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Appraisal of Manufacturing Process and Product Specification by Numerical Approach

C.C. Ihueze and P.C. Onyechi

Department of Industrial /Production Engineering,
Nnamdi Azikiwe University, P.M.B. Awka, Anambra State, Nigeria

Abstract: Four parameters, viscosity, P^H, specific gravity and solid content of Peatone Green Emulsion paint produced in Nigeria were measured for three year monthly production of the company in order to establish the extent of the process control. Control charts, X-chart, R-chart and S-chart were constructed for the parameters under investigation. On the average all the charts show process out of control. We recommend that the company should have an established standard for controlling the quality of their products and for testing for monthly variations. With the control limits established for each of the parameters in this work, the management of this company can effectively and efficiently control the quality of Peatone Green Emulsion paint, if and only if they can adopt it as a standard. It was also observed that both the theoretical process capability and actual process capability is less than unity respectively, the production process is therefore out of control and the process must be stopped for proper appraisal of the process for assignable causes of variation.

Key words: Manufacturing process · P^H value · Control limits · Viscosity · Solid content · Quality control

INTRODUCTION

The use of quality control in a great diversity of manufacturing plants is enough to convince us that no manufacturing business is so different so as not to be able to make effective use of statistical techniques [1]. Variation in product quality is inevitable and wherever variation may exist, statistical quality control could be expected to be useful. However, a good knowledge of the basic concept of statistical quality control is likely to be required for a successful application of the techniques. The word "quality" is the extent to which products; services, processes and relationship are free from defects, constraints and items, which do add value to customers. In this context, when used technically, it refers to some measurable properties of products such the outside diameter of a ball bearing, the bearing strength of an exercise book, the potency of a drug etc. since paint production is a continuous production process and also produced in batches, we are concerned with the measurement of four major parameters, which are indispensable in the production of quality paint [2].

It is necessary to be conversant with some terms like Paint which according to [3], are products containing pigment(s) in liquid or powdered form, for which when applied in substrate form, after some times, an adherent opaque film having protective, decorative or technical properties appears, Viscosity which is a name given to internal friction, which exists between the layers of a liquid or gas in motion, Specific Gravity which is currently known as relative density, Solid Content which is the percentage of non-volatile matters of the paint and P^H (acidity or alkalinity) which is the measure of acidity or alkalinity of paints or other substances.

Before 1942, most statistical quality control applications were mainly in certain plants in the electrical manufacturing industries and the textile industry and the production of ammunition in certain governmental arsenals. Also by 1942 and thereafter, the suggestion was made that this method be applied to other sectors of industries. The first reaction by production engineers and management personnel was "but our business is different". Later, the idea were welcomed and seen as inevitable tool for efficient production [4].

Corresponding Author: C.C. Ihueze, Department of Industrial /Production Engineering, Nnamdi Azikiwe University, P.M.B. Awka, Anambra State, Nigeria. Tel: 08037065761,
E-mail: cc.ihueze@unizik.edu.ng, ihuezechukwutoo@yahoo.com.

Indeed, many researches have been carried out in quality control but not in Golden Emulsion Paint of Nigeria Limited hence this study whose research results will apply to similar industries.

Data Collection and Presentation: The data used for this research work is a secondary data collected from the company's quality control department. The data used here are monthly data collected from the company, recorded during their monthly production. Five samples randomly sampled each month for their respective parameters: solid content, viscosity, P^H (acidity or alkalinity) and specific gravity. The samples as were collected are presented below.

To check whether the production process was under control during the period for which this data was collected, the usual statistical methods for constructing x-chart, r-chart and s-chart will be employed in plotting the graphs for the four test parameters; specific gravity, P^H(acidic or alkalinity), viscosity and solid content.

These parameters are collected, five (5) samples monthly for three years; from January 2004 to December 2006 and used for control charts.

Production Data and Construction of Control ChartsMeasured and Computed Data Tables and Control Charts: The evaluated data for the construction of control charts are as shown in table 1.

Table 1: Computed Data for Control Charts

	2004 Samples for Specific Gravity							
Sample Number	1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	1.25	1.27	1.24	1.26	1.27	1.258	0.03	1.7
FEB	1.24	1.25	1.24	1.27	1.26	1.252	0.03	1.7
MAR	1.27	1.27	1.28	1.27	1.28	1.274	0.01	0.3
APR	1.25	1.27	1.27	1.26	1.25	1.260	0.02	1
MAY	1.23	1.26	1.23	1.27	1.24	1.246	0.04	3.3
JUNE	1.29	1.3	1.3	1.28	1.29	1.292	0.02	0.7
JULY	1.26	1.28	1.25	1.25	1.27	1.262	0.03	1.7
AUG	1.25	1.22	1.26	1.25	1.25	1.246	0.04	2.3
SEP	1.28	1.39	1.27	1.27	1.28	1.298	0.12	26.7
OCT	1.29	1.3	1.3	1.31	1.3	1.3	0.02	0.5
NOV	1.3	1.28	1.28	1.31	1.29	1.292	0.03	1.7
DEC	1.25	1.27	1.26	1.26	1.25	1.258	0.02	0.7
	2005 Samples for Specific Gravity							
Sample Number	1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	1.32	1.29	1.29	1.28	1.3	1.296	0.04	2.3
FEB	1.24	1.26	1.26	1.24	1.27	1.254	0.03	1.8
MAR	1.26	1.25	1.23	1.27	1.25	1.252	0.04	2.2
APR	1.28	1.27	1.26	1.27	1.27	1.270	0.02	0.5
MAY	1.25	1.27	1.24	1.25	1.26	1.254	0.03	1.3
JUNE	1.27	1.25	1.26	1.25	1.26	1.258	0.02	0.7
JULY	1.27	1.22	1.25	1.28	1.26	1.256	0.06	5.3
AUG	1.29	1.25	1.29	1.27	1.27	1.274	0.04	2.8
SEP	1.3	1.27	1.28	1.27	1.29	1.282	0.03	1.7
OCT	1.3	1.32	1.3	1.28	1.31	1.302	0.04	2.2
NOV	1.31	1.28	1.26	1.29	1.26	1.280	0.05	4.5
DEC	1.26	1.28	1.27	1.25	1.27	1.266	0.03	1.3
	2006 Samples for Specific Gravity							
Sample Number	1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	1.24	1.3	1.3	1.29	1.32	1.290	0.08	9.0
FEB	1.33	1.34	1.37	1.28	1.29	1.322	0.09	13.7
MAR	1.29	1.29	1.28	1.26	1.29	1.282	0.03	1.7
APR	1.27	1.28	1.28	1.28	1.24	1.270	0.04	3
MAY	1.28	1.25	1.24	1.29	1.29	1.270	0.05	5.5
JUNE	1.29	1.28	1.28	1.27	1.27	1.278	0.02	0.7
JULY	1.25	1.25	1.27	1.29	1.28	1.268	0.04	3.2
AUG	1.27	1.28	1.29	1.27	1.27	1.276	0.02	0.8
SEP	1.3	1.31	1.32	1.24	1.24	1.282	0.08	15.2
OCT	1.34	1.33	1.3	1.29	1.29	1.310	0.05	5.5
NOV	1.29	1.32	1.32	1.34	1.36	1.326	0.07	6.8
DEC	1.32	1.33	1.35	1.37	1.3	1.334	0.07	7.3

Sample Number	2004 Samples for pH 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	8.2	8.19	8.2	8.18	8.18	8.190	0.02	1
FEB	8.16	8.15	8.19	8.15	8.15	8.160	0.04	3
MAR	8.13	8.16	8.15	8.17	8.14	8.150	0.04	2.5
APR	8.19	8.15	8.16	8.14	8.16	8.160	0.05	3.5
MAY	8.14	8.14	8.17	8.17	8.17	8.158	0.03	2.7
JUNE	8.18	8.16	8.16	8.16	8.13	8.158	0.05	3.2
JULY	8.12	8.19	8.2	8.16	8.13	8.160	0.08	12.5
AUG	8.15	8.15	8.14	8.18	8.15	8.154	0.04	2.3
SEP	8.2	8.09	8.13	8.16	8.17	8.150	0.11	17.5
OCT	8.14	8.18	8.1	8.14	8.12	8.136	0.08	8.8
NOV	8.17	8.15	8.15	8.14	8.16	8.154	0.03	1.3
DEC	8.08	8.1	8.16	8.13	8.13	8.120	0.08	9.5

Sample Number	2005 Samples for pH 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	8.2	8.18	8.17	8.2	8.19	8.188	0.03	1.7
FEB	8.17	8.12	8.16	8.15	8.15	8.150	0.05	3.5
MAR	8.16	8.19	8.14	8.17	8.16	8.164	0.05	3.3
APR	8.2	8.21	8.19	8.15	8.17	8.184	0.06	5.8
MAY	8.15	8.2	8.21	8.17	8.2	8.186	0.06	6.3
JUNE	8.17	8.19	8.15	8.19	8.19	8.178	0.04	3.2
JULY	8.18	8.17	8.2	8.21	8.21	8.194	0.04	3.3
AUG	8.2	8.15	8.21	8.17	8.19	8.184	0.06	5.8
SEP	8.17	8.15	8.16	8.2	8.17	8.170	0.05	3.5
OCT	8.21	8.22	8.2	8.19	8.16	8.196	0.06	5.3
NOV	8.19	8.2	8.21	8.19	8.22	8.202	0.03	1.7
DEC	8.2	8.22	8.18	8.2	8.21	8.202	0.04	2.2

Sample Number	2006 Samples for pH 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	8.21	8.2	8.18	8.22	8.2	8.202	0.04	2.2
FEB	8.18	8.16	8.17	8.17	8.21	8.178	0.05	3.7
MAR	8.2	8.17	8.16	8.19	8.16	8.176	0.04	3.3
APR	8.16	8.18	8.22	8.23	8.23	8.204	0.07	10.3
MAY	8.15	8.16	8.19	8.2	8.15	8.170	0.05	5.5
JUNE	8.14	8.14	8.16	8.13	8.13	8.140	0.03	1.5
JULY	8.17	8.17	8.17	8.19	8.2	8.180	0.03	2
AUG	8.19	8.19	8.15	8.17	8.2	8.180	0.05	4
SEP	8.2	8.2	8.2	8.16	8.22	8.196	0.06	4.8
OCT	8.14	8.21	8.3	8.18	8.18	8.202	0.16	36.2
NOV	8.15	8.2	8.2	8.17	8.17	8.178	0.05	4.7
DEC	8.2	8.23	8.34	8.35	8.21	8.266	0.15	53.3

Sample Number	2004 Samples for Viscosity 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	43	42	46	49	43	44.60	7	8.3
FEB	44	43	46	42	45	44.00	4	2.5
MAR	46	47	47	44	45	45.80	3	1.7
APR	42	43	40	45	43	42.60	5	3.3
MAY	43	42	45	46	44	44.00	4	2.5
JUNE	45	44	43	44	45	44.20	2	0.7
JULY	42	43	45	46	42	43.60	4	3.3
AUG	43	40	41	43	40	41.40	3	2.3
SEP	43	44	42	41	46	43.20	5	3.7
OCT	44	42	44	41	44	43.00	3	2
NOV	45	45	43	40	46	43.80	6	5.7
DEC	43	45	41	44	42	43.00	4	2.5

Sample Number	2005 Samples for Viscosity 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	40	42	43	41	45	42.20	5	3.7
FEB	42	40	43	45	42	42.40	5	3.3
MAR	45	47	44	44	48	45.60	4	3.3
APR	43	45	41	40	44	42.60	5	4.3
MAY	44	47	45	42	45	44.60	5	3.3
JUNE	42	43	41	45	41	44.40	4	2.8
JULY	42	40	42	43	41	41.60	3	1.3
AUG	43	42	41	48	45	43.80	7	7.7
SEP	40	44	42	43	41	42.00	4	2.5
OCT	42	46	43	43	45	43.80	4	2.7
NOV	44	40	40	43	41	41.60	4	3.3
DEC	44	45	47	43	45	44.80	4	2.2

Sample Number	2006 Samples for Viscosity 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	41	43	42	41	44	42.20	3	1.7
FEB	45	45	41	42	43	43.20	4	3.2
MAR	46	41	42	43	44	43.20	5	3.7
APR	42	42	44	47	48	44.60	6	7.8
MAY	43	45	47	46	47	45.60	4	2.8
JUNE	41	41	43	44	45	42.80	4	3.2
JULY	44	44	41	45	47	44.20	6	4.7
AUG	41	42	45	47	48	44.60	7	9.3
SEP	42	43	43	44	45	43.40	3	1.3
OCT	45	45	42	41	42	43.00	4	3.5
NOV	41	41	42	42	45	42.20	4	2.7
DEC	46	47	48	49	45	47.00	3	2.5

Sample Number	2004 Samples for Solid Content 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	50	52	51	54	52	51.80	4	2.2
FEB	49	50	52	48	50	49.80	4	2.2
MAR	51	52	48	51	53	51.00	5	3.5
APR	52	51	50	50	52	51.00	2	1
MAY	51	54	49	49	54	51.40	5	6.3
JUNE	52	51	53	50	53	51.80	3	1.7
JULY	51	50	50	51	51	50.60	1	0.3
AUG	53	52	50	51	53	51.80	3	1.7
SEP	51	52	50	49	50	50.40	3	1.3
OCT	40	50	52	50	51	48.60	12	23.8
NOV	51	51	51	49	50	50.40	2	0.8
DEC	52	51	52	52	52	51.80	1	0.2

Sample Number	2005 Samples for Solid Content 1	2	3	4	5	Mean	Range	Variance S^2*10^{-4}
JAN	51	52	50	53	52	51.60	3	1.3
FEB	50	54	51	52	51	51.60	4	2.3
MAR	54	50	50	51	50	51.00	4	3
APR	53	51	53	53	51	52.20	2	1.2
MAY	52	49	51	49	50	50.20	3	1.7
JUNE	53	55	50	51	54	52.60	5	4.3
JULY	49	49	50	53	51	50.40	4	2.8
AUG	50	49	52	53	53	51.40	4	3.3
SEP	51	52	50	51	54	51.60	4	2.3
OCT	50	50	50	54	49	50.60	5	3.8
NOV	52	49	50	52	51	50.80	3	1.7
DEC	52	53	48	48	49	50.00	5	5.5

	2006 Samples for Solid Content							Variance
Sample Number	52	51	51	52	50	Mean	Range	$S^2 * 10^{-4}$
JAN	50	50	51	53	52	51.20	2	0.7
FEB	49	50	50	52	51	51.20	3	1.7
MAR	49	53	49	50	52	50.40	3	1.3
APR	53	52	51	53	49	50.60	4	3.3
MAY	50	51	51	53	50	51.60	4	2.8
JUNE	53	51	52	51	52	51.00	3	1.5
JULY	51	50	49	50	49	51.80	2	0.7
AUG	53	54	51	52	53	49.80	2	0.7
SEP	54	51	52	54	51	52.60	3	1.3
OCT	49	49	51	52	51	52.40	3	2.3
NOV	54	50	51	51	51	50.40	3	1.8
DEC	52	53	48	48	49	51.40	4	2.3

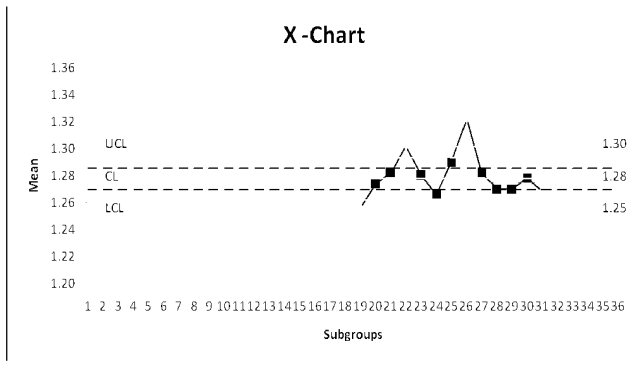

Fig. 1a: The X – chart for specific gravity shows the mean specific gravity of 1.28 with upper and lower limits of 1.30 and 1.25 respectively. The X – chart shows that production of the months of May and August of 2004 were out of control with production of Feb, 2006.

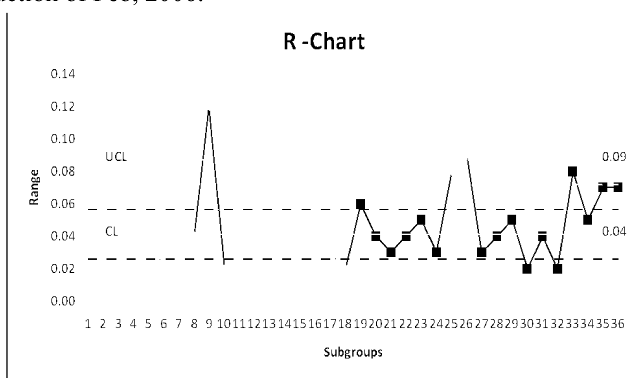

Fig. 1b: The R – chart for specific gravity shows mean range of 0.04 and out of control productions for the months of September of 2004 and February of 2006.

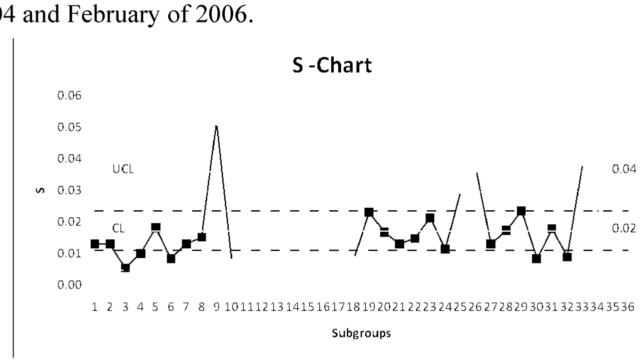

Fig. 1c: The S – chart shows population standard deviation of 0.02 with out of control productions for the month of September of 2004 and for February and September of 2006.

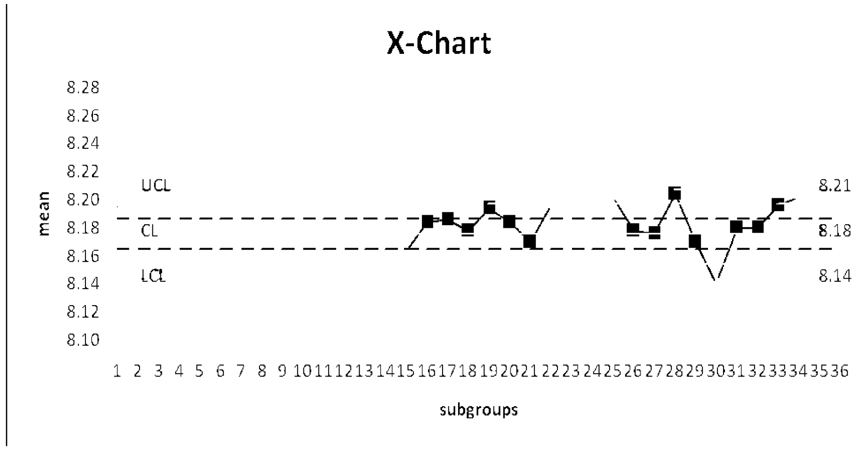

Fig. 2a: For pH value, the X – chart shows out of control for the months of October and December of 2004 and June and December 2006, with upper and lower limits of 8.21 and 8.14 and mean 8.18.

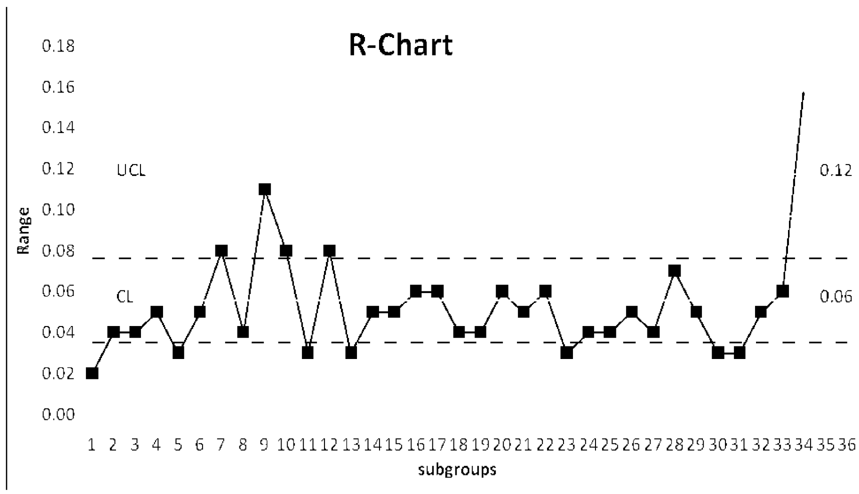

Fig. 2b: Shows a mean range of 0.06 for pH and out of control production in the months of October and December, 2006.

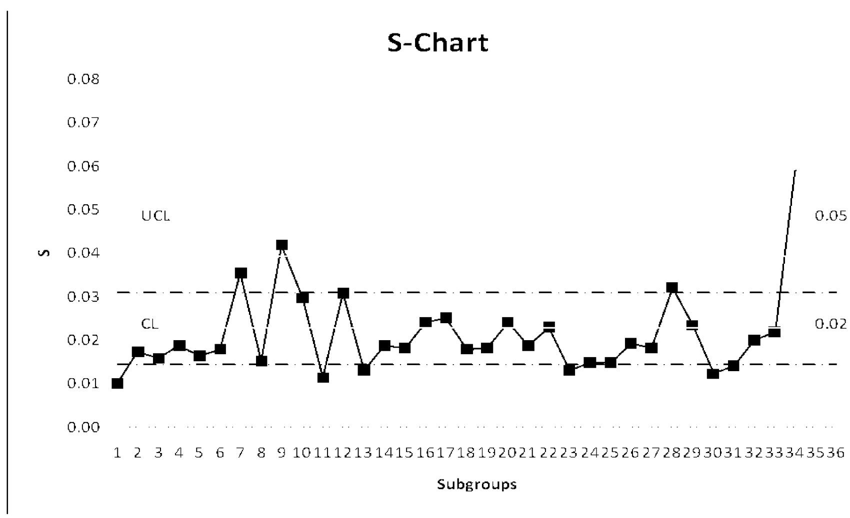

Fig. 2c: Shows mean standard deviation of 0.02 and out of control condition for the months of October and November 2006.

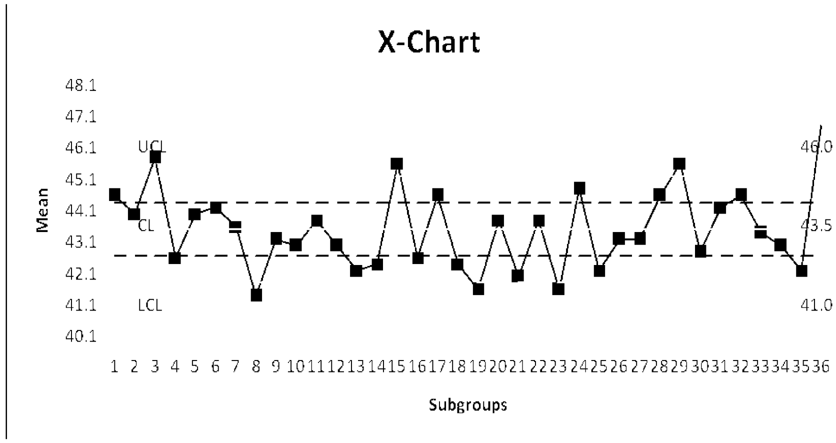

Fig. 3a: For viscosity, X – chart shows mean value of 43.5 with lower and upper specifications of 46 and 41 respectively, also shows out of control for the month of December 2006 only.

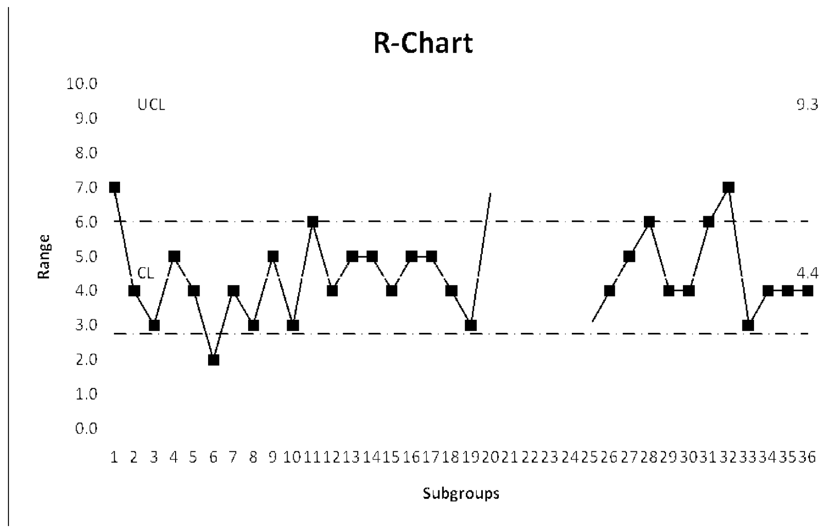

Fig. 3b: For viscosity, R – chart, shows mean range as 4.4, but no out of control situation.

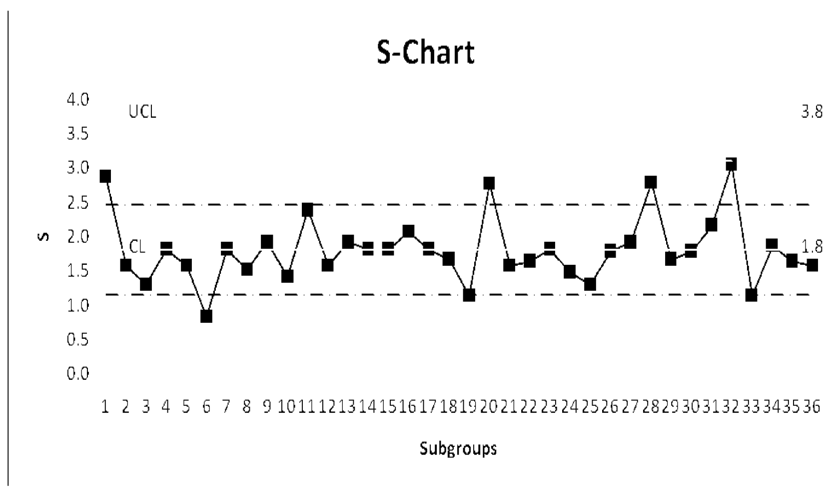

Fig. 3c: For viscosity show mean standard deviation of 1.8 with upper limits of 3.8 and lower limit of 0, No out of control record was made.

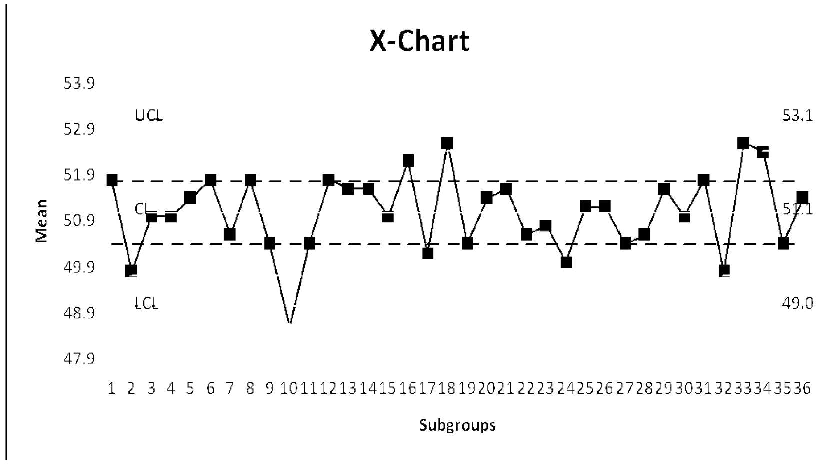

Fig. 4a: For solid content, X – chart shows mean solid content of 51.1 with upper and lower specification limits of 53.1 and 49.0 respectively, with out of control record in the month of October 2004.

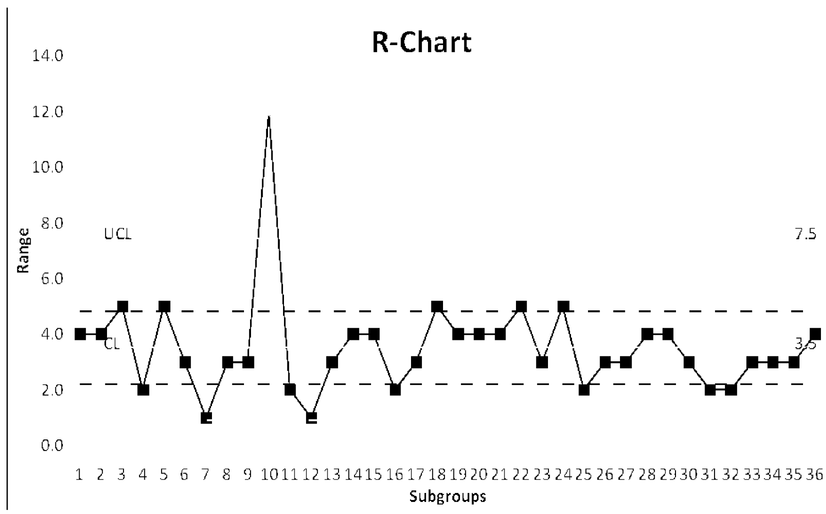

Fig. 4b: R – chart for solid content shows the upper and lower specification limits of 3.5 and out of control condition in October 2004.

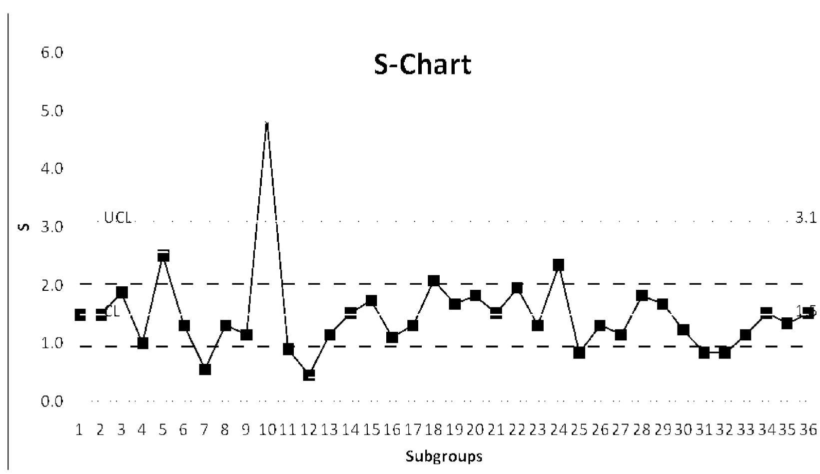

Fig. 4c: S – chart for solid content shows mean standard deviation of 1.5 and upper and lower specifications of 3.1 and 0, while out of control situation is recorded in October 2004.

The control charts are constructed with classical equations for control charts as found in [5-10] using a three year monthly production data recorded for specific gravity, P^H value, viscosity and solid contents of produced Peatone paint to present results as in Figures 1-4, where UCL = Upper control limit, LCL = Lower control limit, CL = control limit as defined and expressed in [10] for construction of control charts.

Validation of Process with Process Capability Index: The process capability index, C_p, is commonly used to establish the relationship between the tolerances specified for the component and the standard deviation for the process that will make it. The equations for evaluation of process capability index are expressed below [10].

$$C_p = \frac{USL - LSL}{6\sigma} \quad (1)$$

Where USL is the upper specification limit and LSL is the lower specification limit.
The actual process capability is given by

$$C_{pk1} = \frac{USL - \mu}{3\sigma} \quad (2)$$

$$C_{pk2} = \frac{\mu - LSL}{3\sigma} \quad (3)$$

$$C_{pk} = \min(C_{pk1}, C_{pk2}) \quad (4)$$

Where μ the mean of the process, C_{pk} is used by the manufacturing engineers to center the process. In production we seek to make $C_{pk1} = C_{pk2}$ and to keep C_{pk} at a value of 1 or greater.

So that by employing the mean and standard deviation charts of Figures 1-4:

For Specific Gravity:

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{1.3 - 1.25}{6*0.02} = 0.42 \quad (5)$$

and

$$C_{pk1} = \frac{USL - \mu}{3\sigma} = \frac{1.3 - 1.28}{3*0.02} = 0.33 \quad (6)$$

$$C_{pk2} = \frac{\mu - USL}{3\sigma} = \frac{1.28 - 1.25}{3*0.02} = 0.50 \quad (7)$$

Since both the theoretical process capability and actual process capability is less than unity respectively, the production process is out of control with regards to specific gravity and the process must be stopped for proper appraisal of the process since $C_p = 0.33<1$.

For P^H:

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{8.21 - 8.14}{6*0.02} = 0.58 \quad (8)$$

and

$$C_{pk1} = \frac{USL - \mu}{3\sigma} = \frac{8.21 - 8.18}{3*0.02} = 0.50 \quad (9)$$

$$C_{pk2} = \frac{\mu - LSL}{3\sigma} = \frac{8.18 - 8.21}{3*0.02} = 0.50 \quad (10)$$

Since both the theoretical process capability and actual process capability is less than unity respectively, the production process is out of control with regards to specific gravity and the process must be stopped for proper appraisal of the process since $C_p = 0.50<1$.

For Solid Content:

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{46 - 41}{6*1.8} = 0.46 \quad (11)$$

and

$$C_{pk1} = \frac{USL - \mu}{3\sigma} = \frac{46 - 43.5}{3*1.8} = 0.46 \quad (12)$$

$$C_{pk2} = \frac{\mu - USL}{3\sigma} = \frac{43.5 - 41}{3*1.8} = 0.46 \quad (12)$$

Since both the theoretical process capability and actual process capability is less than unity respectively, the production process is out of control with regards to specific gravity and the process must be stopped for proper appraisal of the process since $C_p = 0.46<1$.

RESULTS AND DISSCUSSION

The key to quality is to detect when the process goes out of control so that we can correct the malfunction and restore the control of the process. The control chart is the statistical method adopted in the analyses of production process control [11]. From the statistical data gotten from Golden Emulsion Paints Limited for Peatone green emulsion paint, we have been able to establish the process control limits for the four parameters under consideration in the production of paint, using the X-chart, R-chart and S-chart. The following observations are made from the computations presented on charts of Figures1-4:

Both the theoretical process capability and actual process capability is less than unity respectively, the production process is out of control and the process must be stopped for proper appraisal of the process.

Above observations explain assignable causes of variation in the production of Peatone green emulsion paint.

CONCLUSION

The following recommendations and conclusions to Golden Emulsion Paint Limited are made:

- The production manager should stop production and check the causes of variation.
- The production manager should pay much attention to the specific gravity and P^H level of the paint since X-charts for both indicate out of control process.
- The production manager should give attention to variation existing among Specific gravity, P^H, Solid content of the ranges, which indicate out of control process.
- We also recommend that the company should have an established standard for controlling the quality of their products and for testing for monthly variations. With the control limits stated for each of the parameters in this work, the management of this company can effectively and efficiently control the quality of Peatone Green Emulsion paint, if and only if they can adopt it as a standard.
- It is pertinent to mention here that a good, accurate and carefully-carried-out method of sampling should be adopted for accuracy of the statistical data, so as to avoid type I and type II errors.

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