International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

# To Reduce Timer Plate Leakage in VE-Mechanical Pumps Using SPC Techniques

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**Abstract:** ***Six sigma methodologies DMAIC is very important statical process control technique regarding process improvement, control and productivity improvement in manufacturing industries. In an existing manufacturing process DMAIC, Root cause analysis and ISHIKAWA diagrams are powerful techniques to find out the actual causes which are reducing the productivity. During scrutiny of assembly process of VE- pumps critical parameters, which have major impact on productivity and quality were identified by using ISHIKAWA diagram and actual causes of leakage were resolved by root cause analysis. Thus process can be improved and controlled on the basis of SPC techniques. This paper focusing on the DMAIC technique used to improving the existing handing method at BOSCH, Jaipur plant in the assembly of VE-fuel injection pumps. This paper also integrates with implantation of six sigma to define the maximum safe no. of cycles for test timer plates-312.***

**Keywords**: DMAIC, DMADV, SPC Techniques, VE-pump, etc.

## 1. Introduction

The Bosch is in a process of becoming a lead plant within the worldwide for the manufacture of Distributor Pumps (VE- Mechanical and Electronic Diesel Control Pumps) with latest technology & part tolerances of order of few microns. A large number of parts (~200) are assembled during the assembly of VE pumps in assembly line and calibration is performed according to the type of pump & their requirements.

The quality is checked at different stages of assembly & calibration (visual checks, Dry Leakage Test, Wet Leakage Test, calibration and visual checks before packaging). After study of assembly of VE-pumps it was observed that the rejection of pumps is mainly due to leakage from different joints, which are observed during dry and wet testing of pumps. The allowable process variation at Dry testing stage is 40 Pa as against 60 Pa at Wet testing stage, therefore the VE-mechanical pump rejected under Dry test may clear the Wet test successfully. The leakage areas/joints are observed at Wet leakage testing stage and cause of leakages (defects like less/more torque, missing parts, reverse assembly of parts, chip at interfacing surface of two matching parts, damaged parts etc.) are being identified during repairing, which is performed at repair station. Thus scope of the study performed is restricted to reducing the rejection of pumps due to leakage at timer plate joint only as rejection being more in this process. The wet testing is carried out using test timer plate which is re-circulated for a number of cycles and the new/fresh timer plate is integrated or assembled at final calibration stage. Problem areas identified during study is rejection of timer plate due to- rapid increase in roughness on timer plate which was due to improper handling at calibration station, blow hole in housing near timer plate, chips/burrs at interfacing surface of housing and timer plate apart from associates/assemblers being unaware about criticality of roughness on test timer plate.

## 2. Statical Process Control Techniques

The process of an object formation can be controlled and improved by using six sigma methodologies- DMADV (define, measure, analyze, design & verify) and DMAIC process (defines, measure, analyze, improve & control).

These techniques are used in statical quality control which includes fish bone diagram, control charts, root cause analysis, etc. Six-sigma is both a philosophy and a methodology that improves the quality by analyzing data with a statistical approach to achieve quality assurance and quality management with emphasis on continuous quality improvements.

### 2.1 DMAIC

The DMAIC process is an improvement system for existing processes falling below specification and looking for incremental improvement is applicable in finding the cause of leakage at timer plates and process improvement.

- Defining the process or problem that forms the focus of the project.
- Measuring the key variables that drive process performance in order to find leverage points for Improvement.
- Analyzing the data to test hypothetical solution variables.
- Making improvements based on analysis and experimentation, and rolling the improved processes out on a large scale and implementing process management systems, both to hold the gains and identify further opportunities for improvement.
- Than control the system.

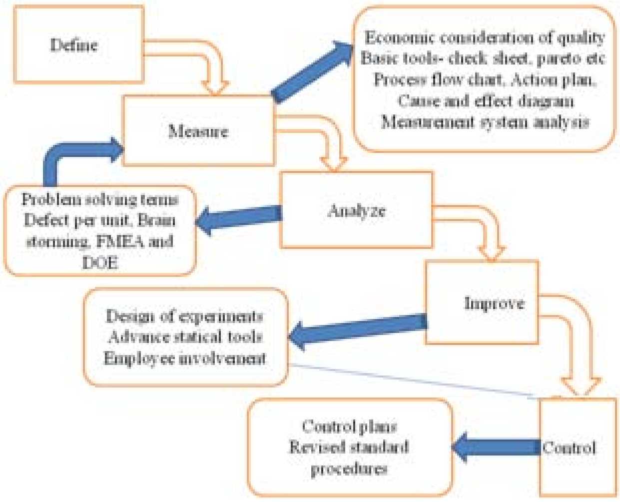



**Figure:** Flow of DMAIC

### 2.2 ISIHIKAWA Diagram

Ishikawa diagram also called fishbone diagrams, cause-and-effect diagrams, are casual diagrams created by Kaoru Ishikawa (1968). The common uses of the Ishikawa diagram are product design & quality defect prevention, and to identify potential factors causing an overall effect. Considering people, machine, material and methods a fishbone diagram is drawn for timer plate leakage as shown in below figure.

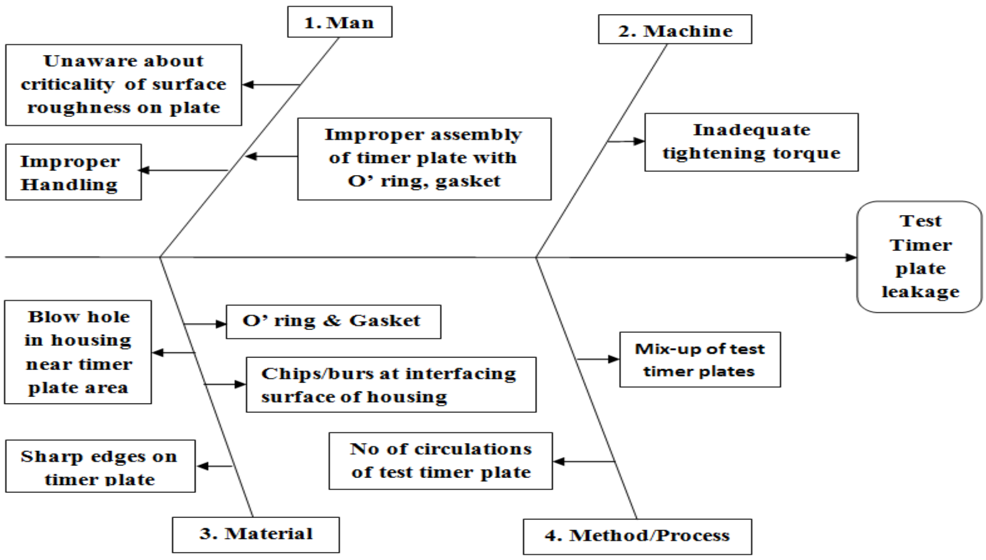



**Figure:** ISIHIKAWA diagram

Thus causes are usually grouped into major six categories, which are sources of variation. These categories include-

- **People:** Associates involved with the process.
- **Methods:** How process is being performed and specific requirements for it, such as procedures, rules etc.
- **Machines:** Equipment, tools and machines etc. required to accomplish the job.
- **Materials:** Raw materials- different parts, pencil, tools, oil etc. used to produce the final product.
- **Measurements:** Data generated from the process that are used to evaluate its quality like- production rate, percentage rejection etc.
- **Environment:** The conditions such as, time, temperature and culture in which the process is being operates.

## 3. Process Flow of VE-Pumps

The process flow of VE- pumps started with Assembly of VE-mechanical pump along with sub-assemblies of distributor head, closing cover, etc. After assembly, it proceeds through Dry testing for tightness, Visual checking-1, Wet testing to find the leakage areas, Calibration for setting delivery of fuel (diesel) at different RPMs, Post-Calibration for assembly of Mounting parts & Test Run and Visual checking-2 for correct assembly and then packing & dispatching to the customers. To overcome the reduced production of pumps two repair stations are established for repairing the rejected/failed pumps during testing for leakage proofing. The sequential flow of all processes is shown in below flow chart.

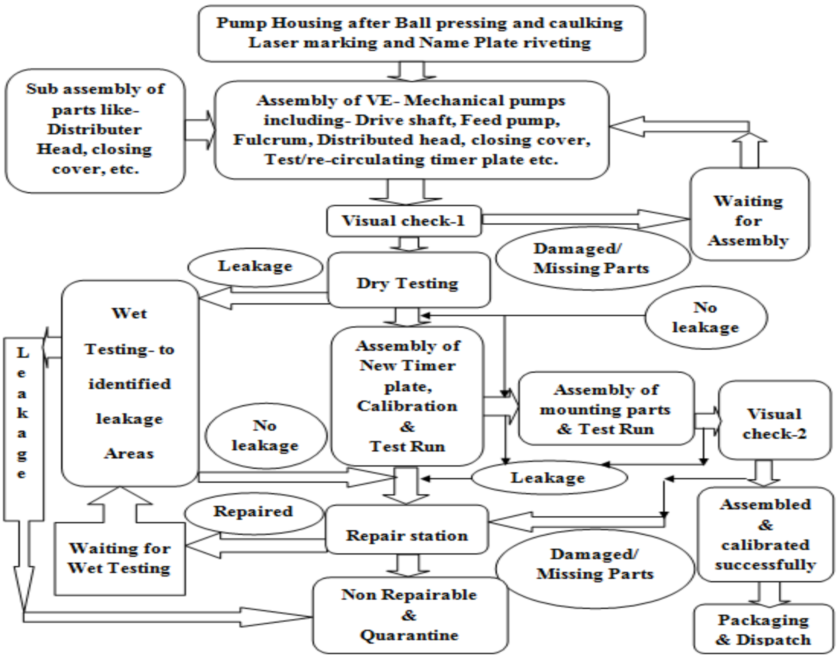



**Figure:** Process flow chart

### 3.1 Procedure

Step-1: After complete assembly, pump is first checked at visual testing station for all parts as per drawing.
- If the pump is found assembled correctly, then it proceeds to dry testing. otherwise
- That pump is being put on the incomplete assembly line or half assembled pump line for reassembly.

Step-2: In dry testing- pump is tested for leakage proofing at a rate of two pumps per 1.2 minutes.
- If a pump does not have any leakage then the pump proceeds through calibration stage. Otherwise-
- That pump proceeds to wet testing.

Step-3: At calibration station VE-mechanical pumps are checked for leakage by the way of setting the delivery values at different load and rpm.
- If the pump fails during calibration (i.e. Leakage found from any part) it proceeds to repair station. Otherwise-
- Pumps proceed to post-calibration.

Step-4: In this stage brackets, sealing caps, covers etc. are assembled. These parts help in mounting of the pump on the vehicle and preventing the Pump from being damaged.
- If any VE-mechanical pump fails during Post calibration it goes to repair station. Otherwise-
- Proceeds through visual checking-2.

Step-5: At another station further visual checking is performed for preventing supply of defective pumps to the customer side.
- If there is any defect found pump send to repair station.
- Correct pumps proceed for packing and dispatch to the customers.
- Step-6: The failure pumps during dry testing are tested at wet testing stage to find the leakage areas at the pumps.
- During testing if any leakage is not found at the pump, that pump proceeds through calibration stage (repeating the steps from step-3 to step-5).
- Those pumps having leakages proceed through repair station for the repairing.

Step-7: All rejected pumps are repaired at the repair station. This step is very important regarding the point of finding the causes of leakage at a joint on the pump. During each testing of leakage proofing, associate marked at the defective/leakage joints on the pump at their respective station.
- After repairing, pump proceeds through wet testing first and if there any leakage is not found then pumps entered the flow process in step-3 with performing calibration i.e. following the steps from step-3 to step-5.
- If any leakage is found then pump is reworked at last at the repair station.
- The repeating leakage at the same area/joint indicates that pump have blow holes and can't be repaired therefore it proceeds to quarantine.

Step-8: Finally rejected pumps (from repair station) are dismantled to quarantine room. Where all good parts are disassembled from the assembly and damaged parts proceed to wastage and parts, those having blow holes, return to supplier.
The VE-mechanical pumps (model no 0460-489, 0460-494 which use timer plate type-312), passes through different testing stations (visual checks-1&2, dry testing, wet testing, calibration, post calibration) for leakage proofing.

### 3.2 Finding rejection data at different testing stations

| No of Days | Production per day | No of pump rejections at different stages of testing | | | | | |
|---|---|---|---|---|---|---|---|
| | | Visual check-1 | Leakage testing(dry) | Leakage testing(wet) | Calibration | Post-calibration | Visual check-2 |
| 1 | 1064 | 0 | 98 | 48 | 0 | 0 | 0 |
| 2 | 1161 | 0 | 87 | 57 | 0 | 0 | 0 |
| 3 | 1166 | 0 | 90 | 60 | 0 | 0 | 0 |
| 4 | 1187 | 0 | 84 | 48 | 0 | 0 | 0 |
| 5 | 1139 | 0 | 92 | 54 | 0 | 0 | 0 |
| 6 | 1110 | 0 | 96 | 45 | 0 | 0 | 0 |
| 7 | 1167 | 0 | 74 | 38 | 0 | 0 | 0 |
| 8 | 1241 | 0 | 78 | 39 | 0 | 0 | 0 |
| 9 | 1284 | 0 | 68 | 51 | 0 | 0 | 0 |
| 10 | 1260 | 0 | 70 | 41 | 0 | 0 | 0 |

### 3.3 Wet Testing Stage

The rejected VE-mechanical pumps are tested at wet testing stage to identify the leakage areas / points at the pumps. Leakage points can be identified with in 2 minutes by supplying air at 0.8MPa-1MPa pressure (generally 0.89MPa) into the pump, as shown in figure.

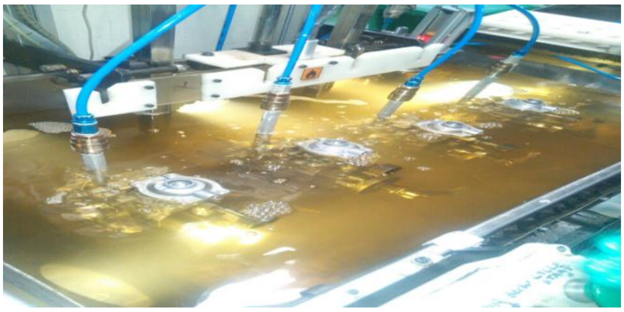


Figure: Wet testing to find the leakage area

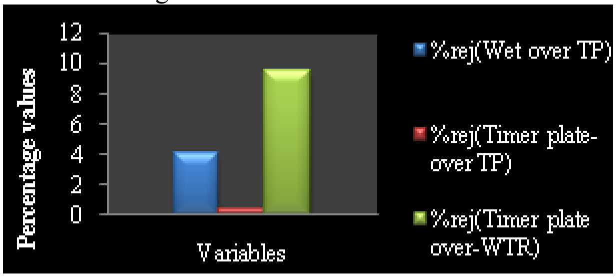
### 3.3.1 Finding rejection data at wet testing stations

| No of Days | Production per day | No of rejections according to type of leakage areas/joints | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Leakage testing (Dry) | Leakage testing (Wet) | Timer plate leakage | Shoulder Screw Leakage | Outlet / Inlet tube leakage | Fitting leakage | Closing cover/LDA leakage | Blow hole & other leakage |
| 1 | 1064 | 98 | 48 | 5 | 6 | 3 | 4 | 2 | 28 |
| 2 | 1161 | 87 | 57 | 4 | 4 | 2 | 3 | 3 | 41 |
| 3 | 1166 | 90 | 60 | 5 | 5 | 4 | 4 | 2 | 40 |
| 4 | 1187 | 84 | 48 | 4 | 4 | 4 | 3 | 2 | 31 |
| 5 | 1139 | 92 | 54 | 4 | 5 | 3 | 2 | 1 | 39 |
| 6 | 1110 | 96 | 45 | 5 | 3 | 3 | 3 | 3 | 28 |
| 7 | 1167 | 74 | 38 | 4 | 4 | 5 | 2 | 1 | 22 |
| 8 | 1241 | 78 | 39 | 4 | 4 | 2 | 2 | 2 | 25 |
| 9 | 1284 | 68 | 51 | 5 | 3 | 4 | 2 | 4 | 33 |
| 10 | 1260 | 70 | 41 | 5 | 4 | 3 | 4 | 3 | 22 |
| Total | 11779 | 837 | 481 | 45 | 42 | 33 | 29 | 23 | 309 |
| Avg. | 1178 | 84 | 48 | 5 | 4 | 3 | 3 | 2 | 31 |
| % over avg, prod[n]. per day | | 7.13% | 4.07% | 0.42% | 0.34% | 0.25% | 0.25% | 0.17% | 2.63% |

### 3.3.2 Table: Contribution of TPR over PP and WTR

| No of Day | Number of pumps | | | % WTR over PP | % TPR over PP | % TPR over WTR |
|---|---|---|---|---|---|---|
| | Production per day | Total rejection(Wet) | Timer plate rejection | | | |
| 1 | 1060 | 48 | 5 | 4.53 | 0.47 | 10.42 |
| 2 | 1161 | 57 | 4 | 4.91 | 0.34 | 7.02 |
| 3 | 1166 | 60 | 5 | 5.15 | 0.43 | 8.33 |
| 4 | 1187 | 48 | 4 | 4.04 | 0.34 | 8.33 |
| 5 | 1139 | 54 | 4 | 4.74 | 0.35 | 7.41 |
| 6 | 1110 | 45 | 5 | 4.05 | 0.45 | 11.11 |
| 7 | 1167 | 38 | 4 | 3.26 | 0.34 | 10.53 |
| 8 | 1241 | 39 | 4 | 3.14 | 0.32 | 10.26 |
| 9 | 1284 | 51 | 5 | 3.97 | 0.39 | 9.8 |
| 10 | 1260 | 41 | 5 | 3.25 | 0.4 | 12.2 |

Pareto: Percentage contribution




## 4. Problem Identification

After collecting the rejection data with process flow study in detail, it is observed that for leakage proofing all VE-pumps passes through different testing stages- visual check, post calibration, calibration, dry testing and wet testing. After data analysis problem is identified as the maximum rejection of VE-mechanical pumps is due to leakage at timer plate type-312, which contributes to 0.38% over per day average production and 9.5% over average rejection at the Wet testing stage.

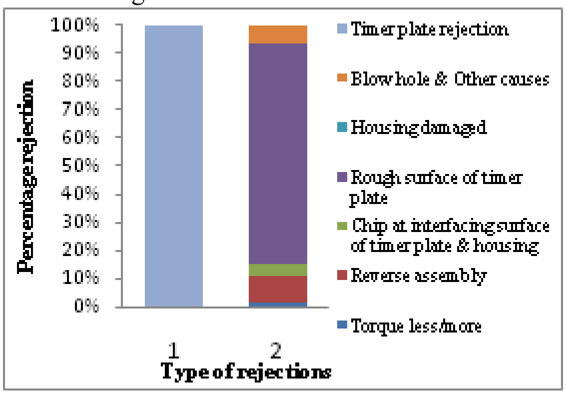
## 5. Timer Plates

These are metallic pieces of medium carbon steel also called dummy plate/test timer, with surface roughness up to 10µm on working side. This timer plate is used in VE- mechanical pumps (model no 0460-489, 0460-494) and circulated between assembly at station-5 and calibration station-42. During repairing of improper pumps at Repair station causes of timer plate leakage aere found out as shown in below table.

**Table:** Timer plate rejection with cause of leakage

| No of Days | TPR | No of timer plate rejections based on different causes | | | | | |
|---|---|---|---|---|---|---|---|
| | | Torque less/more | Reverse assembly | Chip at interfacing surface of timer plate & housing | Rough surface of timer plate | Damaged Housing | Blow hole & Other causes |
| 1 | 5 | 0 | 1 | 0 | 4 | 0 | 0 |
| 2 | 4 | 0 | 0 | 0 | 3 | 0 | 1 |
| 3 | 5 | 0 | 0 | 0 | 4 | 0 | 1 |
| 4 | 4 | 0 | 1 | 0 | 3 | 0 | 0 |
| 5 | 4 | 0 | 0 | 1 | 3 | 0 | 0 |
| 6 | 5 | 1 | 0 | 0 | 4 | 0 | 0 |
| 7 | 4 | 0 | 0 | 1 | 2 | 0 | 1 |
| 8 | 4 | 0 | 0 | 0 | 4 | 0 | 0 |
| 9 | 5 | 0 | 1 | 0 | 4 | 0 | 0 |
| 10 | 5 | 0 | 1 | 0 | 4 | 0 | 0 |
| Total | 45 | 1 | 4 | 2 | 35 | 0 | 3 |
| % over TPR | | 2.20% | 8.90% | 4.40% | 77.80% | 0.0% | 6.70% |

Pareto: Percentage contribution



By using root cause analysis actual causes for all tabulated types of rejections were found out and respective suggestion are given as-

## 6. Implementing the Suggestions

Using root cause analysis actual causes were found out and based on the study of statically process control techniques suggestions were given as-

### 6.1 To reduce roughness on timer plate

**Problem**- Timer plate leakage due to greater rough surface, 3 to 4 cases were observed daily.

**Causes**-
1. Associates are unaware about criticality of surface roughness on timer plates and process.
2. Plates are being used more than defined no. of cycles.
3. Improper handling method at calibration station, which increases the roughness rapidly.

**Successions**-
1. Associates to be made aware about the criticality of surface roughness on timer plates and process.
2. Proper surface finishing should be done after pre define no. of cycles. So that assembly of improper timer plates will be eliminated.
3. New handling method- use the tray with thermocal seat, having holes for inserting timer plates separately. So that plates will not strike each other and thus dents will not developed on surface of the timer plate as shown in below figure.
4. Regrinding should be done after pre define optimum no. of cycles i.e. sixty days.

**Figure:** Timer plates within thermocal seat

**Procedure**-
**Step-1**: Paste a list having "starting date and bin no-1, 2, 3….etc. on every storage bin.
**Step-2**: According to capacity of bin, insert the timer plates within thermocal sheet.
**Step-3**: Circulate the bins in a proper sequence- starting with bin-1 at assembly station-5 and use the plates from the same until it becomes empty completely.
**Step-4**: Then send the bin-1 to calibration station -42 and takes timer plates from next bin-2 and so on.
**Step-5**: After disassembly (station -42) operator must insert all the timer plates into thermocal sheet within the storage bin.
**Step-6**: Do not mix any timer plate from one storage bin into another.
The above proper sequence is followed for all storage bin between assembly station-5 and disassembly satation-42.

### 6.2 To eliminate not achieving required torque

**Problem**- Less torque was observed for two cases one case on 5th day and second was on 7th day.
**Cause**-
- Metallic chips were found at interface surface of housing & timer plate as shown in below figure.


**Figure:** Chip at interfacing surface of housing and plate

**Succession**
- Cleaning at interfacing surface should be done by vacuum cleaner in place of pressurized cleaning because former method is more effective than the later.

### 6.3 To eliminate reverse assembly of timer plates

**Problems**- Four cases of reverse assembly of timer plate were found, which was wrong as per drawing.

**Causes**-
- Sometime operators assemble timer plates in reverse or wrong way against the drawing. It is either due to operator's mistake or lack of instructions given to the operators.

**Suggestions**-
- According to the type of pump instructions should be given to the operators along with drawing of the pump and associates should be aware about the criticality.

### 6.4 To reduce blow holes and other leakage

- Leakage due to blow holes can't be eliminated within the plant but can be reduced at supplier side by improving casting method or process parameters.

## 7. Finding Result

After implanting all the suggestion rejection data was found out at wet testing station

Table: Rejection data at wet testing stages

| No. of days | Prod[n] per day | No. of pumps rejected according to types of leakage areas/joints | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Total rejections (wet) | Timer plate leakage | Shoulder Screw Leakage | Inlet / Outlet tube fitting leakage | Fitting leakage | Housing cover/LDA/ leakage | Blow hole & Other causes |
| 1 | 1126 | 38 | 1 | 5 | 3 | 2 | 2 | 25 |
| 2 | 1086 | 42 | 0 | 4 | 2 | 1 | 2 | 33 |
| 3 | 1052 | 38 | 1 | 2 | 4 | 2 | 3 | 26 |
| 4 | 1128 | 35 | 0 | 3 | 4 | 2 | 1 | 25 |
| 5 | 1022 | 36 | 2 | 4 | 5 | 3 | 2 | 20 |
| 6 | 1108 | 34 | 1 | 4 | 3 | 2 | 3 | 21 |
| 7 | 1188 | 39 | 0 | 3 | 2 | 4 | 2 | 28 |
| 8 | 1098 | 32 | 1 | 2 | 4 | 2 | 3 | 20 |
| 9 | 1190 | 44 | 0 | 3 | 2 | 3 | 1 | 35 |
| 10 | 1127 | 37 | 0 | 2 | 2 | 1 | 2 | 30 |
| Total | 11125 | 375 | 6 | 32 | 31 | 22 | 21 | 263 |
| Avg. | 1113 | 38 | 1 | 3 | 3 | 2 | 2 | 26 |
| Percentage over Avg. PP | | 3.41% | 0.09% | 0.27% | 0.27% | 0.18% | 0.18% | 2.34% |

**Pareto:** Percentage contribution over WTR

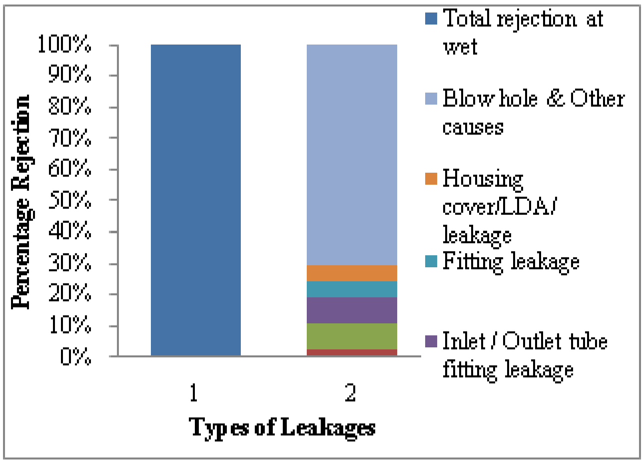



**Table:** Contribution of TPR over PP & WTR

| No. of Days | Production per day | WTR | TPR | %rej(WTR-over PP) | %rej(TPR -over PP) | %rej(TPR-over WTR) |
|---|---|---|---|---|---|---|
| 1 | 1126 | 38 | 1 | 3.37 | 0.09 | 2.63 |
| 2 | 1086 | 42 | 0 | 3.87 | 0 | 0 |
| 3 | 1052 | 38 | 1 | 3.61 | 0.1 | 2.63 |
| 4 | 1128 | 35 | 0 | 3.1 | 0 | 0 |
| 5 | 1022 | 36 | 2 | 3.52 | 0.2 | 5.56 |
| 6 | 1108 | 34 | 1 | 3.07 | 0.09 | 2.94 |
| 7 | 1188 | 39 | 0 | 3.28 | 0 | 0 |
| 8 | 1098 | 32 | 1 | 2.91 | 0.09 | 3.13 |
| 9 | 1190 | 44 | 0 | 3.7 | 0 | 0 |
| 10 | 1127 | 37 | 0 | 3.28 | 0 | 0 |
| Total percentage | | | | 33.71% | 0.57% | 16.89% |

**Pareto:** Percentage contribution of TPR over WTR and TP

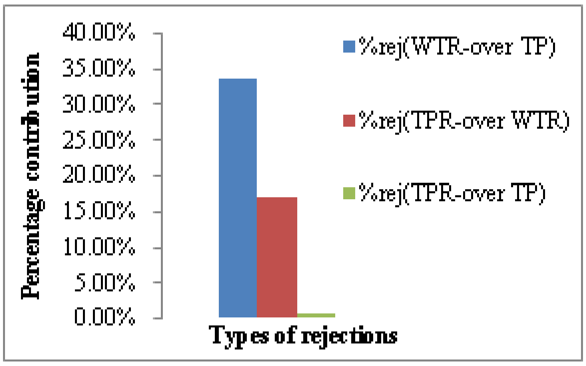
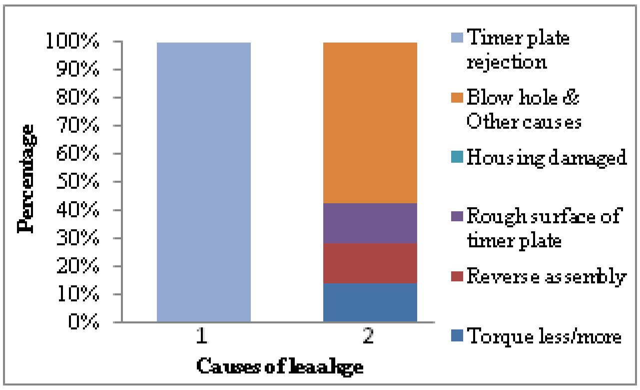



**Table:** Timer plate rejection with cause of leakage

| No. of Days | Timer plate rejection | No. of timer plate rejections according to different causes | | | | | |
|---|---|---|---|---|---|---|---|
| | | Torque less/ more | Reverse/ Wrong assembly | Chip at interfacing surface of timer plate & housing | Rough surface of timer plate | Housing damage | Blow hole &Other causes |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 2 | 0 | 0 | 0 | 1 | 0 | 1 |
| 6 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 6 | 0 | 1 | 0 | 1 | 0 | 4 |

Pareto: Percentage contribution of different causes of leakage over TPR




### 7.1 Explanation of timer plate rejections:

1. At first day one rejection was found as less torque which was due to damaged thread inside the hole at pump's housing (added in blow holes & other causes).
2. On eighth day of scrutiny one rejection was found as assembly of wrong timer plate (type-307), which was a mixed up case of timer plates.
3. On fifth day one rejection was found due to rough surface on timer plate which was due to either improper handling of timer plate or other. The exact reason was unknown to me. Thus this timer plate was replaced with new plate.
4. During ten days of scrutiny four causes were found as- blow holes in the pump's housing that were manufacturing defects and can't be reduced here.

**7.2 Determining the no of working cycles**:

Surface roughness was measured using at starting of each day on each timer plate following the **Rz** method. Using six sigma with 99.74% acceptance no of working cycles were determined as-

**Table:** Roughness values for calculating standard deviation

| Timer plate no. | Increased value per day ($X_i$) | $(X_i - \bar{X})^2$ |
|---|---|---|
| 1 | 0.129 | 0.000025 |
| 2 | 0.124 | 0.0 |
| 3 | 0.124 | 0.0 |
| 4 | 0.12 | 0.000016 |
| 5 | 0.121 | 0.000009 |
| 6 | 0.137 | 0.000169 |
| 7 | 0.117 | 0.000049 |
| 8 | 0.127 | 0.000009 |
| 9 | 0.123 | 0.000001 |
| 10 | 0.122 | 0.000004 |
| Total | $\bar{X} = 0.124$ | $\sum = 0.000282$ |

At first day-Maximum surface roughness of timer plate = 1.487 µm
During nine days average increased surface roughness ($\bar{X}$)= 0.124 µm
Standard deviation-

$$\sigma = \sqrt{\frac{\sum_1^{10}(X_i - \bar{X})^2}{10}} = 0.00531$$

For 99.74% acceptance control limits are defined as-
Upper control limit (**UCL**) = $\bar{X} + 3\times\sigma = 0.1399$
Lower control limit (**LCL**) = $\bar{X} - 3\times\sigma = 0.1081$
For safe no of cycles considering the UCL as max. increased roughness value per day per plate-

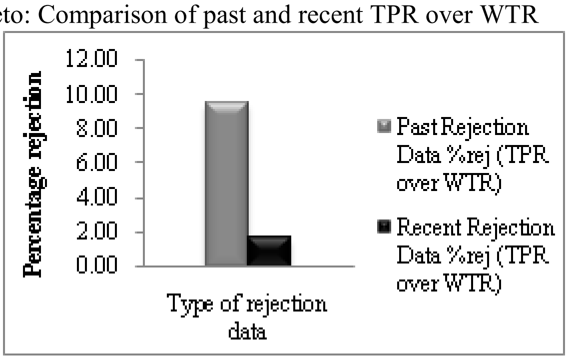
No of days $= \frac{10-1.487}{0.1399} = 60.85 \approx 61$ days
No of cycles = 3×61 =183 Cycles

## 8. Comparison of Results

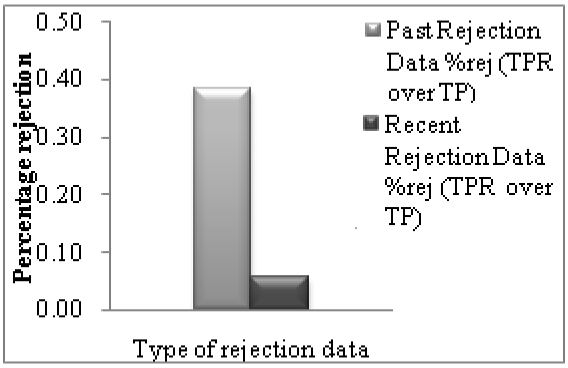
**Table:** Comparison between Past and Recent Rejection Data

| Sr no. | Past Rejection Data | | Recent Rejection Data | |
|---|---|---|---|---|
| | %rej (TPR over WTR) | %rej (TPR over PP) | %rej (TPR over WTR) | %rej (TPR over PP) |
| 1 | 10.42 | 0.47 | 2.63 | 0.09 |
| 2 | 7.02 | 0.34 | 0 | 0 |
| 3 | 8.33 | 0.43 | 2.63 | 0.1 |
| 4 | 8.33 | 0.34 | 0 | 0 |
| 5 | 7.41 | 0.35 | 5.56 | 0.2 |
| 6 | 11.11 | 0.45 | 2.94 | 0.09 |
| 7 | 10.53 | 0.34 | 0 | 0 |
| 8 | 10.26 | 0.32 | 3.13 | 0.09 |
| 9 | 9.8 | 0.39 | 0 | 0 |
| 10 | 12.2 | 0.4 | 0 | 0 |
| Avg. | 9.54 | 0.38 | 1.69 | 0.057 |

Pareto: Comparison of past and recent TPR over WTR




Pareto: Comparison of past and recent TPR over TP




## 9. Conclusion

In the above analysis, the maximum rejections of VE-mechanical pumps were found as timer plate leakage. For timer plate leakage five major causes were found as surface roughness, torque less/ more, metallic chip found between interfacing surfaces of plate & pump housing, reverse assembly and damaged housing. The major cause is rapid increase in surface roughness on the plates, which is due to improper handling of plates at calibration station. After deep investigation this research suggests a proper handling method for timer plates. According to the suggested method timer plates are being inserted into a bin having a thermocal sheet. After implementing the given suggestions it was observed that due to timer plate leakage percentage rejection of VE pump is reduced from 0.38% to 0.057% over total production and wet tightness rejection reduced from 9.7% to 1.69% over wet testing rejection.

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