Reducing Electrical Faults in Pumps Using Pokayoke

Sudharsan.S[#1], S.Bhaskar[#2]
#1 M.E-Industrial Engineering, Department of Mechanical Engineering, Kumaraguru College of Technology, Coimbatore, India
#2 Associate Professor Department of Mechanical Engineering Kumaraguru College of Technology, Coimbatore, India

***Abstract*—** With the rapid growth of innovation and technology, it is not only necessary to accelerate operations but also to create error-free procedures. Such error-free procedures can be realized through the technique called 'Pokayoke'. Pokayoke is a technique that can be used to change process designs such that human error is eliminated. While other management tools only help reducing errors, Pokayoke ensures that an error does not occur in the first place. The project work reviews the various dimensions of Pokayoke as a quality tool and as a mistake-proofing device. The project also scrutinizes the use of Pokayoke in various organizations namely the automotive industry, manufacturing industry, construction industry, the garment industry, and the health care sector, etc. The project also illustrates the design that is done to implement Pokayoke in pump manufacturing industry.
***Index Terms*—**POKAYOKE, Submersible pumps, Electrical Faults, End Cap Design, Productivity.

INTRODUCTION

Poka-yoke (poh-kah yoh-keh) is a quality management concept, coined by Shigeo Shingo in Japan during the 1960s who was one of the Industrial Engineers at Toyota. The initial term was baka-yoke, which means 'fool-proofing'. Poka-yoke helps people and processes work right the first time. Poka-yoke refers to techniques that make it impossible to make mistakes. These techniques can drive defects out of products and processes and substantially improve quality and reliability. The use of simple Pokayoke ideas and methods in product and process design can eliminate both human and mechanical errors. Thus, Poka Yoke is central to the concept of 'Lean' thinking, which aims to reduce waste and make sure that everything and every process is as efficient as possible. The concept of stopping defects or mistakes from happening is central to Poka Yoke thinking. It is not about rectifying mistakes or defects; it is about ensuring that they simply do not happen.

There are five principles observed in applying error-proofing techniques:

i. Prevention – in which the objective is to eliminate any possibilities of a mistake being committed.
ii. Replacement – this involves redesigning or substitution of a component in the product's design to make error-prevention more reliable.
iii. Facilitation – this denotes the process of simplifying the system to avoid complications from which defects due to variables may stem.
iv. Detection – this means rigorous research and testing procedures applied in order to detect variances and deviations.
v. Mitigation – incorporating a component that would minimize if not eliminate the detriments in the event that a possible error does take place.

Poka yoke is more of a concept than a procedure. Thus, its implementation is governed by what people think they can do to prevent errors in their workplace, and not by a set of step-by-step instructions on how they should do their job.

LITERATURE - INTRODUCTION

V.Grout[1] converts the negative impact to a positive one in the concept of ‘Engineering stoppage process’ in the medical sector where workers are empowered with the knowledge of using andon cord (JIDOKA) along with Poka Yoke. Grout[2] enlists the aspects of an effective mistake-proofing design in a health care industry. Robert F. Erlandson[3] visualizes the improved morale, pride and self-esteem of workers with cognitive disabilities. This is achieved by process redesign and increased productivity which gave similar results as of the nondisabled workers. Cristobal Miralles[4]et al. designs a universal workplace for the physically and mentally challenged persons at various workstations which provide a greater accessibility to the disabled persons. Productivity of the disabled workers thus increases to the level of normal workers and a high level of labor integration is achieved. N.F. Treurnicht[5] et al. uses Poka Yoke in the improvement of the potential of Intellectually Disabled Workers in an electronic assembly workstation. By designing a workstation using the Poka Yoke approach for the intellectually disabled workers the productive work is performed and the work process is mistake proofed in the organization. Arash Shahin[6] proposes a framework for Service failure and Service recovery. The author describes Pokayoke as an effective Quality tool for achieving foolproof designs. Badiger[7] et al., demonstrate the use of Pokayoke in improving overall performance and to increase productivity. The author has provided an estimate of the OEE (Overall Equipment Effectiveness) after Pokayoke has been implemented in a shot-peening machine. Yu Cheng Wong[8] et al. reviews the various Electrical and Electronic industries which implemented Lean manufacturing for 4 to 6 years of period. The use of Poka yokes also involved in these various industries for their effectiveness is stated. Saurin[9] provides a framework to assess the effectiveness of Pokayoke devices that have been designed for Quality Control /to control hazards/to eliminate processing errors. Dudek-Burlikowska[10] et al. are of the view that Pokayoke used along with Zero Quality Defects will help eliminate human errors in manufacturing processes to a greater extent. Claudia Isac[11] reviews the use of Pokayoking tools in eliminating defects. Sulek[12] provides a Fail-Safing Methodology to handle Para transit operations. Ferdousi[13] is of the view that Pokayoke along with other total quality management tools like Kaizen can be used to achieve organizational effectiveness in a garment industry. By organizational effectiveness, we mean a ‘reduced lead time’, ‘improved productivity’, and ‘no wastes’. Aguinaldo dos Santos[14] illustrate the use of ‘Application Pokayoking methods’ in the construction industry. Al-Araidah[15] has designed a fuzzy-logic controller to prevent, control and alert the quality of air in naturally ventilated environments. Sadri[16]et al. describes a mistake proofing/fail-safing methodology that takes into account and eliminates errors in the trolley hoist process of the construction industry. Ray and Das[17] suggest the use of lean tools and techniques for improving the machining process capability of automotive manufacturing plants. Desai and Warkhedkar[18] have developed a model for setup time reduction in an automobile industry and have utilized PokaYoke to identify errors and eliminate errors in the first place. Salem[19] et al. suggest the use of the Last Planner System- a tool for various factory floor operations like MPS, MRP, and so on, and have also reviewed the various lean tools and techniques available for use. Jaspreet Gill[20] talks about the inter-relationship between quality and productivity; and has conducted research to find what happens when the quality is given attention to while manufacturing is being done.

STUDIES ON POKAYOKE

John R. Grout [1] et al. have studied the healthcare sector and implemented mistake proofing mechanisms in several areas of the healthcare sector. The author thus designed Pokayoking designs to eliminate medical errors, and to reduce the spiraling costs in the healthcare concern.

Cristobal Miralles [4] *et al*., have designed universal workplaces with the help of PokaYoke for various workstations in an organization. The developed Poka Yokes provided a greater accessibility to the workers with physical and mental disabilities. It was found that the productivity of the disabled workers increased and they were able to work on par with normal workers. Thereby, a high level of labor integration was achieved.

Anil S Badiger [7] et al., have enhanced the Overall Equipment Effectiveness of Shot peening machines using Poka Yoke and Kaizen implementation. Several issues like the aging of the machine, poor performance of the machine, poor housekeeping have been taken up and analyzed. A Poka Yoking device has then been designed to improve the OEE. Results indicate an increase in OEE from 49.9% to 74.68%.

Yu Cheng Wong [8] et al., have reviewed the various approaches and practices of ‘Lean’ manufacturing in 4 different companies of the electrical and electronics sector, which employed ‘Lean’ practices for over 4 to 6 years. The authors have done a comparative review of those companies to see the effectiveness of the practices. The authors have found that continuous improvement, learning and innovation are essential for an organization if it has to continue to maintain its ‘lean’ status.

Sulek [12] et al., provide a Fail-Safing Methodology for Para transit operations. The authors have provided a systems approach to fail-safe people, systems and technologies. The authors have then tested the effectiveness of the fail-safe methods.

Ferdousi [13] et al., have examined the effects of performance improvement in 9 manufacturing firms in Bangladesh after implementing Lean methods of production. It has been found that after lean implementation several changes result: namely a reduction in production costs; an improvement in total productivity; and more.

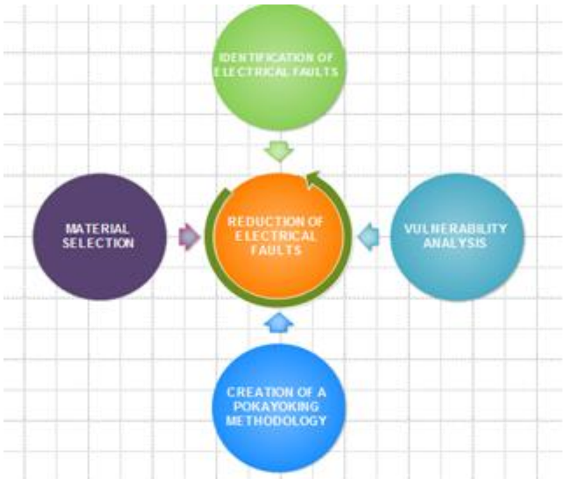
Aguinaldo dos Santos [14] et al. enumerates the use of application Pokayoking methods in the construction industry. The authors have conducted case studies in 6 bricklaying companies in Brazil and England. Results indicate an improved productivity, a lesser waste of time and materials. The “Reduction of Variability” principle has been used to identify and eliminate causes for deviations in the process.

Jaspreet Gill [20] in his paper analyses the relationship between quality and productivity, and the common grounds that they share. The author discusses the need of TQM practices for every enterprise, whether it is big or small. The findings of the author indicate that if quality is improved, the number of defective units per million of the production comes down. Thereby, the productivity tends to increase.

OBJECTIVE AND SCOPE OF THE PROJECT

The overall objective of the project is to eliminate electrical faults with the implementation of pokayoking devices. The scope of the project lies in finding the root causes of electrical faults and eliminating them. The results aimed are at are an increased productivity, an increased cost of quality, an increased lead time. Other results include an improved delivery assurance and an improved customer satisfaction.

Porter's five force methodology was used to find the five forces that have to be initiated to achieve the specified objective.



The five forces to be initiated include: Identification of electric faults, vulnerability analysis, creation of a pokayoking methodology and material selection. Each force has been explained in the subsequent chapters.

The organization where the project has been undertaken is a subsidiary and assembly line division of a reputed pump industry based in South India. The organization has its base in South India, with distributors and suppliers worldwide. The pump industry's subsidiary and assembly line division produces a variety of pumps. One such variety is the 'Submersible Pump' and in turn it has various models that are designed to suit customer requirements.
Specifically, V4 and V6 are the two models of submersible pumps which have the maximum demand and the failure rate. Hence, these versions of pumps are given prior importance. From the initial study and by the analysis of the collected data, it was found the total rejections at the V4 and V6 models collectively to be approximately 6%. The detailed study shows that 43% of the total rejections were due to various 'Electrical Faults' and the remaining 57% of the total rejected where due to various 'Non-Electrical faults'. By the statistics stated above, we can clearly find that the organization has less productivity, increased Cost of Quality, and increased Lead time, delivery failure which subsequently results in affecting the customer at the end.

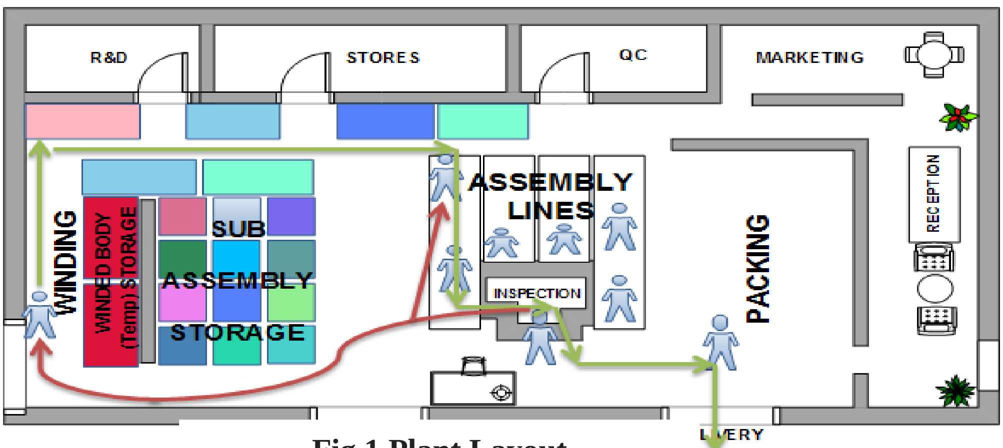


Fig.1 Plant Layout

I. IDENTIFICATION OF ELECTRICAL FAULTS

Initially, the layout of the industry was scanned through for various electric faults. For this, the various sections and the processes in each section were analyzed thoroughly.

The plant has various sections and the assembly flows with winding as the initial section followed by Motor Assembly, Pump Assembly, Coupling of Motor and Pumps, Inspection and finally ends up with Cleaning and Packing.

In the Winding section, the coil is Wound-up in the Stator based on various parameters like HP/KW (for no of Turns), Horizontal or Vertical models, Core Length, etc. Then the Winded Body is stored.

In the Motor Assembly, the rotor, shaft, studs and all other casting modules are assembled and it is passed to the Inspection Section.

In the Pump Assembly, the actual pump of various stages is assembled as per the requirements such as Suction Rate, Delivery Rate and Pumping Height etc. Then it is passed on to the Inspection Section.

In the Inspection Section, the Motor and the Pump are coupled and it is tested for various observations like Rated Voltage, Minimum Starting Voltage, Rated Speed, Discharge Rate, Maximum Current, No load test, Full Load test, etc.

Pumps which meet the 'Specified Requirements' will pass this section. If any abnormalities are found, then it gets traversed back to the respective Workstation or the Assembly line. The pump which passes the Inspection is then moved for cleaning and packing and finally gets dispatched.

After a detailed inspection of the layout and after studying the processes, the following faults were identified in the factory floor:

- Short Circuit (Body Short)
- High Amps
- Low voltage failure
- Continuity
-

VULNERABILITY ANALYSIS

A vulnerability analysis was conducted to find the most vulnerable electrical fault. **Table 1** shows the final worksheet of the vulnerability analysis that had been conducted.

From the relative threat percentages, it is seen that body short problem has the largest relative threat level. Therefore, the body short problem is the one that should be addressed with the help of pokayoking. Thus, the major and the dominating electrical faults which have been identified are:

- Short Circuit (Body short) and
- Low Voltage/High Amp Faults

Hence, based on the vulnerability and need, the following faults are given priority, and pokayokes are developed to fool proof these errors.

Short Circuit or body short is an abnormal, usually unintentional condition of relatively low resistance between two points of different potential in a circuit, often resulting in a flow of excess current. In the case of pumps, the insulation of the coil winding fails and the supply tends to come into contact with parts like Stainless Steel body or at the castings or at any metal part which causes a 'Short Circuit'. This in turn results in High Amps in the motor. The Low Voltage failure is the inability condition of the motor to start at the required minimum Voltage.

EVENT	PROBABILITY	HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	RISK
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interuption of services*	*Preplanning*	*Time, effectivness, resouces*	*Community/ Mutual Aid staff and supplies*	*Relative threat**
SCORE	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 - 100%*
Body Short (Short Circuit)	3	3	2	3	3	2	2	**83%**
Low voltage Failure	2	0	2	2	3	2	2	**41%**
High Amps Resulting	2	1	1	2	3	2	2	**41%**
Continuity Problem	1	1	1	2	2	2	2	**19%**
Air Gap	1	0	0	1	2	3	2	**15%**
Carbon Bearing Seating	2	0	1	1	0	2	2	**22%**
Housing Leakage	1	0	0	1	0	2	0	**6%**
Impeller Block	2	0	2	2	2	2	2	**37%**
Improper coupling of Pump and Motor	1	0	0	1	2	0	3	**11%**
Bending of Shaft	2	1	3	3	1	1	1	**37%**
Improper allignment of Impeller	2	0	1	1	3	0	3	**30%**
AVERAGE SCORE	**1.73**	**0.55**	**1.18**	**1.73**	**1.91**	**1.64**	**1.91**	**28%**

Threat increases with percentage.

RISK =	PROBABILITY *	SEVERITY
0.28	0.58	0.49

Table1 Vulnerability Analysis

The Fig.2 clearly explains the coils inside the pump which gets Short Circuited.

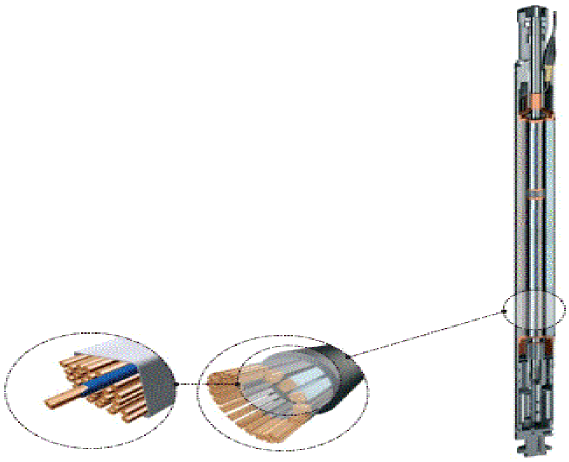


Fig.2 Short Circuit in pumps

The Fig.1 thus depicts clearly the location of the winding, winded coil inside the slots, insulation of the coil and the actual conductor. This solid conductor which is insulated completely gets damaged at the assembly line which causes the insulation failure resulting in the problem of Short Circuit (Body Short).

EXISTING SCHEME

In the factory floor, the coil insulation is tested at 2 stages: first at the stage before winding of the coil is done; and next the coil is tested after the winding is completed. The verified non failure component thus enters the assembly line. The coil damage is then identified only during the testing. This tends to be hazardous to the operator handling the pump. Hence, it is found that the coil gets damaged only in the assembly line. Thus, there is a need to detect the causes of insulation failure and eliminate it before occurrence.

Fig.3 Projected coils that get damaged

As the coil in the Wound-up body has projections on both sides, when the coil reaches the assembly line, it gets damaged. Such damage is not only due to the projections in the coil, but also due to projection in the castings and due to the 'improper finish' of the casting surface.
In the Inspection section, initially the motor starts running at its rated speed. But as the rated speed is the greatest speed of the motor Rust, chips and other foreign particles emerge from the rotor and this in turn contributes to the a damage of the winding.

Employee's skill also plays a vital role in the quality of the winding. An unskilled worker may insert a rotor wrongly which may lead to a damage of the projected coils. Hence, there is a necessity for a skilled labor is required to perform this job
It was noted that linguistic skills of laborers play a major role in coil damage and insulation failure. The plant's supervisors speak in English or in the native language of Tamil Nadu. Laborers who work for the industry are most of the time, not natives of Tamil Nadu. Moreover, they are not English speakers. As a result, they have difficulty in interpreting what is being told by their supervisors, and as a result, they tend to miss most of the instructions from their supervisors. As a result, they access highly protected/ unauthorized storage areas and store sub-components in the wrong locations. Hence, language training becomes mandatory in this case.

Fig.4 Bin arrangement and Storage that

Improper arrangement of the Wound-up Body and the bin shortage also contribute to an 'Insulation Failure' of the projected winding.

Unskilled laborers also contribute much to the Insulation Failure this is primarily due to mishandling of raw materials, the Wound-up body, the fully assembled motor, pumps, and other sub-components.
Thus, Manual Material Handling has been identified to be the major cause of Insulation Failure in the coil.

SUGGESTED PROPOSALS

After adequate literature review and after consultations with in-house designers and factory floor personnel, few vital and practical proposals were suggested to the company for each problem as below.

PROBLEM	SOLUTION
Rotor Chips & Foreign Particles	Use of Industrial Washing Machines
Coil Damage due to Casting Faults	Casting Component Finishing
Human Error (Rotor Insertion)	Training for Employees
Overstocking, Collision	Proper use of Bins
Use of Unskilled Labors	Proper access to the Winding Section
Manual Material Handling	End Caps design

Table2. Proposals for each

For the above stated problems, various suggestions have been proposed as it is tabulated in the above Table.
To avoid the emergence of rotor chips, rust and other foreign particles, the usage of industrial washing machines is proposed. An industrial washing machine is a device used to wash sub-components just before they enter into the assembly. This prevents rotor chips, rust and other foreign particles from disrupting the windings of the cable and from causing an insulation failure.

The next proposal is the casting component's finishing. It has been found that the finishing of the inner side of the casting is the major reason for coil damage. Hence, a suggestion is made for a smoother finishing of the inner side of the casting. When the finishing of the inner surface is smooth, projections and blow holes are removed thus reducing the risk of coil damage.

In order to avoid Insulation Failure due to Rotor insertion the only way is to give proper training to the employees thus making or having a skilled labor for Rotor insertion.

In the next proposal, the organization has been advised to use the right type bins and the right type of bin arrangement. After a study, it has been noted that much of the coil damage occurs as a result of overstocking. Overstocking of bins results in collision and as a result, coil damage results. This can be avoided by following the TQM principle of 'A place for everything and everything in its place'.

Laborers must be trained to recognize the restricted and unauthorized areas. Sign boards can be placed in the native language of the laborers to avoid this problem.

The final and vital proposal is the use of 'End Caps'. Thus by designing end caps the major risk for Insulation Failure can be reduced. End caps are designed and placed as a guard for the projected coils immediately after the winding and then the Wound-up body is stored within them. By this, the damage due to the coil by means of manual handling, collision, overstocking, improper arrangement etc., can be avoided.

An alternative solution is to insert the Rotor, Shaft, Bearings and to enclose the windings with the actual casting component and to store them. This requires a massive change in the layout of the Assembly line. The Wound-up body is taken into the assembly line only if there are any requirements, until then the wound-up body is stored. Thus if an alternative assembly is done and stored, there are more possibilities for the occurrence of tightness or logjam and thus resulting High Amps.

Thus, the DESIGN OF ENDCAPS is the most useful and the vital solution for the organization and is implemented.

ENDCAP DESIGNS

Endcap designs were done using Solidworks for the V4 and V6 versions of pumps.Before initiating the design, the structural differences in both the versions of pumps were studied. Hence, while designing the endcaps, the geometric differences between the pumps were taken into account.
Another aspect that was taken into consideration during the design was 'ergonomic safety'. care was taken to see that the endcaps would be easy to be fixed by human operators without any hazzle.

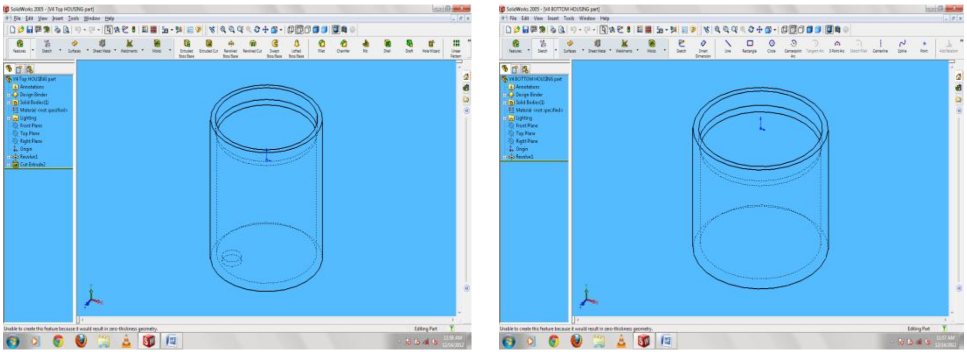


Fig.5 V4 Top & Bottom Housing Design

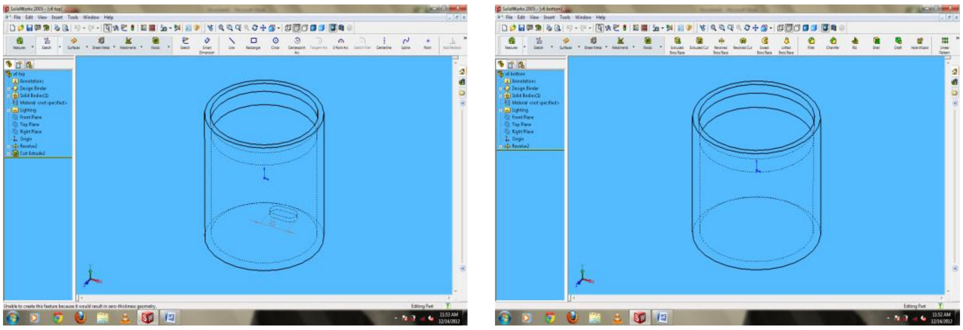


Fig.6 V6 Top & Bottom Housing Design

II. MATERIAL SELECTION

The various materials have been analyzed with their properties and finally it has been concluded to implement the End Caps Design in the PVC (Poly Vinyl Chloride) Material. This material has been selected based on the Economy aspect and based on the ease of availability.

Materials → / Properties ↓	PVC	uPVC	HDPE	LDPE	Polypheylene Thermoplastic	PC
Density (g/cm³)	1.26-1.5	1.39	0.95	0.92	1.06-1.34	1.2
Dielectric Constant (Relative Permittivity) Low Hz Range	3.4-5.5	3.4	2.4	2.3	---	3.17
Elastic (Youngs) Modulas (GPa)	1.4-2.8	2.8	1.0	0.3	2.3-3.9	2.3
Elongation at Break (%)	4-35	15	---	---	20-30	110
Glass Transition Temperature(˚c)	75-103	85	-80	-125	85-210	150
Heat Deflection Temperature (@1.82MPa, 264PSI), (˚c)	70-90	70	---	---	115-135	131
Limiting Oxygen Index (%)	44-53	50	18	18	---	26
Maximum Temperature (Melting)(Solidus), (˚c)	175-190	175	131	112	260-290	---
Specific Heat Capacity Volumetric) (10^3 J/m³-K)	1100-1700	1200	2200	2100	1200-1300	1400
Stiffness to Weight, Tensile (MN-m/kg)	1.1-2	2.0	1.0	0.32	2.1-2.9	1.9
Stiffness to Weight, Flexural (KN-m/kg)	1.6-2.3	2.3	---	---	---	2.0
Strength to Weight Ratio, Tensile (KN-m/kg)	11-33	32	21	7.6	51-63	54
Tensile Strength (MPa)	14-50	45	20	7	55-85	65
Thermal Expansion: 20to100 ˚c (μm/m-K)	60	60	160	220	40-90	---

Table3. Six Sigma Matrix Analyses of Selected Materials

III. RESULTS

As per the proposal of the 'End Caps' placement for manual material handling, the top and bottom housing of the end caps was designed using Solid Works. While designing the end caps, ergonomic safety was kept in mind to ensure that laborers did not have any difficulty in handling the pumps after placement of the end caps.
Economy was one of the important aspects that was considered as the material to be used for the end cap design which had to be inexpensive enough for the industry. Hence, the Poly Vinyl Chloride material was suggested to the company for manufacture of end caps.

Fig.7 V4 Implementation (End cap placement)

This End cap design finally reported zero defects. Thus the productivity increased by around 43% and the threat level of 83% also got decreased by the suggested 'End Cap. Design'.

REFERENCES

1. John R. Grout, John S. Toussaint, "Mistake-proofing healthcare: Why stopping processes may be a good start" Elsevier and Sciencedirect.Com Business Horizons (2009) xxx, xxx—xxx [Article in press].
2. J R Grout, "Mistake proofing: changing designs to reduce error" Qual Saf Health Care 2006; 15 (Suppl I): i44–i49. doi: 10.1136/qshc.2005.016030

3. Robert F. Erlandson, Michael J. Noblett, and Judith A. Phelps “Impact of a Poka-Yoke Device on Job Performance of Individuals with Cognitive Impairments” IEEE Transactions On Rehabilitation Engineering, Vol. 6, No. 3, September 1998.
4. Cristóbal Miralles, Raymond Holt, Juan A. Marin-Garcia, Lourdes Canos-Daros “Universal design of workplaces through the use of Poka-Yokes: Case study and implications” JIEM, 2011 – 4(3):436-452 – Online ISSN: 2013-0953 – Print ISSN: 2013-8423
5. N.F. Treurnicht, M.M. Blanckenberg and H.G. van Niekerk “Using Poka-Yoke Methods To Improve Employment Potential Of Intellectually Disabled Workers” South African Journal of Industrial Engineering May 2011 Vol 22(1): 213-224
6. Arash Shahin, Maryam Ghasemaghaei, “Service Poka Yoke” International Journal of Marketing Studies Vol. 2, No. 2; November 2010 ISSN 1918-719X E-ISSN 1918-7203.
7. Anil S. Badiger, R. Gandhinathan, V. N. Gaitonde, Rajesh S. Jangaler, “Implementation of Kaizen and Poka-yoke to Enhance Overall Equipment Performance - A case study” Journal of manufacturing and industrial Engineering Pages: 24-29.
8. Yu Cheng Wong and Kuan Yew Wong “Approaches and practices of lean manufacturing: The case of electrical and electronics companies” African Journal of Business Management Vol.5 (6), pp. 2164-2174, 18 March, 2011
9. Tarcisio Abreu Saurin, José Luis Duarte Ribeiro,Gabriel Vidor "A framework for assessing poka-yoke devices" Journal of Manufacturing Systems xxx (2012) xxx–xxx [Article in press].
10. M. Dudek-Burlikowska, D. Szewieczek, “The Poka-Yoke method as an improving quality tool of operations in the process” Journal of Achievements in Materials and Manufacturing Engineering Volume: 36 Issue: 1 (Sept2009) Pages: 95-102.
11. Claudia Isac, Alin Isac "Considerations of Poka-Yoke Device in Total Quality Management", Annals of the University of Petroşani, Economics, 2 (2002), 34-38
12. Joanne M. Sulek and Mary R. Lind “Fail-Safe Methods for Paratransit Safety” Journal of Public Transportation, Vol. 8, No. 4, 2005
13. Farhana Ferdousi, “An Investigation of Manufacturing Performance Improvement through Lean Production: A Study on Bangladeshi Garment Firms” International Journal of Business and Management Volume: 4 Issue: 9 (Sept 2009).
14. Aguinaldo dos Santos and James Powell "Potential of Poka-Yoke Devices to Reduce Variability in Construction". Proceedings IGLC-7 26-28 July 1999, University of California, Berkeley, CA, USA
15. Omar Al-Araidah, Mohammad Abdel Kareem Jaradat, Wafa Batayneh "Using a fuzzy Poka-Yoke based controller to restrain emissions in naturally ventilated environments" Elsevier, Expert Systems with Applications 37 (2010) 4787–4795
16. Ramin Sadri, Pouya Taheri, Pejman Azarsa and Hedayat Ghavam, “Improving Productivity through Mistake-proofing of Construction Processes” 2011 International Conference on Intelligent Building and Management Proc .of CSIT vol.5 (2011) IACSIT Press, Singapore
17. Sanjit Ray, Prasun Das, “Improve Machining Process Capability By Using Six-Sigma” 5th International Quality Conference May 20th 2011 Center for Quality, Faculty of Mechanical Engineering, University of Kragujevac.
18. M.S.Desai, R.M.Warkhedkar, “Productivity enhancement by reducing adjustment time and setup change” International Journal of Mechanical & Industrial Engineering, Volume-1 Issue-1, 2011

19. O. Salem, J. Solomon, A. Genaidy, and M. Luegring, "Site Implementation and Assessment of Lean Construction Techniques" Lean Construction Journal 2005 Vol 2 # 2 October 2005 ISSN: 1555-1369.
20. Jaspreet Gill, "Quality follows quality: add quality to the business and quality will multiply the profits" The TQM Journal Vol. 21 No. 5, 2009 pp. 530-539 Emerald Group Publishing Limited 1754-2731 DOI 10.1108/17542730910983434.