Performance of India Mark II Solid Link Suction Pumps in Danida assisted Water Supply Project in coastal Orissa

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Performance of India Mark II Solid Link Suction Pumps in coastal Orissa*

1. Summary

The first IM2 Solid Link Suction pump was installed by the Danida assisted Drinking Water Supply Project in coastal Orissa in December 1986. After some modifications, a batch of 10 more of these pumps was installed by mid-1987 and monitored closely under a field testing programme. By 1989, the field trials indicated favourable results and a draft design was finalised.

The IM2 SLS pump was considered as a viable option in coastal Orissa since water table condition was shallow, the pumps were not prone to corrosion, they had the reliability inherent to the IM2 design and conformed to the concept of a "family" of pumps around the IM2. The main features of the pump's design are illustrated in Fig. 1, below.

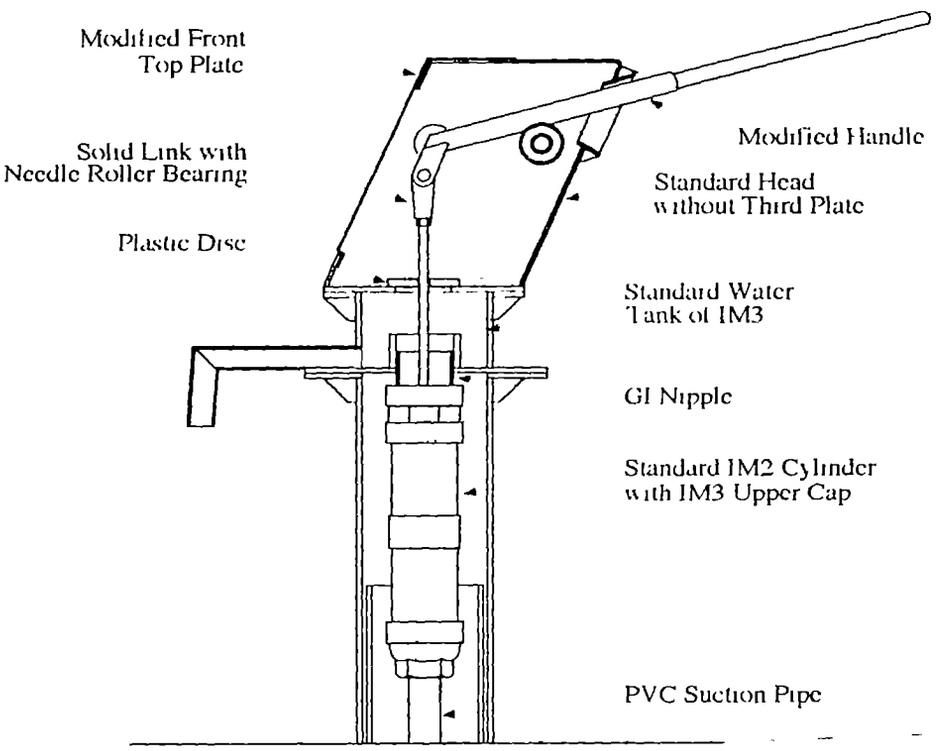

Fig. 1 : A typical IM2 SLS installation

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* Prepared by Raj Kumar Daw, PHE Adviser, Danida assisted IRS & WS Project, Cuddalore, Tamil Nadu in collaboration with LVR Reddy, Project Coordinator, Danida Water & Sanitation Office, Bhubaneshwar, Orissa.

This report is a performance analysis of IM2 SLS pumps at the closure of the Orissa Project in December 1994. While about 750 IM2 SLS pumps had been installed, by September 94, detailed maintenance histories were available for 229 pumps, installed in 6 Blocks of coastal Orissa. This data forms the basis of this report.

Age of Pumps : The age distribution of pumps, as of 30th. September 94, indicated in Table 1, below, showed that 196 pumps (out of 229) were upto 3 years old and that only 33 pumps were between 4 years to 8 years old. Because of this uneven age distribution of pumps, the analysis of maintenance data has been done in two separate groups, of Pumps upto 3 years old and Pumps over 3 years old.

Table 1 : Numbers & Average Ages of Pumps

Age Group of Pumps	Numbers of Pumps	Average Age	
		in Days	in Years
1 to 3 Years Age Group	196	900	2.5
4 to 8 Years Age Group	33	1908	5.2
Total	229	1047	2.87

Annual Average Service Need : All the pumps were under the Two Tier Maintenance System of the project, which meant that they should have been visited once a month for preventive maintenance, at which time replacements and repairs were also done, as needed. Registration Numbers and Dates of Installation provided the identity of each pump. Pump histories chronologically recorded maintenance interventions to each pump by assembly and component needing repair or replacement.

A count of Dates of Service (i.e., dates on which a repair or replacement was necessary, over and above preventive maintenance) showed that the annual average occurrence for service needs or was roughly once in about two years, which was quite low.

This need varied only slightly between the two age groups of pumps (0.55 and 0.45 services per year per pump), with an overall annual average 0.52 services per year per pump. This information is summarised in Table 2.

Table 2 : Annual Servicing Needs

Dates of Service & Pumps	Pump Age Groups		
	≤ 3 Years	> 3 Years	Total
Total Nos of Dates of Service	270	78	348
Total Nos of Pumps	196	33	229
Average Age of Pumps	2.5 Yrs.	5.2 Yrs.	2.87 Yrs.
Avg No. of Services/Pump/Year	0.55	0.45	0.52

Maintenance Indices : The analysis of maintenance data is based on the Dates of Service and has been reduced to an analysis to replacement needs of assemblies or components. Thus, the rare cases of reconditioning of components at site have either been ignored or equated to replacements.

The main types of interventions needed for the two age groups of pumps have been expressed in terms of two indices - **Intervention Index** and **Age Index.**

Intervention Index was the total number of interventions recorded for replacement of an assembly and/or component for all the pumps, expressed as percentages of the total number of pumps.

Age Index was the average age of each type of intervention expressed as a percentage of the average age of all the pumps by 30th. September, 94.

Intervention and Age Indices have been computed separately for each component. As desirable maintenance attributes, a low Intervention Index represented a low percentage of pumps needing maintenance, and a high Age Index showed the need for maintenance at a late part of the pump's life. The results from the calculation of these two indices are summarised in Table 3, below.

Table 3 : Events Index & Age Index of selected Components

	Pumps ≤ 3 Years Age	Pumps > 3 Years Age
Total Numbers of Pumps	196 pumps	33 pumps
Average Age - AgD	900 days	1908 days

Pump		Interv n Index	Age Index	Interv n. Index	Age Index
Assembly	Component				
Head	Nut & Bolt	3.6%	18.3%	33.3%	34.6%
Handle	Assembly	21.9%	29.4%	3.0%	24.0%
	Bearing	31.1%	28.3%	60.6%	44.6%
	Solid L. Roller brg	12.2%	31.8%	3.0%	40.7%
	Solid Link Assy	6.6%	31.1%	3.0%	40.7%
Water Tank	Nut & Bolt	21.4%	26.8%	18.2%	50.6%
Cylinder	Complete	8.2%	40.3%	3.0%	51.1%
	Sealing Ring	7.1%	25.5%	9.1%	32.5%
Plunger	Cup Washer	40.8%	29.7%	24.2%	40.6%
Lower Valve	Assembly	6.1%	22.6%	12.1%	49.5%

2. Conclusions :

2.1 Overall Performance : The hand pumps were under the Two Tier Maintenance System of the project, which meant that they were visited once a month for preventive maintenance. So, while the ideal preventive maintenance schedule would have entailed 12 monthly visits per pump per year, the incidence of interventions requiring replacement of spare parts was appreciably lower, on an average once in 2 years (0.52 interventions per pump per year - refer Table 2).

This is a very significant conclusion proving both the soundness of the design of IM2 SLS hand pump and the validity of preventive maintenance.

When the maintenance data of the two age groups of pumps were compared, it appears that the occurrence of Dates of Service varied only slightly (refer Table 2) though the older pumps show a slightly lower average need of services. However, when the maintenance indices (refer Table 3) of the two age groups are compared, often the replacement needs of the younger age group is far higher than that of older pumps. This is difficult to explain and it could happen for a number of reasons. It is possible that the older pumps, being ordered and installed in small numbers had a higher degree of manufacturing quality control. It is also possible that in the latter years of the project, the preventive maintenance service delivery weakened resulting in higher replacement needs. A third explanation could be that the older pumps' maintenance needs had stabilised where as the younger pumps were still passing through a phase of high maintenance needs.

The conclusions on individual assemblies and components that follow are qualified by the fact that the overall need for replacement of parts of the pump was low. Hence, when comments have been made regarding the high replacement rate of specific components, they are relative statements.

2.2 Performance of Assemblies & Components :

Head & Water Tank Assemblies : In the Head and Water Tank assemblies relatively high replacement needs were seen only for Nuts & Bolts. The high humidity of coastal Orissa and the aggressive ground water could be a probable cause for a higher need for replacement of nuts and bolts. However, this did not explain why in the younger age group of pumps, the Age Index was lower, indicating the need for replacement at an early stage of pump life.

Handle Assembly : In the IM2 SLS design, the modification to the handle was the major departure from the standard IM2. Hence, the assessment of the performance of the modified handle was carefully examined. Within the handle assembly, the performance of handle bearings, the solid link assembly and the solid link's needle roller bearing were given special attention. Since main assemblies such as the complete handle or the Solid Link were replaced in noticeable numbers, their impact on performance of critical components such as bearings was compensated in assessing the individual performance of such critical components.

Both Intervention and Age Indices were unfavourable for complete Handle Assembly replacements in pumps upto 3 years of age. Breakage of the weld between the 25 mm x 25 mm square handle bar and the 20 mm ND handle pipe caused most of these failures. This was clearly a design flaw coupled with manufacturing weaknesses. Hence this combination of handle materials should be revised to handles made of 25 mm x 25 mm bar only.

Handle Bearings showed a relatively high replacement rate in both pump age groups.

The Solid Link Roller Bearing showed a slightly high Intervention Index in pumps upto 3 years old. However, Solid Link Assemblies were replaced but at relatively low rates.

In all components of the Handle Assembly, the Age Index for the younger age group of pumps was lower than the corresponding Age Index values of the older age group of pumps. This was unexpected since it meant that age related performance of the Handle was relatively better for older pumps. While the exact cause for this problem cannot be clearly identified, the probable explanations are in the design weakness mentioned earlier; that the manufacture of handles in later production was qualitatively poorer and that the preventive maintenance system in the field had become more irregular and less effective.

Cylinder, Plunger & Lower Valve Assemblies : The performance of the complete Cylinder was examined as four independent assemblies, Cylinder, Plunger, Upper Valve and Lower Valve, as illustrated in Fig. 2, below.

The replacement of complete Cylinders was not high, but was still noticeable, especially in pumps less than 3 years old. As in the case with handles, the replacement of a complete Cylinder implied that other assemblies like Plunger, Upper Valve and Lower Valve were also replaced. However, the corresponding corrections were not made, except in the case of Cup Washers in the Plunger assembly. This is because the data indicates that independent replacement rates for the Plunger, Upper Valve and Lower Valve assemblies were not high, whereas replacement rate was high for Cup Washers.

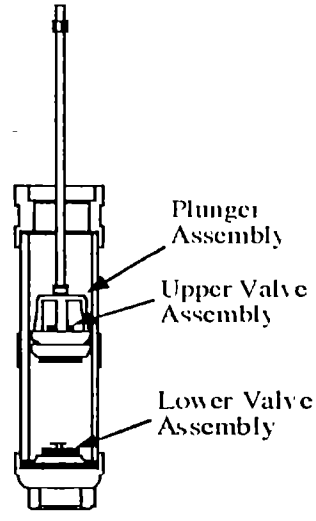

Fig. 2 : Cylinder Assembly

Plunger Cup Washers showed relatively high Intervention Indices in both age groups. This is partly because a replacement of cup washers was counted every time a cylinder assembly was replaced.

Within the two age groups the performance of cylinders in older pumps was noticeable better than their performance in younger pump, for both the Indices. Again, a clear cut explanation is difficult since a standard IM2 component was used and performance of cup washers is not influenced by preventive maintenance. The possible explanation must lie in the trend to replace complete cylinders rather than repair cylinders in the field, at the time of maintenance.

3. Basic Data :

Distribution of Pumps : As mentioned earlier, maintenance histories of 229 pumps, installed in 6 Blocks of coastal Orissa, forms the basis of this performance analysis. The geographical distribution of pumps has been presented in Table 4, below:

Table 4: Geographical Distribution of Pumps

District	Block	Numbers of Pumps	Average Age	
			AgD	AgY
Cuttack	Aul	4	914	2.5
	Chandbali	29	1043	2.86
	Rajnagar	148	893	2.45
Puri	Brahmagiri	10	2488	6.82
	Delang	21	1283	3.52
	Kanas	17	1267	3.47
Totals		229	1046	2.86

Identity of a Pump : Every pump installed by the Orissa Project was identifiable by a Registration Number which described its geographical location to a specific place in a village or habitation. The Date of Installation (DoI) of a pump, along with its Registration No., became the permanent identity of each pump in the project area. This information was computerised as Master Files.

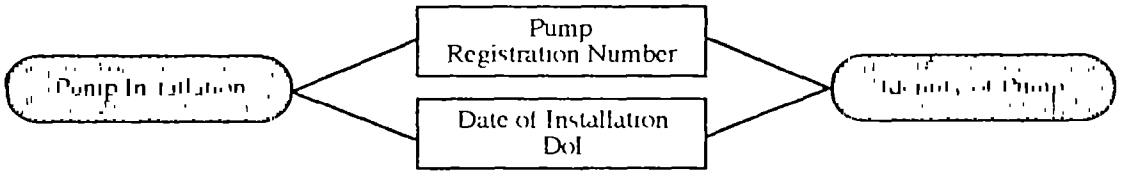

Fig. 3 : Identity of a Pump

Date of Closure (DoC) : DoI provided starting point of a pump's chronological record. For the purpose of analysis, a closing date of 30th Sept. 94 was set as the Date of Closure (DoC) , after which date no further data was considered for analysis.

Ages of a Pump - AgD & AgY: The age calculation of a pump was done in days, AgD and in years, AgY, as the difference between the DoC and the pump's DoI.

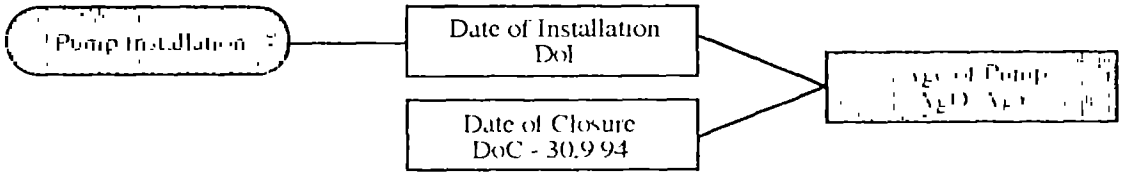

Fig. 4 : Pump Age

The age distribution of pumps is summarised in Tables 5.1, 5.2 and 5.3, below. From Tables 5.1 and 5.2, it can be seen that a majority of the pumps (185 out of 229 pumps) were between 2 years and 3 years old and that all other age groups had relatively smaller numbers of pumps, between 2 to 11.

Because of this uneven age distribution of pumps, the analysis of maintenance data has been done in two separate groups :

- Pumps upto 3 Years : 196 pumps with average age of 2.5 years (Table 5.1)
- Pumps over 3 Years : 33 pumps with average age of 5.2 years (Table 5.2)

Table 5.1 : Numbers & Ages of Pumps upto 3 Years

Age Group of Pumps	Numbers of Pumps	Average Age	
		AgD	AgY
1 to 2 Years Age	11	689	1.9
2 to 3 Years Age	185	913	2.5
Total	196	900	2.5

Table 5.2 : Numbers & Ages of Pumps over 3 Years

Age Group of Pumps	Numbers of Pumps	Average Age	
		AgD	AgY
3 to 4 Years Age	6	1238	3.4
4 to 5 Years Age	8	1715	4.7
5 to 6 Years Age	10	1887	5.2
6 to 7 Years Age	2	2406	6.6
7 to 8 Years Age	7	2592	7.1
Total	33	1908	5.2

Table 5.3 : Age Groups & Average Ages of Pumps

Age Group of Pumps	Numbers of Pumps	Average Age	
		AgD	AgY
1 to 3 Years Age Group	196	900	2.5
4 to 8 Years Age Group	33	1908	5.2
Total	229	1047	2.87

4. Maintenance Data - Definition of Terms:

Date of Service (DoS) : This was the date on which a pump underwent maintenance of any kind. By definition the DoS would have to be more recent in time than DoI. Also a pump could need maintenance more than once. Hence, the maintenance history of a pump could have more than one DoS.

Age of Service (AgS) : Age of Service, in days, was the difference between DoS and DoI. While AgS could be mathematically expressed as AgS = DoS-DoI for the first maintenance occurrence in a pump, in cases of pumps showing multiple occurrences of maintenance, AgS was computed as the period of time between two consecutive DoSs.

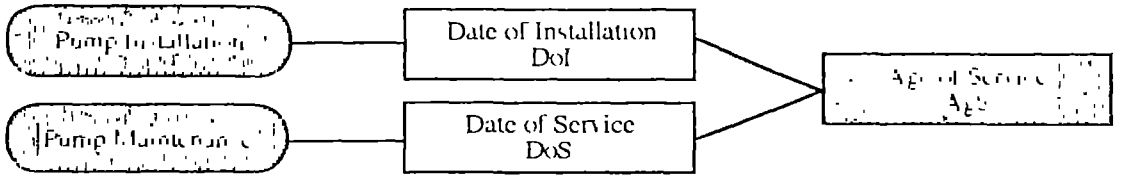

Fig. 5 : Date of Service & Age of Service

Pump Assembly & Pump Component : The nature of a maintenance intervention was described by specifying the Assembly and Component which was replaced. While information on Condition of the Component and Nature of Maintenance Action was available, data revealed that, by and large, most interventions were replacement of Components. Fig. 5 shows the Assemblies of the pump.

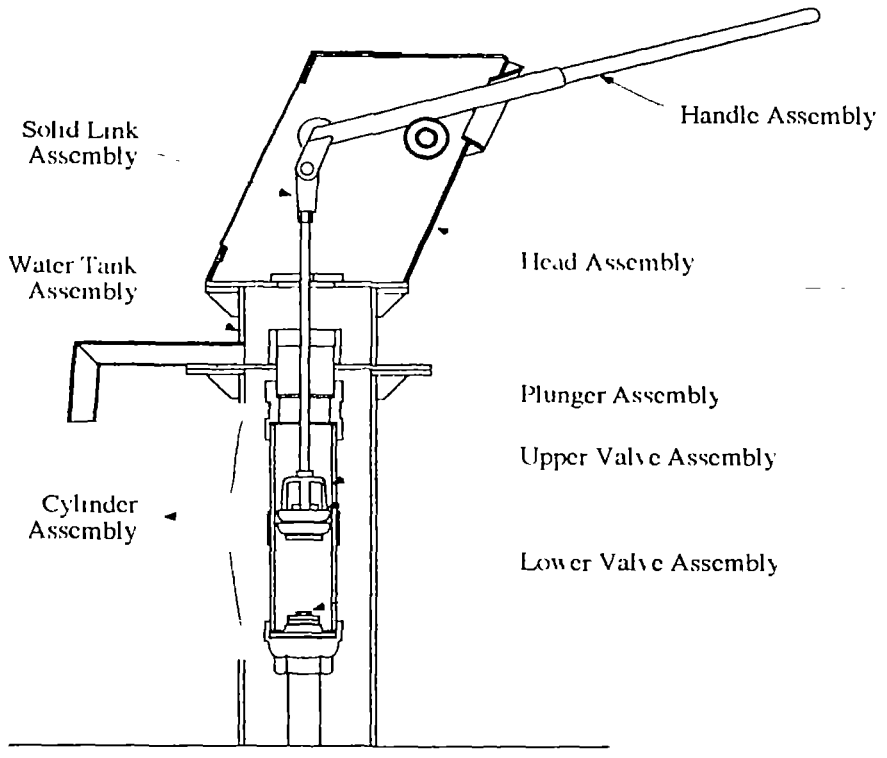

Fig. 6 : Assemblies of the IM2 SLS Pump

Maintenance Intervention : An Intervention to a pump was a record of an Assembly or Components needing replacement. On a given DoS, a pump could need attention to a number of Assemblies or Components. Hence, a pump history could show multiple interventions for the same DoS.

Age of Intervention (AgI) : This was an age calculation, in days, for each Intervention. Since each Intervention had its DoS, the basic computation was similar to the computation of Age of Service, i.e., AgI = DoS-DoI.

However, AgI computations needed corrections since multiple Interventions of a particular type (i.e. the same pump needing the same Assembly/ Component replacement) could occur with different DoS. Corrected values of AgI were arrived at by sorting the maintenance histories of pumps by the Type of Intervention. After the first AgI computation (as DoS-DoI), subsequent AgIs were calculated as the difference between consecutive DoSs for the same pump.

5. Methodology of Data Analysis & Results :

5.1Occurrence of Maintenance Service :

Master File information of Registration Numbers and Dates of Installation provided the identity of each pump, against which, Transaction Files were built with chronological records of Interventions by Date of Service, Assembly and Component.

As mentioned earlier, this method of data compilation led to recording an Intervention to each Component as an independent maintenance event. When examining data of DoS only (and not Numbers of Interventions nor Types of Intervention) the resultant duplication of DoSs was compensated by counting unique DoSs to the same pump. This analysis of data on occurrences of DoS has been presented in Table 6.

Table 6 : Occurrence of Dates of Service

Frequency of Dates of Service	Nos. of Pumps in Age Group		
	≤ 3 Years	> 3 Years	Total
Single Date of Service	147	13	160
Two Dates of Service	31	9	40
Three Dates of Service	11	4	15
Four Dates of Service	7	3	10
Five Dates of Service		1	1
Six Dates of Service		3	3
Total Nos. of Dates of Service	270	78	348
Total Nos of Pumps	196	33	229
Average Age of Pumps	2.5 Yrs	5.2 Yrs	2.87 Yrs.
Avg No. of Service/Pump/Year	0.55	0.45	0.52

It can be seen from the above table that the average number of DoS per pump per year varied only slightly between the two age groups of pumps. The average service needs of the older age group was slightly lower. For pumps upto 3 years old, this value was 0.55, for pumps over 3 years old, this value was 0.45, and the overall average was 0.52 services per pump per year.

This observation is consistent with earlier studies* of pump performance, which have shown that maintenance needs of younger pumps are relatively higher than that of older pumps.

5.2 Occurrences of Maintenance Interventions :

The number of Interventions of one particular Type and its corresponding Ages of Intervention was compiled from the above histories and then averaged. The results, i.e., the number of Interventions needed to each Pump Assembly and Component, and the Average AgI of each specific Type of Intervention, are summarised in Table 7 and are given in detail in Annexure 1; Tables 9.1 to 9.3 and Tables 10.1 to 10.3.

Table 7 : Types, Numbers and Ages of Interventions

Type of Intervention		Pumps ≤ 3 Years			Pumps > 3 Years		
		Numbers of		Avg.	Numbers of		Avg.
Assembly	Component	Pumps	Intervn	AgI	Pumps	Intervn	AgI
Head	Head	1	1	276	2	2	1309
	Insp. Cover				1	1	975
	Insp. Cover Bolt	2	2	295	1	1	975
	Nut & Bolt	7	7	165	11	15	660
Handle	Assembly	43	46	265	1	1	458
	Axle	4	4	275	2	2	756
	Axle Nut				1	1	1193
	Bearing	61	72	255	20	25	851
	Solid L. Roller brg.	24	28	286	1	1	776
	Solid Link Assy	13	13	280	1	1	776
Water Tank	Assembly	2	2	164	3	4	1124
	Nut & Bolt	42	45	241	6	7	966
Cylinder	Body	1	1	543	1	1	2212
	Complete	16	16	362	1	1	975
	Lower Cap				1	1	1044
	Sealing Ring	14	15	229	3	4	621
Plunger	Assembly	9	9	321	2	2	944
	Cup Washer	80	92	267	8	10	774
	Rod	1	1	550	4	4	1220
	Rod Nut				2	2	1609
	Yoke	3	3	287			
Upper Valve	Assembly	6	7	261	4	7	221
	Rubber Seating	1	1	6			
Lower Valve	Assembly	12	13	203	4	5	945
	Rubber Seating	2	2	344			

In order to understand the implications of the information on Interventions in comparative terms, the analysis of Table 7 has been converted to relative terms in Table 8 by the formation of two indices - **Intervention Index and Age Index.**

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* Ericksen and others from the Danida assisted Water Supply and Sanitation Project in Sri Lanka, analysing maintenance data of about 3000 pumps during 1986-90, were able to establish that the service life of all pump components was predictable and followed a damped harmonic behaviour

The **Intervention Index** is the number of Interventions in Table 5, expressed as percentages of the total number of pumps. Similarly, **Age Index** is the Average Age of Intervention expressed as a percentage of the Average Pump Age, i.e., Avg. AgI/ Avg. AgD.

A low value of **Intervention Index** would be interpreted as a low percentage of pumps needing maintenance, and hence would be positive maintenance attribute. On the other hand, a low **Age Index** would be an undesirable attribute since it would be interpreted as the need for maintenance at an early part of the pump's life.

Table 8 : Events Index & Age Index Computations

	Numbers of Pumps Average Age - AgD	Pumps ≤ 3 Years 196 pumps 900 days		Pumps > 3 Years 33 pumps 1908 days	
Pump Assembly	Component	Intervn. Index	Age Index	Intervn. Index	Age Index
Head	Head	0.5%	30.7%	6.1%	68.6%
	Insp. Cover			3.0%	51.1%
	Insp. Cover Bolt	1.0%	32.8%	3.0%	51.1%
	Nut & Bolt	3.6%	18.3%	33.3%	34.6%
Handle	Assembly	21.9%	29.4%	3.0%	24.0%
	Axle	2.0%	30.6%	6.1%	39.6%
	Axle Nut			3.0%	62.5%
	Bearing	31.1%	28.3%	60.6%	44.6%
	Solid L. Roller brg.	12.2%	31.8%	3.0%	40.7%
	Solid Link Assy	6.6%	31.1%	3.0%	40.7%
Water Tank	Assembly	1.0%	18.2%	9.1%	58.9%
	Nut & Bolt	21.4%	26.8%	18.2%	50.6%
Cylinder	Body	0.5%	60.3%	3.0%	115.9%
	Complete	8.2%	40.3%	3.0%	51.1%
	Lower Cap			3.0%	54.7%
	Sealing Ring	7.1%	25.5%	9.1%	32.5%
Plunger	Assembly	4.6%	35.7%	6.1%	49.5%
	Cup Washer	40.8%	29.7%	24.2%	40.6%
	Rod	0.5%	61.1%	12.1%	63.9%
	Rod Nut			6.1%	84.3%
	Yoke	1.5%	31.9%		
Upper Valve	Assembly	3.1%	29.0%	12.1%	11.6%
	Rubber Seating	0.5%	0.7%		
Lower Valve	Assembly	6.1%	22.6%	12.1%	49.5%
	Rubber Seating	1.0%	38.2%		

Table 8 yields some very clear conclusions. These have been discussed in detail earlier in the report, in Section 2, Conclusions.

Annexure 1

Data on Pumps upto 3 Years old

Table 9.1 : Numbers of Pumps & their Ages

Pumps in Age Group	Nos.	Average Age	
		Days	Years
1 to 2 Years Age	11	689	1.9
2 to 3 Years Age	185	913	2.5
Total	196	900	2.5

Table 9.2 : Maintenance Need by Date of Service

Frequency of Dates of Service	Nos. of Pumps
Single Date of Service	147
Two Dates of Service	31
Three Dates of Service	11
Four Dates of Service	7
Total Nos. of Pumps	196
Total Nos. of Dates of Serv.	270

Table 9.3 : Nature & Average Interval of Replacement

Type of Intervention		Interventions		Occurrences of Multiple Interventions
Pump Assembly	Component	Nos.	Average AgeDays	
Head	Assembly	1	276	
	Insp Cover bolt	2	295	
	Nut-Bolt	7	165	
Handle	Assembly	46	265	Twice on 3 pumps
	Axle	4	275	
	Bearing	72	255	Twice on 7 pumps, 3 times on 2 pumps
	Solid Link Assy.	13	280	
	SL Roller Bearing	28	286	Twice on 4 pumps
Water Tank	Assembly	2	164	
	Nut-Bolt	45	241	Twice on 3 pumps
Cylinder	Complete	16	362	
	Body	1	543	
	Sealing Ring	15	362	
Upper Valve	Assembly	6	261	Twice on 1 pump
	Rubber Seating	1	6	
Plunger	Assembly	9	321	
	Cup Washer	92	267	Twice on 8 pumps, 3 times on 2 pumps
	Follower	1	172	
	Rod	1	550	
	Yoke	3	287	
Lower Valve	Assemby	13	203	Twice on 1 pump
	Rubber Seating	2	344	

Data on Pumps over 3 Years old

Table 10.1 : Numbers of Pumps & their Ages

Pumps in Age Group	Nos.	Average Age	
		Days	Years
3 to 4 Years Age	6	1238	3.4
4 to 5 Years Age	8	1715	4.7
5 to 6 Years Age	10	1887	5.2
6 to 7 Years Age	2	2406	6.6
7 to 8 Years Age	7	2592	7.1
Total	33	1908	5.2

Table 10.2 : Maintenance Needs by Date of Service

Frequency of Dates of Service	Nos. of Pumps
Single Date of Service	13
Two Dates of Service	9
Three Dates of Service	4
Four Dates of Service	3
Five Dates of Service	1
Six Dates of Service	3
Total Nos. of Pumps	33
Total Nos. of Dates of Serv.	78

Table 10.3 : Nature & Average Interval of Replacement

Type of Intervention Pump		Interventions		Occurrences of Multiple Interventions
Assembly	Component	Nos.	Average AgeDays	
Head	Assembly	2	1309	
	Insp. Cover	1	975	
	Insp. Cover bolt	1	975	
	Nut-Bolt	15	660	Twice on 1 pump, 3 times on 1 pump
Handle	Assembly	1	458	
	Axle	2	756	
	Axle nut	1	1193	
	Bearing	25	851	Twice on 5 pumps
	Solid Link Assy.	1	776	
	SL Roller Bearing	1	776	
Water Tank	Assembly	4	1124	Twice on 1 pump
	Nut-Bolt	7	966	Twice on 1 pumps
Cylinder	Complete	1	975	
	Body	1	2212	
	Lower Cap	1	1044	
	Sealing Ring	4	621	Twice on 1 pump
Upper Valve	Assembly	7	221	4 times on 1 pump
Plunger	Assembly	2	944	
	Cup Washer	10	774	3 times on 1 pump
	Rod	4	1220	
	Rod nut	2	1609	
Lower Valve	Assemby	5	945	Twice on 1 pump