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"IMPLEMENTATION OF SIX SIGMA IN TRANSFORMER MANUFACTURING INDUSTRY FOR PROCESS IMPROVEMENT"

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ABSTRACT

There has been an increasing awareness of the need to improve quality in the manufacturing sector during the previous two decades. **My Research Work** focuses on the improvement of quality of VPD (vapour phase drying) process in the transformer manufacturing company by the help of **SIX SIGMA DMAIC APPROACH**. The five stages of DMAIC are define, measure, analyze, improve and control. The goal of my research is to use the six sigma DMAIC approach to estimate and solve issues in the VPD process. Proposals for modifications that can be adopted in the organization to improve the efficiency of the manufacturing process are also offered. The focus of this case study is on the transformer manufacturing industry. Some SQC tools are used to examine the data, such as the Pareto graph, process map, FMEA, cause & effect diagram & checklists. The key faults in the VPD process detected and examined by the help of these SQC technologies. The root cause of the defect will be identified, and recommendations for improvement will be made. After the improvement stage, proposals for quality control should be made. It offers a consistent basis for resolving company problems by ensuring that processes are carried out correctly and successfully.

KEYWORDS: VPD, PARETO GRAPH, SQC, CHECKLIST.

1. CONCEPT OF SIX SIGMA:

One of easiest definition of **SIX SIGMA** is "It expects to improve quality by discovering defects, deciding their motivation, and improving cycles to build the repeatability and precision of interaction results. It is an approach and set of devices that assistance us measure what we do and afterwards improve what we do."

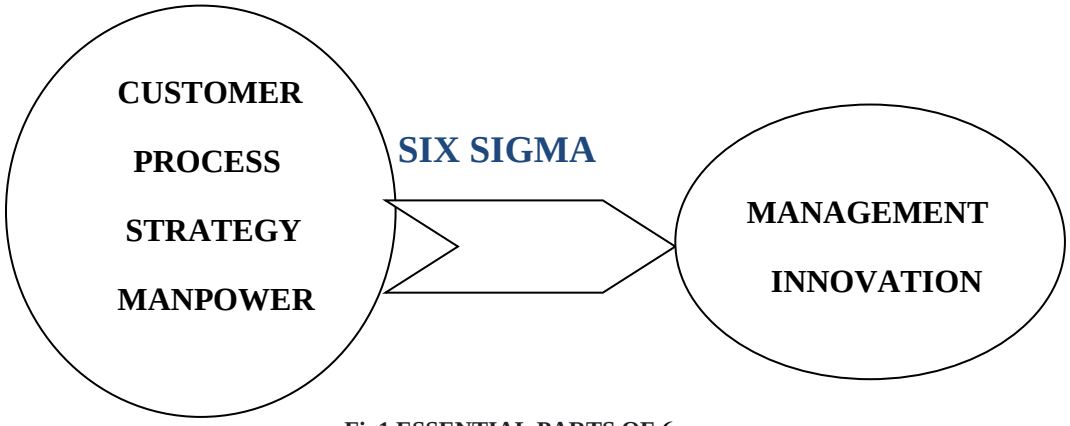

Fig1.ESSENTIAL PARTS OF 6σ

2. DIFFERENCE BETWEEN VARIOUS SIX SIGMA METHODOLOGIES:

SIX SIGMA comprises of two philosophies: **DMAIC** and **DFSS**. DMAIC technique used to improve existing business measures. DFSS technique is normally used to make new cycles and new items or products. DMADV and DFSS are basically similar cycles. DFSS means "Design for Six Sigma" and is simply one more name for DMADV.

DMAIC is more revolved around reacting, on perceiving and settling issues, while DFSS will overall be more proactive, a strategies a thwarting issue DMAIC is for products or services that the affiliation offers as of now; DFSS is for the arrangement of new products or services and cycles. DMAIC relies upon amassing or worth based cycles and DFSS is based on advancing, R& D, and plan. DMAIC approach can be implemented in any production process for minimizing defects. DMAIC identifies analyses and annihilates the root causes of imperfections simultaneously and in this manner assist with accomplishing prevalent degrees of value through improved efficiency.

3. SIX SIGMA TOOLS FOR QUALITY CONTROL:

The Seven Quality Control tools are graphical what's more, measurable instruments which are regularly utilized in QC for nonstop improvement. Since they are so generally used by pretty much every level of the organization, they have been nicknamed the **MAGNIFICENT SEVEN (7QC).** They are pertinent to upgrades in all components of the interaction execution triangle: variety of value, process duration and yield of efficiency. They are in alphabetical order, cause and effect diagram, check sheet, control outline chart, histogram, Pareto graph, scatter chart and stratification. In Six Sigma, they are broadly utilized in all periods of the improvement strategy: define, measure, analyze, improve and control (DMAIC).

i. CAUSE & EFFECT DIAGRAM:

A viable device as a feature of a problem solving process is the CAUSE & EFFECT DIAGRAM called the Ishikawa graph or fishbone graph. This method is valuable to trigger thoughts and advance a fair methodology in bunch meetings to generate new ideas where people list the apparent sources [**causes**] concerning results [**effect**].

ii. CHECK SHEET :

The check sheet is utilized for the particular data collection of any ideal attributes of a cycle that will be improved. It is regularly utilized in the control period of the Six Sigma DMAIC improvement procedure.

iii. CONTROL CHART:

Control chart offer the investigation of variation and its source. They can give monitoring, furthermore control, and can likewise provide guidance for upgrades. They can isolate exceptional from normal causes issues of an process.

iv. HISTOGRAM:

In the analysis period of the Six Sigma improvement approach, histograms are usually applied to find out about the distribution of the data inside the outcomes Ys and the causes Xs gathered in the measure stage and they are likewise used to acquire an agreement of the potential for upgrades.

v . PARETO GRAPH:

A method to develop a Pareto graph is as per the following:

1) Characterize the issue and process characteristics to utilize in the diagram.

2) characterize the timeframe for the chart – for instance, week after week, every day, or shift. Quality enhancements over time can later be produced using the data decided inside this progression.

3) Get the total number of times every trademark happened.

4) Position the attributes as indicated by the sums from stage 3.

5) Plot the no of occurrences of every trademark in diving request in a structured presentation alongside a cumulative percentage overlay.

6) Trivial columns can be lumped under one segment assignment; nonetheless consideration should be practiced not to preclude little however significant things.

vi. SCATTER PLOT:

The scatter plot is a helpful method to find the relationship between two variables, X and Y, i.e., the relationship. A significant highlight of the scatter plot is its perception of the connection design, through which the relationship can be resolved.

vii. STRATIFICATION:

Stratification is fundamentally utilized in the analyze stage to separate information in the look for special cause variety in the Six Sigma improvement philosophy. The main choice in utilizing Stratification is to decide the models by which to define. Models can be machines, material, providers, movements, day and night, age gatherings, etc.

4. WORKING OF SIX SIGMA CACULATOR:

Fundamentally, Six Sigma is the use of numerical formulas and strategies to eliminate absconds and product varieties. Six Sigma's point is to improve and build efficiency in the cycles (like how to address variety) and product. Make certain to keep these Six Sigma estimations and equations convenient when you have accumulated your information and start making your computations. There are some significant needs for any organization, like limiting costs, complying with time constraints, further developing availability, smoothing out cycles, and cutting waste. This load of assignments leads to the effective finishing of the task when performed accurately. The outcomes were positive and supported the organization's general presentation.

5. REVIEW OF PAST STUDIES:

A large number of research papers were found during this literature review that was specifically devoted to six sigma. These research papers generally discussed the DMAIC philosophy of six sigma in detail:

V.PRANAVI Et al. (2021)[1] paper presents Actuality based critical thinking utilizing DMAIC approach for minimizing defects in sheet metal work of art strip off imperfection in an undertaking to move toward six sigma quality level in a main MNC vehicle producer. DMAIC identifies analyses and annihilates the root causes driver of imperfections simultaneously and in this manner assists with accomplishing prevalent degrees of value through improved efficiency.

NISHANT BHASIN Et al. (2021)[2] paper presents a contextual analysis wherein the Six-Sigma idea was carried out in the improvement of the interaction of activity of an restaurant to meet the client assumptions and was examined to contemplate the effect.

MUHAMMAD HAMAD SAJJAD Et al. (2021)[3] currently examine, minimization of waste as far as sack rejection at a polypropylene bag fabricating method is accomplished. The Six Sigma DMAIC approach is received which results in half waste decrease and an impressive expense saving.

MANISH BHARGAVA Et al. (2021)[4] paper contains the Six-Sigma DMAIC approach that was utilized to diminish the cycle variety of inward and external races of ball bearing for improving product quality.

TEUN GRAAFMANS Et al. (2020)[5] literature gives the expected advantages of utilizing measure mining procedures in Six Sigma based interaction improvement drives. PMSS is helpful as a rule to help Six Sigma-based cycle improvement exercises.

6. RESEARCH OBJECTIVES:

The objective of my research work is to identify defects and to solve defects in the vapour phase drying (VPD) process with the help of six sigma DMAIC methodology in the transformer manufacturing industry. An inadequacy of vapour phase drying process is found to be a big problem in a transformer industry. The objectives of the present work can be listed as follows:

1. DMAIC methodology opens the market for the cost efficient drying for small power transformers as well as distribution power transformers with vapour phase drying technology.
2. To reduce the chances of failure of transformer .
3. Main focus on the quality improvement of vapour phase drying process.
4. To identify current problem and to reduce major problem in the VPD process with the help of Six Sigma DMAIC methodology.
5. Root causes for the problems will be determined and suggestions for improvement will be suggested.
6. To reduce the overall production cost of the transformers and increase efficiency.

7. VAPOUR PHASE DRYING PROCESS (VPD) IN A TRANSFORMER MANUFACTURING INDUSTRY:

The transformer is closed down and the high and low voltage bushings curve dismantled. Transformer oil is released into a capacity vessel. The transformer tank must be well heat protected. A heating tent must be put over the transformer tank. The trademark highlight of the dissolvable vapour to gather in favor on the coldest spots of the transformer makes great transformer tank protection totally essential. The vapour stage is associated with the transformer tank through adaptable tempered steel pipes. The fundamental segments of the VPD equipment displayed in Figure:

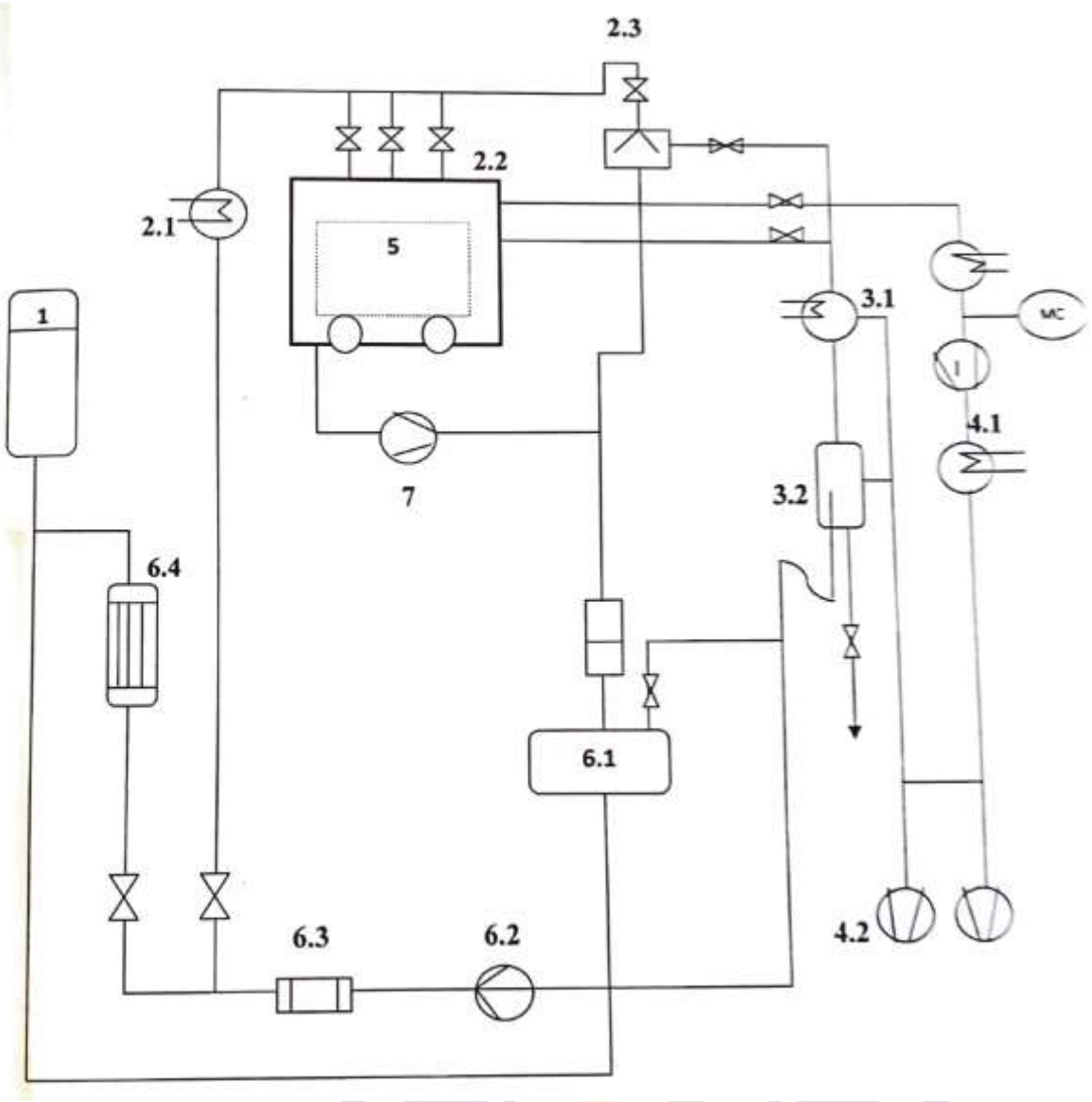

FIG 2. DESIGN OF VPD EQUIPMENT

1. STORAGE VESSEL FOR SOLVENT
2.1 HEAT EXCHANGER
2.2 EXPANSION VALVE WITH NOZZLES
2.3 DISTILLATION DEVICE
3. 1 MAIN CONDENSERS
3.2 WATER SEPERATING VESSEL
4.1VAPOUR PUMPING DIVISION
4.2 LEKAGE PUMP
5. TRANSFONNERS
6.1 CONDENSATE COLLECTING TANK
6.2 SOLVENT FEEDER PUMPS
6.3 SOLVENT FILTER
6.4 HEAT EXCHANGE DEVICE
7. OIL FEEDER PUMP
MC -PARTIAL PRESSURE

8. USE OF DMAIC METHODOLOGY IN VPD PROCESS:

Data compilation & interpretation is the main activity of CASE STUDY, which helps in computing the exhibition of organization. Data compilation is of prime significance were the all out number of deformities happened because of lacking of VPD process. This data are referenced as Pareto Chart. Data compilation Info is fundamental prerequisite of any case study. Different devices are utilized in Data compilation & interpretation which are given in the table.

STEP	AIMS	DESCRIPTION	TOOLS TO USE
DEFINE	What is the problem?	Develop a clear definition of project that includes identify the current problem in process that can be improvement are done.	1.1. Team Charter 1.2 Process Map (current process) 1.3 Pareto chart
MEASURE	How are we doing?	Analyze the process to identify the problem.	2.1 Fishbone diagram 2.2Measurement Analysis
ANALYSE	What is wrong?	Identify the root causes of the problem.	3.1Root cause analysis 3.2 Process Map (expected process)
IMPROVE	Fix the problem	Sufficient improvement actions to prevent defects from occurring .	4.1 Failure mode and Effect analysis
CONTROL	Maintain the gains and publish results	Control measures put in place to ensure results are achieved and maintained.	5.1 Checklists

TABLE 1. VARIOUS TOOLS USED IN DMAIC METHODOLOGY

8.1 DEFINE STAGE:

USE OF PARETO CHART-

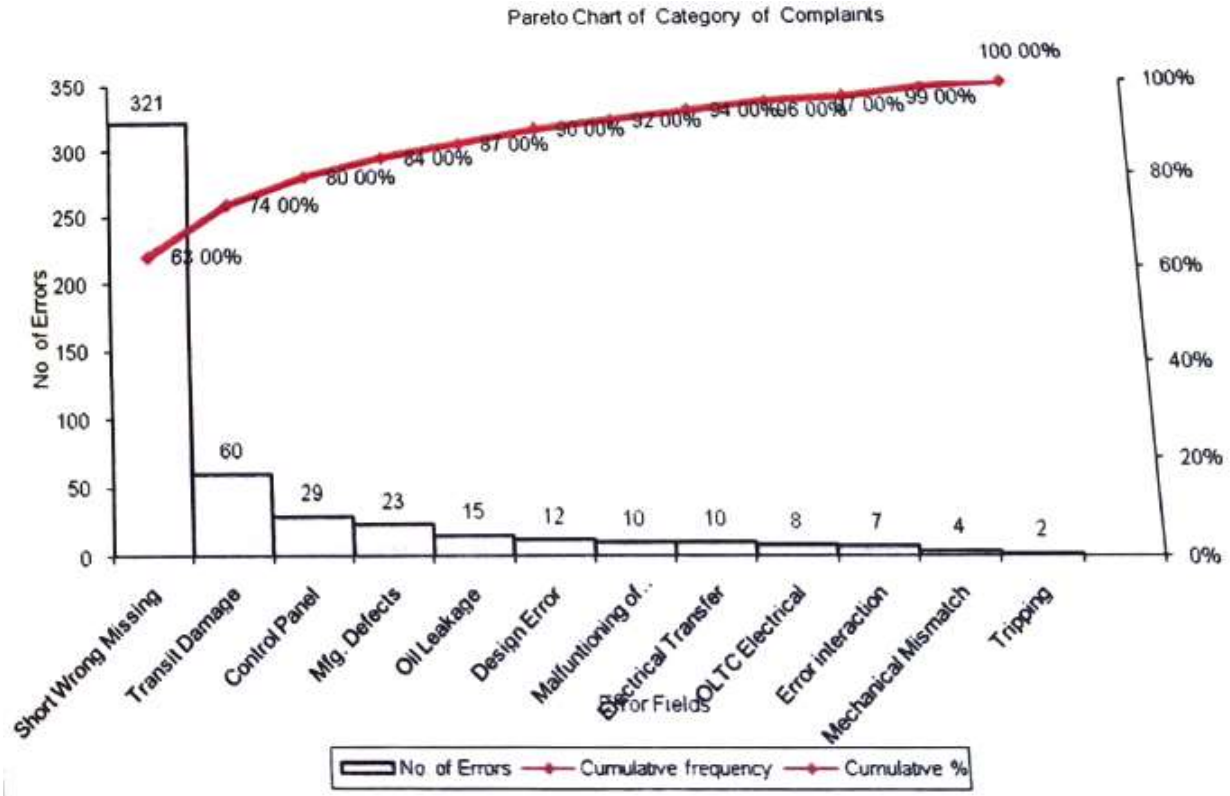

FIG3. PARETO CHART

8.2 MEASURE STAGE:

CALCULATION OF EET (EQUIVALENT EXPOSURE TIME)-

HUMIDITY (in%)		Equivalent Factor of humidity	Insulation temperature		Equivalent Factor of insulation temp.	Atmospheric temperature (in"C)		Equivalent Factor of atmospheric temperature
0	7	0.1	0	19	1.1	0	10	0.5
8	15	0.3	20	29	1.0	11	15	0.6
16	25	0.5	30	35	0.9	16	20	0.8
26	40	0.8	36	40	0.8	21	25	1
41	50	1.0	41	45	0.7	26	30	1.2
51	60	1.3	46	50	0.6	30	90	1.5
61	70	1.7	51	55	0.5	-	-	-
71	80	2.1	56	100	0.4	-	-	-
81	90	2.5	-	-	-	-	-	-

TABLE 2. CALCULATION TABLE FOR EET

8.3 ANALYZE STAGE:

USE OF CAUSE AND EFFECT DIAGRAM-

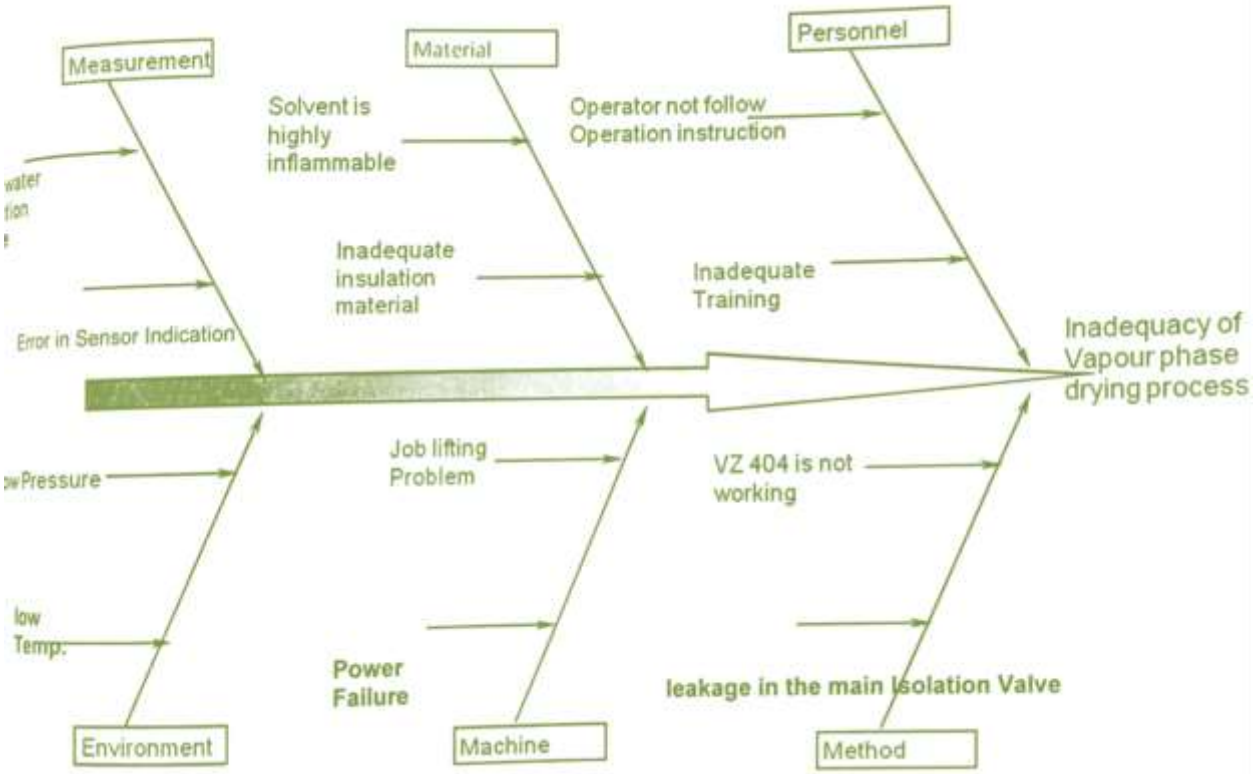

FIG.4 USE OF CAUSE AND EFFECT DIAGRAM FOR INADEQUATE VPD PROCESS

8.4 IMPROVE STAGE:

FMEA (FAILURE MODE AND EFFECT ANALYSIS)-

X's -DEFECTS	IMPROVEMENT STEP
X_1 - Malfunctioning of VZ404 (SPECIFIC WATER EXTRACTION RATE)	Rectification by Micafil representative
X_2- Deterioration of dissolved or Solvent Properties	Sample of solvent tested. No deterioration of solvent properties after 1st year of service
X_3 - wrong measurement of water extraction rate in IPL	i. Water measurement sensor to be changed ii. Water level measure scale to be changed & calibration
X_4- wrong entry of insulation weight	i. Insulation weight is 3 star point in checklist ii. Design style changed included in new checklist for vapour phase drying
X_5-Wrong Placement of Temp. Sensor	Involve in new checklist for Vapour phase drying (Visual display mode)

TABLE3. DEFECTS AND IMPROVEMENT ACTIONS REQUIRED

8.5 CONTROL STAGE:

USE OF CHECKLIST FOR MALFUNCTIONING OF SPECIFIC WATER EXTRACTION RATE-

SR. NO.	CHECK POINT	ACTIVITY	STATUS AND ACTION STEPS
1.	Whether there in any software related problem?	Checked position of flap of VZ404 Check phase found "closed" in place of "open" this issue solved in software	ok
2.	Whether there is leakage in main Isolation valve?	Checked , no leakage observed in main isolation valve	ok
3.	Observe VZ404 Reading of only vacuum line	i. Vacuum line isolated Autoclave and VZ404 process run should be zero. The reason is we were checking in isolation, but values observed in condenser 217 61, 26, 4.5, 13.9, 23.5 g/ht. so & 221 by 15/04/09 there is some wetness or moisture entry into vacuum line. ii. Flashing of Vacuum line done. But still moisture observed in Vacuum line.	i. Check function of VZ404 with next charge. ii. Leakage observed in condenser 217 by 04/04/2021

TABLE4. CHECKLIST FOR WATER EXTRACTION RATE

9.RESULTS & DISCUSSION:

Based on the findings in my case study, we can save a significant amount of money by using six sigma DMAIC approach in a vapour phase drying (VPD) process to eliminate 90% of these faults and the annual cost savings from these faults or defects is

6687 rupees. The use of DMAIC technique in the field of VPD process provides a number of benefits' over traditional drying methods, including:

i. Temperature homogeneity in a whole process.

ii. Reduced processing time.

iii. Better insulation dryness quality.

iv. The use of a microcontroller to regulate the whole process.

v. A set of measurements collected in order to estimate the EET for post-drying processes, such as incorrect water extraction in IPL, sensor indication mistake.

In this research, the transformer manufacturing sector implemented a Six Sigma DMAIC approach to address the problem and achieve quality sustainable growth with the following aims:

i. minimize performance issues

ii. Minimize moisture,

iii. Improve customer experience,

iv. and increase transformer lifespan.

Daily basis, there were 50 defects in the process. We can't keep track of every one of them, so we choose a random sample of ten per day & keep track of how many defects fall short to minimize the defect in the whole Process. We discovered that five of the ten issues result in a defect.

i. 10 defects were monitored in a sample.

ii.There were 50 defects in the population.

iii. Period of 5day (MONDAY TO FRIDAY) (elective)

Iv .The number of defects is five.

v. Openings per defect =1

vi. cost/defect=25/ (elective)

A six sigma calculator indicates that these 50 samples have 50 opportunities (a Procedure) and 25 defects, resulting in a DPMO of 500,000.This corresponds to a Z value of 0, & the 1.5 shift was added to happen at a process sigma of 1.5.

No of products in a sample	10	At least 30 for a sample
Total population from which a sample taken	50	
Duration of sample	22	Days monday to Friday(all working days) -5
Gross no of defects	5	Approx method if the counted defects≤5
No of opportunities for defect/ product	1	
Cost/defect (elective)	25	
Anticipated long term shift	1.5	Worst case short long term process shift
Data compilation over the	Very long duration	1.5 shift factor

Outcome	Current situation	90 percent defect reduction
Total opportunities	50	
Total defects	25	3
Defects/million opportunities	500000	50000
Sigma value :long term {performance}	0 applied LT Shift 0	1.65
Sigma value :short term {capability}	1.5 applied ST Shift 1.5	3.15
Defects /year	297	30
Cost of defects per year	7425	743

ANNUAL DEFECT COST SAVING= 6687 rupees

With 50 defects daily basis, we will observe 297 defects per year, at a cost of 7425 rupees. By adopting Six Sigma DMAIC methodology, PROJECT TEAMS eradicate 90percent of the overall of these defects; we will save a bunch of cost. Also the yearly economic benefits from defects are 6687 rupees.

10. CONCLUSION OF MY STUDY:

It has been discovered that using the Six Sigma DMAIC technique to improve the performance of the VPD process is quite advantageous. The insufficiency of the VPD process has been identified as a major issue in the Transformer manufacturing sector. Degradation of solvent characteristics, incorrect measurement of water extraction in IPL, incorrect entry of insulation weight, incorrect location of temperature sensor & other factors contribute to the inefficiency of the VPD process.SPC most effective tool Checklist can be used to assess problems like "Wrong situation of Temperature Sensor" in the vapour phase drying process.The water measurement sensor should be replaced as soon as possible to avoid the problem& the water level measurement scale needs to be adjusted and calibrated. In the meanwhile, this approach is being sought for the drying of new ultra highcapacityTransformers that must be constructed on the job instead of u sing of hot\air drying technology. This DMAIC approach provides the opportunity for costeffective drying for compact power transformers and distribution power transformers using VPD technique. By applying Control phase tools like checklists, we can increase the overall productivity of the production process. By applying tools of DMAIC methodology in my case study (VPD Process), defects can be removed up to great extent. We can save a great deal of money. There are many advantages of DMAIC methodology in vapour phase drying process over conventional drying process such as uniformity of temperature, reduction in process time, improved quality of dryness of insulation and effective process control through a microprocessor achieved.

11. FUTURE SCOPE OF WORK:

The six sigma improvement system was developed by Motorola in and from that point forward the examples of overcoming adversity of six sigma execution in large manufacturing units have been main stream. Yet there are very few little and medium scale manufacturing organizations who have taken advantages of this strategy. It is generally utilized in by manufacturing organizations. The six sigma strategy can likewise be use in similar organizations in different units & processes to target various issues and procure productive outcomes. This investigation will help in by making a base for additional improvement. For further progression the six sigma improvement system can be joined with lean a device which is called lean six sigma. This technique can be utilized to defeat the two strategies to make the cycle more normalized and mistake free.

My Research Work is to identify defects and to solve defects in only in **VPD Process** with the help of **six sigma DMAIC method** in transformer manufacturing industry, but there are still several avenues of research that need to be addressed. The following are some of the salient ones:

1.Most of the cases, industries are initiating their projects with DMAIC approach to improve performance of their existing processes rather than going for DFSS approach to design their new processes or products . We can adopt DFSS approach to design new processes.

2. Any other process rather than VPD process can be analyze by implementing DMAIC methodology.
3. The integration of Six Sigma with other methodologies is an important area for further study. Hence, further empirical study is suggested to enhance knowledge in this area by investigating the impact of potential integrations to identify key constructs.
4. It is necessary to carry out empirical exploratory research to determine the weaknesses of Six Sigma for which improved or additional tools are appropriate

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