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IMPROVING PRODUCT QUALITY OF SECURITY EQUIPMENT USING SPC

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Abstract: *There are some basic quality characteristics and some basic unconformity of Security Equipment (Safes, Deposit safes, ATM Safes, Vault Rooms) that occurs during production process and which should be controlled. The stability of the process for variable sample size is controled using u-chart, which shows the average number of defects (failures) per product. Quality improvement of products is carried out by determination of the critical failures using Pareto analysis and by determination of corrective actions that should be taken.*

Key words: *Security Equipment, u-chart, Quality improvement, Pareto analysis*

1. INTRODUCTION

Unlike developed countries, statistical process control in our country have not yet reached the true extent of use even for companies that are certified according to standard ISO 9000. The reason is certainly insufficient knowledge of mathematical statistics which is basis of the SPC and the insufficient use of computers.
The essence of the application of these methods is the rapid spotting of errors and selection of parameters that influence to the process instability. This provides opportunity for corrective measures to be taken in order to countionously improve quality of products and processes and thereby achieve high customer expectations and ensure competitiveness in the increasingly demanding global market.
Below is an example of application of SPC methods in the process of producing the security equipment that is manufactured in the company PRIMAT EQUIPMENT - Baljevac.

2. PRODUCTION OF SAFETY EQUIPMENT IN THE COMPANY PRIMAT EQUIPMENT - Baljevac

Company PRIMAT EQUIPMENT LTD - Baljevac produces metal security equipment that is used to store valuables such as important documents, cash, jewelry and others. Product range includes:

- commercial safes - type STARPRIM and STARPRIM/N,
- specific purpose safes such as deposit safes and components for ATM safes,
- vault rooms - MODULPRIM type,
- vault doors – DOORPRIM type,
- security doors,
- Fireproof doors
- Wall and furniture safes type PT and ZT and
- Cabinets for weapons of type A, B and C.

Security equipment products are certified by the German Institute Verband der Schadenversicherer Köln (VdS) in accordance with European standards EN 1143-1. This standard defines the anti - intrusion levels of security which anti burglary security grade is measured in units of resistance RU (Resistant Unit). Commercial and specific purpose safes are made in sizes from 15 to 780 liters and with security grade from 1 to 5 while the vault rooms in modular construction ModulPrim and vault doors DoorPrim are made with security grade from 0 to 9.

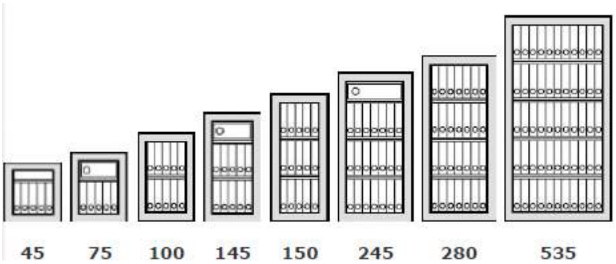

Fig.1. Models of commercials and speccific purpose safes

Company PRIMAT EQUIPMENT LTD - Baljevac has introduced QMS (Quality Management System) in compliance with the requirements of ISO 9001:2008. Processes and production technologies of metal security equipment are based on our own experience and business and technical collaboration with partner PRIMAT Inc. from Maribor, who is also the majority owner of the company.
Method of product inspection and method of recording the results of inspection to ensure product quality in accordance with the requirements of the QMS is defined by procedure for controlling product POB-824-101. This procedure implies use of attribute quality control charts and Pareto analysis. Integral part of procedure are control

plans that are developed for all types of security equipment. They defined sampling method ie. the sample size and frequency of control process.

3. ERROR CLASSIFICATION

The basic feature of these products is reflected in the provision of security of valuable items stored in them and it is therefore necessary that the quality characteristics that provide this functional demand are full controlled and that the same measures are critical to the products of this type. Conformity of products is documented by plan / record of product checking which include the value of functional measures.

Since these safes are used in banks and offices, it is necessary to satisfy the aesthetic appearance and ease of functioning, ie. opening, closing and locking. It is therefore necessary to monitor errors that affect to these quality characteristics and to take corrective measures for elimination of the causes and for prevention of their recurrence.

The technological process is divided in three parts: safe shell assembly by welding, door assembly and black assembly. Depending on the safe security grade and a size range, there are different control plans and the requirements that products have to satisfy.

Production form of commercial safes - type STARPRIM is a small-series from 5 to 50 pieces. On the other hand, there are 44 different models of this safes based on the size and grade of security.

Table 1. Error classification

i	**Controlled error**
1	Removing residue from welding
2	Control of the welds on the armor system
3	Fine grinding of corners and welds on the armor system
4	Fine grinding of doors
5	Location of safety pin
6	Holes for the rack mounts
7	Dorr flatness
8	Control if hinge is welded
9	Positioned and grinded fabric number
10	Flatness of armour system plates
11	Control of locking parts
12	Control of welds at door housing
13	Easy opening of doors
14	Straightness and angularity of envelope
15	Removing concrete residue from housing
16	Gap between door and casing
17	Alignment between housing and doors
18	Control of parts for piles admission
19	Alignment of the pipe with the bottom

For the implementation of statistical process control and comparation of products with different models and different levels of security, it is necessary to group similar errors in order to eliminate difference in the names of errors and to provide a sufficient number of samples for monitoring process stability. Thus, for example error No. 11 - "Control of lock parts" includes the following errors:

- wrong position of sound beeper
- error of locking mechanism,
- improperly installed rail guides and
- lack of dividers.

Errors in the process of making commercial safes type STARPRIM are classified into 19 groups and are shown in Table 1.

4. U- CONTROL CHART

U - control chart for variable sample size was chosen for statistical process control. Basic parameter of **u**-chart is the average number of defects per unit in the sample:

$$u_i = \frac{\sum_{j=1}^{n} c_{ij}}{n_i} \qquad (1)$$

where: n_i-size of *i*-th sample

The average number of defects / errors of entire population ie. central tendency of the process is:

$$CL_u = \bar{u} = \frac{\sum_{i=1}^{s}\sum_{j=1}^{n_i} c_{ij}}{\sum_{i=1}^{s} n_i} \qquad (2)$$

The position of the control limits is variable and depends on sample size so the value of the control limits have to be calculated for each point in the control chart

$$GKG_u = \bar{u} + \frac{3\cdot\sqrt{\bar{u}}}{\sqrt{n_i}} \qquad (3)$$

$$DKG_u = \bar{u} - \frac{3\cdot\sqrt{\bar{u}}}{\sqrt{n_i}} \qquad (4)$$

During the period from 30.12.2010. to 07.04.2011. total number of errors is monitored using **u**-chart according to the classification shown in Table 1. The results are shown in Table 2.

The average number of defects per unit is calculated on the basis of the equation (1).

The value of the central line is:

$$CL_u = \bar{u} = \frac{\sum_{i=1}^{s}\sum_{j=1}^{n_i} c_{ij}}{\sum_{i=1}^{s} n_i} = \frac{538}{341} = 1.578$$

Control limits are calculated using following equations:

$$GKG_u = 1.578 + \frac{3\cdot\sqrt{1.578}}{\sqrt{n_i}} = 1.578 + \frac{3.768}{\sqrt{n_i}}$$

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All points on **u**-chart (Fig.2) are within the control limits and can be considered that the previous process was stable. Data processing and graphical representation of was performed using MS Excel. By locking unnecessary cells, chart can be used by executives who do not have specific knowledge of SPC and MS Excel. It is enough to enter the measured values in the provided fields and the program will automatically performs all necessary processing. In case of deviation points which are outside the control limits, measures are taken according to a procedure that monitors the implementation of control charts to prevent occurrence of nonconformities.

Table 2. Measured data and calculated parameters for u-karte

i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	**Σ**
n_i	15	10	10	10	15	10	10	6	10	10	30	10	50	30	10	6	9	10	15	10	5	10	10	15	15	
G1	15				14	3			10	9	26															**77**
G2	8	1			5	9	10																			**33**
G3	11	4	8	7	14	8	9	2	7	3	29	8	18	28	2	1	4	4	3	10	2	7	3	10	3	**205**
G4								2																		**2**
G5																		2								**2**
G6															2		3	6		8				11		**30**
G7	1				2								1													**4**
G8																1										**1**
G9				1																						**1**
1G0		1																					6			**7**
G11																				1				3		**4**
G12								1																		**1**
G13												2				2	1		8				3			**16**
G14																										**0**
G15															3	5	9	6		8		5		4	13	**53**
G16												3	33	14	1	6	4		1		1	5	10	7	1	**86**
G17																						5	2			**7**
G18						2	4	1																		**7**
G19																1	1									**2**
Σc_i	**35**	**6**	**8**	**8**	**35**	**22**	**23**	**6**	**17**	**12**	**55**	**13**	**52**	**42**	**8**	**16**	**22**	**18**	**12**	**27**	**3**	**22**	**24**	**35**	**17**	**538**
$U_i=\Sigma c_i/n_i$	2,33	0,60	0,80	0,80	2,33	2,20	2,30	1,00	1,70	1,20	1,83	1,30	1,04	1,40	0,80	2,67	2,44	1,80	0,80	2,70	0,60	2,20	2,40	2,33	1,13	
CLu	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	1,58	
GKGu	2,55	2,77	2,77	2,77	2,55	2,77	2,77	3,12	2,77	2,77	2,27	2,77	2,11	2,27	2,77	3,12	2,83	2,77	2,55	2,77	3,26	2,77	2,77	2,55	2,55	
DKGu	0,60	0,39	0,39	0,39	0,60	0,39	0,39	0,04	0,39	0,39	0,89	0,39	1,04	0,89	0,39	0,04	0,32	0,39	0,60	0,39	0,00	0,39	0,39	0,60	0,60	

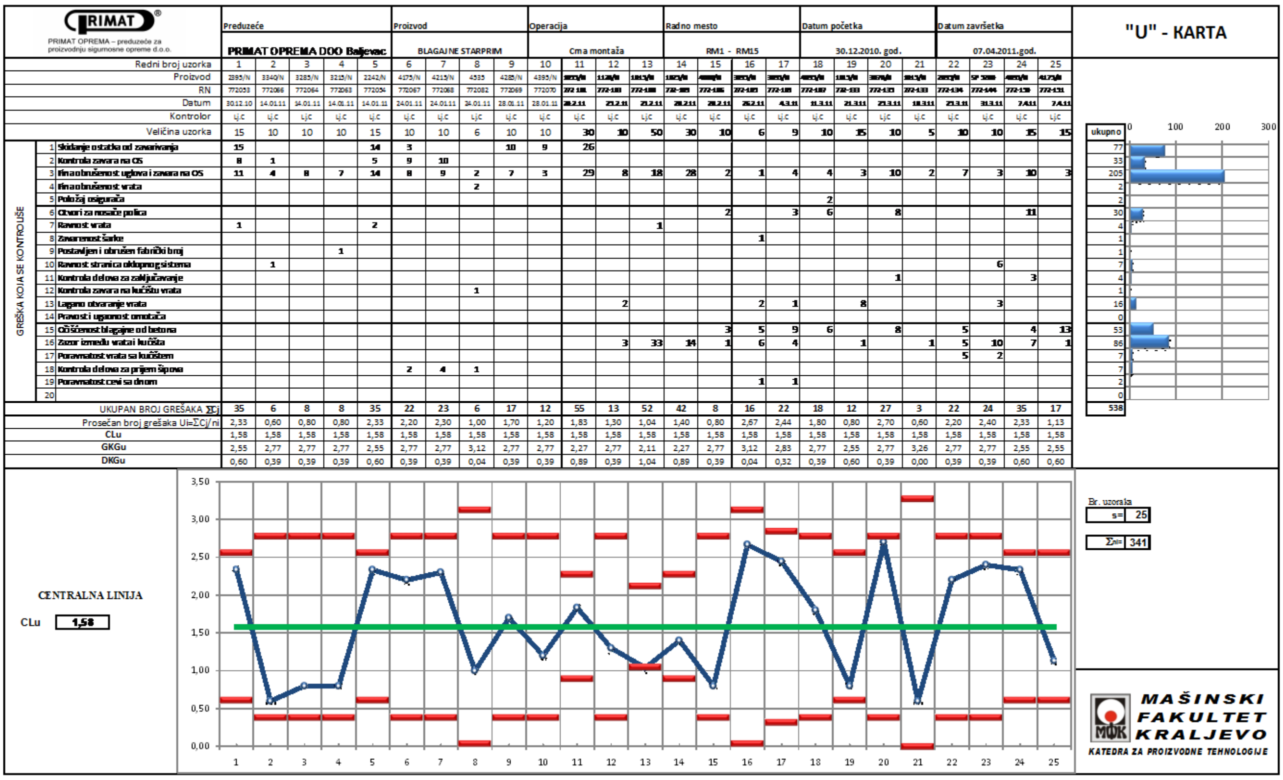

Fig.3. U-chart for variable sample size

5. PARETO ANALYSIS

The number of occurrences for each observed error is shown on the right side by adequate histogram. If ranking of errors is made by its number, ie. the percentage of participation (Table 3) we can notice that the most common error is G3- Fine grinding of corners and welds on the armor system (38.1%) which does not belong to the line of critical errors, but from the aesthetic aspect is very important. Errors G3, G16, G1, G15 and G2 are ≈ 85% of all errors (Group A in Table 3 and area A in Figure 3) and therefore is necessary to provide corrective actions for their elimination. In addition, it is necessary to consider errors from group B (error G6, G13, G10 and G17) that make ≈ 10% of and take steps to reduce them in the next stage. Other errors (class C) are less than 5% of all errors and at this stage it is not necessary to analyze them.

Table 3. Classification of errors according to the the number of occurrences

G_i	n_i	cum	n_i (%)	cum (%)	Group
G3	205	205	38,10%	38,10%	A
G16	86	291	15,99%	54,09%	
G1	77	368	14,31%	68,40%	
G15	53	421	9,85%	78,25%	
G2	33	454	6,13%	84,39%	
G6	30	484	5,58%	89,96%	B
G13	16	500	2,97%	92,94%	
G10	7	507	1,30%	94,24%	
G17	7	514	1,30%	95,54%	
G18	7	521	1,30%	96,84%	C
G7	4	525	0,74%	97,58%	
G11	4	529	0,74%	98,33%	
G4	2	531	0,37%	98,70%	
G5	2	533	0,37%	99,07%	
G19	2	535	0,37%	99,44%	
G8	1	536	0,19%	99,63%	
G9	1	537	0,19%	99,81%	
G12	1	538	0,19%	100,00%	
G14	0	538	0,00%	100,00%	
Σ	538				

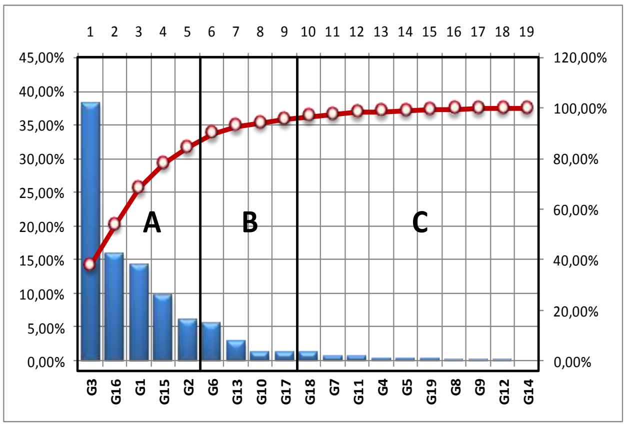

Fig.3. Pareto graph

6. CONCLUSION

Companies that want to improve quality of their products and reduce the costs of quality must constantly work to improve the quality system which includes the necessity of applying statistical methods to control the manufacturing process.

Control charts are highly applicable tools to determine the ability of the manufacturing process. Although attribute control charts provide smaller insight into the state of the process than is possible by using numerical control charts, their application is very useful and economically justified. On the basis of performed analysis we can conclude that the process of making safes from the program of security equipment in the company PRIMAT EQUIPMENT-Baljevac is stable but that there are significant opportunities to improve quality. The data analysis allows the selection of parameters that influence on the occurrence of errors in the production process and gives opportunity to eliminate the causes of errors in order to ensure a higher level of product quality.

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