India Mark II Hand Pumps with Open Top Cylinders in Low Lift Application

Maintenance Data Analysis from 1986 till March, 1992.

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1 Summary:

1.1 The Orissa Drinking Water Supply Project is a bilaterally aided project implemented by the Deptt. of Rural Water Supply & Sanitation - RWSS (originally Public Health Engineering Department - PHED) of the Government of Orissa and is assisted by Danida, Government of Denmark. The project area is in the coastal saline tract of Orissa, covering an area of 20 blocks in Balasore, Cuttack and Puri districts, aiming to provide drinking water in about 3,083 villages to a population (1991) of about 2.4 million people.

1.2 Phase I of the project, during Aug. 1985 to Dec. 87, resulted in the installation of about 1600 hand pumps on tube wells in 3 blocks. In Phase II of the project about 2000 hand pumps were installed by Aug. 89 in 5 blocks and an additional 600 pumps were installed in 4 additional blocks.

1.3 Among the activities of Phase I of the project, the **Hand Pump Testing Programme** was taken up as a Research & Development activity, under the Training & Maintenance Division of the project. The purpose of the testing programme was to conduct field trials on existing designs of hand pumps in order to provide a basis for choosing an appropriate design of a hand pump for the hydrogeological conditions of the project area.

1.4 The India Mark II hand pump with modifications of the Open Top Cylinder, Light T-Bar handle, Third Plate, and modified Head was one of the pumps chosen for field trials. 29 such pumps were installed in **Low Lift** configuration, with cylinders placed between 9 m and 12 m below ground level and came to be termed as the **IM II OTC LL hand pumps** in the Orissa project. These pumps were installed on newly constructed wells during 1986 in Delang Block, about 35 Km south of Bhubaneshwar. The deep well configuration of the same pump, tested by UNICEF and World Bank in Coimbatore came to be called as the **IM III**.

1.5 In the Orissa projects test programme, water quality problems affected the performance and usage of pumps on 13 sites out the original 29 installations. After an average usage of about 11 months, these 13 installations were removed and reinstalled on 13 other new tube wells in Delang block.

1.6 All the 29 pumps were monitored on a regular basis upto 1989. At the time of such visits, preventive maintenance was completed, depth of water level in the tube well from the ground level was measured, and the discharge of the pump was recorded. Periodically the data collected during monitoring and other visits was analysed and reported.

1.7 By the end of 1988, it was apparent that this pump, showed substantial technical and cost advantages over the standard India Mark II Deep Well hand pump in the of project area. However, the problem of corrosion of 2 1/2"diameter GI riser pipes in the OTC application was one of the main disadvantages of large scale introduction of the IM II OTC LL pump in coastal Orissa where aggressive water quality was emerging to be a serious problems.

1.8 Therefore it was decided to use the proven advantages of the IM II OTC LL design in future installations of the project. Features such as the light T-bar handle and third plate were adopted for installations of Phase II A of the project, along with installation of the standard pump cylinder at 9 m to 12 m below ground level, i.e. in the low lift configuration. It was also agreed that the IM II OTC LL installations in Delang block should continue to be monitored and a larger number of OTC LL pumps be installed in one block, on new tube wells reasonably free of water quality problems to be constructed by the project.

1.9 This paper confines itself to an analysis of the maintenance data of the 29 IM II OTC LL pumps since their installations in 1986 and up to 31st. March 1992.

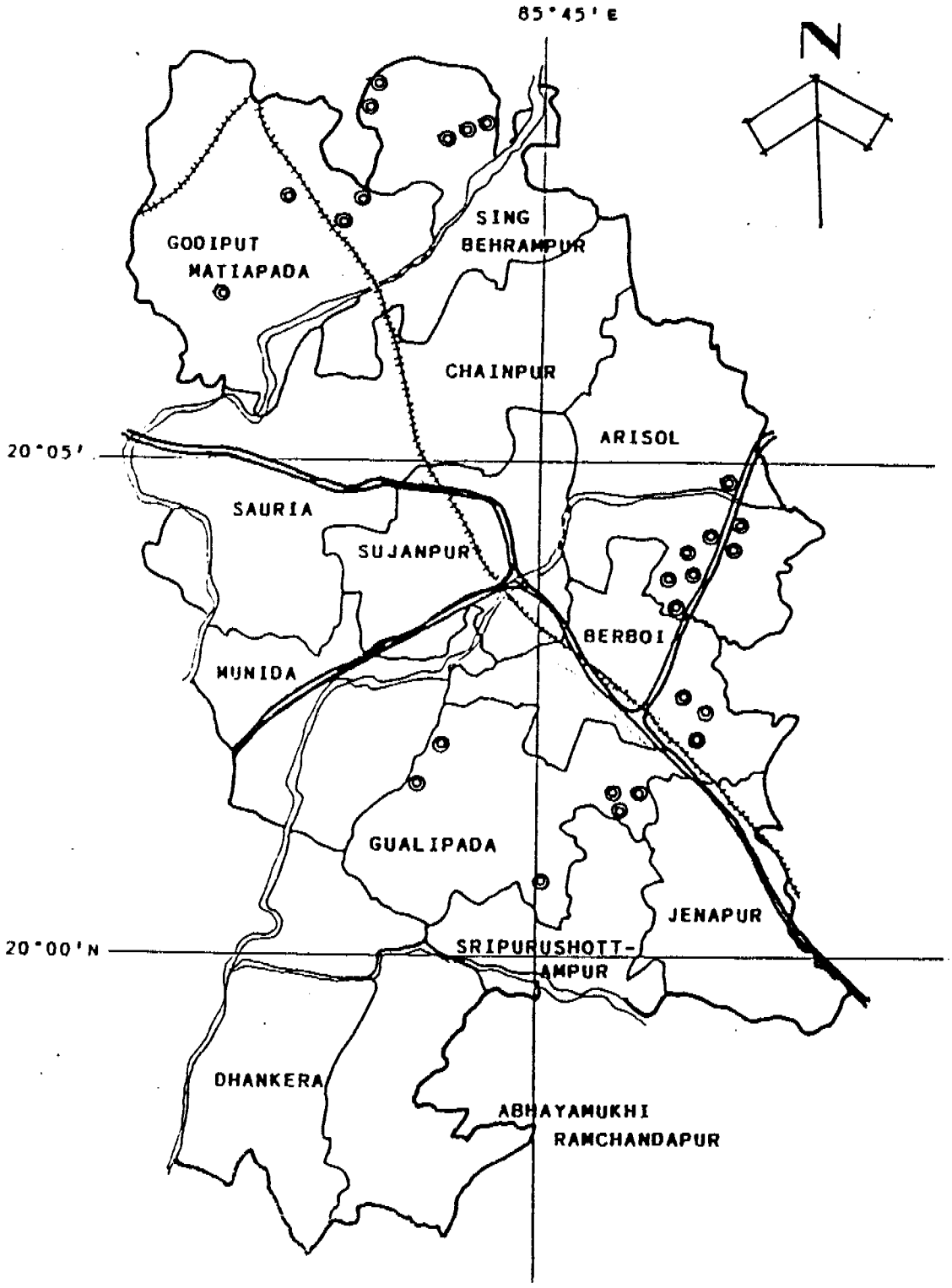


Fig. 1 : Block Map of Delang showing locations of IM II OTC LL installations

2 General Conclusions:

2.1 The modifications to the India Mark II deep well hand pump i.e., the Third Plate, modified Head, Light T-Bar Handle, modified Water Tank, 2 1/2" diameter Riser Pipes, and Open Top Cylinder made the resultant pump, the **IM II OTC Low Lift pump** suited to the conditions of the Orissa project which did not need a deep well pump.

2.2 These modifications presented substantial advantages in cost since the length of riser pipe was substantially reduced, offsetting the price difference between 2 1/2" diameter pipe and 1 1/4" diameter pipe. Of much more significance was the fact that maintenance of the pumps became much more simpler and required much fewer tools.

2.3 Modifications such as the light T-bar handle and the third plate contributed to a replacement rate of handle bearings decreasing the possibility of impact and mishandling of pump handles. These modifications also eliminated the need to remove handle axles when dismantling pumps. Nitrile cup washers in the pump cylinder showed excellent performance, with a low replacement rate.

2.4 The water quality of the project area posed a serious drawback in using 2 1/2" GI riser pipes due to corrosion related problems. In the fist instance, it resulted in a high need to remove riser pipes, substantially reducing the advantage of the OTC system. It also led to a high replacement rate of riser pipe assembly components, increasing the maintenance cost.

3 Specific Conclusions:

The data accumulated for the 29 pumps since their installation in 1986 till 31st. March 1992 lead to the following conclusions:

3.1 **Pump Age:** The average of the pumps, from their installation and upto 31st. March 1992, was 4.79 years. The details of dates of installation and removal of pumps from each site are given separately.

3.2 **Continuity of Installations:**

- 13 installations were relocated after about 11 months, in 1987, due to water quality problems in the original wells.

- Subsequently, 4 pumps in 1989, 1 pump in 1990 and 9 pumps in 1991 were removed after the corresponding wells were rehabilitated. Pumps with non-corrodible below-ground assemblies, but not of the OTC design, were reinstalled on these wells.

- Therefore, of the original 29 IM2 OTC LL pumps installed in 1986, 15 installations remained by March 1992.

3.3 **Monitoring Visits to Pumps:** During 1986 to 89, the pumps were under intensive monitoring. During this period, routine visits for monitoring and preventive maintenance averaged a time interval of a little over 2 months between consecutive visits. Routine visits accounted for 83.4% of the total visits, indicating that most maintenance needs were predictable. Similarly, unforseen visits were 3.7% of the total visits, indicating that break-downs were low and avoidable. A total of 699 visits were recorded for 29 pumps till December 1989. This data is presented in **Table 1.**

Table 1 : Analysis of Visits to Pumps

Purpose of Visit	Nos.	Percentage
Routine Visits	583	83.4%
Unforseen Visits	26	3.7%
Other Visits	90	12.9%
Total Visits	**699**	**100.0%**

From January 1990, the intensive monitoring schedule was discontinued and the pumps were handed over to the regular maintenance system in the project.

3.4 **Component Replacement Patterns:** The consumption of spare parts from the maintenance records for 29 pumps (installed on 42 sites) upto 31st. March 1992 have been summarised in **Table 2** below:

Table 2 : Summary of Consumption of Spare parts

Sl. No.	Spare part	Remarks	Nos. of Occurences	Nos. of Pumps	Percentage of Total Pumps	Average Interval in Years
1.	Head - Insp. cover	Replacement	7	7	24 %	3.1 yrs
2.	Head - Insp. cover bolt	"	4	4	14	3.37
3.	Head - Nuts/bolts/washers	"	26	21	72	1.87
4.	Handle - Axle	"	1	1	3	3.6
5.	Handle - Bearings	"	12	10	34	1.86
6.	Handle - Chain	Repair	3	3	10	2.49
7.	Handle - Chain bolt	Replacement	4	3	10	0.46
8.	Water Tank	"	2	2	7	2.83
9.	Water Tank - Nut/Bolt/Washer	"	24	18	62	1.33
10.	Riser Pipes	Repl+Repr+Cl	27	16	55	2.03
		Repl. only	10	7	24	2.46
11.	Pump Rods	Repl+Repr+Cl	23	15	51	0.88
		Repl. only	18	13	44	2.42
		Repr.+Clng.	5	5	17	2.75
12.	Cylinder complete	Repl+Repr+Cl	8	7	24	3.02
		Repl. only	5	5	17	2.81
13.	Cylinder Sealing rings	Replacement	5	5	17	2.1
14.	Cylinder Upper cap	"	2	2	7	2.7
15.	Plunger Cup washers	"	24	16	55	2.65
16.	Upper valve complete	"	3	3	10	3.88
17.	Upper valve guide	"	3	3	10	3.81
18.	Upper valve rubber seating	"	9	8	28	3.23
19.	Lower valve complete	"	2	2	7	2.58
20.	Lower valve 'O' ring	"	15	11	38	2.12
21.	Lower valve rubber seating	"	2	2	7	2.87

From the above the table, the following main conclusions emerge:

1. **Nuts, Bolts and Washers** : The replacement of nuts, bolts and washers constituted the most common maintenance occurrence. 72 % and 62 % of pumps needed this replacement on the head and water tank, respectively with average occurrence intervals 1.87 years and 1.33 years respectively.

2. **Handle Bearings** : This is the only other significant component need in above-ground maintenance, with 34 % pumps needing bearing replacement with average occurrence intervals 1.86 years.

3. **Riser Pipes** : Unexpectedly, interventions required due to riser pipe problems were quite significant, on 55 % pumps with an average interval of 2.03 years. This could have been due to initial installation problems compounded later by corrosion related problems. Need for riser pipe interventions also nullified the advantages of the OTC system.

4. **Cylinder Replacements** : This constituted interventions on 24 % pumps with an average interval of 3.02 years. This also went against the advantages of the OTC system. Here the problems of scaling, collection of corrosion debris were some of the causes of the problems.

5. **Pump Rods** : Interventions due to pump rods was very significant, on 51 % pumps with 0.88 years average interval. Again corrosion was the main cause. However, these interventions would have used the advantages of the OTC system.

6. **Cup Washers & 'O' Rings** : These two components, also using the OTC system accounted for interventions on 55 % and 38 % of the pumps with average intervals of 2.65 years and 2.12 years.

3.5 **Maintenance Categorisation:** Whether a pump was working or not, all interventions or interruptions to a pump, which led to any maintenance, repairs or replacements, was considered as "**maintenance**". Pump maintenance was categorised into three main groups:

1. **Above Ground Minor Maintenance - AMI:** This class of maintenance generally limits itself to repairs and replacements of nuts and bolts mainly.

2. **Above Ground Major Maintenance - AMJ:** Major replacements and maintenance to the head (e.g. replacement of inspection covers), handle (e.g. replacement of bearings) and water tank of the pump, i.e., components above the ground level, was classified in this category.

3. **Below Ground Assembly Maintenance - BG:** This category included maintenance to connecting rods, riser pipes and cylinder. BG maintenance needed a further categorisation. Those maintenance interventions which needed only removal of connecting rods for cylinder repair (by picking up the plunger and the check valve and bringing them above ground for maintenance) were classified as **BG-OTC**. Below ground maintenance which required the removal of riser pipes (e.g. to reach the cylinder) were categorised as **BG-RP**.

A method of statistical analysis, based upon the analytical method in life insurance, was applied to the detailed maintenance data in order to make projections on the need different types of interventions. This method of analysis was developed by the Danida assisted water supply project in Sri Lanka. A number of graphs have been generated using this analysis. As will be seen below, the results of the analysis are worth attention.

Table 3 : Analysis of some Maintenence Interventions

Statistical Parameter	Type of Intervention					
	AMI	AMJ	Only Handle Bearings	BG (RP & OTC)	BG (RP)	BG (OTC)
Numbers of Sites	36	20	10	32	19	32
Numbers of Occurrences	60	24	12	69	32	61
Mean time between Occurrences	2.08	4.22	5.04	3.77	4.25	3.72
Standard Deviation	1.46	2.5	2.75	1.68	2.0	1.52
Correlation Coefficient	0.96	0.96	0.90	0.99	0.98	0.99

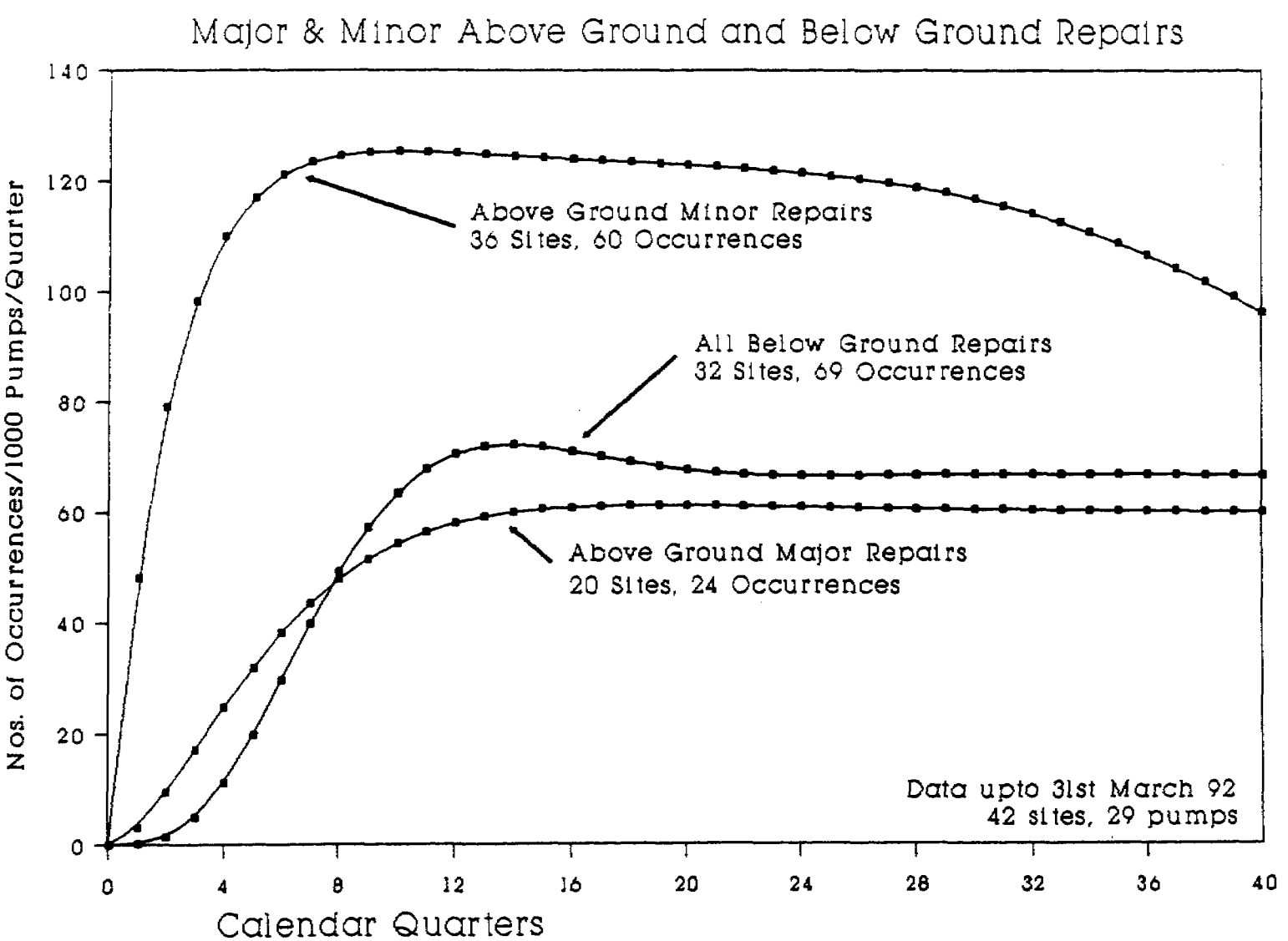
The graphs show a projection of the occurrence rates in Nos. of Occurrences/1000 pumps/Calendar Quarter over a period of 40 Quarters (10 years), for different types of maintenece needs, based upon the maintenece data collected so far during the field tests. The following graphs have been compiled:

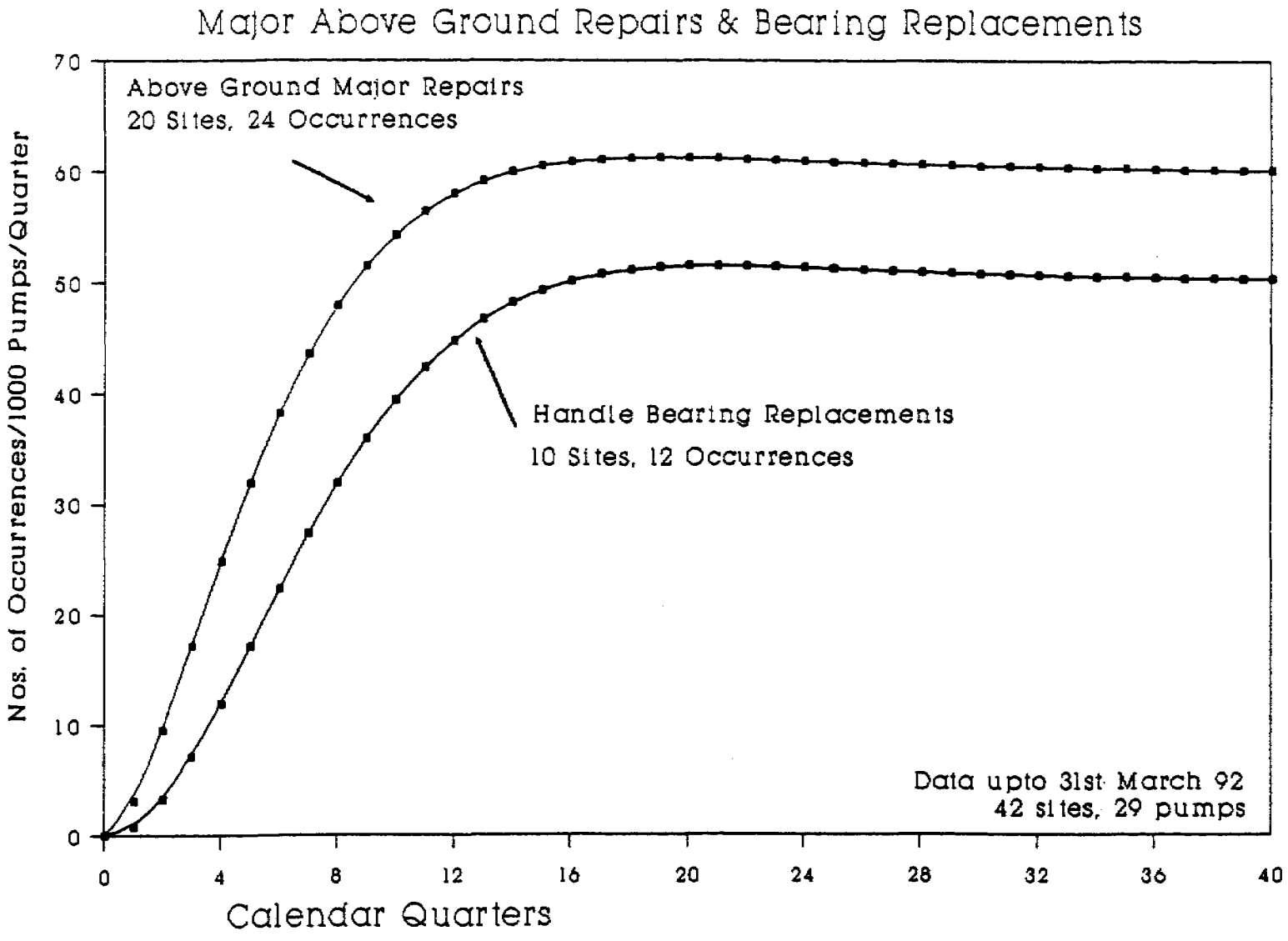
1. **Major & Minor Above Ground and Below Gound Maintenence** : This graph gives the comparison between the three maintenence categories. As is evident from the graph, Above Ground Minor Repairs have a much higher rate of occurrence than Above Ground Major or Below Ground Repairs.

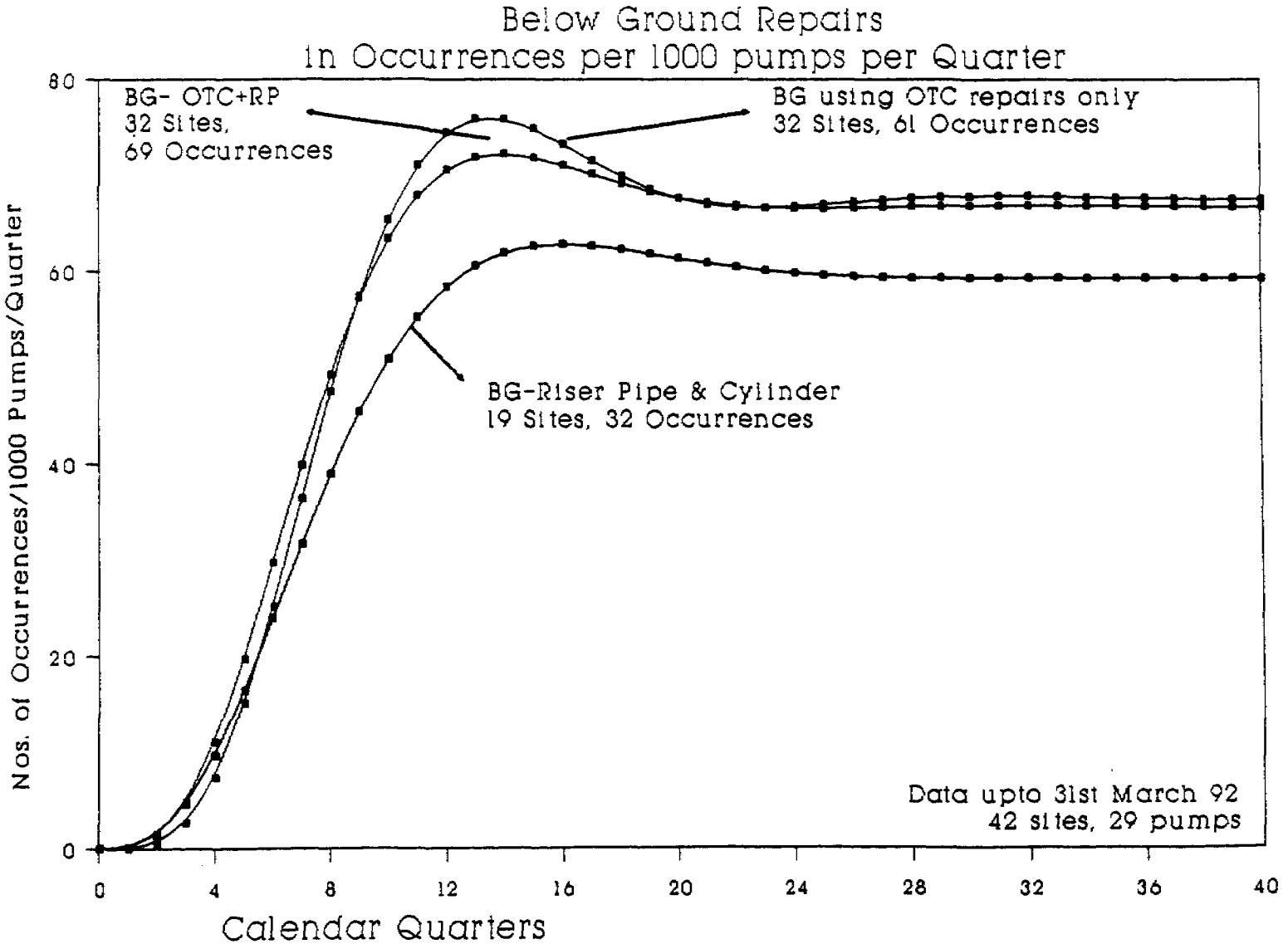
2. **Major Above Ground Repairs & Bearing Replacements** : In major above ground repairs since handle bearing repairs constitute the most important component, the occurrence of these two have been compared. As expected, their occurrence patterns are very similar.

3. **Below Ground Repairs** : Below ground repairs limited to riser pipe and cylinder interventions would require removal of the riser pipe assembly. Other below ground repairs, of the rod, cup washers, upper valve and lower valve (including 'O' ring) would have used the OTC system. These two types of occurrences, i.e., BG-RP and BG-OTC have been compared with all-BG interventions. All three graphs show similar patterns, BG-OTC is much closer to all-BG and BG-RP is lower. All these indicate consistency in the data.

4. **Below Ground Maintenance Needs - Comparison between IM2 and IM2 OTC LL** : In this graph, data on a group ofIM2 deep well pumps is compared with the IM2 OTC group for below ground maintenance occurrences. For the IM2 DW group, behaviour of installations of 1985, 86, and 87 have been presented separately. The "All IM2, 1985-87" curve then provides a basis for comparison with the IM2 OTC installations. As can be seen, the "All IM2" curve and "IM 2 OTC" curve are very similar in nature. The lower position of the OTC curve is a clear indication of its generally lowere below ground maintenence occurrence.


Major & Minor Above Ground and Below Ground Repairs
Nos. of Occurrences/1000 Pumps/Quarter
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
36
40
Calendar Quarters
Above Ground Minor Repairs
36 Sites, 60 Occurrences
All Below Ground Repairs
32 Sites, 69 Occurrences
Above Ground Major Repairs
20 Sites, 24 Occurrences
Data upto 31st March 92
42 sites, 29 pumps


Major Above Ground Repairs & Bearing Replacements
Above Ground Major Repairs
20 Sites, 24 Occurrences
Handle Bearing Replacements
10 Sites, 12 Occurrences
Data upto 31st March 92
42 sites, 29 pumps
Nos. of Occurrences/1000 Pumps/Quarter
Calendar Quarters
0
10
20
30
40
50
60
70
0
4
8
12
16
20
24
28
32
36
40


Below Ground Repairs
In Occurrences per 1000 pumps per Quarter
BG- OTC+RP
32 Sites,
69 Occurrences
BG using OTC repairs only
32 Sites, 61 Occurrences
BG-Riser Pipe & Cylinder
19 Sites, 32 Occurrences
Data upto 31st March 92
42 sites, 29 pumps
Nos. of Occurrences/1000 Pumps/Quarter
0
20
40
60
80
0
4
8
12
16
20
24
28
32
36
40
Calendar Quarters

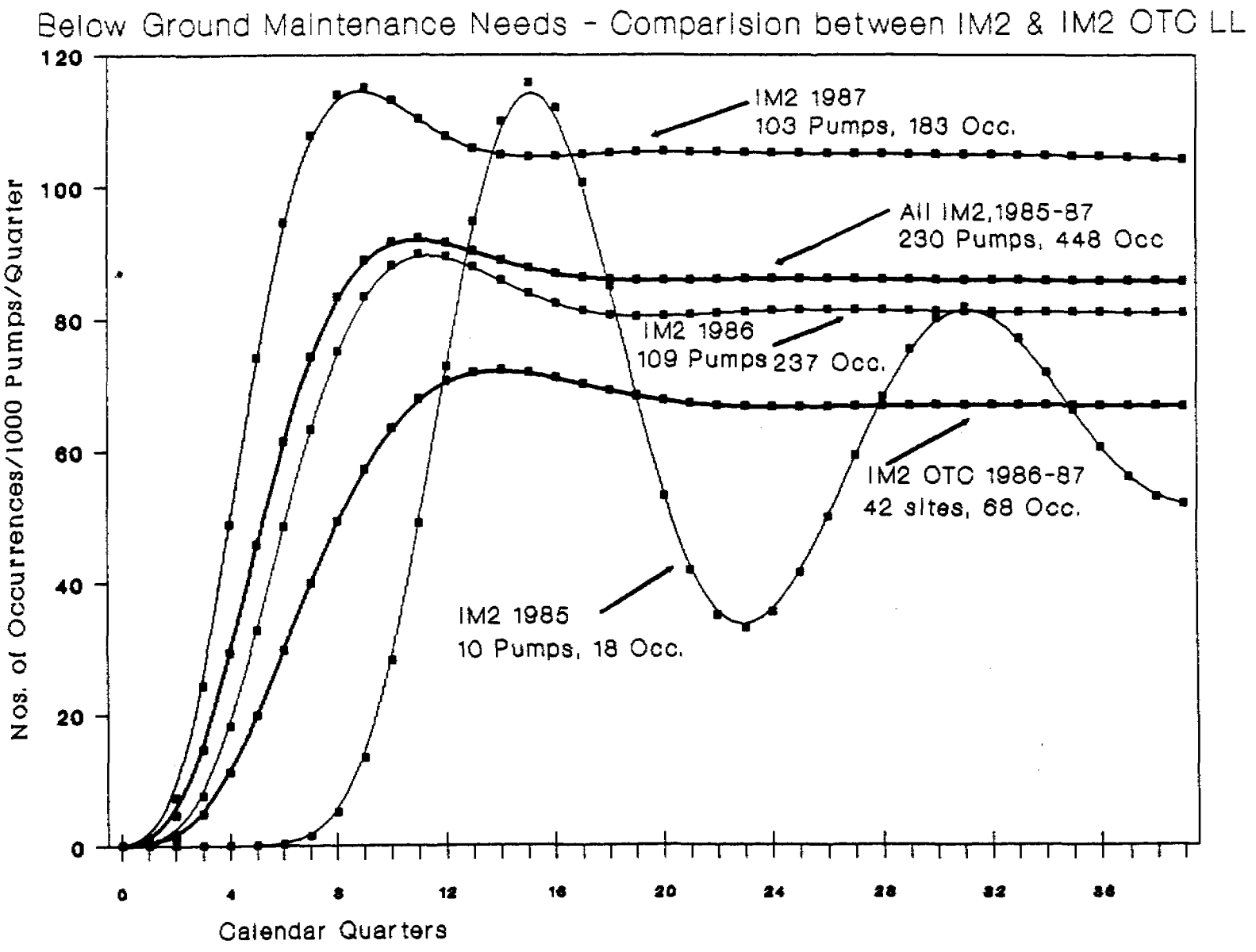

Below Ground Maintenance Needs - Comparision between IM2 & IM2 OTC LL
Nos. of Occurrences/1000 Pumps/Quarter
120
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
36
Calendar Quarters
IM2 1987
103 Pumps, 183 Occ.
All IM2,1985-87
230 Pumps, 448 Occ
IM2 1986
109 Pumps 237 Occ.
IM2 OTC 1986-87
42 sites, 68 Occ.
IM2 1985
10 Pumps, 18 Occ.

Table : Summary of pump age by 31.03.92 for 29 nos. IM2 OTC pumps installed on 42 sites

	Site	Regn. No.	Habitation	Dates of Instl.	Dates of Removal	Age Yrs	Remarks
1	ARAGARH	13122400301	MUDULI SAHI	03/03/86		6.08	Continuing.
2	ARAGARH	13122400302	BEHERA SAHI	02/07/86		5.75	Continuing.
3	ARAGARH	13122400303	GODHI SAHI	02/07/86	31/08/87	1.16	
4	ARAGARH	13122400304	GODHI SAHI	28/07/86	30/05/87	0.84	
5	ARISOL	13122405501	BHOI SAHI	09/04/87	05/09/91	4.41	
6	ARISOL	13122405502	GHATESWARPUR	09/04/87	20/07/89	2.28	
7	BANGA	13122400401	JENA SAHI	29/05/86		5.84	Continuing.
8	BANGA	13122400402	HARIJAN SAHI	06/07/86		5.74	Continuing.
9	BHANSARA	13122400801	TANGI	02/06/86	05/07/87	1.09	
10	BHANSARA	13122400802	TANGI BHANSARA	29/05/86		5.84	Continuing.
11	BHANSARA	13122400803	NIMABASANTA (BHOISAHI)	25/06/86		5.77	Continuing.
12	BHANSARA	13122400804	NIMABASANTA	18/07/86		5.71	Continuing.
13	BOLAKANA	13122408503	DOMASAHI	15/05/86	09/07/87	1.15	
14	BOLAKANA	13122408504	TALABANIA	02/05/86	27/04/91	4.99	
15	BOLAKANA	13122408505	PARIDASAHI	31/05/86	17/05/91	4.96	
16	BRAMHANATARABOI	13122405602	BRAHAMAN SAHI	19/04/87		4.95	Continuing.
17	BRAMHANATARABOI	13122405604	BHOI SAHI	06/04/87	26/08/91	4.39	
18	BRAMHANATARABOI	13122405605	MALI SAHI	06/04/87	26/08/91	4.39	No repairs.
19	GODIPUT-MATIAPADA	13122400203	HARIPUR MAJHISAHI	30/05/86	27/03/87	0.82	
20	GODIPUT-MATIAPADA	13122400204	HARIPUR	30/05/86	27/03/87	0.82	
21	GODIPUT-MATIAPADA	13122400205	HARIPUR DOMASAHI	30/05/86	31/03/87	0.84	
22	GODIPUT-MATIAPADA	13122400207	BARAPADA MUASAHI	18/07/86		5.71	Continuing.
23	HUMARA	13122410401	DIGAMBAR SAHI	26/05/86		5.85	Continuing.
24	HUMARA	13122410402	MAJHISAHI	26/05/86	24/05/91	5.00	
25	HUMARA	13122410404	TALASAHI	26/05/86		5.85	Continuing.. No repairs.
26	JAMUNAJHARAPADA	13122400102	JAMUNA MAJHISAHI	17/06/86	30/03/87	0.78	
27	JAMUNAJHARAPADA	13122400103	JAMUNA TALASAHI	17/06/86	29/03/87	0.78	
28	JAMUNAJHARAPADA	13122400104	JAMUNA TALASAHI	17/06/86	30/03/87	0.78	
29	JAMUNAJHARAPADA	13122400105	JAMUNA MUASAHI	17/06/86	29/03/87	0.78	
30	JAMUNAJHARAPADA	13122400107	JHARAPADA BHOISAHI	18/07/86		5.71	Continuing.
31	JAMUNAJHARAPADA	13122400108	JHARPADA GUDIASAHI	22/11/86		5.36	Continuing.
32	JOKANARUA	13122409402	TELISAHI	08/07/87	30/03/91	3.73	
33	KHELAUR	13122311403	PROPER	08/04/87		4.98	Continuing.
34	KHELAUR	13122311404	SAHAPADA	08/04/87		4.98	Continuing.
35	MACHAPADA	13122411003	WARD NO.7	31/05/86	30/05/91	5.00	
36	NUAGAN	13122311302	DIHASAHI	10/04/87	19/05/90	3.11	
37	ODATARABOI	13122409102	MALLIKA SAHI	07/04/87	08/11/89	2.59	
38	ODATARABOI	13122409103	JENASAHI	07/04/87	30/04/91	4.07	
39	RENCHA	13122409301	MOHANTY SAHI	06/07/87	15/12/89	2.45	
40	RENCHA	13122409304	KASHIABINDHA	06/07/87	16/07/89	2.03	
41	RENGAL	13122402602	ICHHAPUR	12/06/86	28/03/87	0.79	
42	RENGAL	13122402604	TALASAHI	18/07/86	28/03/87	0.69	