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A comprehensive analysis of warehouse operations and product integrity management at Pon Pure Chem (P) Ltd., Chennai

Neha Uttam, Priyanka Verma, Aurobindo Parida

Abstract—In this paper, we study and address the some major supply chain and operational challenges at Pon Pure Chem (P) Ltd. Chemicals Co. Pon Pure Chem (P) Ltd. is a well-known chemical distribution company, which usually imports a large variety of chemicals from various countries and distributes them to customers in India. During this process, the aim of the company is to maintain the integrity of the chemicals with minimum loss during transporation and storage at the warehouse. The problems arise mainly due transporation of chemicals from sea port and storage at the warehouse. The study tracks the life cycle of the materials from the primary source of reception at port to the final point of selling to the customer. A complete study was done on various challenges and solutions were given with detail description. The problems were grouped in two categories: at operational level and at product integrity level. At operational level, time study was carried out to determine the standard time for the suitable utilization of human resources. The loss of volatile chemical compounds due to evaporation was another major issue. This issue was analysed by developing a stepwise backward regression model which could give information about the loss of chemicals in percentage. At product integrity level, the customer complaints were studied and then Pareto analysis, followed by Root cause analysis was conducted.

Index Terms—Supply chain, Distribution, Warehouse,Standard time, Human resources,Product integrity, Root cause analysis, Pareto analysis, stepwise backward regression.

1 INTRODUCTION

Pure Chemicals group is a leading chemical distributor. It is the twelfth largest distributor of chemical in Asia. This group has an experience of about three decades in trading and distribution of chemicals. It was founded by Mr. M. Ponnuswami in 1981. Since then, it is one of the most preferred chemical suppliers by both domestic and international customers. At present, the company has 25 offices and warehouses at various locations in India with more than 450 employees [1]. It also has overseas offices in Dubai, Sri Lanka, Australia, Kenya and Singapore. It imports chemicals from various countries and distribute them among its customers within India. It is having its own warehouses to store the chemicals. The whole process of transportation of chemicals is shown in the form of a flowchart (Fig.1).

One of the key elements of any supply chain and distribution system is the warehouses. The various roles of warehousing are storing products, controlling inventory, accommodating variability and providing a common delivery point to customers [2].Warehouses determine efficiency and effectiveness of a distribution network [3]. The major problems of warehouse operation are associated to these four major warehouse functions. For both design and operation of warehouse, performance evaluation is important. Baker and Canessa have identified works regarding the warehouse design [4]. Berg and Zijm showed the three types of warehouses: Distribution warehouse (products from various suppliers are stored and delivered whenever required), production warehouse (used to store raw materials and finished products) and contract ware house (on the behalf of customers) [5]. The performance

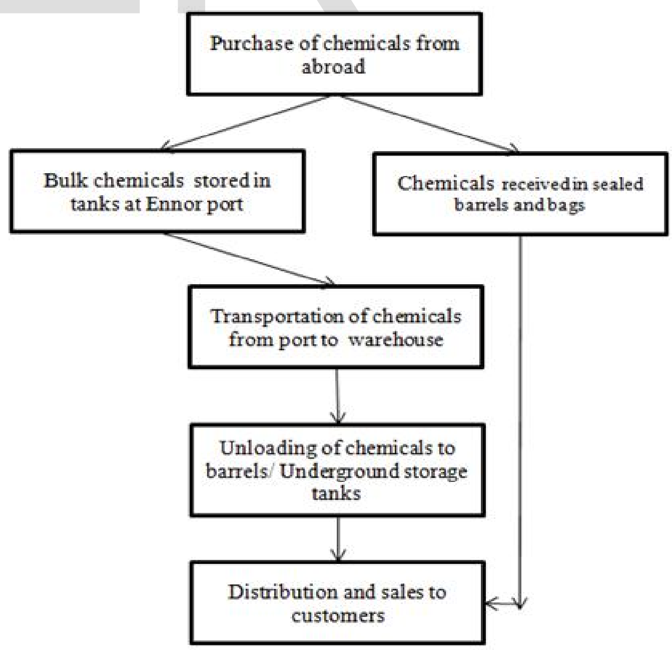

Fig.1. Flowchart for transportation of chemicals atPon Pure Chem (P) Ltd. Chemicals Co.

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of any warehouse can be evaluated in terms of service, throughput, space utilization, and cost. For performance evaluation, the approaches used are benchmarking, analytic models, and simulations [6]. Stop watch time study is generally used to eliminate the non value adding activities and hence to find the standard time.

The second major issue in chemical distribution is product integrity. Product integrity means product is to be delivered to customers at the same quality level as it was shipped from other countries. Customer expectations are satisfied by product integrity in every respect [7]. It should retain same attributes after handling at port and at warehouse as they had when they were first shipped from manufacturers. The meaning of product integrity is much broader as comparison to technical performance. Customer satisfaction is very important for any industry and this is also true for chemical distribution industry. Various quality control tools can be used for maintaining the integrity [8,9]. The challenge for any distribution company is to maintain the properties of the product as it is supplied by the manufacturer. It becomes more difficult in case of the chemical distribution.

The third major issue is faced in evaporation loss which is a major concern as it ultimately results in loss of compound and hence affects the cost. Chemical industries are more prone to evaporation loss as various chemicals are volatile in nature. If amount of evaporation loss is known, then methods to prevent it can be applied. The evaporation losses are calculated considering the inputs: wind speed, ambient temperature, type of the tank, type of seal and color of the tank [10]. Dobrota et al. discussed the problem of LNG (Liquefied natural gas) evaporation and its estimation [11].

This paper is divided into the various sections. In section II, we have described the problem addressed in the study. In section III, formulae used for the calculation are given. In section IV, Methodology adopted for this study is discussed. Section V consists of the results and discussion part. In section VI, we give recommendations, conclude and mention the future scope of our work.

2 PROBLEM DESCRIPTION

In this paper, we have studied mainly about transportation of chemicals and operations involved at the warehouse. Supply chain is efficient when it can supply right product to right customer at the right time. The major challenges identified in the supply chain of chemicals are: Time study, evaporation loss and product integrity.

It was observed during the warehouse operation study that ineffective utilization of man hours, poor availability of resources and no shift based work system are the major issues. To know the number of worker required, standard time is important. Standard time is defined as, "The time taken by an average skilled worker, to complete a particular job using a set method with a normal pace, considering the appropriate allowances". Standard time is used for planning (workforce and materials requirement), modeling, simulation, payments of wages, staffing, evaluating a worker and line balancing. Efficient use and allocation of resources is primarily based on correct estimation of standard time. Standard time can be estimated through the work measurement techniques such as work sampling method, stop-watch time study and predetermined time study. We have used stop watch time study to estimate the standard time due to unavailability of historical data, requirement of calculating time for major operations and there are repetitive works. By the help of time study, calculation of normal time and standard time for each of the operations is done to identify the bottlenecks and limiting factors. AtPon Pure Chem (P) Ltd. Chemicals, standard time for performing the operation was experience based before the conduct of this study. Operational level employees were challenging the time and the management was unable to measure accurate resource consumption, accurate measurement of productivity and utilization. Estimation of standard time sets the benchmark for an operator to perform a task. The emphasis is on the segregation of various activities during the life cycle of a product to come up with an optimum solution.

For the calculation of standard time, the following formulae are used [12].

Observed Time = $\sum$ ((Observed readings) / Number of observations)………………………………………………… (1)

Normal Time or Basic Time = Observed Time * Rating Factor…………………………………………………………….. (2)

Standard Time = Normal Time + Allowance..……………. (3)

Human Productivity = Total Output/Manpower…………. (4)

Total Required Time = (Required time/barrel)*Number of barrel + periodic time Set-up time…………………………… (5)

Number of Worker = Total Required Time/ Available Time…………………………………………………….……… (6)

Second major issue at thePon Pure Chem (P) Ltd. Chemicals is the operational and evaporation loss as volatile chemicals are handled. For evaporation loss calculation, a stepwise backward regression model is developed and validated to predict the percentage loss from the properties of the chemical and environmental-operational factors. Recommendations for reducing evaporation loss are given after identifying the critical factors impacting evaporation of the chemicals.

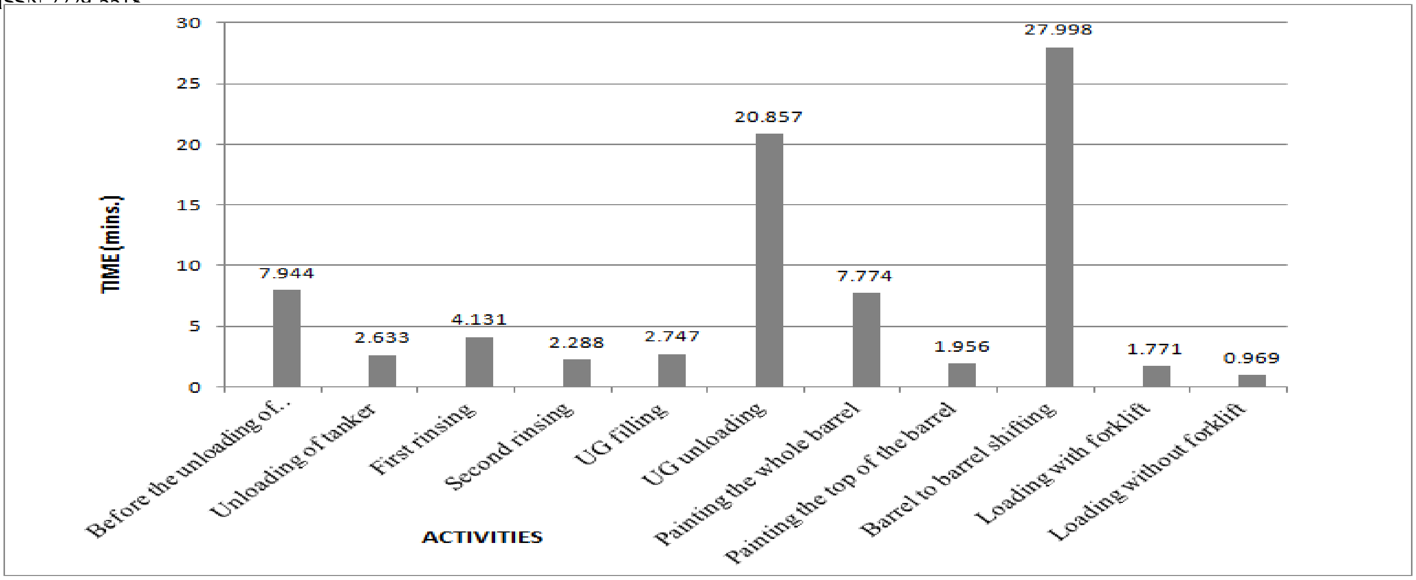

Fig.2. Average time for various activities

Quality deterioration (lack of maintenance of product integrity) is identified as a critical issue due to increasing number of consumer complains. Product integrity is having internal and external dimensions. Internal integrity means there is a match in product's function and structure. External integrity refers to a match in performance of the product and expectations of the customers. Product integrity is important as it shows how a customer is attracted to a product and get satisfied. It differentiates a successful company from an unsuccessful one. For this purpose, major sources of contamination are identified and recommendations to eliminate contamination are provided.

3 METHODOLOGY

This paper mainly focuses on the estimation of standard time, evaporation loss and product integrity in the supply chain of chemicals.

Estimation of standard time by stopwatch time study involves recording of operation followed by implementation of rating factor and allowances. This standard time is further used for calculation for required manpower. Evaporation loss is estimated by the factors which directly affect it. Backward regression analysis is done on historical data and developed regression equation.

Reason for loss in product integrity is identified by root cause analysis. Using frequency of occurrence of loss in integrity, Pareto chart is developed, so that focus can be directional. Then suggestion and recommendations are given accordingly.

A. Time study

Time study is done to calculate the average time for the major operations at the warehouse and finally standard time is calculated. For this purpose, the major operations in the warehouse are identified and segregated.

Major focus is on those operations in which repacking is required as in the case of liquid chemicals. The bulk chemicals are transported from the port to the warehouse in the tankers. From tankers it is unloaded to empty barrels or underground storage. During the whole process of the warehouse, the major operations identified are: Barrel unloading, loading, rinsing, underground filling, underground unloading, painting and barrel to barrel shifting. The average time for the various operations is shown in Fig.2.

After calculating the standard time, periodic work (repetitive work, which does not add any value to the product such set up time and tool change over time) is estimated in terms of time. Required workers are calculated and finally number of assigned workers and suggested workers are compared. 19 workers were assigned for various operations in the warehouse. The suggested workers were 17 as per calculation (Table 1). The number of workers which were correctly assigned, under loaded and overloaded is shown in the table. The available time for each of the worker was 450 minutes (excluding the allowances for lunch and tea break), in a day.

On the basis of information given by the warehouse and the calculated standard time, the total time engaged in each of the operations was calculated. The data for the three months of was used.

From the Fig.3, it is clear that first rinsing requires the maximum time. Loading without forklift and underground filling requires the minimum time. The workers which were required for the rinsing operation were overloaded and for loading operation were underloaded.

1: Calculation of number of workers

S.No.	Operations	Cycle Time (mins.)	Required worker	Assigned worker	Suggested worker	Remarks
1	Unloading of tanker-I	2.63	1.26	2	2	Correctly assigned
2	Unloading of tanker-II	2.63	1.28	2	2	Correctly assigned
3	Taking the barrel to filling area	0.66				
4	Rinsing	3.52	2.35	2	3	Overloaded
5	Draining	0.61	0.41	1	1	Correctly assigned
6	UG filling	2.75	0.58	2	2	Correctly assigned
7	UG unloading	4.90				Correctly assigned
8	Painting the whole barrel	7.77	0.78	1	1	Correctly assigned
9	Painting the top of the barrel	1.96	0.96	1	1	Correctly assigned
10	Barrel to barrel shifting	28.00	0.62	2	1	Underloaded
11	Unloading (Intact barrel)	1.99	0.35	2	2	Correctly assigned
12	Loading	1.77	0.79	4	2	Underloaded
Sum				**19**	**17**	

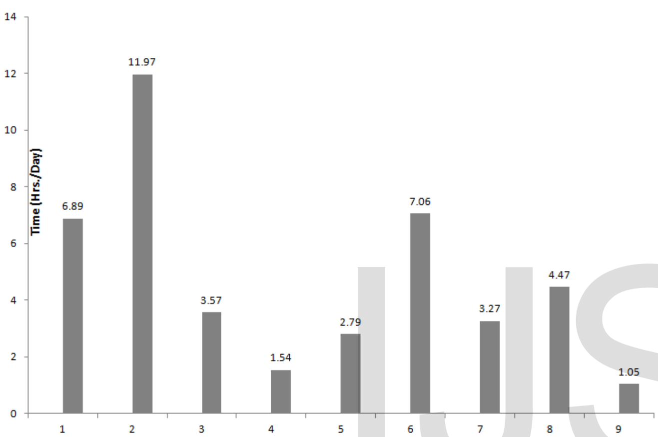

Fig.3. Time for various operations at warehouse

1: Unloading of tanker, 2: First rinsing, 3: Second rinsing, 4: UG filling, 5: Painting the whole barrel, 6: Painting the top of the barrel, 7: Barrel to barrel shifting, 8: Loading with forklift and 9: Loading without forklift

B. Product integrity

The customer complaints of last one year were used to find the major causes for the contamination. The customer complaints were divided into 5 major categories: Chemical reaction, testing problem, presence of foreign particles, rusting of barrels and planning. Then these complaints were analyzed by the help of Pareto analysis (Fig.4). From Pareto analysis, the first three categories were found as major causes of the customer complaints; which were responsible for about more than 80% of the customer complaints. Root cause analysis of all the major causes was done. The sub-causes of all the major categories were identified, further analyzed and finally suggestions were given.

From root cause analysis (Fig.5), it was found that main causes for the customer complaints were physical change, high content of certain components and presence of foreign particles. Physical change was due to improper handling, improper checking of barrels during procurement and insufficient storage conditions. There was the mismatch between the certificate of analysis of the supplier and the customer. Lack of proper flow of information among the various departments of the company also caused the problem. These two sub-causes resulted in high content of certain components which was undesirable in the chemicals. In the presence of foreign particles category, resin particles and moisture were the major factors, which were the result of non-segregation of coated and uncoated barrels at the storage area.

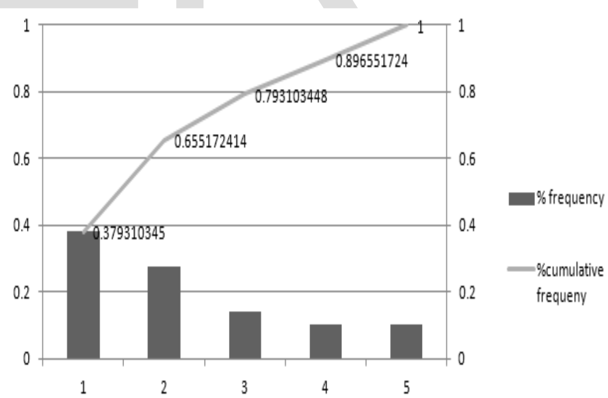

Fig.4.Pareto analysis of customer complaints

1: Chemical Reaction/Physical Change, 2: Testing Problem/High content, 3: Presence of Foreign particles, 4: Rusting of barrels and 5: Planning Problem

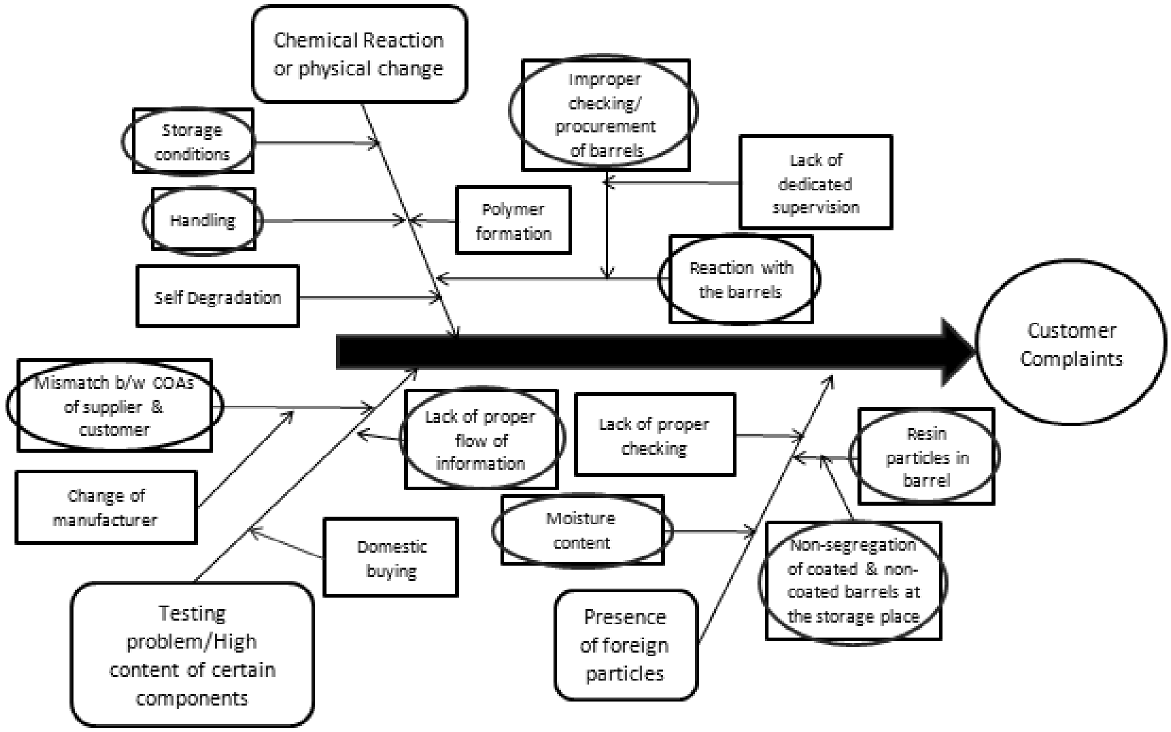

Fig.5. Root cause analysis

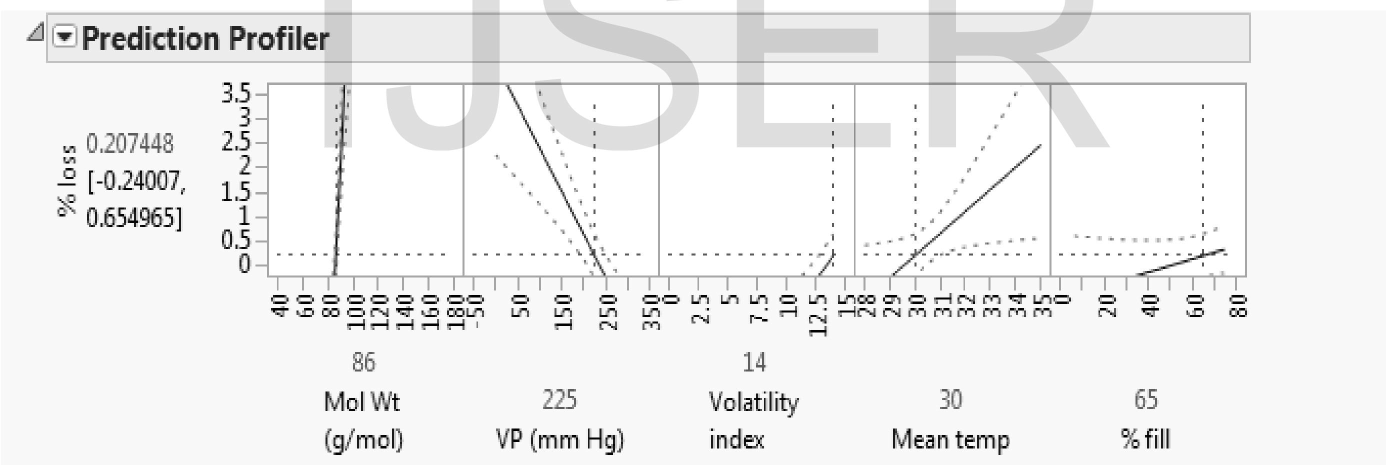

Fig.6. Prediction of % loss for hexane

C. Evaporation Loss

Evaporation loss of chemicals was a major concern at the warehouse. Exact information of evaporation loss was difficult to estimate. A backward stepwise regression model was developed to calculate the evaporation loss by considering the following inputs: molecular weight of the chemicals (mol/g), vapor pressure of the chemicals (mm Hg @ 250-350C), mean temperature on day of transport from port to warehouse, % fill in tanker, tanker volume and volatility index. The dependent variable is the % loss.

Example: Prediction of % loss for Hexane at temperature of 350^{o} C and 65% fill volume is 0.207448 as shown in the Fig.6.

Stepwise backward regression analysis on initial six independent factors resulted into five factors, which affect % loss due to evaporation. R-square with these five factors is shown in Fig.7.

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Summary of Fit

RSquare	0.87575
RSquare Adj	0.8012
Root Mean Square Error	0.291995
Mean of Response	0.523843
Observations (or Sum Wgts)	25

Fig.7. Summary for stepwise back regression model

4 RESULTS AND DISCUSSION

Based on the three problems considered, these are our findings:

In case of time study:

There will be increase in human productivity by 11.8 by reduction of two workers at the warehouse. This is clearly shown in the Fig.8.

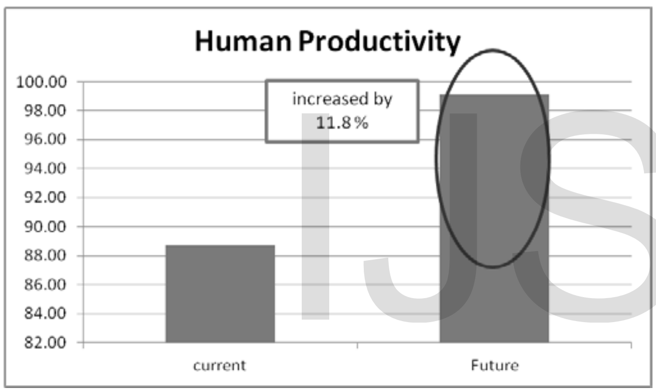

Fig.8. Increase in human productivity

In case of product integrity:

There will be the reduction of customer complaints by 72.5% (Decrease from 29 to 8). Eight are those which cannot be controlled in any case.

In case of evaporation loss:

It is clear from the graph that if exact R-square values can be found than actual percentage loss of evaporation can be calculated (Fig.9).

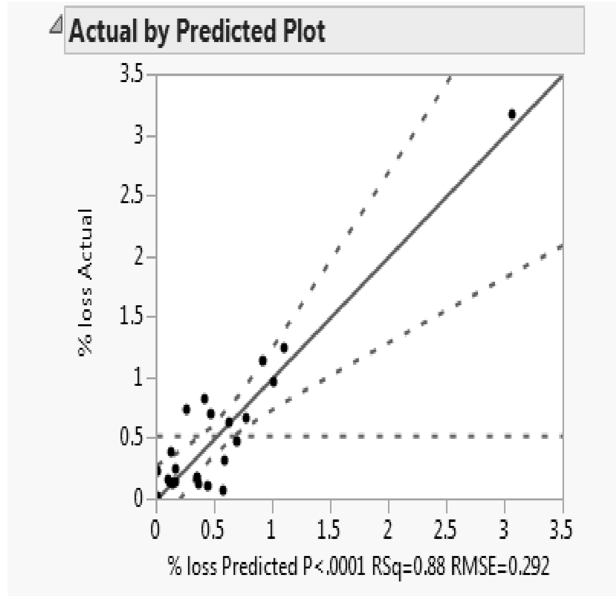

Fig.9. Actual vs. Predicted plot for backward regression

The equation for estimation of percentage loss by backward regression model is as follows:

$$\%Loss = -71.36 + 0.152Mt + 0.79vp - 7335i + 1.91T + 0.04533f + \{(Mt-100.0)+0.03504 \times (i-4.030)\} + \{(vp-80.41)+0.1021 \times (T-30.96)\} + \{(vp-80.41) + 0.0004079 \times (f - 63.76)\} + \{(i-4.030)-1.627 \times (T-30.96) \times (-1.627)\}$$

where,
Mt : Molecular weight (g/mol)
Vp : Vapor pressure (mm Hg)
T : Mean temperature (°C)
i : Volatility index
f : Percentage fill

Here, % loss is a dependent variable and rest variables are independent variables. This equation is valid for those chemicals which are having high volatility.

5 RECOMMENDATIONS, FUTURE SCOPE AND CONCLUSION

In this section, recommendations are discussed for all the three problems. In case of time study, the worker is shifted to avoid overloading for certain operations. For example: worker from loading operation (under-loaded operation) to rinsing operation (over-loaded operation), shown by Fig.10.

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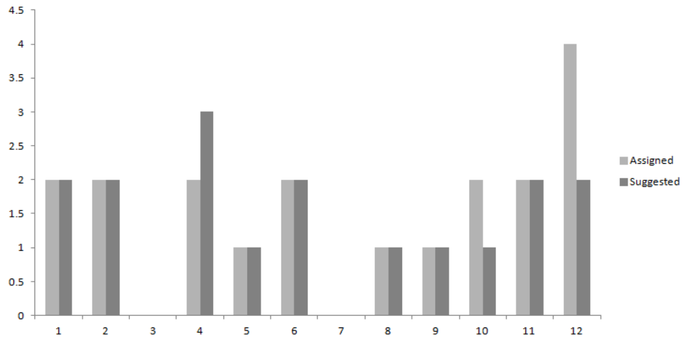

Fig.10. Number of worker

1: Unloading of tanker-I, 2: Unloading of tanker-II, 3:Taking the barrel to filling area, 4: Rinsing, 5: Draining, 6: UG filling, 7: UG unloading, 8: Painting the whole barrel, 9: Painting the top of the barrel, 10: Barrel to barrel shifting, 11: Unloading (Intact barrel) and 12: Loading.

Proper planning is required for the smooth and efficient work. There is the necessity to reduce the non value adding activities to increase the efficiency of the workers. Conveyor system can be used to transport the barrels from one place to another. It can reduce the time and increase the efficiency. Its safety aspect is to be studied. Benchmarking and training for the workers is required more frequently.

In case of product integrity, during inspection of barrel in rinsing operation top of barrel remain unchecked and become one of reason for contamination. To avoid this, spectrophotometric techniques should be used. Change in the physical properties of chemicals can be controlled by using separate pipes or cleaning of a pipe. Human error can be avoided by proper training, following of standard of procedures and monitoring. Improper checking of barrels can be controlled by dedicated supervision. Storage conditions can be improved by proper planning of capacity. Early dispatch of chemicals can also reduce the complaints.

Further the model for the calculation of evaporation loss can be validated by varying the input variables. Evaporation loss can be minimized by increasing the % fill in the tanker, by using proper sealing lids and proper handling.

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