Capstone Design Project
Stock Keeping Units Allocation for ICI Paints

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ABSTRACT

As part of our Capstone Design Project we will design the SKU (Stock Keeping Units) allocation system for the Imperial Chemical Industries (ICI) Paints Royal Warehouse located in Barrio Palmas, Cataño. In the manufacturing plant (located in Carolina) a productivity and efficiency analysis of the gallons (Latex & Solvent) filling lines will be performed in order to come with solutions to maximize time utilization and minimize customers complaints about the delivery of the orders. Moreover, we will be analyzing how the task design in the filling lines impact the operator's physical capabilities and health. We will search for any solution to minimize fatigue and eliminate as much as possible any potential hazard to the employees and ICI Paints property.

SINOPSIS

Como parte de nuestro proyecto de diseño, desarrollaremos la localización de los productos dentro del almacén de Imperial Chemical Industries (ICI) Paints localizado en "Royal Industrial Park", Cataño. En la planta de manufactura localizada en Carolina, se realizará un análisis de productividad y eficiencia de las líneas de llenado para evaluar y encontrar soluciones para maximizar la utilización del tiempo y minimizar las reclamaciones de los clientes en relación a la entrega de sus ordenes. Además, se estará analizando cómo el diseño de las operaciones en las líneas de llenado afecta las capacidades físicas del operador. Se buscarán soluciones para minimizar fatiga y eliminar en la medida que sea posible los riesgos potenciales que puedan afectar a los empleados y la propiedad de ICI Paints.

I- INTRODUCTION

The Imperial Chemical Industries (ICI) Group is one of the foremost chemical companies in the world with an impressive record in innovation. Reshaping activities in 1997 delivered a decisive shift into the specialty chemicals sector. The Group now consists of the following businesses: Coatings (Paints), Specialty Products (National Starch, Quest, Industrial Specialties), Materials (Acrylics and Polyurethane) and Industrial Chemicals (Chemicals and Polymers and a number of Regional Business).

The ICI Group has leading international positions in paints, industrial adhesives, specialty starches, specialty synthetic polymers, fragrances, flavors, food ingredients, specialty oleochemicals, polyurethane chemicals and systems, acrylics and chlorofluorocarbons (CFC) replacements.

This project will be developed in two of the major operation departments of ICI Paints Puerto Rico, Distribution and Manufacturing. In order to be loyal to a continuous improvement policy that the company has adopted, we will perform a productivity and efficiency analysis on the Latex (Water based products) and Solvent (Solvent Based Products) gallon filling lines to contribute to the system optimization. The analysis will consider both filling techniques (manual and automatic) and is going to be performed in the manufacturing plant located in Carolina, Puerto Rico. Also, on these lines we will be analyzing how the task are designed to determine if they fit with the operator capabilities, in order to reduce fatigue and eliminate any potential hazards to ICI most valuable asset: people. Also, as part of the company policy, the management decided to centralize its entire finished goods inventory in a new distribution center (Royal Industrial Park located in Cataño). In this new facility we will develop the SKU (Stock Keeping Units) locations for Banner, Glidden, Reliance and Superior brands. This design will emphasize on the minimization of the picker's (operators that pick/select the merchandize for its delivery) trips from the shipping point to the bays.

II- PROJECT DESCRIPTION

This project will be divided in two major parts, which are:

A- EVALUATION OF THE EXISTING FILLING LINES PROCEDURES

In the evaluation of the filling process we will perform a labor content analysis of the current manual and automatic filling process to determine all the activities involved in the filling of one gallon of either latex or solvent products. In order to provide a complete set of standards and recommendation to the ICI management, the following operations or procedures will be analyzed:

1- PR-016 **Transfer / Pigging line to fill (cleaning),** (Addendum # 1). This process establishes the necessary steps for the setup of the transfer lines.
2- PR-028 **Transfer line inspection** (Addendum # 2). Once the transfer line is clean, an inspection is performed to prevent product contamination.
3- Manual labeling of plastic and metal cans.
4- Manual market code, UPC (Universal Product Code) and Batch Number placing.
5- PR-017 **Automatic Gallons Filling (Solvent),** (Addendum # 3).
6- PR-019 **Gallons / Quarts Hand Filling** (Addendum # 4).
7- PR-000 **Automatic Label Placing.**
8- PR-000 **Automatic Gallons Filling (Latex).**

The product routing for an automatic fill of a latex gallon are built on drawings 509-EQ-042 (Addendum # 5) and 509-M-017 (Addendum # 6) revised 4-21-99. With this in mind, a time study using the snapback stopwatch for the manual operations and a work sampling for the automatic filling process will be performed. These techniques, which where learned in the Systems Design II course, are going to be used with the purpose of determining the actual filling process time.

Also, the work station design will be evaluated using the Recognizable Risk checklist of OSHA (Occupational Safety and Health Administration) to determine whether the task that the personnel is performing is safe or could represent a future injury or trauma.

Once all the data is collected, a set of recommendations is going to be issued for the evaluation of the ICI management.

B- DESIGN OF A NEW SKU LOCATION FOR ALL ICI PAINTS BRANDS

The SKU location system is going to be developed based on the June-99 annual sales forecast review provided by Mr. Jonathan Waite (Plant Manager) on June 2, 1999 (Addendum # 7). The system will be developed considering the following factors:

1- Brand
2- Volumes
3- Technology (Latex, Solvent)
4- Packaging Size (Gallons, Quarts and Pails)

III- OBJECTIVES

Our main objective for this senior design project is to present a complete and professional work to ICI Paints Puerto Rico management that represents the knowledge obtained from different topics learned throughout our industrial engineering studies. More over, an excellent organization and distribution of the matter will be applied to the reports and the presentations. This includes the application of the skills and techniques that will reflect our ability and preparation to perform future engineering tasks as professionals. With the results obtained from this project, ICI Paints of Puerto Rico will have additional and new information that will help them to improve their productivity and their methods, in order to provide a fast respond to the customer's demand and market globalization.

IV- PROJECT JUSTIFICATION

As result from our investigation and meetings with the ICI Paints management, we have found that some areas in the plant need to be improved. Also, to ensure an effective use of the space in the new warehouse, an SKU allocation system has to be developed.

The plant area where we will concentrate our study is in the gallon filling lines, which are not been used at their maximum capacity and the monthly production cannot be completed without working overtime. Some of the reasons that could be causing these problems would be the following:

1- Lines are not balanced.
2- Lack of standards for manual and automatic operations.
3- Lack of training to operators.
4- Insufficient personnel.

Due to these reasons, the lines have some breakdowns, long changeover times and long lead times.

Another condition to be evaluated that concerns the company management is the identification and elimination of potential hazards that the employees and operators can be exposed to.

The new warehouse facilities acquired by the company need a reliable SKU location system to simplify and optimize the space utilization. The company needs to accommodate all the products, that where usually kept in five different warehouses, into this warehouse.

V- METHODOLOGY

For the project development we will use different techniques from the Industrial Engineering field. The courses that present the techniques to be used are:

A- System Design II Course

1- Development of standard times for the filling line using the stop watch method (Snapback technique) for the manual operations.
2- Perform a work sampling of the automatic operations in the lines.
3- Analyze the collected data using the Dixon test to eliminate the points that are out of the control limits.
4- Assign causes to eliminate the points that are out of control.
5- Obtain the employee or operator's efficiency level using the Westinghouse Method.
6- Analyze the working conditions using the International Labor Office chart to determine allowances.

B- Human Factors Course

1- Utilization of the risk factor list (OSHA 1995 draft proposed ergonomic standard) to determine the operations that could represent a potential hazard for the employee's health.

C- Facility Planning and Layout Course

1- Design the allocation system for the Superior, Reliance and Banner (SRB) products that will be located in the new warehouse at the Royal Industrial Park in Cataño. The system design will be developed based on a 40 days product volume, product technologies (Latex or Solvent) and product sizes.

VI- HUMAN FACTORS

To identify problematic tasks and evaluate factors that could represent risks to the operator's health we have decided to apply the OSHA 1995 draft proposed ergonomic standards risk factor lists. The identification of problematic tasks is a process composed of two parts:

1- Educate or train the operators about muscle-skeletal disorders (MSD) and possible risk factors to which they could be exposed.
2- Identification and evaluation of the risk factors (if any) of the tasks made by the operators.

Once the problematic tasks are identified, the risk factors for each would be determined. In our case we decided to evaluate all the four operator's tasks in the filling and packaging line, so we should go directly to the risk factor lists.

The OSHA risk factors list consists of three check lists:

1- List A: for upper extremities (hands, wrists, arms, shoulders and neck).
2- List B: for back and inferior extremities.
3- List C: for carrying or material transport activities.

The steps to follow are the following:

1- Write down the general information required in the left-hand superior part of the first page.
2- If the operator executes more than one task, write down each task in the provided space.
3- Estimate the time that the operator will take to execute the task. If the operator executes more than one task, estimate the time to execute each task and separate it by risk factors associated with different work areas.
4- Circulate the risk factor punctuation. If the operator is exposed to the risk factor for more than 8 hours, circulate the value in the column D and add 0.5 for each additional hour.
5- In column F write down the selected value in column C or D and add the value of column E if necessary.
6- Repeat the same procedure for risk factor lists A and B.
7- Complete list C and then write down the result obtained in the space provided in list B.
8- Sum all the values of column F in lists A and B respectively. Write down the total for each list in the space provided.
9- If the value for lists A or B exceeds 5, conclude that the operator is in risk of MSD.
10- Independent of the total value of the lists, it is very important to identify the risk factors with higher values.

VII- PROCEDURE

The different operator tasks evaluated for this line are the following:

1- Take empty cans from the pallet to the turntable.

2- Fill the New Way machine with the paper labels.
3- Watch over Neupak machine and fill with caps the sealing machine.
4- Maintaining the boxes open while keeping the packing machine working.

The operations were videotaped and analyzed by our working group. Using the OSHA risk factor lists we found out that the following risk factors were present for each task:

Task 1 *- Take empty cans from the pallet to the turntable*

1- Upper extremity
   a) Pinch more than 2 pounds
   b) Elbow above mid-torso height
2- Back and lower extremity
   a) Severe forward bending of torso more than 45°
3- Manual handling
   a) Lift one-handed
   b) Lift between 1 to 5 times per minute
   c) Lift above the shoulder
   d) Lift below the knuckle

Task 2 *- Fill the New Way machine with the paper labels*

1- Upper extremity
   a) Pinch more than 2 pounds
   b) Elbow above mid-torso height
2- Back and lower extremity
3- Manual handling

Task 3 *- Watch over Neupak machine and fill with caps the sealing machine*

1- Upper extremity
   a) Pinch more than 2 pounds
   b) Elbow above mid-torso height
2- Back and lower extremity
3- Manual handling
   a) Lift one-handed

Task 4 *- Maintaining the boxes open while keeping the packing machine working*

1- Upper extremity
   a) Hard objects press into skin
   b) Localized vibration
2- Back and lower extremity
   a) Severe forward bending of torso more than 45°
3- Manual handling

The following result points were obtained for each of the three tables:

Table 1: *Results points*

Task #	A	B	C	B+C
1	4	2	**6**	**8**
2	4	2	0	2
3	4	0	2	2
4	2	4	0	4

Analyzing the results obtained from our tables we can conclude that the operator on our task #1 (take empty cans from the pallet to the turntable) is the only person in the whole line that is in great risk of MSD. This operator's task score in the tables is over 5 in both B-C (total back and lower extremity and manual handling). This means that we have to concentrate on this worker's task above all others and look for ways to modify and make this task safer. For the other tasks (which do not represent imminent danger to the operator) we will make some recommendations to make them more efficient.

VIII- WORK SAMPLING

L.H.C. Tipett first introduced the Work Sampling method in 1940 under the name of "ratio delay". This original application took place in the British textile industry. The method is based upon the laws of probability. A sample taken at random from a large group tends to have the same pattern of distribution as the large group or universe.

The work sampling procedure in its simplest form consists of making observations at random intervals of one or more operators or machines and noting whether they are working or idle. Analyzing the idle time we can calculate the Standard Time for the operation.

Our study was taken in the line for labeling, filling and packing of latex gallons for ICI Paints in Carolina. Since the whole line is automated, work sampling would be applied to analyze it. This study involves the basic steps for the implementation of the Work Sampling method.

IX- PROCEDURE

A- Selection of Area to be Analyzed

For this study we choose to evaluate the line for labeling, filling and packaging of latex gallons. We found out that this line was not producing to its entire capacity and we expect that with a few modifications and improvements the line would increase its productivity and lead times will be minimized.

B- Evaluation of Activities

The line consists of five (5) important activities or operations:

1- Labeling the gallons
2- Filling the gallons
3- Integrating the gallon handle
4- Packing four (4) gallons per box
5- Palletizing

These activities are all done by automated machines.

C- Preliminary Study

A preliminary study of two hours was taken with the Random Reminder set at 32 observations per hour. The total tally distribution for every activity is found on the next page. This table also provides the proportion and proportion percent for each activity based on the two hours analyzed.

D- Sample Size determination

Based on the data collected in the preliminary study we determined the sample size to study at a 95% of confidence level and 5% of accuracy. Since our preliminary study consisted in 64 observations, we used the normal distribution formula for this calculation:

$$N = \frac{Z^2_{\alpha/2}(1-P)}{E^2 P} \qquad [1]$$

where P is the proportion of downtime, which in this case would be 44% or 0.44. For a 95% of confidence level, $Z_{\alpha/2}$ would be 1.96. The formula would be as follows:

$$N = \frac{1.96^2(1-0.44)}{0.05^2(0.44)} = 1{,}976 \text{ observations}$$

= 62 hrs.
= 7.72 days

N = 8 days @ 32 observations/minute

The collected sample data is found on the following pages.

E- Calculation of Standard Times:

After all samples for the eight (8) days are taken we proceed to calculate the standard time per operation.

$$\text{Normal Time} = \text{TN} = \frac{\text{Total Time * Proportion}}{\text{Production}} \qquad [2]$$

$$\text{Standard Time} = \text{TE} = \frac{\text{Normal Time}}{\text{Allowance}} \qquad [3]$$

The production for this eight (8) days would be the following:

Production = 750 cans/hr.
8 hr. production = 6,000 cans
8 days production = **48,000 cans**

The total time for this production would be:

Total time = 2,048 observations
@ 32 observations per hour
= 64 hours
= **3,840 minutes**

The allowance for each machine in the line with two 15 minute breaks = 30 minutes

$$\text{Allowance Factor} = 1 - \frac{30\text{ minutes}}{480\text{ minutes}} = \mathbf{0.9375}$$

The proportions for each machine are:

$$\text{Proportion} = 1 - \frac{\Sigma \text{ Downtime observations}}{\text{Total observations}} \qquad [4]$$

Labeler machine $= 1 - \frac{1120}{2048} = \mathbf{0.453}$

Filler machine $= 1 - \frac{1103}{2048} = \mathbf{0.462}$

Bail-O-Matic machine $= 1 - \frac{1157}{2048} = \mathbf{0.484}$

Packer machine $= 1 - \frac{1182}{2048} = \mathbf{0.423}$

Palletizing machine $= 1 - \frac{1571}{2048} = \mathbf{0.233}$

The Standard Times for the machines are:

For the Labeler machine:

$$\text{TN} = \frac{(3{,}840\text{ min})(0.453)}{48{,}000\text{ cans}} = \mathbf{0.036\ min/can}$$

$$\textbf{TE} = \frac{0.036\text{ min}}{0.9375} = 0.039\text{ min/can} = \mathbf{2.32\ seg/can}$$

For the Filler machine:

$$TN = \frac{(3{,}840\,\text{min})(0.462)}{48{,}000\,\text{cans}} = 0.037\ \text{min/can}$$

$$TE = \frac{0.037\,\text{min}}{0.9375} = 0.040\ \text{min/can}$$

TE = 2.37 seg/can = 9.47 seg/4 cans [1]

For the Bail-O-Matic machine:

$$TN = \frac{(3{,}840\,\text{min})(0.484)}{48{,}000\,\text{cans}} = 0.039\ \text{min/can}$$

$$\textbf{TE} = \frac{0.039\,\text{min}}{0.9375} = 0.042\ \text{min/can} = \textbf{2.52 seg/can}$$

For the Packer machine:

$$TN = \frac{(3{,}840\,\text{min})(0.423)}{48{,}000\,\text{cans}} = 0.034\ \text{min/can}$$

$$TE = \frac{0.034\,\text{min}}{0.9375} = 0.036\ \text{min/can}$$

TE = 2.20 seg/can = 8.80 seg/box [2]

For the Palletizing machine:

$$TN = \frac{(3{,}840\,\text{min})(0.233)}{48{,}000\,\text{cans}} = 0.019\ \text{min/can}$$

$$TE = \frac{0.019\,\text{min}}{0.9375} = 0.021\ \text{min/can} = \textbf{1.26 seg/can}$$

TE = 5.04 seg/box = 151.20 seg/pallet [3]

F- Determination of the Line Downtime:

By the analysis and studies made to the line, we find the Packing machine to be the bottleneck for such line. Therefore, the line will have a downtime proportion of **0.577**.

[1] The filler machine fills 4 cans at a time.
[2] The packer machine packs 4 cans in one box.
[3] The palletizer machine palletizes 30 boxes.

X- RECOMMENDATIONS

The following are a series of recommendations made to the ICI Paints company for the gallon filling production lines.

A- Tasks

Task 1 *- Take empty cans from the pallet to the turntable*

With the use of a rotating pallet positioner, the operator controls the working height by a foot control. The perfect ergonomic height could be adjusted according to operator's body size and reach to prevent back injury that can be produced from improper bending and reaching. The operator could reach the empty cans more efficiently.

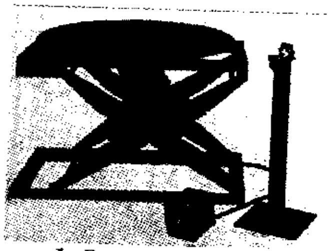

Figure 1: *Rotating pallet positioner*

The following risk factors would be eliminated:

1- Severe forward bending of torso more than 45°
2- Lift below the knuckle

With the use of a work platform some adjustments can be made in order to reach the ideal working height. Now the operator could be at the adequate height relative to the turn table.

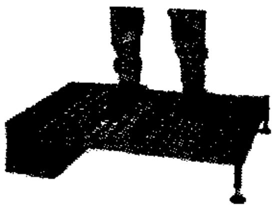

Figure 2: *Work platform*

The following risk factors would be eliminated:

1- Elbow above mid-torso height
2- Lift above shoulder

Task 2 *- Fill the New Way machine with the paper labels*

In a utility cart the paper labels could be kept at a reasonable height for the operator (not in top of the labeling machine).

The following risk factor would be eliminated:

1- Elbow above mid-torso height

Figure 3: *Utility cart*

The operator will be more comfortable sitting in a sit/stand stool while loading the labeling machine. The stool could be adjusted to the right sitting height.

Figure 4: *Sit/stand stool*

The following risk factor would be eliminated:

1- Squatting

Task 3 *- Watch over Neupak machine and fill with caps the sealing machine*

With the use of a work platform some adjustments can be made in order to reach the ideal working height. Now the operator could be at the adequate height to insert the caps in the sealing machine and, thus, reaching the inserting section with both hands.

The following risk factors would be eliminated:

1- Elbow above mid-torso
2- Lift one-handed

Task 4 *- Maintaining the boxes open while keeping the packing machine working*

The use of a floor pad could help minimize the localized vibration applied to the operator by the machine and relieve the stress caused to the lower back while standing for a long period of time.

B- Data Analysis

The following series of recommendations to the company are made based on data taken and analysis made for the labeling, filling and packing of latex gallons production line.

We recommend having only three operators working in the entire line. We need one operator in each of the following machines: Labeler, Filler and Packer. There is no need for any additional personnel because it is unnecessary and it will incur extra costs for the company.

Rotating personnel to different machines will help the operators develop skills and understand the procedures for different machines, thus helping to know and understand the whole production process. With this rotation the operator will not be exposed to the same physical stresses and monotonous work during the entire shift.

The turntable should be used at all times.

The operators in charge of the labeler and filling machines should be trained adequately in order to attend efficiently any breakdowns and emergencies without the need to wait for technicians and plant managers to solve the problem.

Have the buffer in front of the line constraint (between the Filler and Bail-O-Matic machines) filled and prepared to keep the next machines working.

XI- CONCLUSIONS

The recommendations made for the different tasks performed by the operators will definitively help minimize health risks. Some risk factors will be eliminated and the operators would be dealing with safer tasks. A list of solutions that would eliminate some risk factors is included as part of the recommendations. If we were to evaluate these different tasks using the OSHA 1995 draft proposed ergonomic standards risk factor lists, integrating the recommendations given we would obtain the following result points on the tables:

Table 2: *Result points*

Task #	A	B	C	B+C
1	2	0	3	3
2	2	0	0	0
3	2	0	0	0
4	2	4	0	4

Comparing this table with the original table we could clearly see the improvements that would be obtained by integrating our recommendations to each task.

By applying the Work Sampling methodology we calculated standard times for each machine and determined the downtime for the whole line. Based on this analysis made we made a series of recommendations to the company. The application of such recommendations will help minimize machine breakdowns, changeover times and lead times and will make the process run smoother and more efficiently.