0	7.2	16	700
018	Bettatha Puram	990	0.05	0.05	7.1	136	1600
019	Pannimadat	1140	0.15	0.05	7.0	236	1800
020	Pappanaicken Palayam	771	0.25	0.05	7.2	74	1300
021	Madathur	502	2.00	0.20	7.3	43	800
022	Varapalayam	521	1.10	0.10	7.3	40	500
023	Kunnathur	718	0.05	0.05	7.4	54	1000
024	Manickkam Palayam	926	0.35	0.15	7.3	120	1300
025	Ellapalayam	1250	0.55	0.30	7.2	244	1500
026	Kottapalayam	1490	0.30	0.20	6.9	322	1600
027	Sengadu	477	0.05	0.05	7.2	23	600
028	Agraharasamkulam	602	0.30	0.10	7.1	62	900
029	Marugan Nagar	482	0.15	0.05	8.0	52	700
030	Chettipalayam	2463	0.25	0.15	7.0	564	3000
031	Thumbagouden Palayam	589	0.25	0.05	7.4	68	800
032	Parvathi Puram	649	0.40	0.10	7.0	68	900
033	Narasima Puram H	1330	0.30	0.25	6.9	352	1900
034	Narasima Puram (P)	1040	0.60	0.30	6.9	220	1500
035	Nanjundapuram	508	0.10	0	7.0	67	700
036	Annapalayam	479	0.15	0.10	7.4	46	600
037	Annapalayam	3400	0.15	0.10	7.2	1190	5000
038	Palli Nilayam	1285	0.05	0.05	7.2	380	1900
039	Barathinagar	2834	0.35	0.30	7.0	656	3200
040	Boyampalayam	1654	0.05	0	7.1	320	2000
041	Pangu Palayam	1070	0.50	0.30	7.2	212	1400
042	B R Puram	5220	0.15	0.10	7.6	1560	7000
043	Perumanullur	882	0.15	0	7.3	152	1200

Sl. No. of Pump	Name of Habitation	Total dissolved solids PPM	Iron Total PPM	Ferrous PPM	pH	Chlorides as Chlorine PPM	Electrical Conductivity at µmoh/cm
044	Athikkadu	504	0.35	0.15	7.1	30	600
045	Ettiveeram Palayam	1040	0.30	0.20	7.0	176	1400
046	Muttian Kinaru	418	0.20	0.15	7.6	30	600
047	Velandi Palayam	438	0.40	0.10	7.2	37	500
048	Sokkanur	684	0.60	0.25	7.3	88	900
049	Rakkaya Palayam	464	0.05	0	7.6	40	700
050	Parasapalayam	478	1.60	0.30	7.3	18	700
101	Machigoundenpudur	897	0.05	0	7.4	156	1300
102	Seerapalayam	658	0.05	0	7.3	48	900
103	Chinna Mathan Palayam	389	0.05	0	7.3	21	450
104	PKV Pudur	854	0.05	0	7.9	148	1100
105	Machipalayam	421	0.05	0	7.3	28	550
106	Vallipuram	894	0.05	0	7.3	184	1300
107	Annuppar Palayam	2910	0.15	0.05	6.9	760	3400
108	Chennimalai Palayam	403	0.05	0	7.4	21	600
110	Kullathupudur	362	0.05	0	7.7	73	500
112	Nanjagoundenpudur	622	0.05	0	7.3	56	800
113	Achipatty	825	0.05	0	7.3	110	1100
114	Kurumbapalayam	640	0.05	0	7.3	68	900

Specifications for India Mark II Handpump

The handpump shall conform to IS 9301 - 1984 in all respects excepting the following.

Head assembly

1. Handpump head base to have 75mm dia hole instead of guide bush.

2. Bracket opening increased to allow a minimum stroke length of 127mm.

3. Additional flange similar to the head flange (St.Mark II) with the guide bush welded at the center of the additional flange. The guide bush ID to be increased to 15mm.

4. The handle assembly to have 60mm square bearing housing with bearing seatings internally ground. Final dimension of bearing seatings 47 - 0.017-0.042. The handle assembly to be electrogalvanised to 50 microns (min.) thick or painted. Inside of bearing housing not to be electrogalvanised or painted.

Water tank assembly

1. Height is increased by 25mm.

Stand assembly (telescopic)

1. Height is reduced by 75mm.

Cylinder assembly

1. Nitrile rubber cup seals and modified spacer.

2. Two piece upper valve guide.

3. Length of 2-3/4" NB threads on reducer caps is increased by 8mm.

4. Plunger rod of stainless steel.

Specifications for India Mark III Handpump

The handpump shall conform to IS 9301-1984 in all respects excepting the following.

Head assembly

1. Handpump head base to have 75mm dia hole instead of guide bush.

2. Bracket opening increased to enable a minimum stroke length of 127mm.

3. Additional flange similar to head flange (St.Mark II) with the guide bush welded at the center, The guide bush ID to be increased to 15mm.

4. Handle assembly to have 60mm square bearing housing with bearing seatings internally ground. Final dimension of bearing seatings 47 -0.017-0.042. The handle assembly to be electrogalvanised to 50 microns (min) thick or painted. Inside of bearing housing not to be electrogalvanised or painted.

Water tank assembly

1. 2-1/2" NB seamless coupler instead of 1-1/4" coupler.

2. Height of water tank increased by 25mm.

Stand assembly (telescopic)

1. Height reduced by 75mm.

Cylinder assembly

1. Top cap to suit 2-1/2" NB riser pipe.

2. Bottom cap to have conical housing to receive pick up check valve and thread at the bottom to suit 2 1/2" NB intake pipe.

3. Nitrile rubber cup seals and modified spacer.

4. Extended follower with threads to pick up check valve.

5. Two piece upper valve guide.

6. Check valve assembly. with two piece valve, conical base, 'O' ring, cage and stainless steel lifting rod.

7. Both caps to have hexagonal outside rib for ease of installation and dismantling.

8. O.D. on cylinder not to exceed 91mm.

9. The height of the cylinder increased by 51mm.

10. 2 1/2" NB pipe, 3m long to be coupled at the bottom of the cylinder as intake pipe.

11. Plunger rod of stainless steel.

Field Testing of Experimental Pump Components

Piston seals

1. The following types of piston seals were tested.

   (a) Chrome tanned leather
   (b) Semichrome tanned leather
   (c) Vegetable tanned leather
   (d) Rubberized chrome tanned leather
   (e) Nitrile rubber
   (f) Teflon with graphite impregnated

2. The leather seals of all types were found to have wide variations in their life-span which illustrates that the performance of the leather piston seals was not consistent. The nitrile rubber seals were more consistent in their performance. The analysis of the life factor of different types of piston seals (see Table 6) illustrates the following.

   (a) The average life period of chrome tanned, semichrome tanned and rubberized chrome tanned seals are more or less same.

   (b) The average life period of vegetable tanned seals is 2.9 times that of the average chrome tanned seals.

   (c) The average life period of nitrile rubber seals is 3.4 times that of the average chrome tanned seals and 1.2 times that of the average vegetable tanned seals.

   (d) The graphite-impregnated teflon split seals were found to have the highest average life period for all types of seals tested. However the quantity tested was only 3 sets. These seals were found to score the brass cylinder liner and subsequent seals may not work for a long period.

   (e) The nitrile rubber seals (modified design) in operation have a higher average life period when compared to the failed nitrile rubber seals. This proves that the latest design is better than the old design of nitrile rubber seals. The new seal is expected to have an average life of 1200x100 M^4 equivalent to 879 days of normal pump operation.

Coatings on the connecting rod

3. In some wells connecting rods were found rusted within a month. To evaluate the performance of various types of coatings/materials in corrosive water, the following type of connecting rods were tested in the same borewell.

   (a) Electrogalvanised mild steel rods

(b) Hotdip galvanized mild steel rods

(c) Polyurethane coated mild steel rods

(d) Natural rubber coated mild steel rods

(e) Stainless steel rods

4. The chemical analysis of well water selected for testing the connecting rods is given as follows.

(a) Total dissolved solids - 5220 PPM

(b) Total iron content - 0.15 PPM

(c) Chlorides as chlorine - 1560 PPM

(d) Electrical conductivity - 7000 µmoh/cm

(e) pH - 7.6

5. The observation noted during two years of field testing and our recommendations on usage are listed in Table V-1.

TABLE V - 1
COMPARISON OF VARIOUS TYPES OF CONNECTING RODS

Sl. No.	Type of connecting rod tested	Observations	Recommendations
1.	Electrogalvanized mild steel rods	Even in mildly corrosive water, zinc plating disappears in one to two months time and thereafter rust patches appear.	The zinc plating is adequate only to withstand corrosion-related problems during transportation. This type of rod should be used only in non-corrosive water.
2.	Hot dip galvanized mild steel rods	The zinc film was intact even after two years of operation. No sign of rust was visible.	This appears to be highly corrosion-resistant and perhaps the most cost-effective solution in most of the cases.
3.	Polyurethane coated mild steel rods	Coating peels off after 3 to 4 months and thereafter exposed surfaces get rusted.	As the coating peels off, it is not recommended for use without further testing.

4.	Natural rubber coated mild steel rods	The coating on the coupler surface wears out due to abrasion between the rod coupler and the GI pipe and the exposed surfaces get rusted. However there was no sign of rust on the 12mm dia rod and coating was intact even after two years.	It is a very promising method of providing resistance to corrosion even against corrosive water. It is specially suitable for pumps with a uPVC rising main as the rubber coating on the rod and coupler will eliminate the damage to the pipe due to abrasion.
5.	Stainless steel rods	No sign of rust was noticed after two years of operation.	This is the most effective solution in highly corrosive water. However it is 5 to 6 times more expensive than the mild steel rod options described above.

<u>uPVC Rising main pipe and different type of connectors</u>

6. The 75mm diameter OD and 5mm wall thickness uPVC pipe was used as a rising main and tested in 20 borewells. Different types of joints listed here were tested.

   (a) Solvent cemented joint
   (b) Threaded joint
   (c) Quick coupler joint
   (d) Tension connector joint
   (e) Compression connector joint

<u>Solvent cemented joint</u>

7. The pipes were joined at the time of erection at the site and curing time given for each joint was 15 min. Many of these joints failed i.e. slipping of joints and shearing at the neck of the bell. The following are possibly the reasons for the failures.

   (a) The gap between the joints (bell and socket) was excessive and therefore the bonding was not proper;

   (b) The quality of solvent cement used was inconsistent.

<u>Threaded joints</u>

8. The ends of the pipes were threaded to suit each other. These joints sheared at the threaded portion due to the stress concentration, as uPVC is sensitive to notching effect. Thereafter a separate thick coupler with threads on each piece as shown in Figure V-1 was made and tested. These couplers were epoxy cemented at the ends of the pipe in a factory. This

special threaded connector worked without any failure for 2 years in a well with 30M cylinder setting. Further testing of this joint is recommended.

Quick coupler joint

9. This is a moulded coupler having male and female parts. They were joined at the ends of the rising main pipe using solvent cement well before the installation in a clean environment. These couplers cracked and were broken due to their brittleness. There were problems in removing the rising mains from the borewell due to the lever protruding on the sides.

Tension connector joint

10. It consists of a male coupler which has two grooves on the periphery of the pipe. Similarly, the female coupler has two grooves on the inner side. Openings are provided on the outer circumference of the female pipe as shown in Figure V-2 through which uPVC rods can be inserted after assembling the joints. Two rubber O-rings were introduced in two grooves in the female coupler to provide sealing. Another o-ring was introduced in a groove in the male coupler to prevent entry of mud and sand particles into the joint. The male and female couplers were cemented at the ends of the pipes by epoxy cement in a factory prior to installation. These joints are easy to assemble and disassemble and worked well for two years except for a leakage problem in a few cases. The leakage was mainly due to the unsymmetrically machined O-ring groove in the female connector. After two years of operation many of these couplers were broken. This may be due to the poor quality pipe used for manufacturing these couplers. If the couplers are moulded properly, this type of connector may be a good solution for rising main joints.

uPVC cylinder

11. A uPVC pipe of 63.5mm diameter ID and 75mm diameter OD was used as a cylinder. The advantages of the uPVC cylinder were low cost, corrosion proof and choice of multiple generations of cylinder surface area accomplished by shortening the connecting rod. At the bottom of the cylinder pipe, a ring was fixed by solvent cemented joint which has a concave or taper surface to suit the foot valve base. Minimal wear is noticed on the uPVC cylinder after 2 to 3 years of operation and this may be due to the usage of nitrile rubber as piston seals. In one case the cylinder pipe was cracked after two years which may be due to abrasion with the rock surface inside the borewell.

Sand trap

12. The sand trap developed by the Sholapur Well Service was fixed above the standard cylinder to collect the sand particles and to prevent particles falling into the cylinder when the pumping stopped. Approximately 25 grams of sand particles were collected in the sand trap after one year of usage in 5 cases. There is a clear evidence to prove that the use of sand trap improved the average life of leather piston seals by 30 percent.

Bottom intake pipe

13. The bigger diameter pipe was fixed under the cylinder to reduce the intake velocity, which in turn reduces the intake of sand particles. The intake pipes were found to prolong the life of piston seals. Different sizes of intake pipes i.e. 2", 2 1/2" and 4" NB were tested. The following are the conclusions.

(a) A two-inch diameter bottom pipe is not effective.

(b) A four-inch diameter intake pipe is found to be very effective but due to the higher OD (115 mm) of the pipe, it becomes difficult to withdraw the pipe at the time of repair. With a slight obstruction in the borewell, withdrawal of the 4" diameter pipe becomes very difficult. To cite an example of effectiveness, in one well 25 grams of sand particles were collected in a sand trap over a one-year period. In the same well after fixing a 1.5 mt long and 4" diameter intake pipe at the bottom of the cylinder, less than 5 grams of sand was collected in the sand trap during one-year of operation.

(c) In India Mark III pumps a 3 meter long section of 2-1/2 inch diameter pipe, the same as the rising main pipe was used for the intake pipe. No problems were experienced while withdrawing the pipe and it was found to be effective in reducing sand intake.

Plastic handle bearings

14. An alternate bearing design developed by SKAT* was tested. This bearing assembly consists of two identical sets of a polyamide (delrin) outer race, a polyacetal (zytel) inner race and a steel spacer bush as shown in Figure V-3. A tab on the outer race locks in place into a slot in the bearing housing to prevent rotation of the outer race with respect to the bearing housing. The metal spacers of the two sets of bearing components are nipped up between the two end bushings in the head, when the axle nut is tightened, holding the spacers and the inner race in place. When the handle is moved the outer races run on the inner races. Thrust faces of the inner sides of the inner races lock the latter in place axially while those on the outer sides form a barrier/labyrinth to prevent the entry of dust between the bearing faces.

15. Few samples of plastic bearings were machined from the bar stock material. Since the provision of a tab on the outer race is not possible by machining, the outer race was fixed in the housing by epoxy adhesive in two samples. These plastic sample bearings failed due to a crack developed in the outer race after 3 months of operation. Two more similar samples were tested which had grub screws fixed on the housing to lock the slot in the outer race to arrest the movement between the outer race and the housing. These bearings failed after 2 to 3 months of operation due to the bearing collar in the inner race cracking completely on one side of the

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* Swiss Center for Appropriate Technology at ILE, Institute for Latin American Research and for Development Cooperation, University of Saint Gall.

housing. It was not possible to ascertain the reasons for the premature failure of bearings.Further investigation is necessary to develop plastic bearings for the India Mark III handle.

Pump rod centralizer

16. Simple snap-on rod centralizers made of polythene and about 50mm outer diameter were tested to prevent the connecting rod rubbing against the inner surface of the rising main. Due to the reduced stiffness of the polythene material, the guides started moving up and down during pumping and after some period they fell off due to extensive wear on the inner diameter. In many of the installations it was noticed that the connecting rod couplers rub against the inner surface of the rising main resulting in cracks in the rising main. Further development work is needed on this problem.

Rising main centralizer

17. Star type rubber guides were developed and tested to eliminate rubbing of the uPVC rising main against the sides of the borewell. These rubber guides were initially placed at an interval of 6 meters. This was found to be inadequate to prevent rubbing. Hence the rubber guides were used at 2 meter intervals. This arrangement reduced the external rubbing problem very much, but the rubber star guides were themselves worn out in 2 years in most of the borewells due to abrasion. Further work to develop pipe centralizers suitable for installation in unlined borewells is needed.

Rubber compression fitting

18. The rubber compression fitting was developed to hold the uPVC rising main in the water tank assembly. It consists of a flange with a taper cone welded in it to receive the taper rubber cone. The taper rubber cone has a hole in the center to suit the outer diameter of the rising main pipe. The rubber cone when compressed by the water tank bottom flange holds the riser pipe firmly. The system worked very well and no failure was noticed during 3 years of field testing. This type of joint is strongly recommended for holding uPVC rising mains. Refer to Figure V-4 for more details.

2" (50mm) ID cylinder assembly - VLOM-type handpump

19. When the depth of the cylinder setting is more than 45 meters, pumping in the Standard Mark II becomes difficult. Hence, to reduce the pumping load the cylinder size was reduced from 2.5" to 2". Two pumps with 50mm cylinder assembly with extractable plunger and foot valve, 50 NB GI riser main, a modified water tank and a standard head assembly were tested at 60M setting. The users were happy to operate these pumps as the pumping effort was reduced considerably. These pumps worked without any problem for over two years. The use of 50mm cylinder for extra deep well application is recommended.

Platform

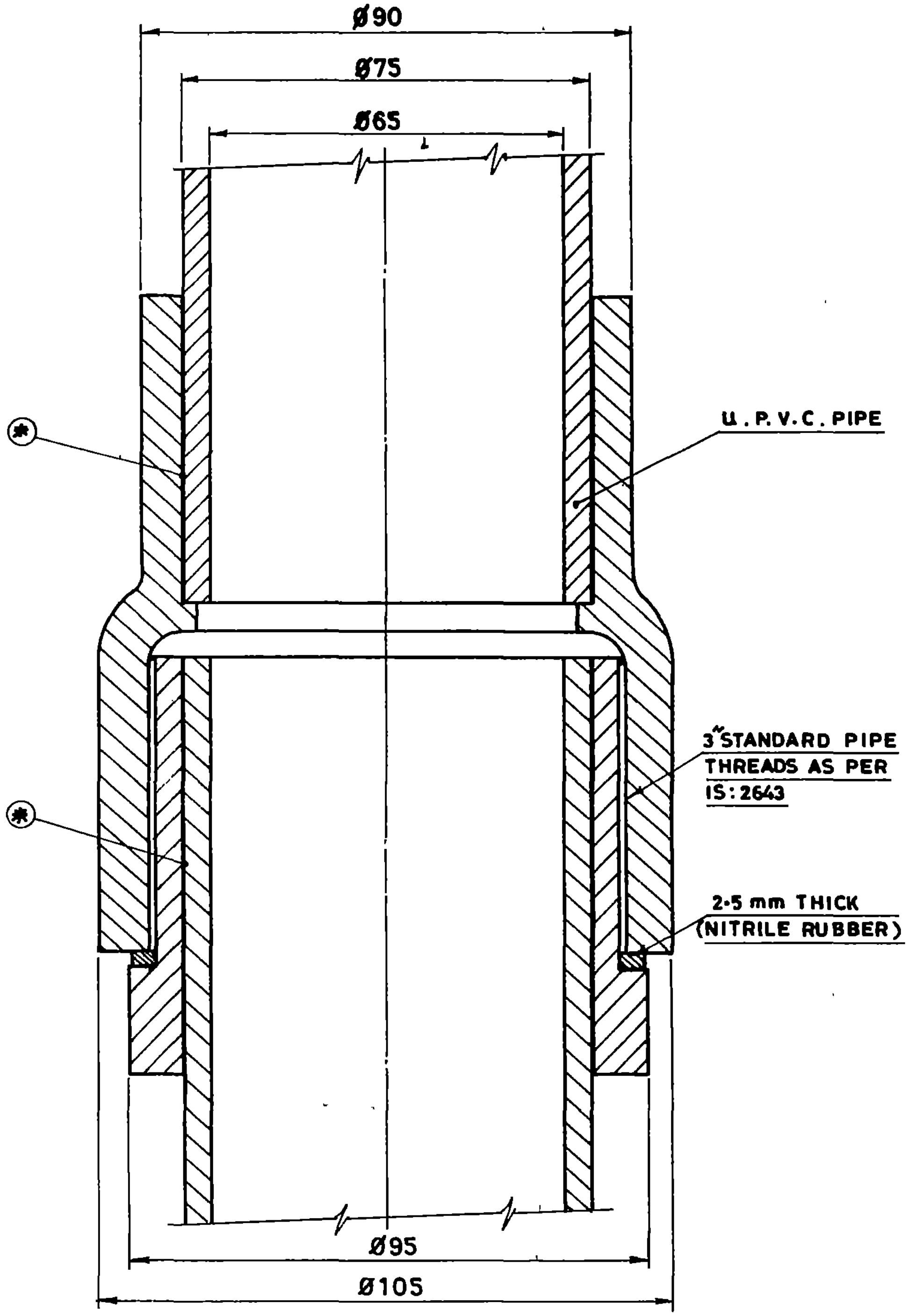
20. In the standard platform design, the foot rest was not large enough for the users to stand conveniently to operate the pump. Splashing of water outside the platform resulting in stagnation of water around the platform was another problem. To overcome these problems different designs of platforms were constructed and tested. The platform shown in Figure V-5 was found to be the most suitable. This has the following special features.

(a) The spout is in the center of the platform which reduces the splash of water outside the platform considerably;

(b) The foot rest is much bigger i.e. instead of 600x600mm it is 1000x1000mm. This provides enough space for users to stand and to operate the pump comfortably; and

(c) The distance between the end of the handle in its lowest position and the foot rest has been reduced from 450mm to 225mm. This change reduced the banging of the handle on the bottom bracket stop considerably.

FIGURE V-1

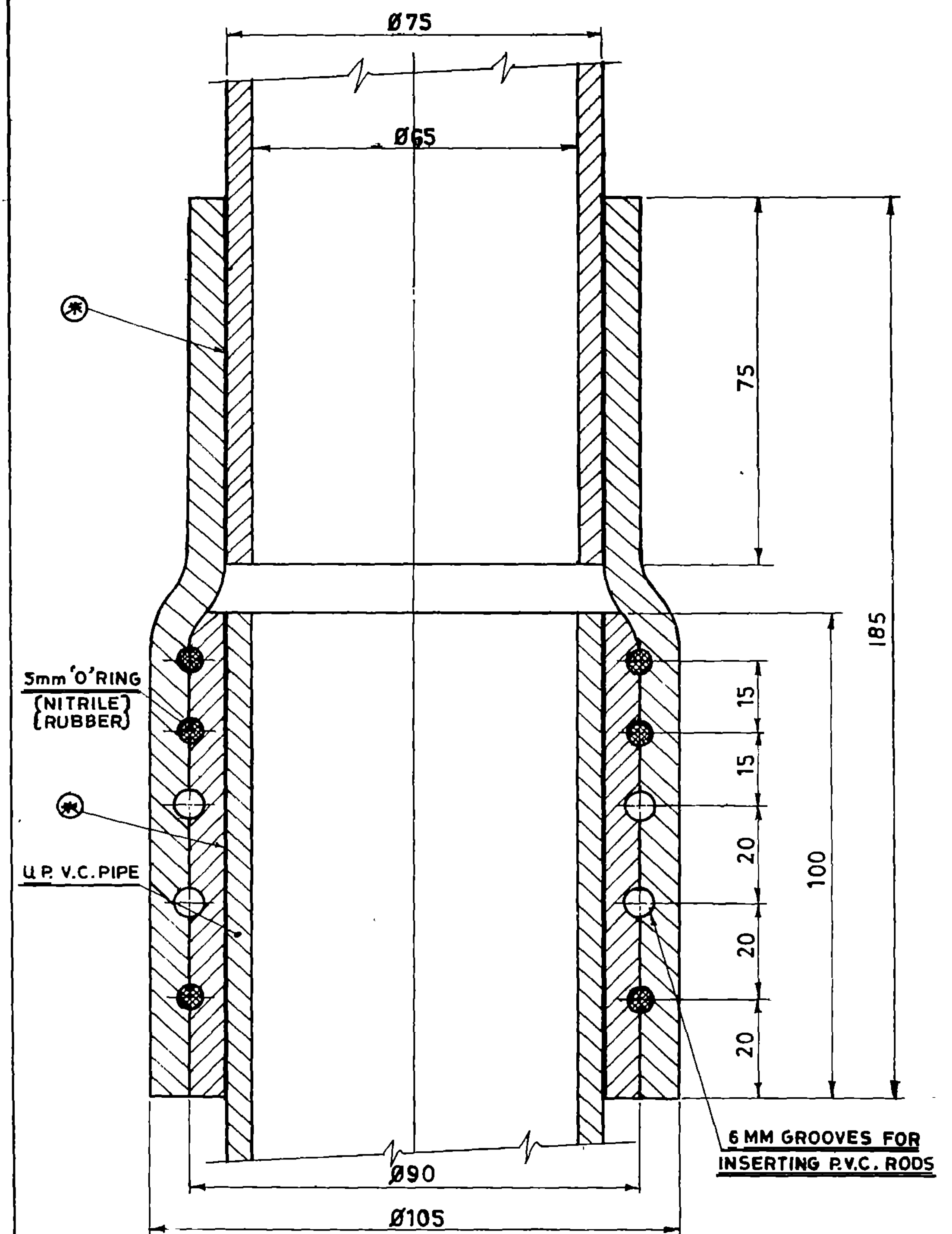


(*) SOLVENT CEMENTED

MATERIAL :- P.V.C.

HAND PUMP PROJECT INT/087/013	
THREADED COUPLER JOINT	SCALE:- 1:1
	DRG. No. :- -

FIGURE V-2

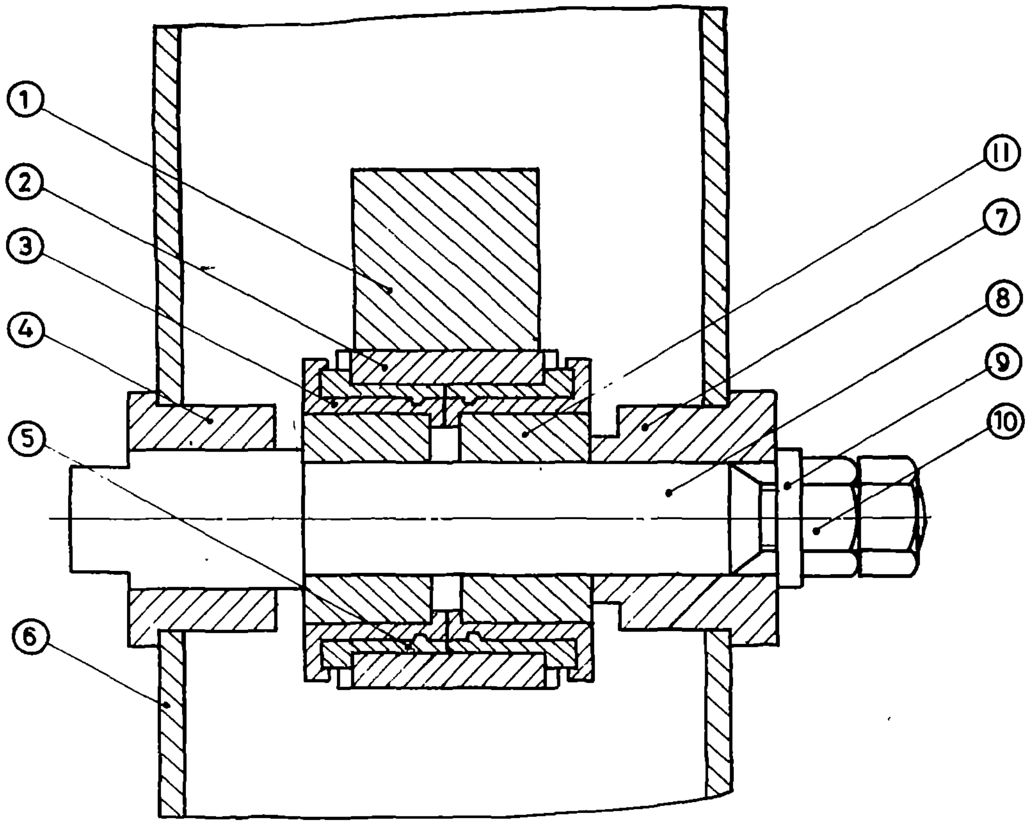


(*) SOLVENT CEMENTED

MATERIAL :- P. V. C.

HAND PUMP PROJECT INT / 087/013	
TENSILE CONNECTOR	SCALE:- 1:1
	DRG. No.:-

FIGURE V-3



11	2	SPACER	Gr.A, IS:2062
10	2	HEX. NUT	M12
9	1	WASHER	4mm THICK
8	1	HANDLE AXLE	Gr.04 Cr.18 Ni.10 Mn Z, IS:6603
7	1	AXLE BUSH (RIGHT)	Gr.A, IS:2062
6	2	SIDE PLATE	Gr A, IS:2062
5	2	OUTER BUSH	DELRIN 100 (500)
4	1	AXLE BUSH (LEFT)	Gr A, IS:2062
3	2	INNER BUSH	ZYTEL 101
2	1	BEARING HOUSING	Gr A, IS:2062
1	1	HANDLE BAR	Gr A, IS:2062
PART NO.	NO. OFF	DESCRIPTION	MATERIAL

HAND PUMP PROJECT

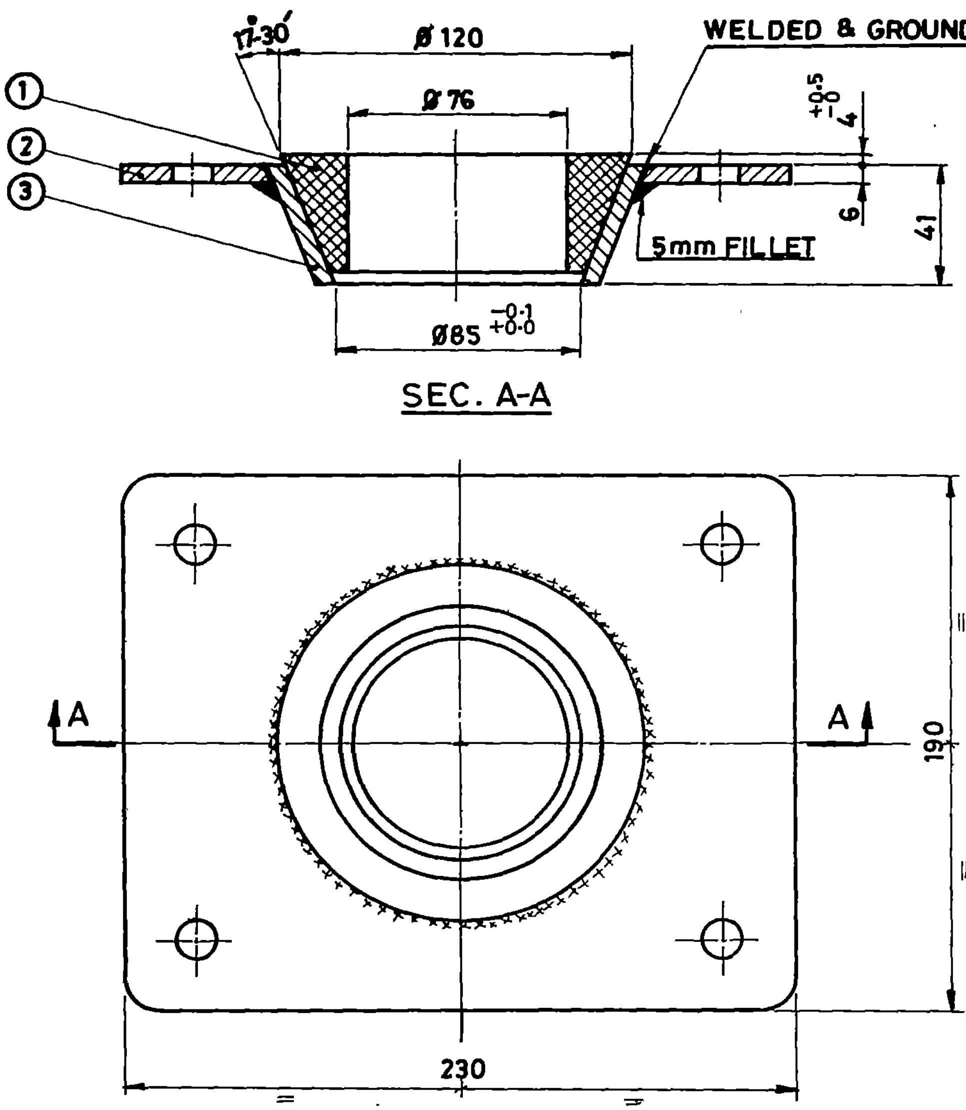
INT / 087/013

PLASTIC BEARING ASSL'Y

SCALE:– 1:1

DRG. No. :–

FIGURE V-4



PART NO.	NO. OFF	DESCRIPTION	MATERIAL
3	1	M.S. CONE	IS: 226 ST 42
2	1	CONE FLANGE	IS: 226 ST 42
1	1	GROMMET	RUBBER

HAND PUMP PROJECT

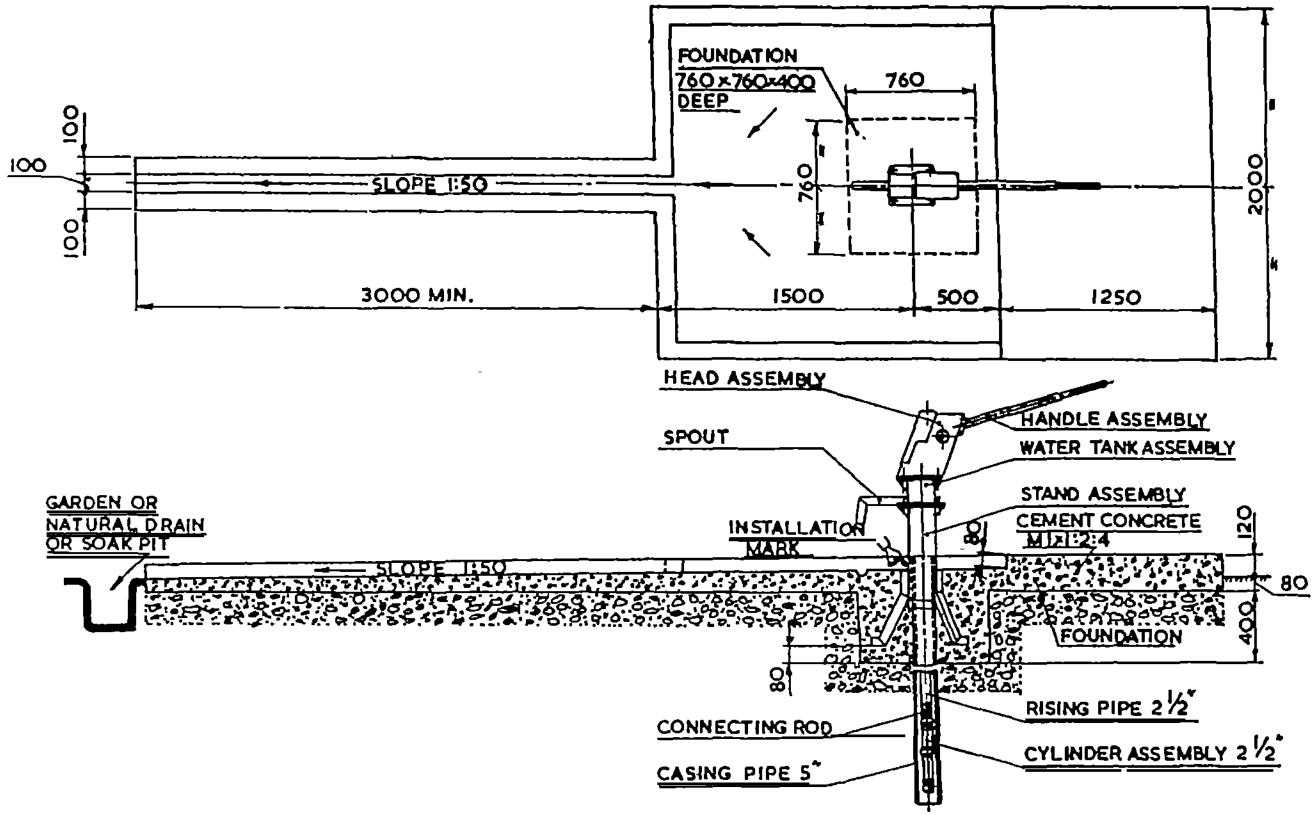
INT / 087 / 013

RUBBER COMPRESSION FITTING

SCALE :- 1:2

DRG. No. :-

FIGURE V-5



HAND PUMP PROJECT
INT /087/013

PLATFORM DETAILS OF
IM II & IM III PUMPS

SCALE :- N.T.S.

DRG. No. :-

Installation and Borewell Details

Sl. No. of HP	Name of habitation	SWL during installation in M	Depth of cylinder installed	Date of installation	Approx. population in the village	Yield of borewell in LPM	Depth in M	Name of union
1	Manickavasaga Nagar	37.2	43.7	27-12-83	450	30	69.0	Corporation
2	Thippanur	28.7	36.0	29-12-84	300	130	60.0	P N Palayam
3	Vadamadurai	35.0	49.0	26-11-83	350	140	78.4	-do-
4	NGGO Colony	33.2	45.9	5-12-83	200	48	81.5	-do-
5	Lakshmi Nagar	23.6	40.7	28-12-83	150	51	92.5	-do-
6	State Bank Colony	15.3	39.2	5-12-83	450	195	90.4	-do-
7	VKV Nagar I	28.2	41.7	5-12-83	400	60	84.4	-do-
8	VKV Nagar II	25.1	40.9	25-11-83	300	23	91.2	-do-
9	Sarvodaya Colony	30.1	40.0	25-11-83	300	34	95.3	-do-
10	Jangamanaicken Palayam	29.6	40.7	26-11-83	200	23	82.7	-do-
11	Nehru Colony	24.0	36.0	28-12-83	350	112	42.7	-do-
12	Vethilaikali Palayam	21.0	36.0	10-12-83	220	225	80.8	-do-
13	Thullukkanur	7.6	29.2	23-12-83	300	25	90.5	-do-
14	Nehru Nagar	11.4	29.8	23-12-83	350	132	92.1	-do-
15	Periyamatham Palayam	12.7	28.8	22-12-83	550	23	75.3	-do-
16	Chinnamatham Palayam	11.5	27.0	22-12-83	400	80	72.0	-do-
17	Thaneerpandal	18.5	32.0	22-12-83	250	21	91.1	-do-
18	Bettatha Puram	24.0	47.4	22-12-83	200	45	91.5	-do-
19	Pannimadai	36.4	43.8	28-12-83	200	23	83.0	-do-
20	Pappanaicken Palayam	27.0	38.4	11-2-84	150	166	182.8	-do-
21	Madathur	23.5	36.6	26-12-83	200	505	138.0	-do-
22	Varpalayam	26.3	39.2	7-1-84	250	328	152.1	-do-
23	Kunnathur	30.7	38.9	6-1-84	420	322	86.0	Annur
24	Manickkam Palayam	25.2	36.2	6-1-84	250	132	87.7	-do-
25	Ellapalayam	22.1	35.7	25-1-84	400	23	105.7	-do-
26	Kottaipalayam	16.5	30.0	13-1-84	450	32	89.9	S S Kulam
27	Sengadu	19.9	30.0	12-1-84	300	15	91.5	-do-
28	Agraharasamakulam	14.5	30.0	16-1-84	400	34	59.1	-do-
29	Marugan Nagar	28.8	39.0	8-1-84	550	25	91.2	Madukkarai
30	Chettipalayam	26.2	39.0	10-2-84	500	65	89.1	-do-
31	Thumbagouden Palayam	5.8	29.7	26-1-84	400	114	82.0	-do-
32	Parvarthi Puram	23.7	36.7	26-1-84	200	45	75.3	-do-
33	Narasima Puram H	28.6	39.0	9-1-84	400	23	105.2	-do-
34	Narasima Puram (P)	27.2	39.6	3-2-84	200	29	104.3	-do-
35	Nanjundapuram	24.6	36.0	5-3-84	100	256	183.0	P N Palayam
36	Anna Nagar	11.2	30.0	14-2-84	560	45	85.4	Avinashi
37	Ammapalayam	11.6	29.5	15-2-84	200	23	92.3	-do-
38	Palli Palayam	11.3	24.0	16-2-84	300	48	70.8	Tiruppur
39	Barathinagar	10.5	28.0	17-3-84	400	144	91.4	-do-
40	Boyampalayam	11.1	24.0	14-2-84	200	25	85.4	-do-
41	Pongu Palayam	16.7	30.1	13-2-84	200	34	84.0	-do-

Sl. No. of HP	Name of habitation	SWL during installation in M	Depth of cylinder installed	Date of installation	Approx. population in the village	Yield of borewell in LPM	Depth in M	Name of union
42	B R Puram	17.9	21.0	13-11-84	250	268	65.4	Corporation
43	Perumanullur	27.0	36.2	12-2-84	300	43	86.4	Tiruppur
44	Athikkadu	12 7	30.0	18-3-84	225	28	75.5	-do-
45	Ettiveeram Palayam	31.2	39.0	17-3-84	175	70	91.5	-do-
46	Muttian Kinaru	21.5	33.0	17-3-84	200	15	75.4	-do-
47	Velandi Palayam	21.7	30.0	16-5-84	200	9	92.0	Avinashi
48	Sokkanur	16.8	29.7	17-5-84	150	85	60.1	Tiruppur
49	Rakkaya Palayam	10.7	27.0	7-7-84	400	14	44.5	-do-
50	Porasapalayam	32.3	40.0	25-7-84	215	351	44.8	-do-
51	Palaniswami Nagar	26.8	33.3	21-8-85	250	NA	103.2	P N Palayam
52	Nullur	7.1	30.0	7-10-85	350	8	91.0	Pollachi North
53	Vijaya Nagar	9.2	30.0	8-10-85	400	NA	NA	Pollachi South
54	Unjavellampatti	4.6	30.0	9-10-85	400	48	90.0	-do-
55	Thirumurugan Poondi	14.0	30.0	18-10-85	358	NA	NA	Avinashi
56	Vallipuram	17.0	30.0	19-10-85	350	30	74.5	Tiruppur
57	Mathampalayam	22.9	36.0	8-4-86	300	23	63.7	P N Palayam
58	Kullunampathy	14.4	33.0	9-4-86	200	NA	NA	Tiruppur
59	Ayyampalayam	14.8	36.0	21-8-86	300	NA	NA	-do-
60	Pungampalayam	8.0	33.0	19-11-85	400	23	89.1	Karamadai
61	Annupparpalayam	12.4	30.0	1-2-85	500	45	91.4	Tiruppur
62	P K V Pudur	14.0	27.0	15-9-85	500	29.1	68.6	Madukkarai
63	Anna Nagar	14.0	39.0	7-1-87	400	45	78.4	P N Palayam
64	Kullakapalayam	10.5	36.0	21-5-87	500	48	90.0	Pollachi North
65	Chinnavedampatti	30.0	45.0	18-7-87	500	NA	98.3	S S Kulam
66	Rengammal Colony	38.0	45.0	27-12-87	300	9	105.2	P N Palayam
67	Vadamadurai	37.4	48.0	31-12-87	450	45	95.0	-do-
101	Rajagopal Layout	17.7	30.0	6-12-83	350	51	75.3	Corporation
102	B R Puram	21.5	30.0	17-12-83	300	268	65.4	-do-
101	Machigounden Pudur	18.0	27.0	17-10-84	300	30	71.0	Madukkarai
102	Seerapalayam	6.0	25.0	13-3-85	250	23	61.9	-do-
103	Chinna Mathan Palayam	15 9	30.0	12-12-83	200	140	82.5	P N Palayam
104	PKV Pudur	18.2	30.6	28-2-84	300	29	68.6	Madukkarai
105	Ranganathapuram	8.8	33.0	29-2-84	450	42	89.9	Tiruppur
106	Valli Puram	15 0	33.0	29-2-84	410	30	74.5	-do-
107	Annuppar Palayam	16.2	32.7	1-3-84	500	40	91.4	-do-
108	Chennimalai Palayam	11.3	25.0	9-5-84	250	14	91.0	-do-
109	Rakkayapalayam	9.7	27.0	10-5-84	225	14	71.0	-do-
110	Kullathupudur	14.8	27.0	10-5-84	270	45	91.4	-do-
111	Cettipalayam HC	14.7	30.0	11-5-84	500	76	74.4	Madukkarai
112	Nanjengoundenpudur	10.3	30.0	26-11-84	320	64	75.2	Pollachi North
113	Achipatty	25.0	31.0	13-4-85	150	9	76.2	-do-
114	Kurumbapalayam	8 2	33.0	19-6-85	350	23	69.0	-do-
115	Thillainagar	24.4	33.0	9-8-85	400	15	76.2	-do-
105	Nachipalayam	8.2	31.0	15-3-85	350	19	79.3	Madukkarai
115	Kullakkpalayam	9.5	33.0	18-12-85	500	40	90.0	Pollachi North

Handpump Monitoring Format

1. The format of the handpump field data recording form was designed to be compact to make it easy for the engineer in the field to record essential data quickly and accurately and easy for the computer operator to be able to enter the data. The most time-consuming activity, also facilitated by a concise form, is "cleaning" the data, or checking the accuracy of descriptions of repairs and attribution of the cause of problems with the pump.

2. The form is a record of what, if anything was done to the pump; why something was done; what, if any parts were repaired or replaced; how many tools were used and how much repair time was involved. The form provides cells for entry of data and is mostly self-explanatory. There are two basic types of interventions to the pumps: essential and non-essential interventions. Essential interventions are those required to restore the pump to normal function when it is not producing any water at all, or too little. These types of interventions are coded "EIBD" (essential intervention, breakdown) or "EIPP" (essential intervention, poor performance). A breakdown is obvious: no water can be pumped. Poor performance is defined by a pump test (described in para 5), performed before the intervention to see if repair is needed and after the repair to ensure that the pump is working normally.

3. Non-essential interventions consist mostly of minor adjustments to the pump, such as tightening slackened bolts or lubrication, whose purpose is to prevent a problem from developing. This type of non-essential intervention is coded "PM" for "preventive maintenance". Other types of optional interventions could be clearing of debris from the drive head or replacing a normally functioning, but damaged component with a new one, or changing a component for testing purposes. The code for such an intervention will be "OT" for "other".

4. If a part is replaced, a number corresponding to how many parts were replaced will be entered in the column and row corresponding to the code for the part. If a part is repaired or adjusted but not replaced, then a tick is entered into the appropriate cell. Codes are available to indicate whether an entire assembly, for example the handle assembly (HA), was replaced, or one of its components, for example, the bearings (HB).

5. A pump test defines objectively whether the performance of the pump is within the normal range and needs no intervention, or so poor that repair is essential. A pump test is required for each monthly routine visit to a demonstration pump, which will determine if any intervention is necessary. If none is necessary, the information is recorded and another site may be visited. If the pump test indicates poor performance and the

pump is repaired, a second test is carried out after the repair to see if normal function has been restored. Normal hydraulic efficiency is the filling of a standard 13 liter water jug in 40 full strokes or less. Poor performance is indicated by using more than 75 strokes to fill the container. A breakdown is recorded when the pump will not pump at all or takes more than 100 strokes to fill the container.

6. A leakage test is conducted to determine the number of strokes required before water comes out of the spout. The number of strokes thus recorded determines the type of intervention that is necessary which is based on the following norms.

Number of Strokes	Action required
(a) Less than 5 strokes	No intervention necessary
(b) More than 5, but less than 20 strokes	Intervention necessary due to poor performance
(c) More than 20 strokes	Intervention necessary due to breakdown

7. The data forms should be checked at least once a week by the supervisor of the personnel responsible for entering the data. The supervisor should verify the accuracy of the data and make sure that any remarks written about the intervention are intelligible to the computer operator.

INSPECTION AND REPAIR REPORT FOR INDIA MARK II

PUMP CODE   INDIA MARK II: MODIFIED [ ]   VLOM [ ]   FORM CHECKED BY:
DATE:
PERIOD:

			COMPLAINT DATE (if any).							Design change (if any)			
			REPAIR/INSPECTION DATE:								Sub-	2nd	1st
			LEAKAGE (STR/REFILL)								compo	date	date
			DISCHARGE (L/CYCLE)								nent		
			HANDLE DISPLAY (CM)										
			STATIC WATER LEVEL (M)										
P	LB	CL	CHAIN LUBRICATED										
A	HD	HA	HANDLE ASSY										
R		HB	BEARING										
T	F	DH	HEAD										
S		DC	FRONT COVER										
		DX	AXLE										
R	RH	CH	CHAIN-HANDLE B&N										
E		CP	PUMP ROD										
P	PR	RP	PIPE										
L		RJ	JOINT										
A	PS	PL	LEATHER										
C		PN	NITRILE RUBBER										
E	PE	PE	PISTON ASSY										
D		PV	PISTON VALVE										
O		PB	CYLINDER BODY										
R		PY	CYLINDER ASSY										
R		BC	BOTTOM/TOP CAP										
E	FV	FA	FOOT VALVE ASSY										
P		FO	FOOT VALVE O-RING										
A	OT	BR	BOLT REPLACED										
I		NR	NUTS REPLACED										
R		WT	WATER TANK										
			BREAKDOWN OR POOR PERFORMANCE (BD OR PP)										
			OTHER REASON (PM or OT)										
			INT. NUMBER										
			DISCHARGE (FINAL)										
			HANDLE SIDEPLAY (FINAL)										
			MANHOURS FOR REPAIR										
			NUMBER OF STAFF										
			TOTAL PARTS COSTS										
			SUPERVISOR NOTES: WRITE DOWN WHAT WAS DONE TO THE PUMP										

Reliability of handpumps: Frequency of intervention to maintain test pumps

1. The reliability of a handpump may be expressed as the number of times the pump has to be repaired or adjusted to restore it to normal service. As shown in Annex VII, the Project recorded the type and number of interventions needed to keep the test pumps functioning normally for most of the time. The time that the pumps were out of service was also recorded, which is known as "downtime". Reliability is generally a design attribute, while downtime reflects on the maintenance system. The VLOM handpump concept attempts to modify the design of a pump to make it easier to maintain by the users themselves, rather than by a distant team, who have to be summoned when a non-VLOM pump needs repair, often taking weeks to arrive.

2. Tables VIII-1 and VIII-2 give a breakdown of the type of maintenance intervention by a semiannual reporting interval. Figures VIII-1 through VIII-6 are comparisons of average interventions observed during semiannual reporting intervals and illustrate improvements in the reliability of the India Mark III pumps compared to the India Mark II pumps. Essential intervention in Mark III pumps were 23.5% less when compared to the Mark II pumps.

TABLE VIII-1
AVERAGE INTERVENTIONS BY TYPE PER SEMIANNUAL INTERVAL

Type of test pump - India Mark II
Average age - 3.83 years

	INTV.	EI	EIBD	EIPP	PM	OT	TOTAL	COUNT
	1	0.37	0.08	0.29	0.90	0.00	1.27	48
Semi	2	0.63	0.17	0.46	1.40	0.25	2.28	48
interv	3	0.90	0.21	0.69	1.23	0.29	2.42	48
	4	0.69	0.31	0.38	0.92	0.42	2.03	48
	5	1.08	0.50	0.58	0.42	0.92	2.42	48
	6	0.89	0.56	0.33	1.02	1.77	3.68	48
	7	0.75	0.61	0.14	0.28	1.56	2.59	36
	8	0.79	0.76	0.03	1.70	1.42	3.91	33
	9	0.42	0.39	0.03	0.82	0.79	2.03	33
Total		6.52	3.59	2.93	8.69	7.42	22.63	-
Mean *		1.7	0.9	0.8	2.3	1.9	5.9	

TABLE VIII-2
AVERAGE INTERVENTIONS BY TYPE PER SEMIANNUAL INTERVAL

Type of test pump: India Mark III
Average age: 2.26 years

	INTV.	EI	EIBD	EIPP	PM	OT	TOTAL	COUNT
	1	0.50	0.11	0.39	0.72	0.72	1.94	18
Semi	2	0.44	0.22	0.22	1.22	0.56	2.22	18
interv	3	0.38	0.13	0.25	0.69	0.88	1.95	16
	4	0.62	0.23	0.39	0.77	0.39	1.78	13
	5	0.58	0.33	0.25	1.00	0.50	2.08	12
	6	0.44	0.11	0.33	0.33	0.44	1.21	9
Total		2.96	1.13	1.83	4.73	3.49	11.18	-
Mean *		1.3	0.5	0.8	2.1	1.5	4.9	-

* Mean is derived by dividing the total number of interventions by the average age of the test pump

3. Figure VIII-1 compares the average number of interventions of all types for both versions of pumps per semiannual reporting interval. The Mark III pump shows consistently fewer interventions to be necessary on average than the Mark II pump. The steep decline during the last reporting interval for each pump (ninth for the Mark II and sixth for the Mark III) is believed to reflect lower usage as a result of increased rainfall during that period and reliance by the users on alternate sources.

4. Figure VIII-2 compares the average frequencies of **essential interventions**, consisting of repairs of **breakdowns** and **poor performance**. The Mark III pump needed significantly fewer essential repairs per pump than the Mark II pump except for the first interval during which the designs of several experimental components, including rubber piston seal and foot valve were modified to correct minor problems.

5. Figure VIII-3 compares the average frequencies of breakdowns - the most serious type of fault requiring an intervention. The average frequency of breakdowns was consistently lower for the India Mark III pumps than for the India Mark II pumps after the rectification of the initial experimental components. The mean EIBD frequency for the Mark III pumps was 44% less than the mean EIBD frequency for the Mark II pumps.

6. Figure VIII-4 compares the average frequencies of a less serious type of fault for which an intervention is essential-**poor performance**. The average frequencies of essential intervention due to poor performance for both pumps was erratic for the first five intervals. A clear declining trend emerges for the Mark II pumps after the fifth interval. In general the India Mark III pumps were more reliable for this category of fault. The

explanation for the erratic trend is that three types of leather were tested during the first three years, chrome tanned, semichrome tanned and vegetable tanned. Nitrile rubber seals were introduced in the second year. Chrome and semi-chrome tanned seals were much less reliable than the vegetable tanned seals, and were gradually phased out of the test. Rubber seals were more reliable than the best leather seals. The reliability of seals is discussed separately in Annex IX.

7. Figure VIII-5 compares the average frequencies of **"other"** interventions. This type of intervention was never undertaken separately from another repair intervention. Usually, a worn out part or some defect was discovered and corrected while repairing another fault. Other interventions also may have resulted from replacement of a normally functioning component in order to test a revised design. It can be seen that the latter reason kept the frequency of OT interventions higher for the Mark III pumps than the Mark II pumps for the first four intervals, but was overtaken by the steadily increasing average frequency for Mark II pumps for OT interventions, because of increasing replacement of pump rods and rising mains as a result of corrosion, noticed when taking them out of the well to change piston seals.

8. Figure VIII-6 compares the average frequencies of **preventive maintenance** for the two versions of the pump. There is no significant difference, which is not surprising, since most preventive maintenance consisted of adjustments to the above-ground components usually lubrication of the chain, cleaning of any debris found in the pump head and tightening of slackened fasteners.

Figure VIII-1

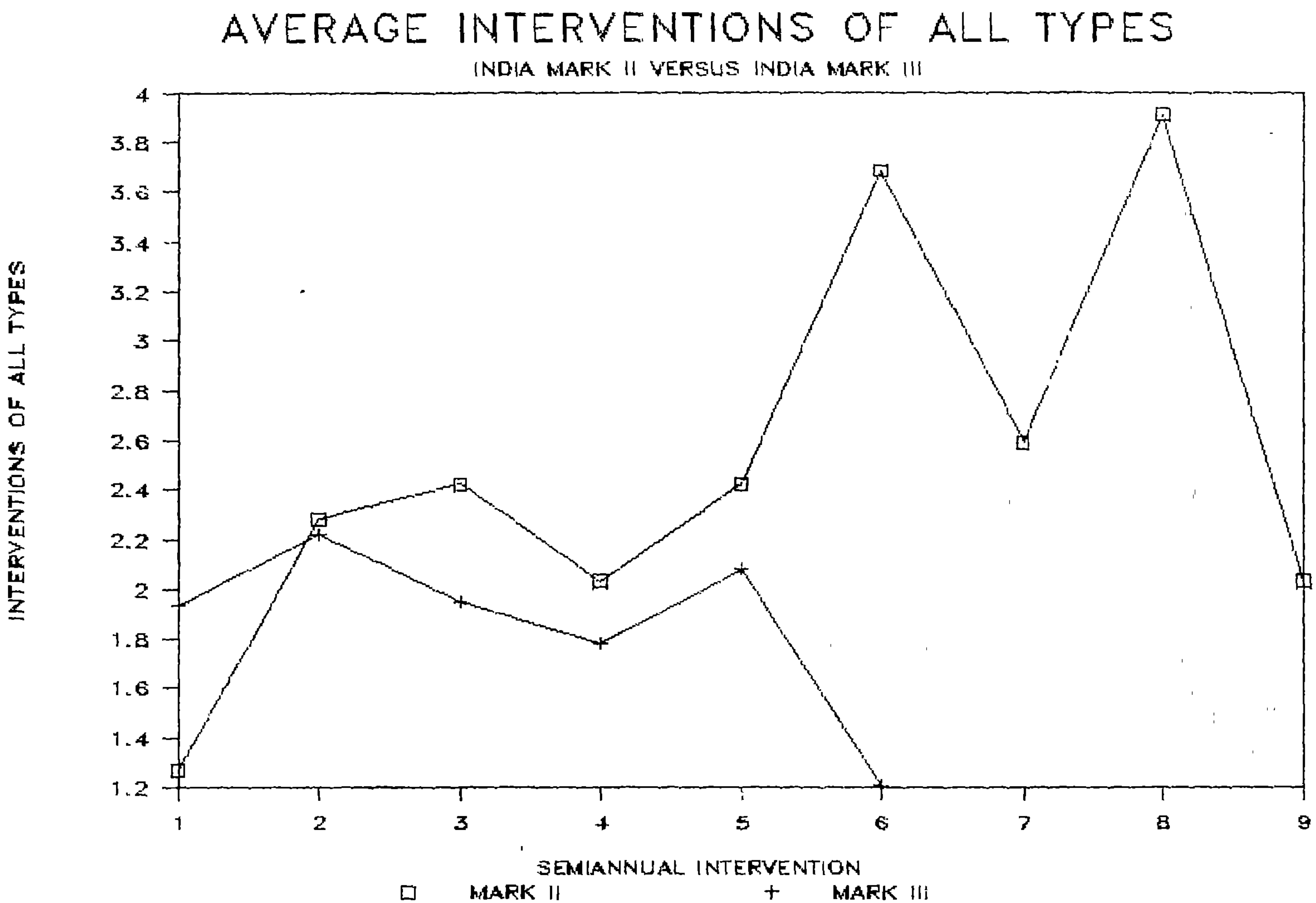


Figure VIII-2

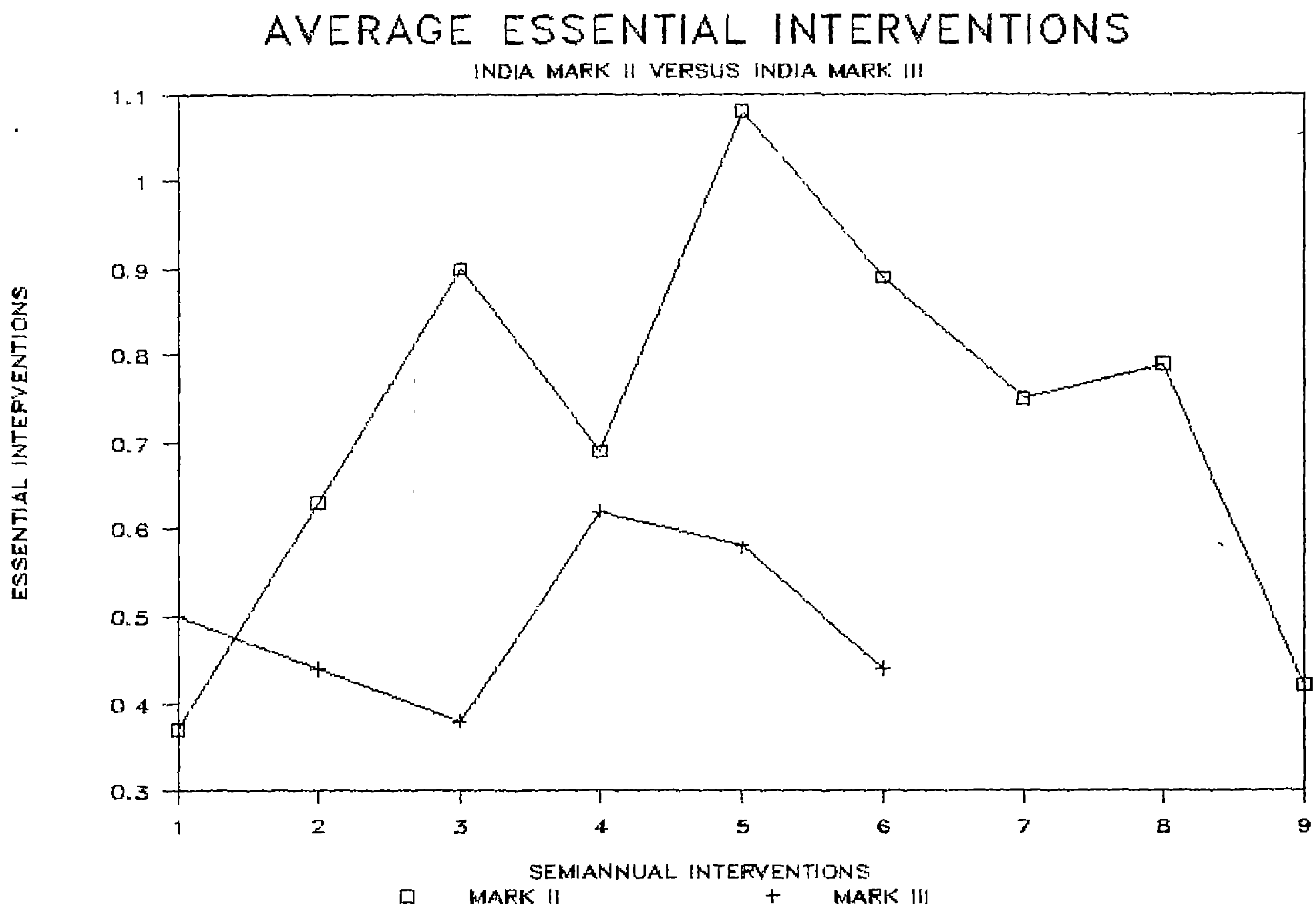


Figure VIII-3

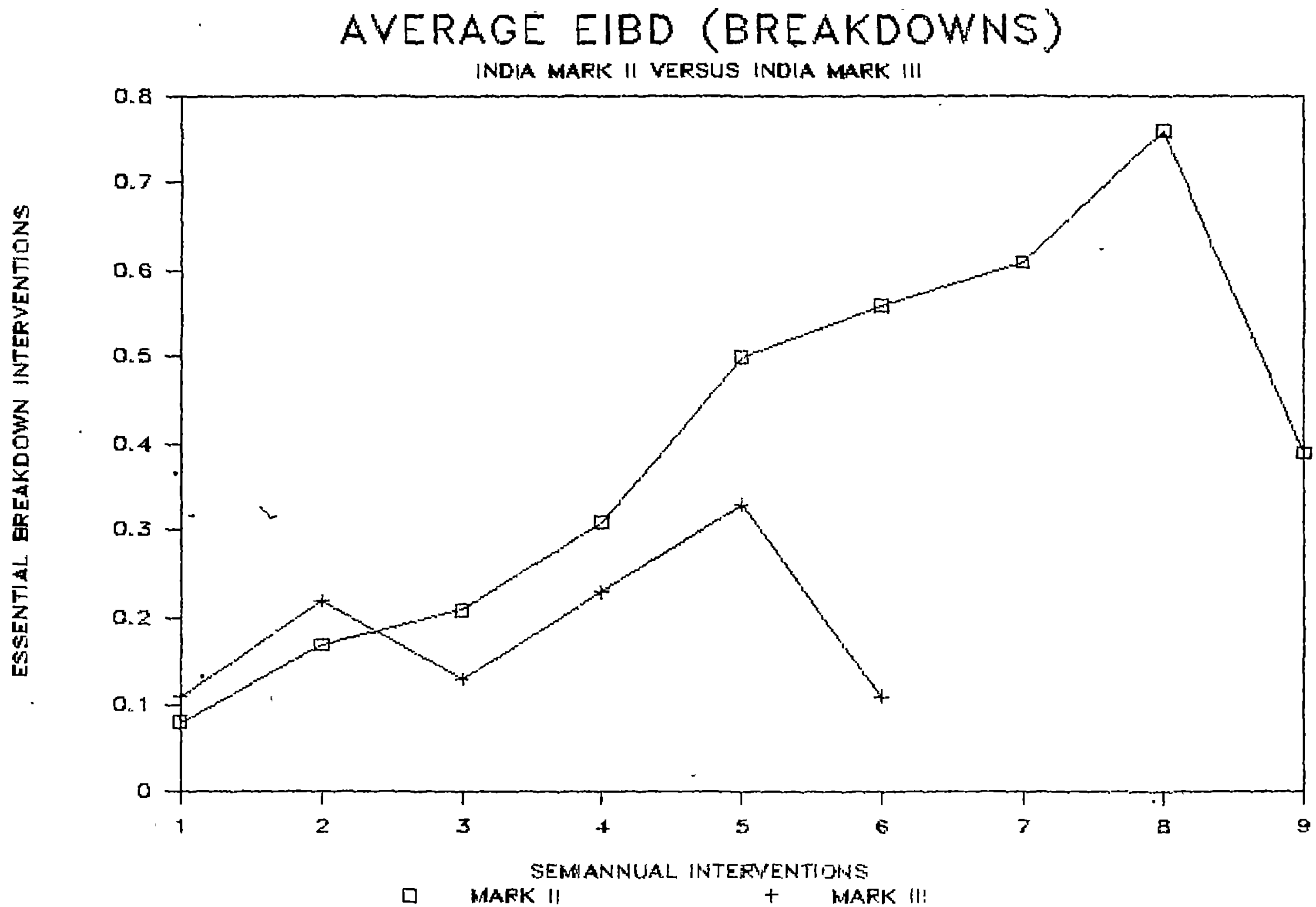


Figure VIII-4

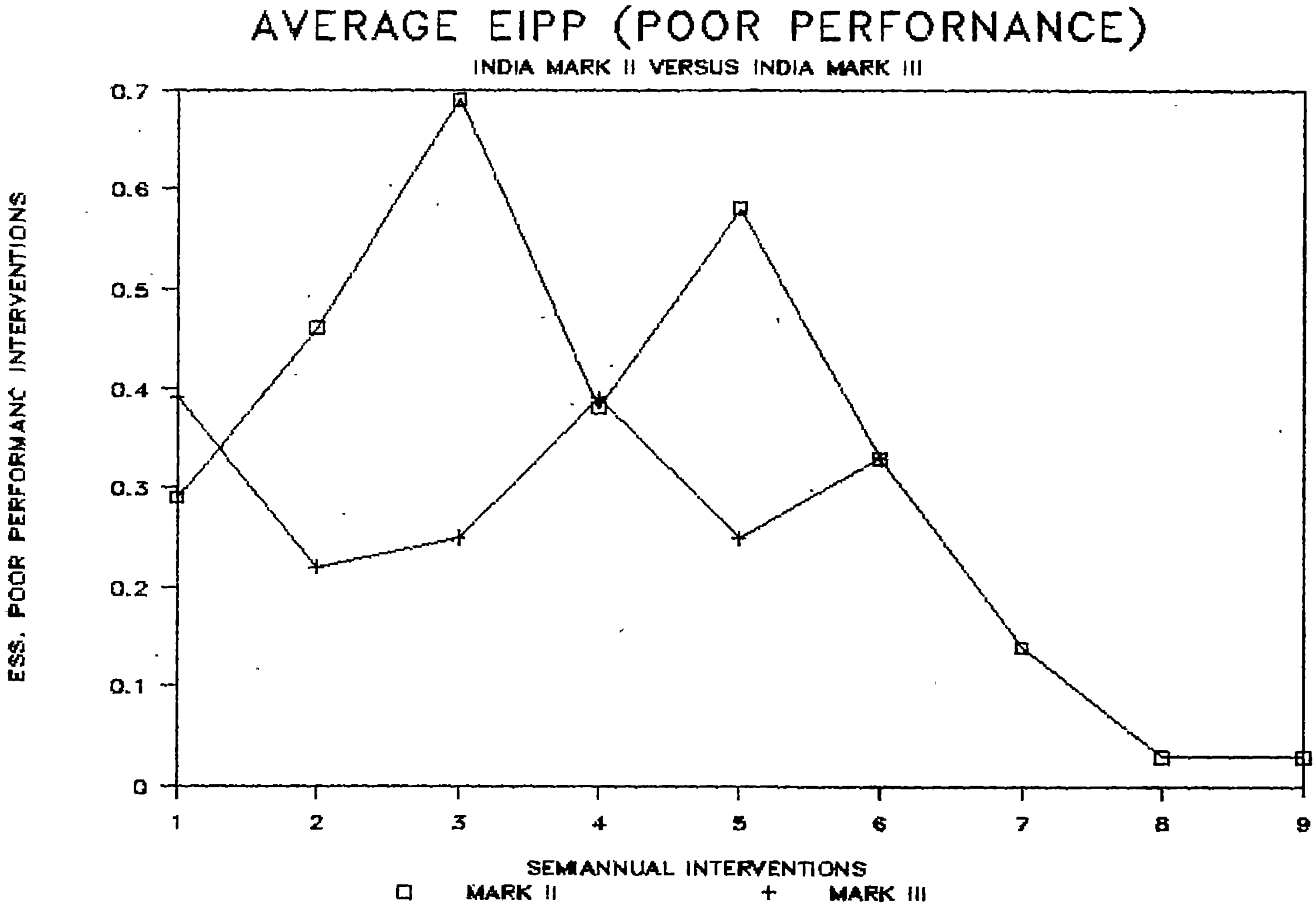


Figure VIII-5

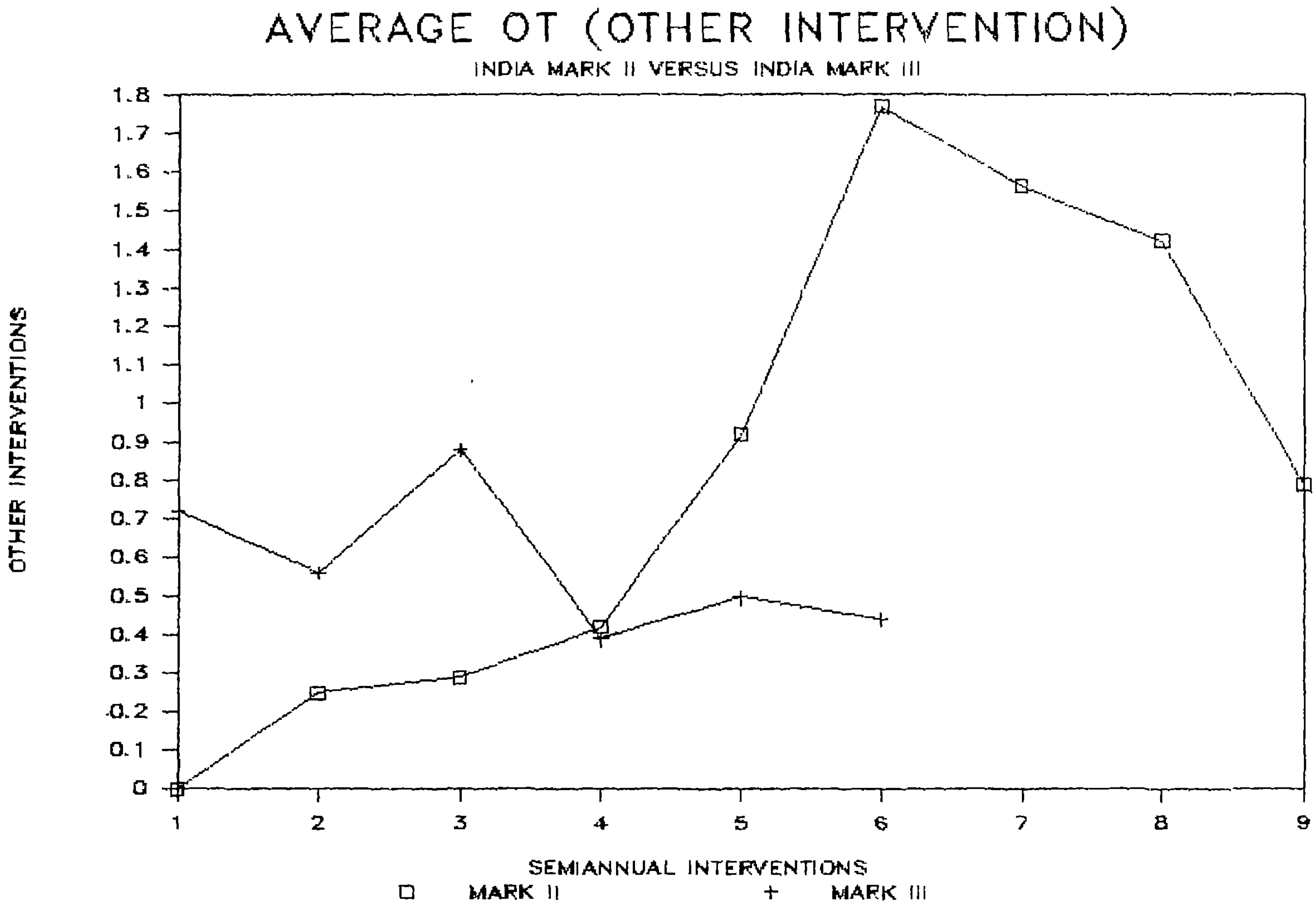
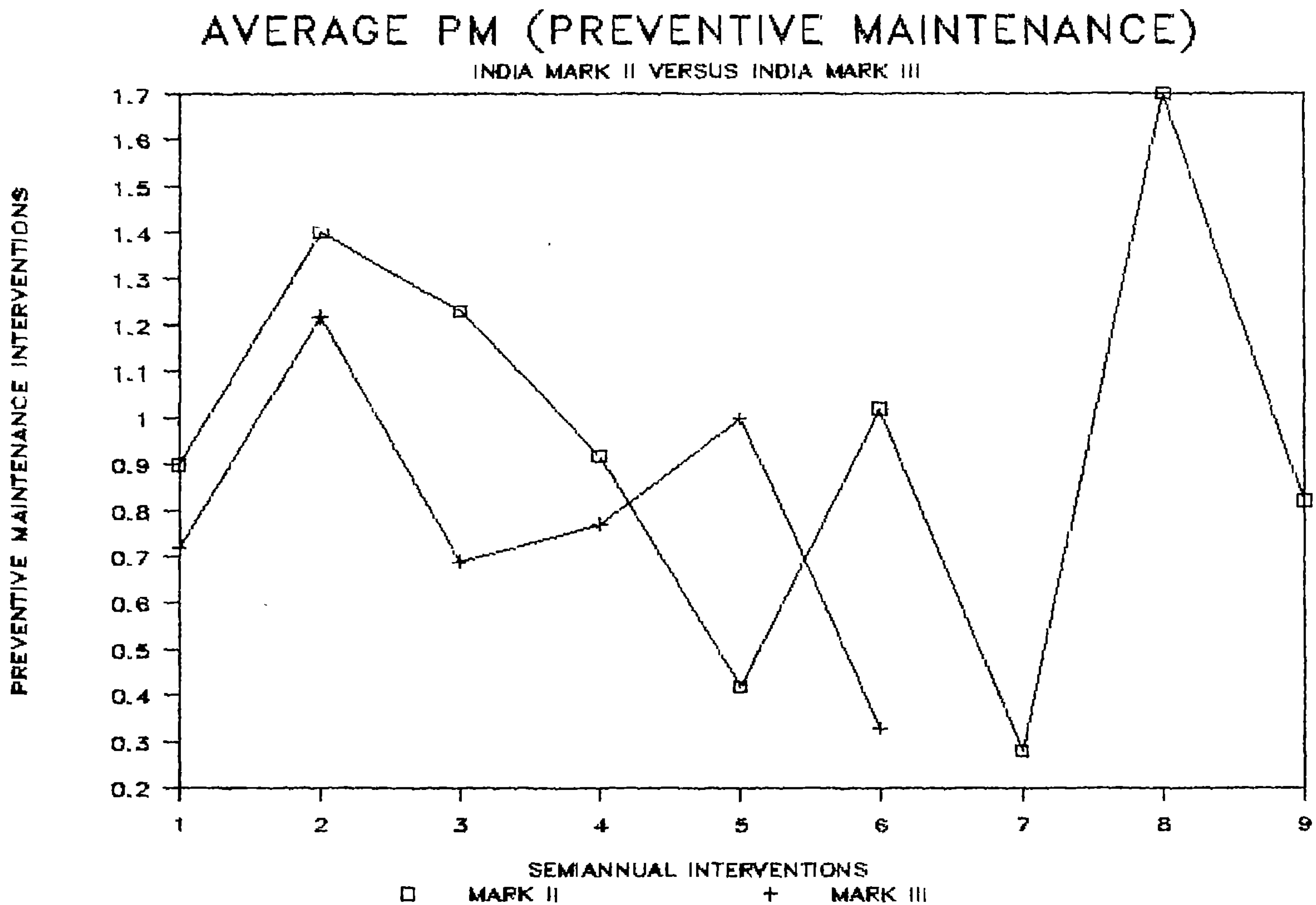


Figure VIII-6



Frequency of replacement of parts

1. The reliability of a handpump may also be expressed as the frequency of replacement of its components. A highly reliable handpump may, however, not be appropriate for a village if its repair by a local mechanic is made difficult or impossible by its design features, such as mechanical complexity, unusual fasteners (needing special tools), exotic spare parts or if repairing the below ground components can be done only with the help of lifting gear not present in or near the village.

2. Tables IX-1 and IX-2 give a breakdown by component of the average frequencies of replacement per semi-annual reporting interval for each of the components of each version of the pump. Figures IX-1 through IX-8 depict information graphically as curves comparing the frequencies for that component for the Mark II and Mark III test pumps.

TABLE IX-1
AVERAGE FREQUENCY OF PARTS REPLACEMENTS

Type of test pump - India Mark II
Average age - 3.83 years

Part	Semiannular interval									Annual
	1	2	3	4	5	6	7	8	9	Freq.
Handle assembly	0.00	0.02	0.13	0.06	0.19	0.17	0.11	0.12	0.12	0.24
Bearing	0.04	0.17	0.08	0.04	0.17	0.00	0.06	0.00	0.00	0.15
Chain	0.00	0.02	0.06	0.02	0.19	0.17	0.08	0.15	0.00	0.18
Pump rod	0.00	0.02	0.04	0.27	0.33	0.48	0.31	0.64	0.76	0.74
Rising main (pipe)	0.02	0.75	0.56	0.79	0.94	0.85	0.75	1.24	0.64	1.71
Rising main (coupler)	0.02	0.81	0.56	0.96	1.31	1.60	1.36	1.70	0.73	2.36
Piston seal	0.35	0.58	0.75	0.46	0.69	0.54	0.36	0.15	0.18	1.06
Piston valve	0.02	0.04	0.02	0.00	0.10	0.23	0.22	0.09	0.03	0.20
Foot valve assembly	0.00	0.02	0.04	0.06	0.06	0.08	0.19	0.21	0.09	0.20
Cylinder assembly	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.02
Cylinder body	0.00	0.00	0.00	0.02	0.00	0.21	0.06	0.06	0.03	0.10
Cap	0.00	0.00	0.00	0.08	0.08	0.13	0.08	0.12	0.15	0.17
Bolts	0.00	0.00	0.00	0.10	0.08	0.50	0.47	0.46	0.15	0.46
Nuts	0.00	0.04	0.00	0.10	0.25	1.56	1.67	0.97	1.00	1.46
Others	0.00	0.00	0.04	0.00	0.04	0.06	0.17	0.06	0.00	0.10
Total	0.45	2.47	2.28	3.00	4.47	6.58	5.89	5.97	3.88	-

TABLE IX-2
AVERAGE FREQUENCY OF PARTS REPLACEMENT

Type of test pump - India Mark III
Average age - 2.26 years

Part	Semiannual interval 1	2	3	4	5	6	Annual Freq.
Handle assembly	0.00	0.06	0.13	0.08	0.08	0.00	0.16
Bearing	0.00	0.00	0.00	0.31	0.00	0.00	0.14
Chain	0.00	0.00	0.06	0.15	0.00	0.00	0.09
Pump rod	0.11	0.00	0.00	0.00	0.17	0.22	0.22
Rising main (pipe)	0.00	0.00	0.25	0.00	0.25	0.33	0.37
Rising main (coupler)	0.00	0.00	0.25	0.39	0.42	0.33	0.62
Piston seal	0.44	0.39	0.38	0.46	0.50	0.33	1.11
Piston valve	0.17	0.11	0.19	0.00	0.00	0.00	0.21
Foot valve assembly	0.00	0.22	0.00	0.08	0.08	0.00	0.17
Cylinder assembly	0.00	0.00	0.06	0.00	0.03	0.03	0.05
Cylinder body	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cap	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bolts	0.00	0.00	0.13	0.00	0.00	0.11	0.11
Nuts	0.06	0.11	0.25	1.15	0.25	0.44	1.00
Others	0.33	0.28	0.19	0.08	0.00	0.00	0.39
Total	1.11	1.17	1.89	2.7	1.78	1.79	-

3. Figure IX-1 compares average frequencies for replacement for all parts. The India Mark III pump shows about the same frequency of replacement for parts as the Mark II pump for the second through the fourth reporting intervals, with a declining trend toward its initial value by the end of the test. The frequencies of replacement of Mark II pump parts increase to a level of about three times that of the Mark III pumps, primarily because of increasing rising main and pump rod replacement frequencies.

4. Figure IX-2 compares the frequencies of replacement of rising main pipes for the Mark II and Mark III pumps. For the Mark II pump the rising main was second in frequency of replacement and first in contribution to the overall spare parts cost. The small diameter standard rising main pipes have to be removed each time a piston seal needs replacement, or any other problem arises with the below-ground components. The dismantling and reassembling of the pipes causes damage to the surface of the pipes,, which are sites for accelerated corrosion. Finally, the restricted space inside the small diameter pipes results in abrasion between the pump rod and rising main during pumping, which accelerates corrosion both on the inside of the rising main and on the pump rod. By contrast, there are relatively few problems with the larger 2 1/2 inch diameter GI rising main pipes and

they were mainly confined to problems with the joints. This indicates that careful quality control must be exercised over the rising main couplingsand careful installation should be ensured. The greater wall thickness of the 2 1/2" GI rising main should enable it to survive many years in a well before corrosion perforates it. Figure IX-3 compares the frequency of replacement of Mark II and Mark III rising main couplers. The replacement frequency for couplers in the Mark II pump is significantly higher when compared with the Mark III pump for the same reason mentioned above.

5. Figure IX-4 indicates that pump rod replacements for the Mark II pump resemble the trend for rising mains, which would be expected, given the evidence in the preceding paragraph. As expected pump rod replacements for the Mark III pumps were far lower than for the Mark II pumps.

6. Figure IX-5 compares the replacement frequencies for foot valves for the two versions of the pump. They are significantly different: the Mark III foot valve is extractable, and slightly more complex than the fixed Mark II foot valve. Both are located at the bottom of the cylinder assembly, as shown in Figure 4. The Mark III foot valve was a new design, or rather had several designs initially of which one was finally selected. The reason for the higher initial frequency of Mark III foot valves was mostly due to design changes until the design stabilized. The curve for the Mark II foot valve shows a rising trend, which is a function of normal wear on the metal valves.

7. Figure IX-6 compares the replacement frequencies for handle assemblies and bearings for both versions of the pump. The mean annual frequency of handle assembly replacement in the Mark II and Mark III pump has been 0.24 and 0.16 respectively. At the time of first replacement of the bearings, the bearing seats in many handles were found to be oversized. This necessitated the replacement of the handle assembly itself. The problem is due to improper design and manufacturing of handle assemblies.

8. The handles with square bearing housing and 47-0.017-0.042 dia bearing seats were manufactured and field results were very encouraging. This change in design reduced significantly the distortions due to welding in the bearing seats. Further, these handles were not hotdip galvanized but electrogalvanised and no reaming operation in the bearing seats was allowed after welding and electrogalvanising. This resulted in the better quality of handle bearing seats.

9. The handle never fails due to corrosion and therefore it is not necessary to hotdip galvanize the handle. In fact, applying one coat of primer and two coats of aluminum paint will be the right process. The handles normally fail either due to deep serration of the quadrant or oversized bearing seats. Since the handle assembly is one of the most expensive single

components in the pump, it would seem that rebuilding of handles in a factory or a field workshop would be a better proposition rather than discarding the handle assembly as is being done at present.

10. Figure IX-7 compares the frequencies of replacement for the chain. The chain is identical for both versions of the pump and the replacement frequencies appear to be much the same for both versions of the pump.

Discussion of piston seal reliability

11. Figure IX-8 compares the frequency of replacement of seals for the Mark II and Mark III versions of the pump. There is no obvious trend for either pump. The best explanation for this is that the test started with chrome tanned leather seals only, later phasing in semichrome tanned and vegetable tanned seals and after two years, nitrile rubber seals. Individual plots of the working lives of seals of the various materials showed that among the leather seals, vegetable tanning lasted the longest, semichrome and chrome tanned about the same and nitrile rubber better than any leather seal.

12. Figure IX-9 compares curves plotting the distribution of the number of replacement interventions from high to low work output expressed in terms of quadric meters (a ton of water lifted one meter). Fewer replacements over a long work interval is the most desirable situation and would be indicated by a steep slope. Piston seals last longer in the Mark III pump than in the Mark II pump. This evidence seems to support the hypotheses that:

(a) The rising main pipes of the Mark III pumps are subject to less abrasion from the pump rods, and therefore less metal filings fall down seals;

(b) All Mark III pumps had three meter long 2 1/2 inch diameter intake pipes attached below the cylinder. This means that solid material from the unlined hard rock borehole was less likely to be taken into the Mark III pump cylinders during operation.

13. Table 6 illustrates clearly that nitrile piston seals have the highest average life period of 861x100 M4 and highest minimum life of 210x100 M4. The nitrile seals in operation have registered a maximum life of 2539x100 M4 (equivalent to more than 5 years for a pump working 7 hours a day and pumping 5.46 m3 of water per day, against a head of 25 mts). In fact the nitrile seals with modified spacer under operation in 27 pumps indicate that the average life of nitrile piston seals will go well beyond 1200x100 M4 which is equivalent to approximately two-and-a-half years of operation of a pump working 7 hours per day. The change-over from leather piston

seals to nitrile piston seals will increase the MTBF from the present 6 months to 2 years. However when the nitrile rubber piston seals with modified spacer are to be used in the existing cylinder, it is necessary to change either the cylinder body or the cylinder brass liner, as the nitrile rubber piston seals are very sensitive to rough surfaces. To improve the working life of piston seals, as a matter of routine maintenance, the cylinder brass liner should be replaced every four to five years.

14. It is interesting to note that the mode of failure of the leather piston seals was a gradual wearing away of the lip, while none of the nitrile rubber piston seals wore out. They failed mostly due to tearing. The conclusions are as follows.

 (a) Nitrile rubber is more resistant to abrasion than leather;

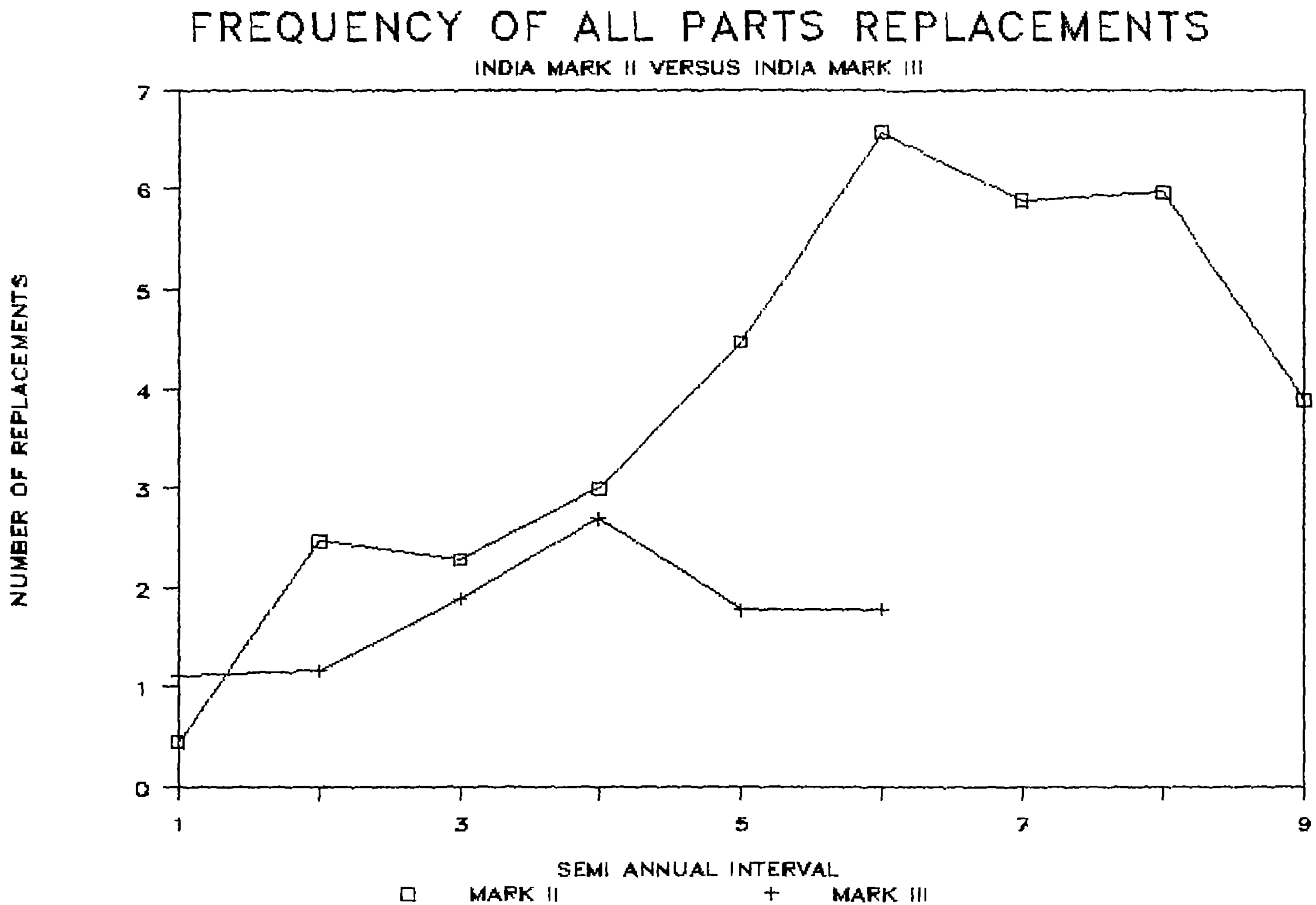
 (b) The rubber piston seal with a modified spacer is more durable and less prone to tearing;

 (c) Sand does not get embedded in the nitrile piston seals and therefore the brass liner does not get damaged due to abrasion as in the case of leather piston seals.

15. It appears that the use of a sand trap increases the life of piston seals by 30 percent. This is apparently due to sand particles getting trapped in the sand trap which would have otherwise fallen on the piston seals, thus resulting in the increased rate of wear. However, to establish the advantage of fitting a sand trap it is necessary to carry out field trials on a larger scale.

16. While not yet definitely confirmed by analysis, seals of both materials appear to last longest in the first generation, with each succeeding generation needing replacement sooner than its predecessor. It is to be expected that the surface finish of the cylinder becomes progressively rougher with use, and seals will be abraded at a faster rate. This phenomenon may be inevitable and therefore classified as "normal wear" for the brass sleeve. However, it may be that repositioning of the piston in a slightly different section of the cylinder results in accelerated abrasion because sediments (deposited on the cylinder wall where it is not wiped by the seal) act as a "grinding compound", and the smooth surface of the cold-drawn brass tube is roughened more quickly. Washing of the cylinder with a detergent and then wiping it with cloth when replacing the seal is recommended. The evidence also suggests that a more reliable piston seal will have considerable impact on the cost of maintenance of the Mark II pumps and moderate impact on that of the Mark III pumps.

Figure IX-1



FREQUENCY OF ALL PARTS REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0
1
2
3
4
5
6
7
1
3
5
7
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-2

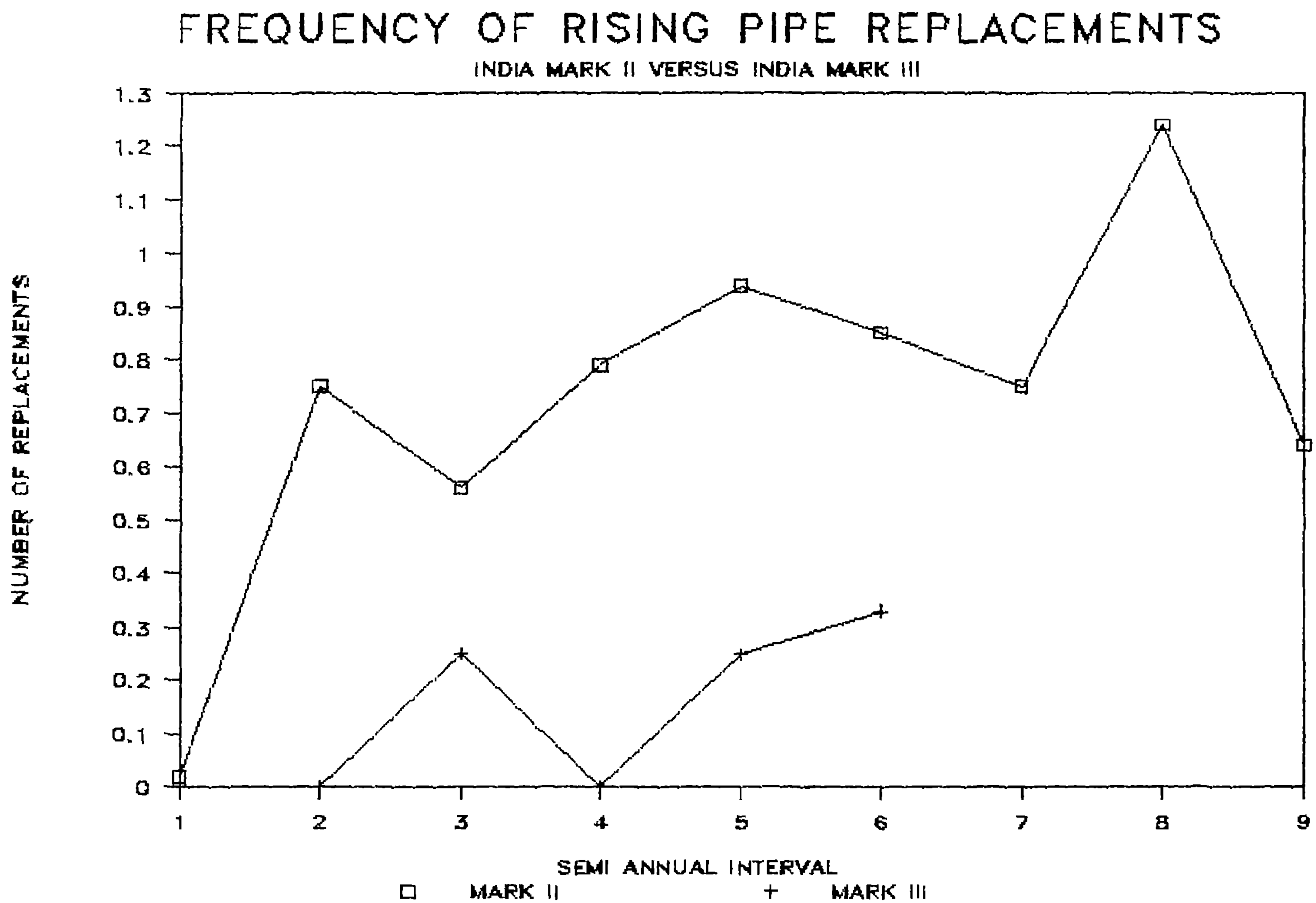

FREQUENCY OF RISING PIPE REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-3

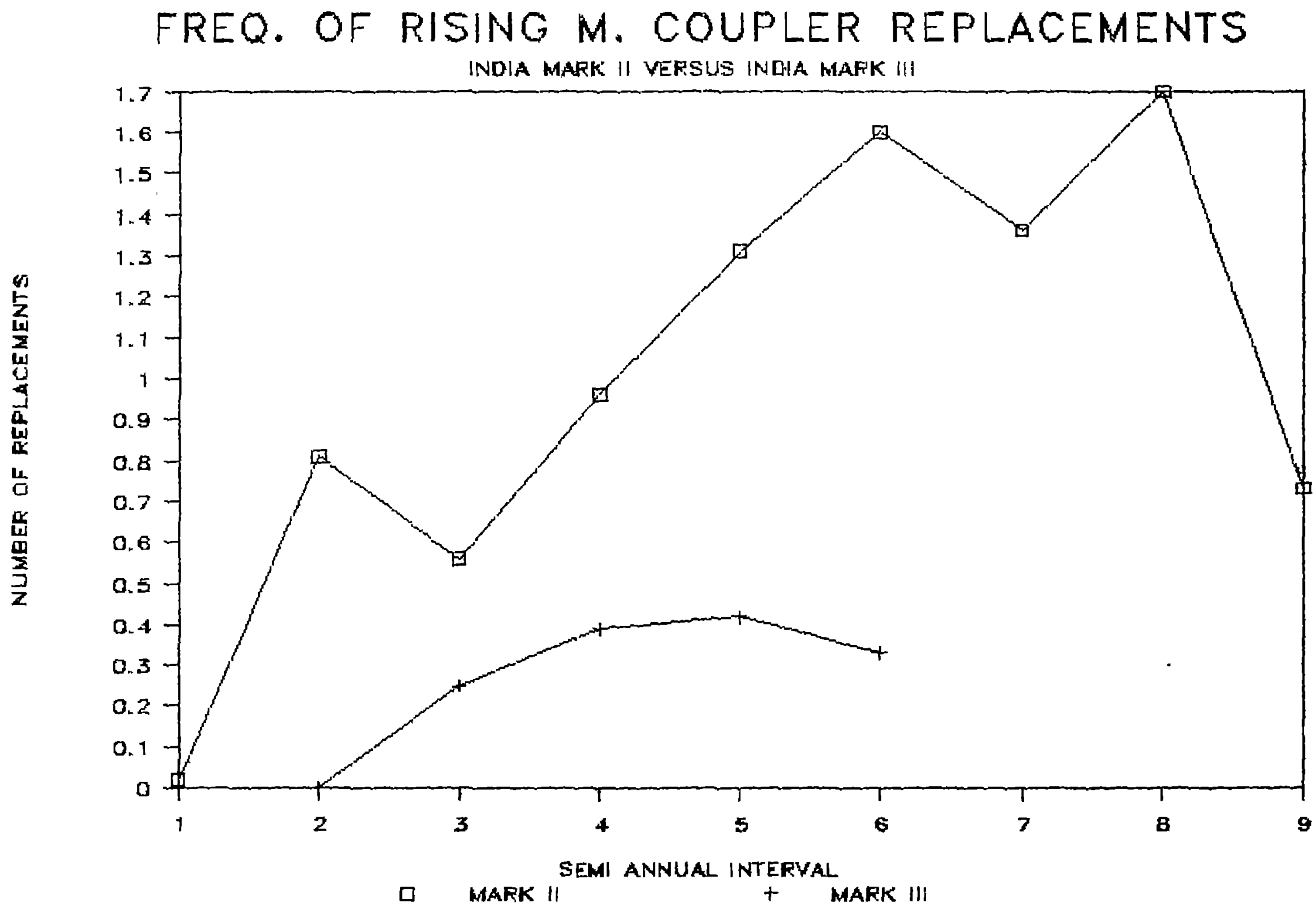
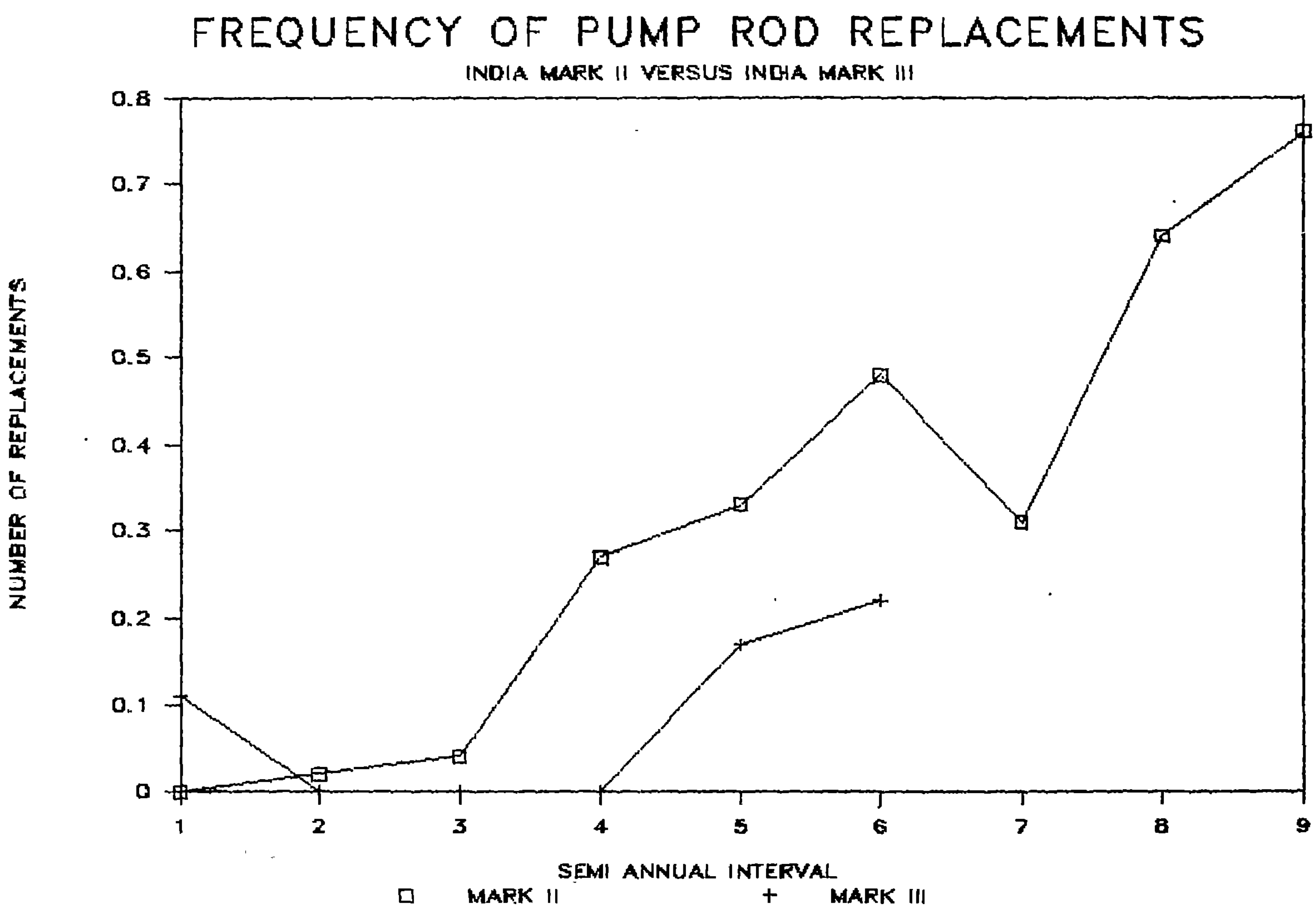

FREQ. OF RISING M. COUPLER REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-4



FREQUENCY OF PUMP ROD REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-5

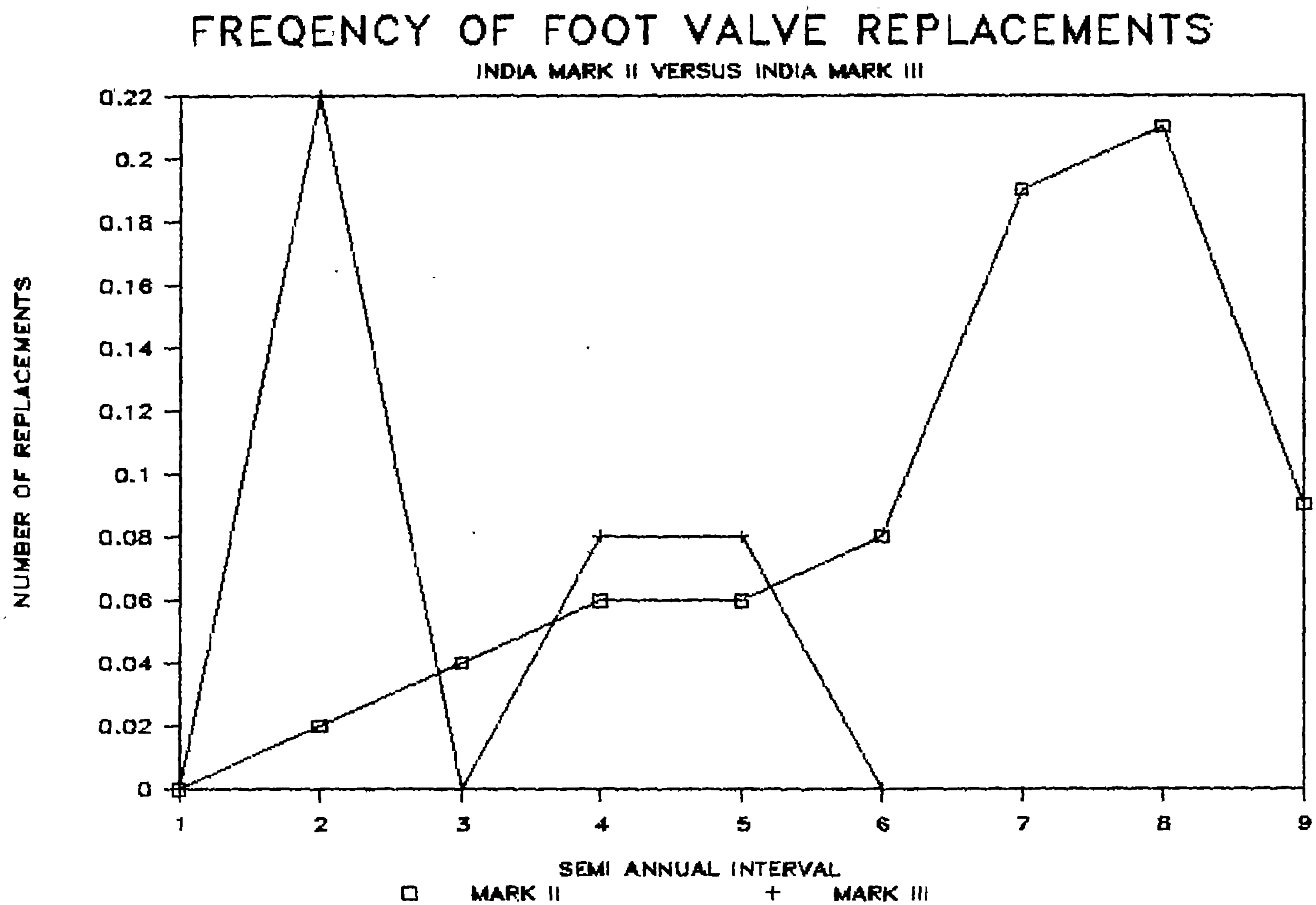
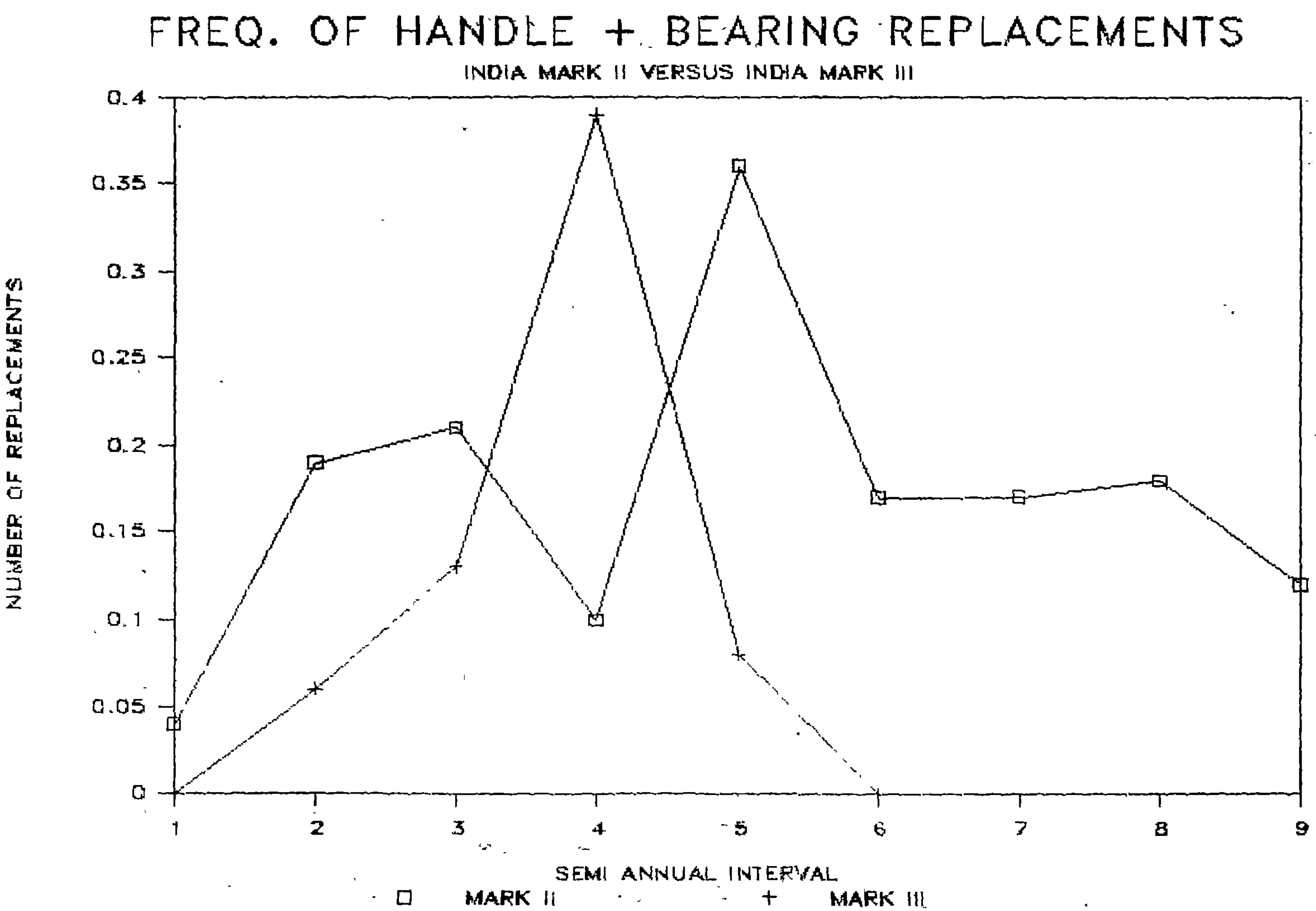

FREQENCY OF FOOT VALVE REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-6



FREQ. OF HANDLE + BEARING REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-7

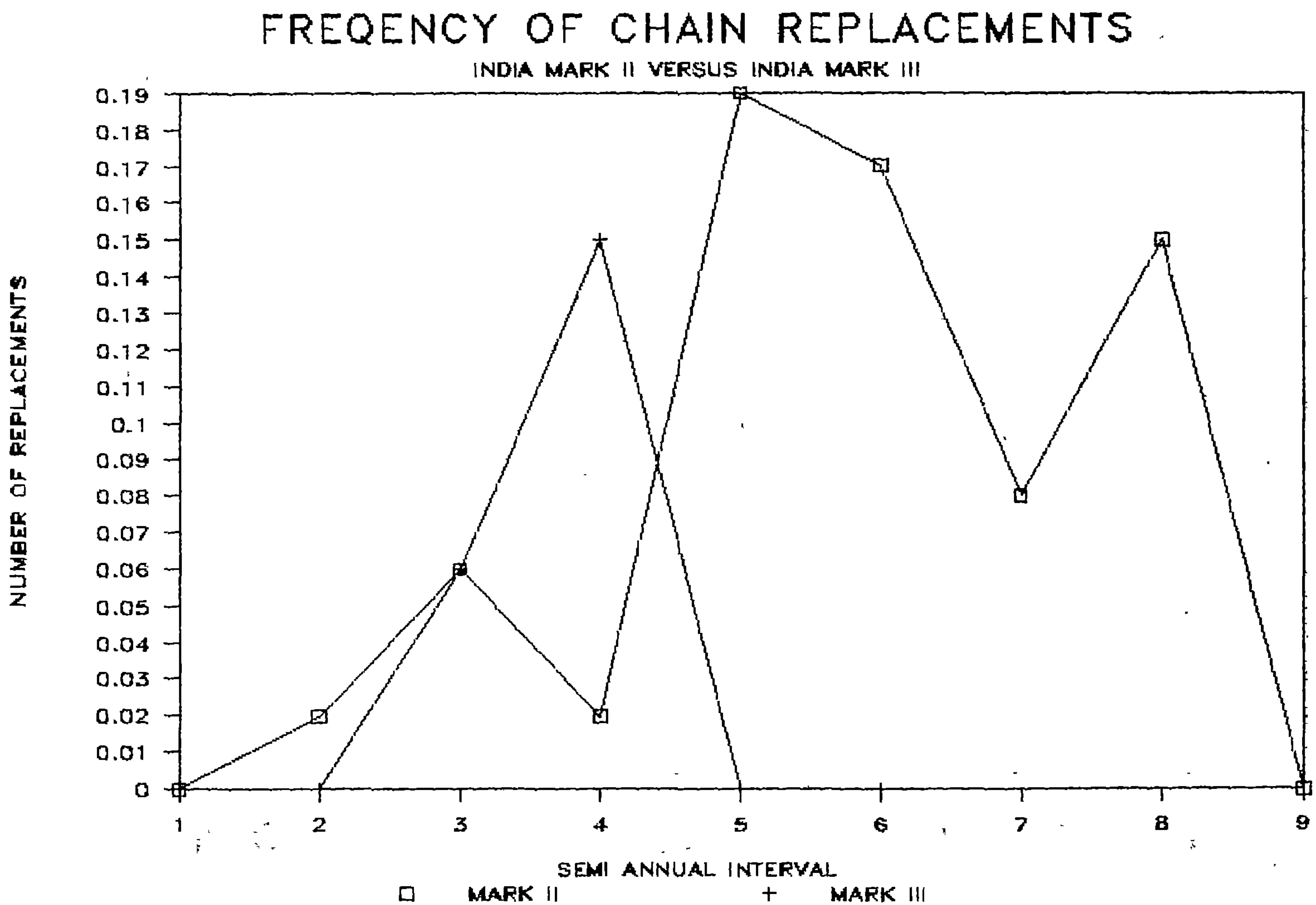
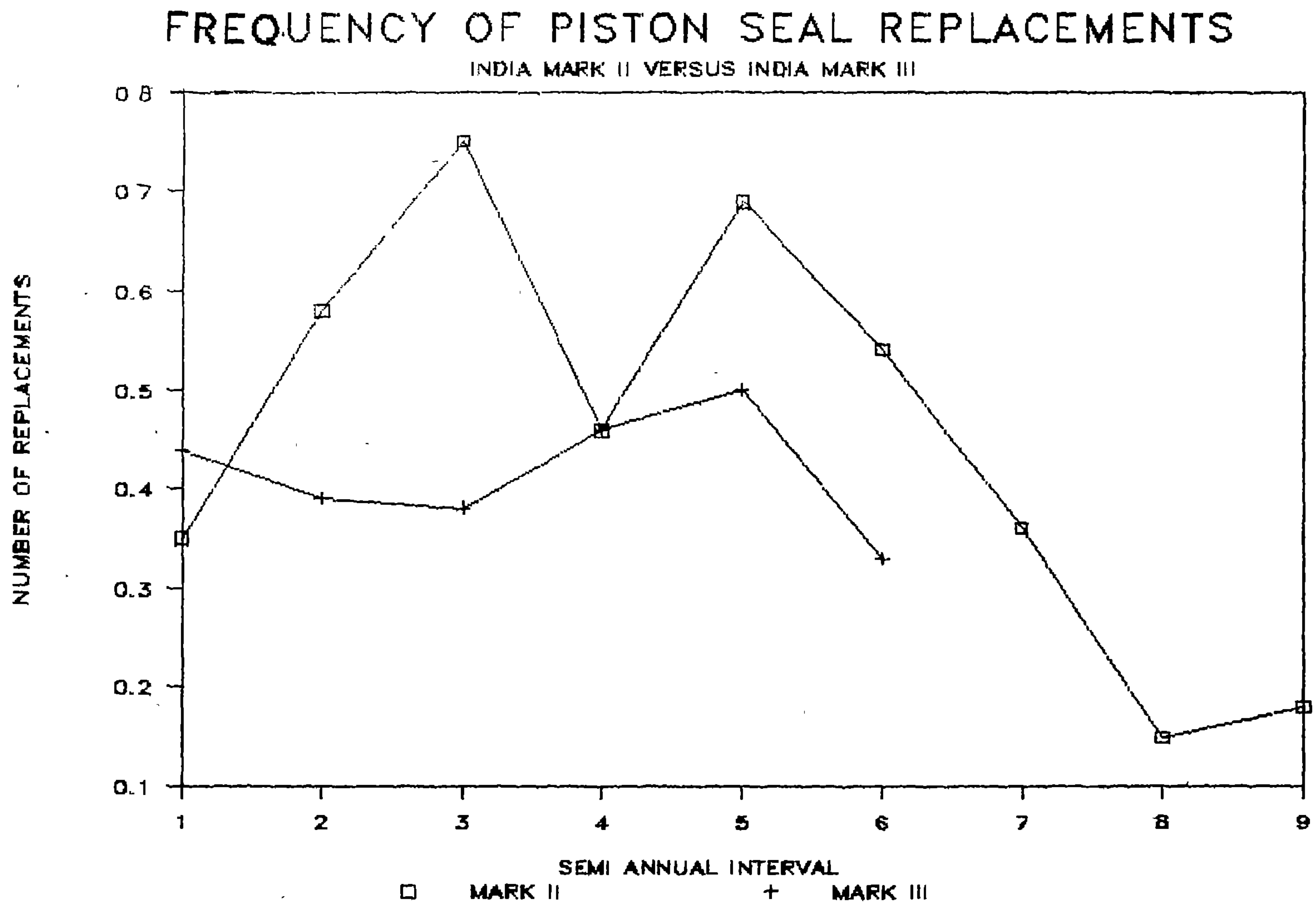

FREQENCY OF CHAIN REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Figure IX-8


FREQUENCY OF PISTON SEAL REPLACEMENTS
INDIA MARK II VERSUS INDIA MARK III
NUMBER OF REPLACEMENTS
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
8
9
SEMI ANNUAL INTERVAL
MARK II
MARK III

Spare Parts Replacement Costs

1. Tables X-1 and X-2 give a breakdown of average costs of replacement parts over the test period for the Mark II and Mark III versions of the test pumps. Figure X-1 compares the average and mean costs of replacement parts per semiannual reporting interval. The annual mean costs were Rs.423.50 per year for the Mark II pump and Rs.228.20 per year for the Mark III pump - a difference of approximately 25%.

TABLE X-1
AVERAGE SPARE PARTS COST

Type of test pump - India Mark II
Average age - 3.83 years

	Semiannual interval									Annual
Part type	1	2	3	4	5	6	7	8	9	Mean
Handle assembly	0.0	6.8	44.2	20.4	64.6	57.8	37.4	40.8	40.8	81 7
Bearings	2.0	8.5	4.0	2.0	8.5	0.0	3.0	3.0	0.0	8 1
Chain	0.0	1.2	3.6	1.2	11.4	10.2	4.8	9.0	0.0	10.8
Pump rod	0.0	0.8	1.6	10.8	13.2	19.2	12.4	25.6	30.4	29.8
Rising main (pipe)	2.3	85.5	63.8	90.1	107.2	96.9	85.5	141.4	73.0	194.7
Rising main (coupler)	0.3	13.0	9.0	15.4	21.0	25.6	21.8	27.2	11.7	37.9
Piston seal	3.2	5.2	6.8	4.1	6.2	4.9	3.2	1.4	1.6	9.6
Piston valve	0.5	1.0	0.5	0.0	2.5	5.8	5.5	2.3	0.8	4.9
Foot valve assembly	0.0	1.2	2.4	3.6	3.6	4.8	11.4	12.6	5.4	11.7
Cylinder body	0.0	0.0	0.0	2.8	0.0	29.4	8.4	8.4	4.2	13 9
Cylinder cap	0.0	0.0	0.0	2.0	2.0	3.3	2.0	3.0	3.8	4.2
Cylinder assembly	0.0	0.0	0.0	18.0	18.0	0.0	0.0	0.0	0.0	9.4
Bolts	0.0	0.0	0.0	0.2	0.2	1.0	0.9	0.9	0.3	0.9
Nuts	0.0	0.0	0.0	0.1	0.3	1.6	1.7	1.0	1.0	1.5
Others	0.0	0.0	2.4	0.0	0.9	0.9	3.7	9.1	0.0	4.4
Total	8.3	123.2	138.3	170.7	259.6	261.4	201.7	285.7	173.0	423.5

TABLE X-2
AVERAGE SPARE PARTS COST

Type of test pump - India Mark III
Average age - 2.26 years

Part type	Semi-annual interval 1	2	3	4	5	6	Annual Mean
Handle assembly	0.0	20.4	44.2	27.2	27.2	0.0	52.7
Handle bearing	0.0	0.0	0.0	15.5	0.0	0.0	6.9
Chain	0.0	0.0	3.6	9.0	0.0	0.0	5.6
Pump rod	4.4	0.0	0.0	0.0	6.8	8.8	8.8
Rising main (pipe)	0.0	0.0	57.0	0.0	57.0	75.2	83.7
Rising main (coupler)	0.0	0.0	7.5	11.7	12.6	9.9	18.5
Piston seal	4.0	3.5	3.4	4.1	4.5	3.0	10.0
Piston valve	4.3	2.8	4.8	0.0	0.0	0.0	5.3
Foot valve	0.0	5.5	0.0	2.0	2.0	0.0	4.2
Cylinder assembly	0.0	0.0	9.0	0.0	24.5	33.0	29.40
Bolts	0.0	0.0	0.3	0.0	0.0	0.2	0.2
Nuts	0.1	0.1	0.3	1.2	0.3	0.4	1.1
Others	0.7	2.7	0.4	0.2	0.0	0.0	1.8
Total	13.5	35.0	130.5	70.9	134.9	130.5	228.20

2. Rising main costs accounted for about 55% of the mean annual costs for the Mark II pumps and 32% of mean annual costs for the Mark III test pumps. This is the single most expensive part to be replaced in both the pumps. Figure X-2 compares the two types of rising mains (pipe and coupler) by cost per semiannual reporting interval, where it is seen that costs escalate with age of the pump, which is to be expected, but for the Mark II pumps, the reason is primarily abrasion-induced corrosion. For the Mark III pumps, the reason is poor quality joints affecting 17% of the sample. The lesson here is to ensure good quality joints, or be prepared for high replacement costs for the larger diameter rising main pipes. But if installed correctly, then considerable savings can accrue from lower replacement frequencies.

3. Figure X-3 compares the replacement part costs for both versions of the pump for piston seals. The trend is erratic, reflecting the erratic performance of the first groups of leather seals and final stabilizing effect of the more reliable nitrile seals. While the cost of the piston seal is relatively low, it is the chief contributor to maintenance costs because of its high frequency of replacement.

4. Figure X-4 compares the replacement part costs for both versions of the pump for pumping elements, including the cylinder body, piston assembly (excluding the piston seal) and end caps of the cylinder.

5. Figure X-5 compares the replacement part costs for both versions of the pump for pump rods. Lower average replacement frequencies for pump rods in the Mark III pumps account for lower average costs. The mean annual cost for replacement of pump rod was Rs.8.90 for the Mark III pump and Rs.29.80 for the Mark II pump.

6. Figure X-6 compares the replacement part costs for both versions of the pump for the handle assembly. As discussed in Annex IX, the handle assembly is not an inexpensive item, and should be considered for rebuilding instead of the scrap heap. There is a necessity to tighten the quality control on bearing fitments together with a change in design and production procedures. This item accounts for 20% of the mean annual costs for the Mark II pump and 16.5% of the mean annual costs for the Mark III pump.

7. Figure X-7 compares the replacement part costs for foot valves for both versions of the pump. The early foot valve designs for the Mark III pumps had to be changed during the first and second years of operation, but stabilized after three years and may be considered adequate. Most of the costs had to do with the rubber O-ring seal around the bottom of the assembly and the difficulty of keeping it in place during extraction, especially if the rising main was full of water, causing a downward rush of water past the O-ring. For the Mark II pumps, valves were replaced at a steadily increasing rate, due to normal wear. The components involved are not particularly expensive.

8. Figure X-8 compares the replacement part costs for chains for both versions of the pump. Chains were replaced when they rusted and wore out. Weathering is one of the reasons for chain replacement. Lubrication will slow the rate of corrosion, but will not prevent ultimate stiffening and loss of function. The chain was not an important contributor to the overall parts replacement costs.

9. Figure X-9 compares the replacement part costs for "other" parts for both versions of the pump. These were mostly fasteners and not important contributors to overall parts replacement costs.

10. The rising main, handle assembly and piston rod accounts for 81.25% of mean annual cost of parts replaced in the Mark II pump and 51.39% of mean annual cost of parts replaced in the Mark III pump.

11. The introduction of nitrile rubber and the HDPE pump rod centralizer will substantially reduce the damage due to abrasion to the rising main and pump rod. This will reduce the part replacement costs for the pump rod and rising main.

12. Observations and conclusions are based on the data obtained from a small batch of test pumps working under specific hydrogeological and socio-economic conditions. The consumption of spare parts will vary significantly with water quality, depth of installation, usage pattern and the quality of well construction and pump installation.

Figure X-1

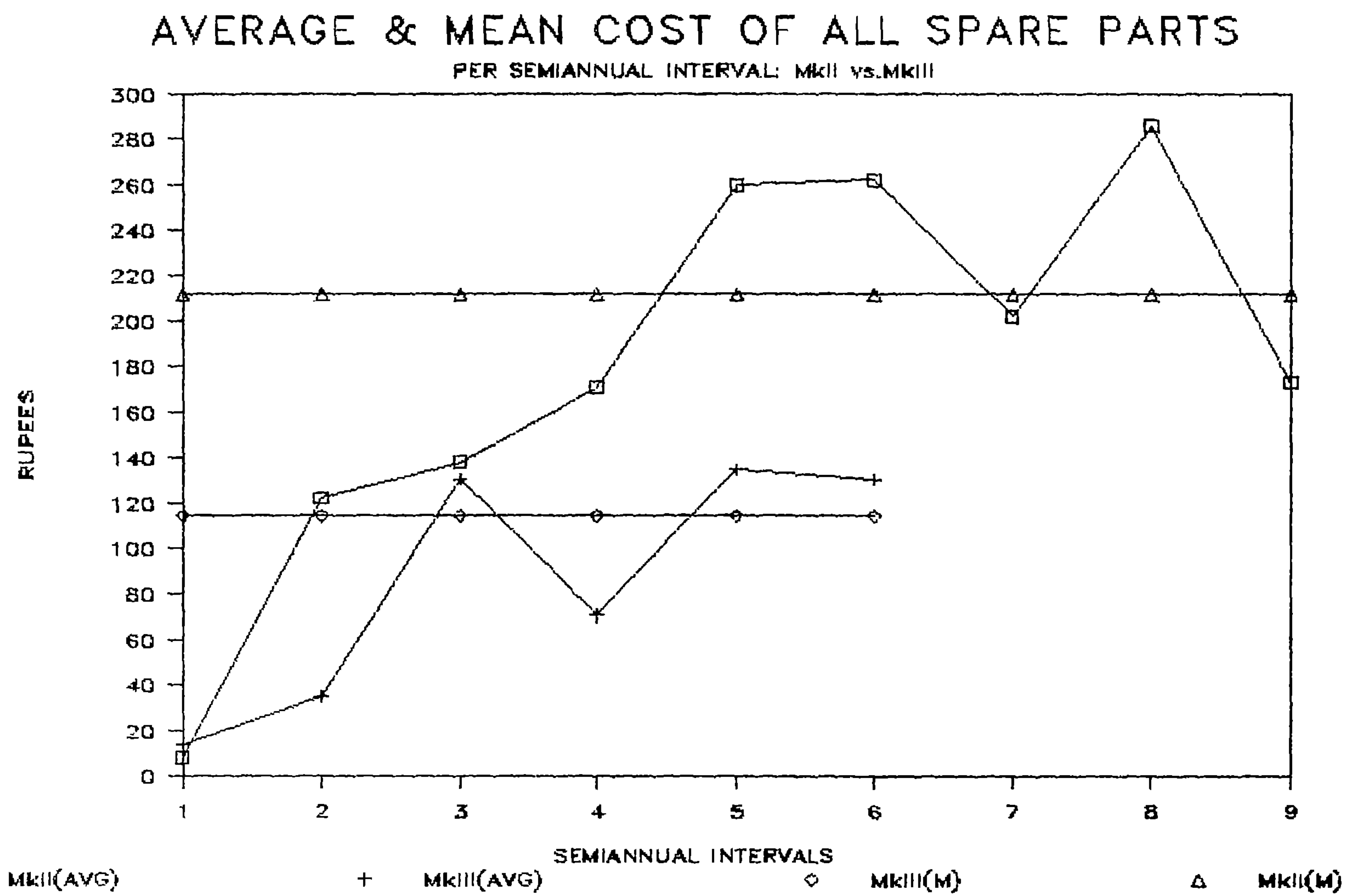
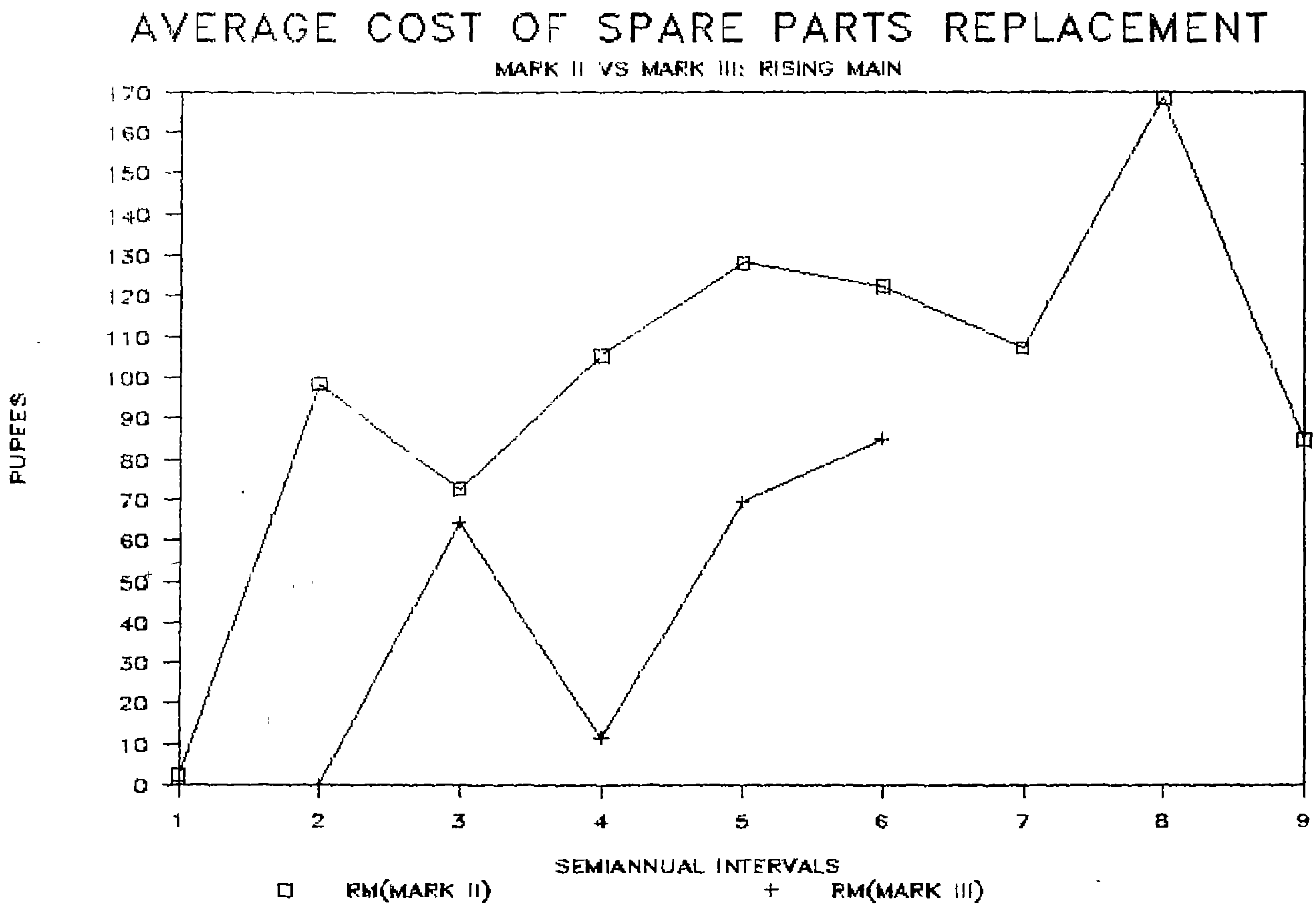

AVERAGE & MEAN COST OF ALL SPARE PARTS
PER SEMIANNUAL INTERVAL: MkII vs.MkIII
RUPEES
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
MkII(AVG)
MkIII(AVG)
MkIII(M)
MkII(M)

Figure X-2



AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: RISING MAIN
RUPEES
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
RM(MARK II)
RM(MARK III)

Figure X-3

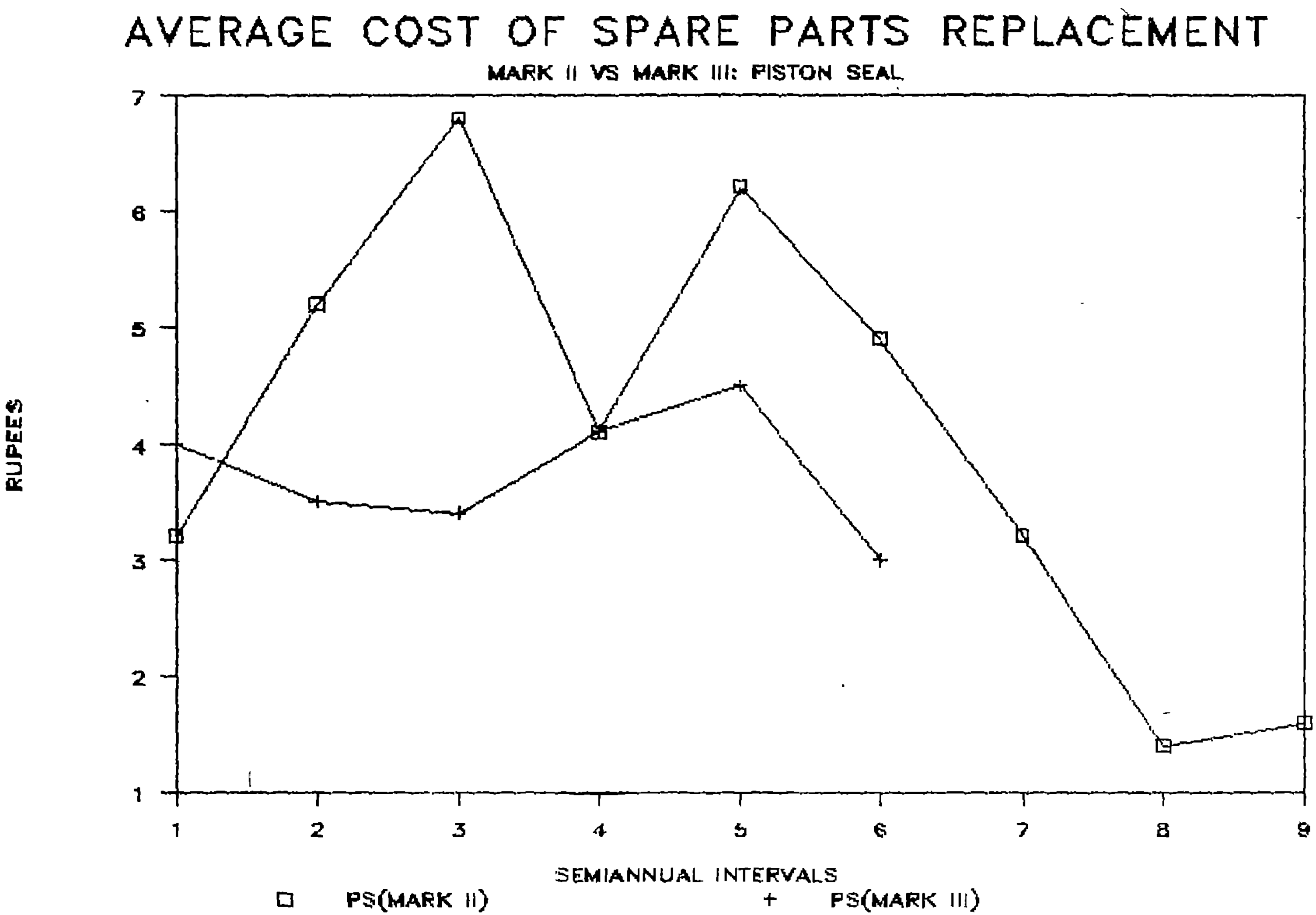
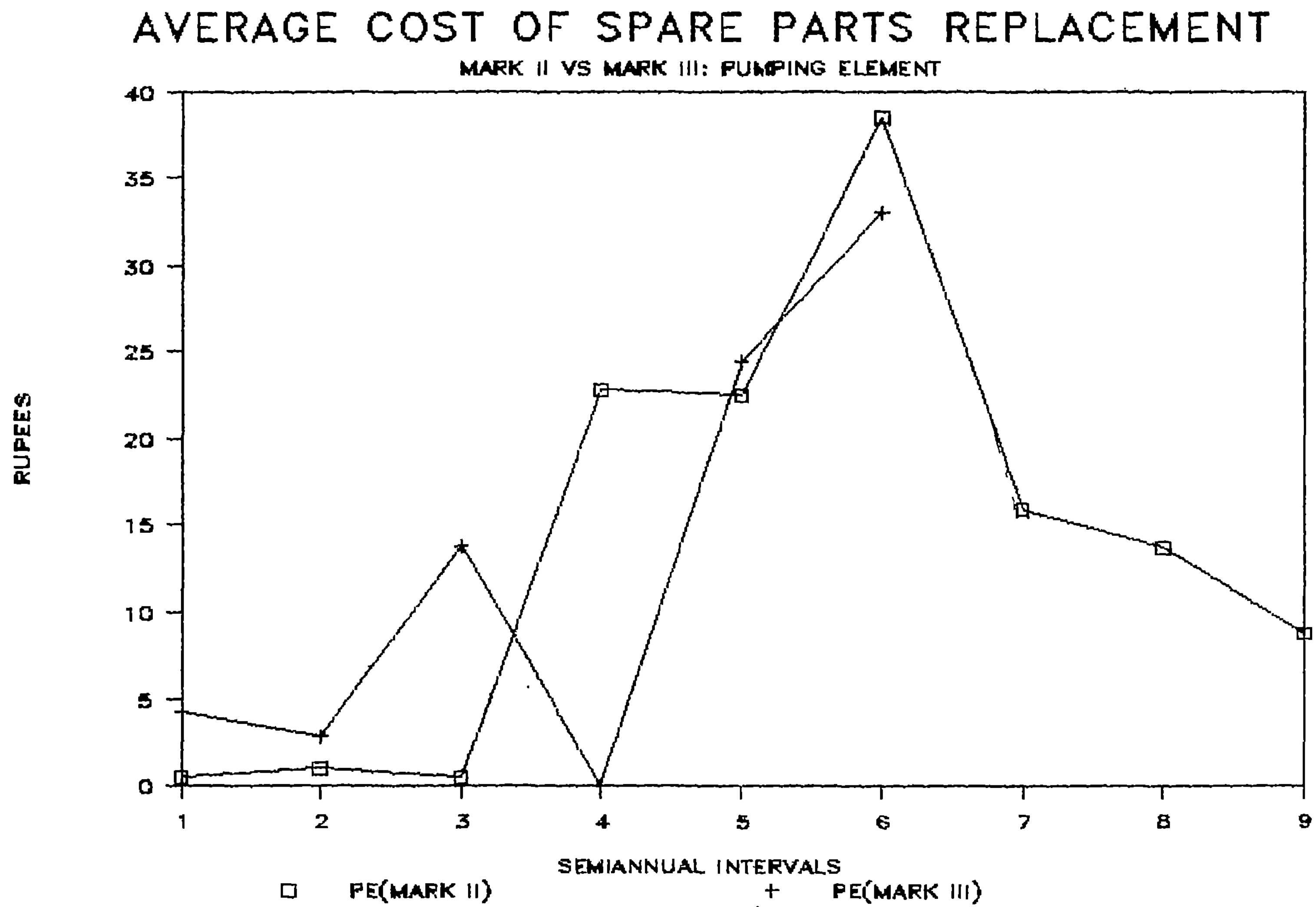

AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: PISTON SEAL
RUPEES
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
PS(MARK II)
PS(MARK III)

Figure X-4



AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: PUMPING ELEMENT
RUPEES
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
PE(MARK II)
PE(MARK III)

Figure X-5

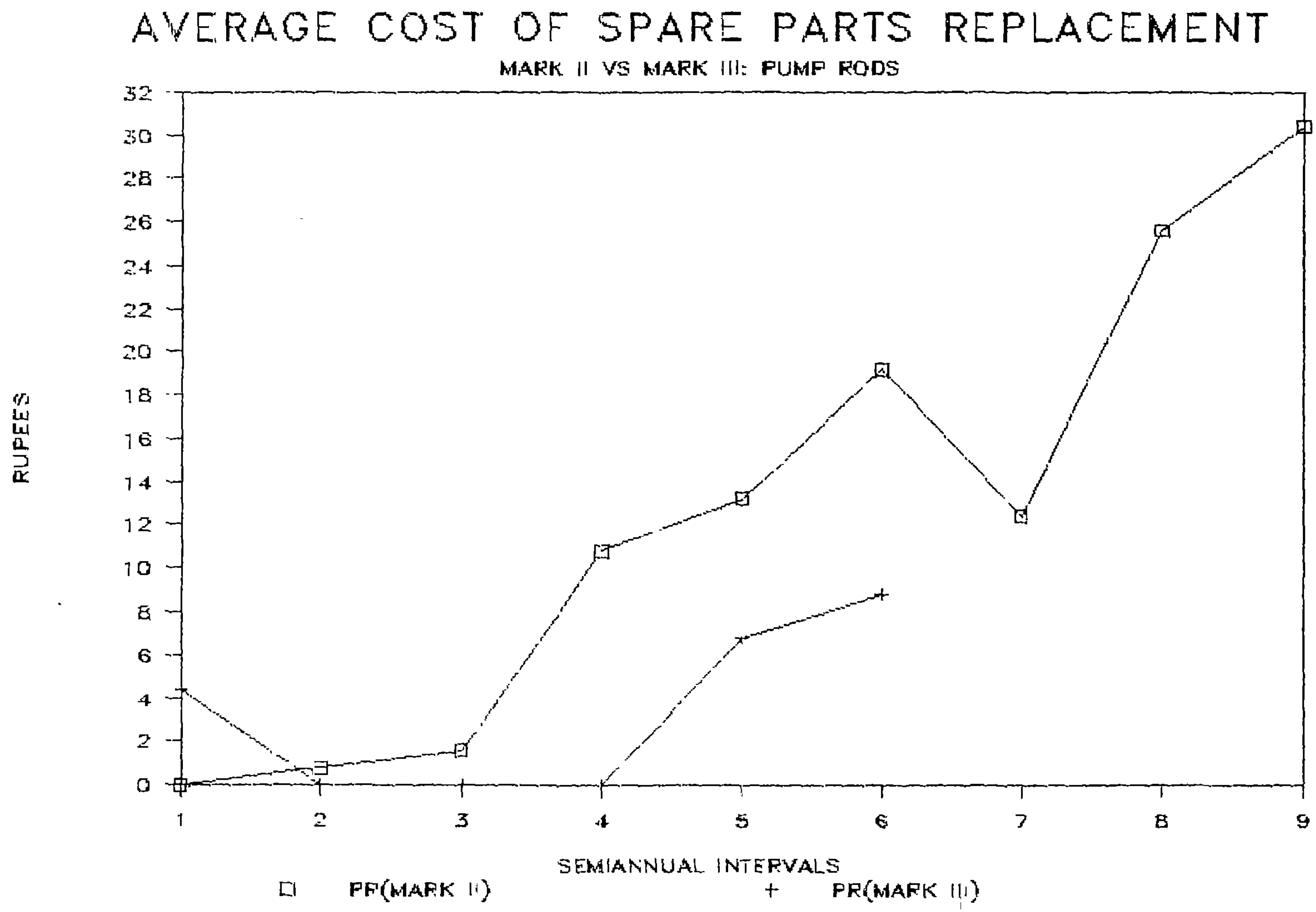

AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: PUMP RODS
RUPEES
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
PR(MARK II)
PR(MARK III)

Figure X-6

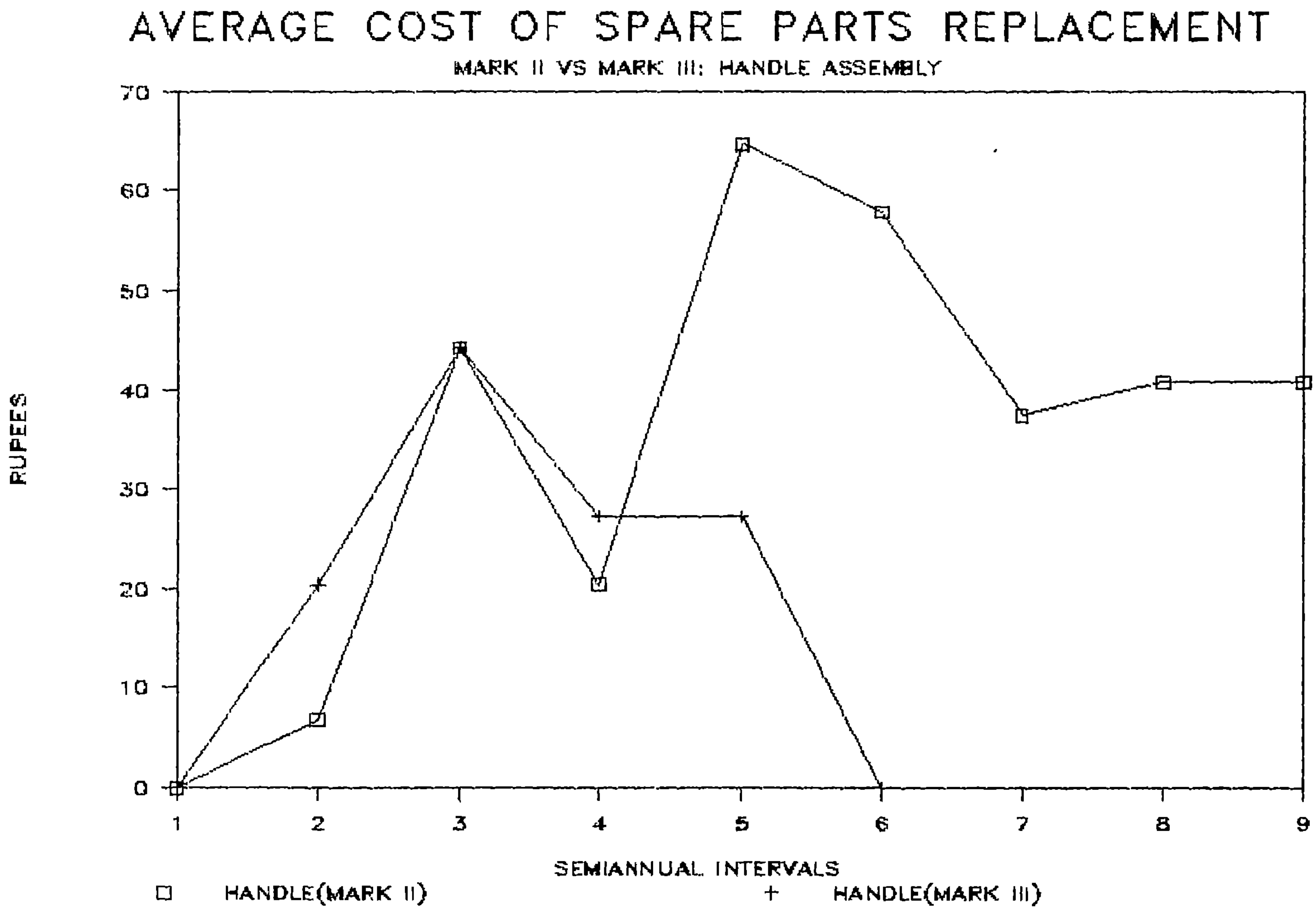

AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: HANDLE ASSEMBLY
RUPEES
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
HANDLE(MARK II)
HANDLE(MARK III)

Figure X-7

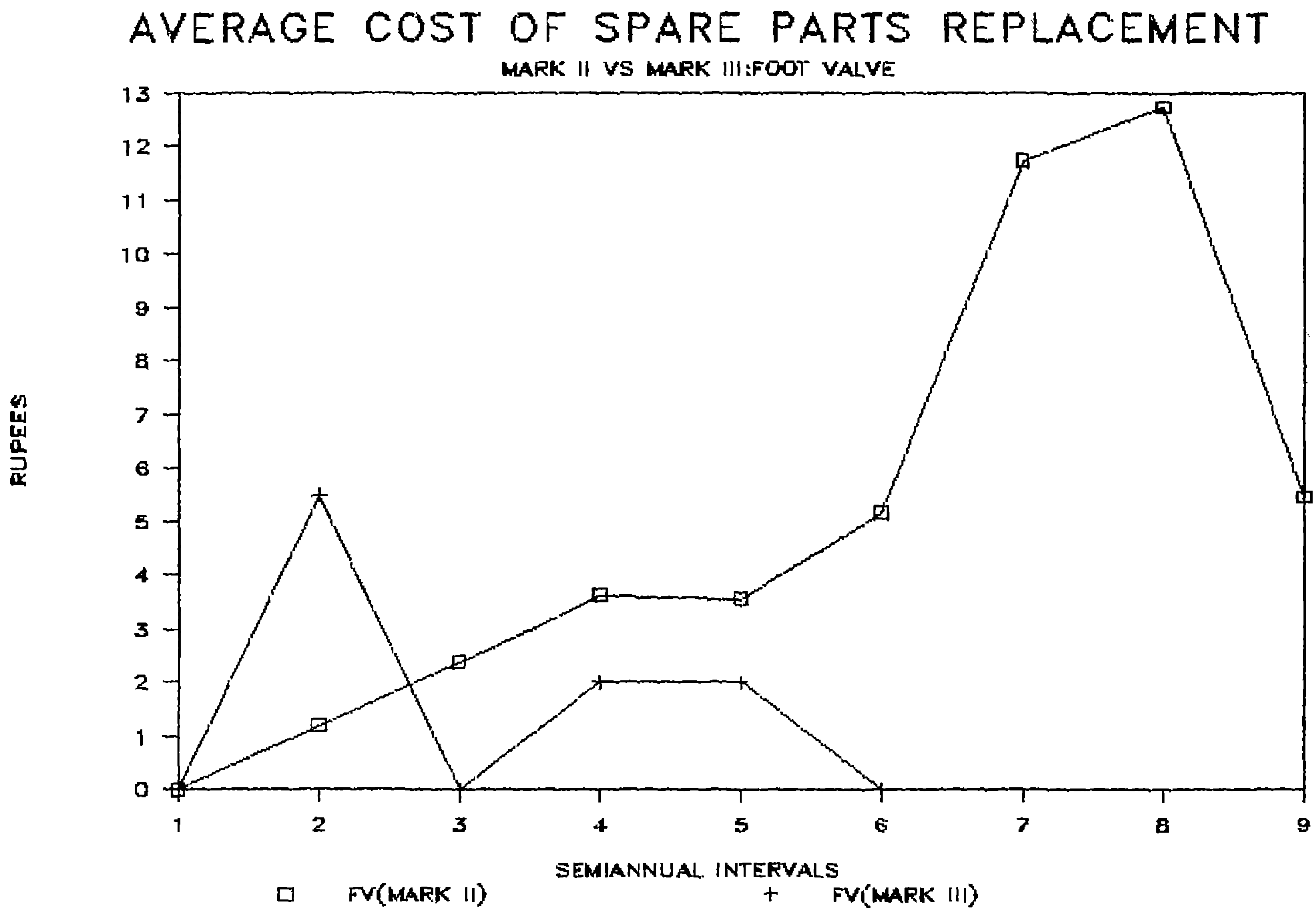
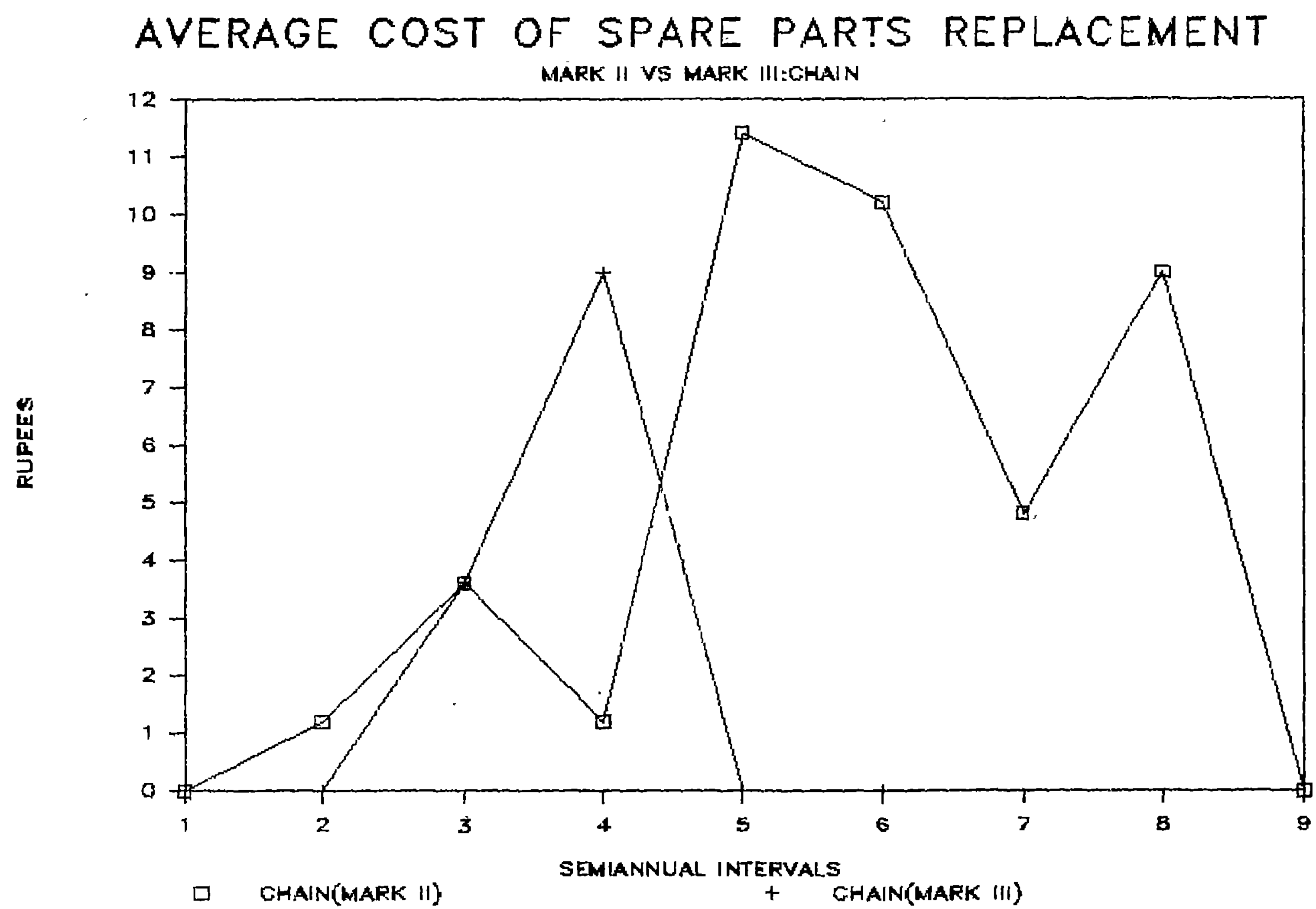
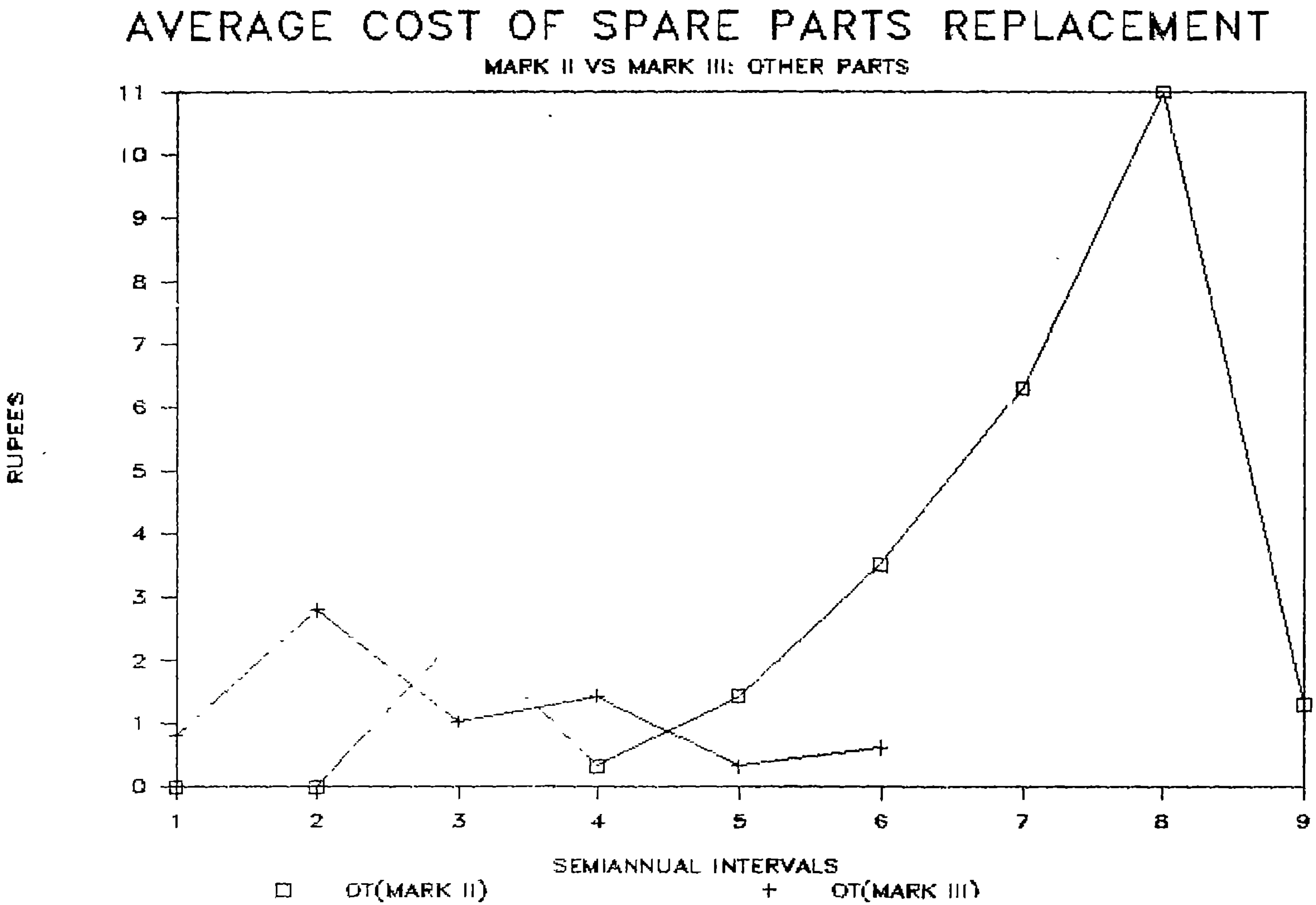

AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III:FOOT VALVE
RUPEES
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
FV(MARK II)
FV(MARK III)

Figure X-8



AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III:CHAIN
RUPEES
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
CHAIN(MARK II)
CHAIN(MARK III)

Figure X-9



AVERAGE COST OF SPARE PARTS REPLACEMENT
MARK II VS MARK III: OTHER PARTS
RUPEES
0
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5
6
7
8
9
SEMIANNUAL INTERVALS
OT(MARK II)
OT(MARK III)

Recommended spares for two-year normal maintenance of 100 India Mark II handpumps

Sl.No.	Item	Replacement recorded per pump per two years	Recommended spare parts
1.	32mm NB GI pipe (medium class) of 3M long threaded at both ends and fixed with a coupling	3.42	400
2.	Seamless coupling socket, medium class 32mm	1.30	150
3.	Piston seal (NBR)	2.12	250
4.	Connecting rod 12mm dia x 3M long	1.48	200
5.	Handle bearings (set)	0.30	35
6.	Handle with bearings	0.48	50
7.	Chain with coupling welded	0.36	40
8.	Piston (upper) valve assembly	0.40	50
9.	Foot (check) valve assembly	0.40	50
10.	Cylinder cap	0.34	40
11.	Cylinder body with liner	0.20	25
12.	Cylinder assembly	0.04	5
13.	Piston assembly	0.04	5
14.	Axle	0.05	10
15.	Hexagonal bolt M12 x 1.75 x 40mm long	0.92	100
16.	Hexagonal nut M12 x 1.75mm	2.92	350
17.	Chain bolt and nut M10 x 1.5mm	0.12	25
18.	Sealing ring	-	50
19.	Cover bolt M12 x 1.75 x 20mm long	-	25
20.	Special washer for axle	-	25
21.	Additional plate with guide bush welded	-	10
22.	Spacer for bearings	-	25

Recommended spares for two-year normal maintenance of 100 India Mark III handpumps

Sl.No.	Item	Replacement recorded per pump per two years	Recommended spare parts
I.	65mm NB GI pipe (medium class) of 3M long threaded at both ends and fixed with a coupling	0.74	75
2.	Seamless coupling socket, medium class 65mm	0.50	75
3.	Piston seals (NBR)	2.22	250
4.	Connecting rod 12mm dia x 3m long	0.44	50
5.	Handle bearings (set)	0.28	30
6.	Handle with bearings	0.32	35
7.	Chain with coupling welded	0.18	25
8.	Piston (upper) valve assembly	0.42	50
9.	Foot (check) valve	0.34	40
10.	Foot valve assembly complete	-	15
11.	Cylinder body with liner, bottom cap and top cap	0.20	25
12.	Cylinder assembly	0.05	5
13.	Plunger rod	-	5
14.	Plunger yoke body	-	5
15.	Follower	-	5
16.	Axle	-	5
17.	Hexagonal bolt M12x1.75x40mm long	0.22	100
18.	Hexagonal nut M12x1.75mm	2.00	300
19.	Chain bolt and nut M10x1.5mm	-	25
20.	Foot valve O-ring	-	150
21.	Cover bolt M12x1.75x20mm long	-	25
22.	Special washer for axle	-	25
23.	Additional plate with guide bush welded	-	10
24.	Spacer for bearings	-	25
25.	Push rod with check nut	-	10

Comparison of capital costs of India Mark II versus India Mark III pumps

Item	Cost (Rs.) Mark II	Mark III	Increase (Rs.)	Increase %
Drive head	280	280	-	-
Handle assembly	340	340	-	-
Water chamber	260	280	20	8
Pedestal	600	600	-	-
Rising Main with coupling (24m)	1040	2064	1024	99
Pump rod (24m)	320	320	-	-
Cylinder assembly	450	600	150	33
Total	3290	4484	1194	36

Travel time for mobile van and block mechanic

Sl. no.	Total number of handpumps	Area in sq. km.	Radius in km.	Travel distance up and down in km.	Total travel time in minutes
1.	300	1256	20.0	40.0	60
2.	600	2512	28.3	56.6	85
3.	1450	6071	44.0	88.0	132
4.	1935	8101	50.8	101.6	152

Note: 1. The density of handpumps is assumed as 0.239 handpump per sq. km.

2. The average speed of mobile van and motor cycle is assumed as 40 km per hour.

Variable expenses of mobile team with van

Item	Mark II	Mark III
1. Average round trip distance travel per pump	40 kms	102 kms
2. Total travel per pump per year (distance x number of visits per year)	57.6 kms	16.3 kms
3. Total number of pumps estimated to be maintained	300	1950
4. Total travel per year (2 x 3)	17280 kms	31785 kms
5. Fuel cost per km	Rs.1.00	Rs.1.00
6. Total fuel cost per year (4 x 5)	Rs.17,280	Rs.31,785
7. Van maintenance cost per year	Rs. 9,816	Rs.15,465
8. Total variable expenses (6+7)	Rs.27,096	Rs.47,250

Variable expenses of block mechanic with motorcycle

Item	Mark II	Mark III
1. Average round trip distance travel per pump	88 kms	56.5 kms
2. Total travel per pump per year (distance x number of visits per year)	35.2 kms	67.2 kms
3. Total number of pumps estimated to be maintained	1500	600
4. Total travel per year (2 x 3)	52,800 kms	40,320 kms
5. Fuel cost per km.	Rs.0.15	Rs.0.15
6. Total fuel cost per year (4 x 5)	Rs.7,920	Rs.6,048
7. Motor cycle maintenance cost per year	Rs.3,000	Rs.2,300
8. Total variable expenses (6+7)	Rs.10,920	Rs.8,348

Note: Density of pumps is assumed as 0.239 pump/square kilometer.

Estimated cost of modifications of the standard India Mark II pump

Sl.No	Item	Quantity	Cost
1.	Nitrile cup seal	1 set	Rs. 20.00
2.	Cylinder body	1 No.	Rs.130.00
3.	Piston valve	1 No.	Rs. 17.00
4.	Modified spacer	1 No.	Rs. 25.00
5.	Additional flange	1 No.	Rs. 30.00
6.	Machining of 75mm dia hole in the pump head		Rs. 28.00
	Total cost		Rs.250.00

Estimated annual savings in maintenance after modifications

Sl No	Item	
1.	Expected number of visits per pump per year by mobile van before modifications (pump working on an average 7 hours per day)	2
2.	Expected number of visits per pump per year by mobile van after modifications	1.44*
3.	Reduction in number of visits per pump per year	0.56
4.	Savings due to reduction in maintenance cost due to reduced need of mobile van (Rs.392.10 divided by 1.44) x 0.56 (refer Table 14)	152.50

* This value has been taken from Table 4. The value in fact will be much less and savings will be higher than indicated here.