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The Magic of SPC

SPC - Statistical Process Control : Any process, from typing letters, answering customer queries, direct mail campaigns, sales presentations, product display and restocking -- ANY process must first be designed (usually trial and error or design of experiments), then implemented, then disciplined. ***If the process is under control the final product or result will always be what you expect from the process and there will never be a need for rework, scrap or poor quality.***

Tons of books have been written on the subject -- a lot of it theoretical and beyond the scope of most small businesses. What follows is a case study which shows huge paybacks from near zero investments are not only possible, but quite simple to apply. The logic and method can be applied to any process. It usually starts with a study of your lists.

Case Study

Over $100,000 a year savings is the result of SPC and Design of Experiments. This, over a two month period by an intern, on a part-time basis. The company: Eight Million in sales, 83 people strong, 75 of whom work in the factory. And it's just the tip of a potential iceberg!

It all started with an idea and a letter to the local college.

May 3, 1991

Ms. Donna Durlack
SIP Director
Southwestern College, Chula Vista

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Dear Donna:

I am the new General Manager at Corsair Marine in Chula Vista where we are making the slickest trimaran in the world. It is winning races left and right and you must pay $1000 plus 10% down just to get on the waiting list to buy one! Quality is of prime concern and it can only be achieved through minute attention to every step in the process of converting chemicals and hardware into a beautiful boat.

The company has been in business over five years and the debt to asset ratio is on the debt side which means a shortage of cash. However, in accordance with your charter, that of assisting small to medium sized companies succeed within this very tough California manufacturing environment, I am asking for your help.

I need to set up SPC charts in various areas of the plant, train my people to use them (90% of my workforce is Hispanic and English is their second language - sometimes). I also need to establish data collection systems such as temperature, time, humidity, dust levels, etc. Thus my apparent need is for an intern or two from both disciplines.

Sincerely, Wayne Lundberg, CMfgE - General Manager

Donna brought Mike Hendrix for a plant tour. We started in the lamination shop where 23 busy-bees were at work. Then to the assembly area where another 30 people were busy screwing and gluing things together to complete a 27 foot long trailerable trimaran.

My presentation was something like “I have three people doing nothing but repairing voids between gel-coat and lamination, another two people cleaning up and fixing minor details before the boat is delivered. We have a long list of complaints from customers and many rework items on the final check-list. Although we deliver a quality boat, it is costing a lot in rework and after-the-fact inspection. My workforce is Hispanic and our check-list is in English. Most workers have high-school degrees but from Mexico. For all practical purposes the force is illiterate. But smart!”

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For Southwestern College this was the first time an intern was put to work for a prospective employer on this kind of project. Other interns had been put out to various employers working a regular shift, doing regular work. But this was a challenge which fit perfectly with two new programs the college had started. One, SIP, which is Supplier Improvement Program. The other, a Federal grant to recruit area students, minorities and women into the engineering profession.

Mike came to work and started writing a journal:

Engineering Internship Program

Summary of Journal Entries

Corsair Marine - Michael S. Hendrix

Project Start 24 June - End 15 Aug. 1991

The project began with one week of familiarization with the plant, key personnel, materials used, procedures used and process. My instruction by Willard Hanson indicates that for this type of product, cross-sectional density is the most effective key process indicator and that macroscopic water contamination is the most catastrophic cause of product failure. Other key variables for this facility may include: microscopic water contamination, entrapment of volatile, run times, temperature, glass to resin rations, excessive vacuum pressures, excessive time under vacuum, design of part, materials, processes, procedures, training and workmanship.

Examination of the plant’s pressurized air system does, in fact, reveal excessive water content, which is being introduced into the product at the carpet station during clue spraying and into the laminate during blow-out at various points. In addition to this, periodic failures of the gel-coat mixing pump and resin-catalyst mixing pump, as well as significant damage to air tools. This initial finding is discussed with the General Manager (Wayne Lundberg) and then referred to Maintenance Manager (Bob Harland) for action.

A search through the facility for previously collected, meaningful organized data is very disappointing. There are only two sources to work with. An in-factory final inspection checklist of greater than a dozen revisions with no

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coherent structure between revisions and a binder of initial purchase owners survey forms. while I am told that there is a wealth of meaningful data stashed from various past projects and documentation procedures it can not be located.

Problem #1 - The General Manager does not want me to do a Macro Process Flow or Process Analysis. He specifies that the scope of the project is to be limited to existing data, measurement instruments on hand, zero to minimal cost expenditure, and refinement of processes currently in use only. His action plan is to get charts on the floor as soon as possible using simple, no-cost successes in order to fuel enthusiasm on the floor toward SPC. Since discussion avails naught to convince, I will begin Monday using a composite spreadsheet/database with graphing to collect and organize existing data.

Talk about a nightmare! Just trying to get data entered is braindeadening due to having to cross-reference the incoherent revisions of the final inspection checklists. Not only is it too time-consuming but it is of doubtful value because of the data that it doesn't contain. Thus I find myself having a second discussion with the General Manager restating my desire to begin with a Macro Process Flow Study. Instead he recommends my using a common yellow note-pad to tabulate the existing data, which as it works out, is a very effective solution in overcoming the disorganization of the information. Still, I have my doubts that the resulting Pareto is an accurate reflection of reality. I have seen a great deal of undocumented rework and on-the-spot floor repairs going on continuously and view it as an enormous hole in this analysis. Reservations notwithstanding I deliver my initial Pareto analysis to Wayne. It indicates that carpet defects and gel-coat repairs and voids constitute the bulk of current low quality, followed by loose-long-missing & malfunctioning hardware and general cleanliness. Carpet defects has the greatest number of hits but gel-coat and voids have the greatest cost added factor. After reviewing the analysis Wane request that analysis of the carpet be my first SPC target. Wayne tells me that if the tools necessary for Histogram measurement charting are not available in the plant then I may acquire them and seek reimbursement from petty cash, within the limits of $20.00 per tools and not more than three tools. These restrictions are seemingly unreasonable, and I do not agree with this “Zero Dollar” philosophy attached to my internship with the company. I find it necessary to

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discuss it with Wayne. Our discussion yields the following information: Because of a slump in sales plus the limited time span of the project and uncertainty as to whether SPC implementation will be able to continue unless I am willing to stay on with the company after August 15 or else a full-time permanent employee be found to replace me in the capacity of SPC, then his responsibilities as General Manager forces him to constrain company investment in hardware associated with the project to a necessary minimum. While this viewpoint is extremely aggravating to me personally because of the very sever limits t places on my potential and possible achievements, notwithstanding, in his place I would be forced to the same position. I can not argue his logic, conclusions nor responsibility and doubt that either of us are overly pleased by the necessity of this situation.

Evaluation thus begins on the carpet station within set parameters.

The immediate response of the associates is to request a variety of new tools in order for them to improve their workmanship. I tell them that their requests are noted but that the disposition of their request hinges on the results obtained from measurement charting. Conversation with personnel performing the sales final inspection and final assembly personnel performing the final checklist indicates that the carpets defects are based on visible seams caused by crows-footing, gaps at the seams, ripples at joining edges between the hull and main deck, and pull-up/detachment of the carpet at various points. since no standardized measurements currently exist to quantify these subjective qualities, they will have to be invented, and tools researched that will that need.

First measurements chart 17 seams, 6 on the flat surfaces, and 11 at the corners. the flat surface seams are highly visible and necessary because of material width and direction of material orientation. These are the only seams that the craftsman can pattern-match to prevent crows-footing. Seams in the corners can not be pattern-matched because of the vertical slope of the corner angles and will display crows-footing no matter what craftsmanship is applied. there are no visible ripples measured, no pull-ups, only two measurable gaps created by complex contours at the lip of the aft hatch combing, and 11 hits on pattern-mismatch. Design orientation seems to be the major problem and could easily be resolved as the current cause of quality hits by shifting the direction of orientation, this would yield the side

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benefit of eliminating all six (most objectionable) flat surface seams. I think it is time to inquire about design parameters and subsequent change procedures.

Inquiry result: Chief Designer (Ian Farrier) states that the vertical hull carpet orientation is his decision based on creating the illusion of greater height in the interior of the boat. Sitting in the boat, however, with a swatch of carpet scrap fails to confirm the illusion. There are simply too many reference points, not the least of which is a ‘T’ pattern created by the intersection of the hull carpet and hull to main deck trim strip. I request a presentation of the initial chart with my findings an a request for change approval to Wayne, who invites the Company President (John Walton) to join us. Approval is given with the condition from John Walton that measurements continue on vertical pattern orientation for four or five more boats so that initial findings are confirmed and validated as to the primary cause of defects. Wayne will give the section supervisor approval to change as soon as he is sure of the findings. I begin instructing the craftsmen in measurement charting through three more boats.

Date: 12 July, 91 - Wayne OK’s the change and asks if I can move into lamination side on Monday morning to analyze for the cause of voids. Float hulls have been selected as the test area for analysis by Lamination Manager (Harold Kenaga). Lack of instrumentation (a scale accurate to .1 lbs. on the floor thermometers, a hand held elapsed counter, and a hand held thermocouple) forces me to focus on the interrelationships of temperature, process time sequences, weights, entrapment and application mixing procedures. An additional restriction now surfaces: My time allocation at the plant is floor hours per day (7am - 11am), but this is sometimes in conflict with the lamination schedule plus there is a slow down on the line due to the slump in sales. The result is that my first set of samples on five boats takes eight workdays to collect and analyze. My analysis indicates that a reduction in voids between the first skin - foam - second skin can be achieved by reducing mixing variables from ten to two and control of the weight of resin going into the part.

The primary suspect cause that I can attack is entrapment caused by two factors: vacuum bridging and second skin cures first. A design of experimental change in process is granted by the General manager for the

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next float hull produced along with 100% tap-out to confirm quality improvement. The results are heartening, the bleeder blanket pattern is nearly perfect under vacuum, plus a reduction of resin waste of 10 lbs (combination bucket scrap, blanket weight, and part saturation) and a time reduction of 10 minutes. A 100% tap-out finds zero voids.

The float hull team is not only sold on SPC, but demands a photo of their achievement and all stations in lamination want to jump on the SPC bandwagon. four more float hulls are produced using the experimental procedure with no void defects. Again I ask Wayne for necessary instrumentation to pursue further improvement, specifically a device for measuring system vacuum and fluctuations and a triple beam scale good to .1 gram for measuring the small weight differences between cut-out samples produced by different methods. He says that he will try to build a vacuum recorder himself and forwards the requisition for the scale. The supply clerk states that it won’t arrive for three weeks. Wayne recommends that I perform further design of experiments within existing constraints, and begin applying the lessons learned in float hulls to main hulls and main decks.

Following the approach, I begin measurement charting on the main hulls. Whenever the lamination schedule conflicts with my schedule, I do design of experiments to acquire data not provided by material manufacturers of resin except through purchase of lab time from them.

Several interesting things are learned in this way: #1, T-30 resin gels at an internal reaction temperature of 85`f regardless of catalyst ratio. Get time is a function of exothermic temperature. #2, Resin with a catalyst ratio too low to gel at ambient air temperature can be force kicked into gel when subjected to 105’f by external means. At this temperature all resin samples gel at the same time delta without regard to catalyst ratio. #3, Existing mixing charts are based on ambient air temperatures and makes the assumption that resin temperature in the barrel is the same as ambient air temperature, is the same as mold temperature. This assumption is grossly untrue, therefore which source is the correct reference temperature for mixing? Experiment indicates that it is the temperature of the resin as it comes out of the barrel but there is a delta factor that increases as the temperature differences increase and gross temperatures increase. further experiments will be required to calculate this ‘fudge factor’. #4, Resin gels slower under vacuum that in ambient air. This

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seems due to a net temperature reduction as the part first goes under vacuum and to the active removal of reaction volatiles under vacuum. Delta time increases average 10 minutes with 15 minutes as the upper limit.

An interesting sidelight is that the vacuum process also lowers the peak exothermic temperature and this in turn is the variable most critical for maximum strength and modulus of the finished composite material. #5, Even marginally measurable macroscopic water contamination wicked into the glass fabric is catastrophic. Less than one drop of water will destroy the bonding characteristics of an area of 4" diameter. Pressurized air systems, overnight dew-point on the facility floor, and workers dripping sweat into the material are the major source contributors to this hazard.

After three sets of initial histogram measurements are taken to provide necessary baseline information, experimental change of process is implemented on main hulls and three hulls are produced, all of which are free of voids. The new Head of Lamination Section [Pedro] is both cooperative and enthusiastic about the benefits of SPC. Next I am moving to initial measurements of the main deck molding process, there is only enough time for one sample before I have to move to the final assembly area for analysis of hardware and gel-coat touch-up.

Date: 2 Aug. 91. Measurement charting in the final assembly are indicates that the bulk of hardware defects are due to engineering changes in the parts which were not followed-up by subsequent changes on hardware fasteners. There also seems to be a problem in the template for main deck cut-outs, examination shows the template to be severely gouged by previous routing operations and in need of repair. A breakdown of gel-coat touch-ups reveals that 60% are due to correctable imperfections in the mold, 20% by process defects which create blisters (an area yet to be analyzed) and 20% due to trimming operations which will remain as residual unless trimming operations can be eliminated. So far three boats have been sampled in final assembly and only one more day remains on the facility floor; Wayne wants me to give a brief overview of SPC methods to his section supervisors on Monday, Tuesday and Wednesday of next week, with project termination and presentation on Thursday at the college.

John Walton calls me into the office for a meeting with himself and Wayne for an overview of project results. John steers the conversation to his

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ulterior motive during this meeting. Hull 278, John Walton's boat goes into the mold tomorrow... what process improvements have been consolidated through SPC that can be incorporated into the manufacture of his boat? Wayne and I detail and argue the conclusions relative to the results of the design of experiments and experimental process changes. We have a lot of highly suggestive evidence but insufficient numbers of samples and inadequate measurement equipment to constitute proofs as yet. Our summary that the form of hard opinion based on incomplete analysis, remains unknown, and intuitive correlations. John Walton requests that I spend my last day on the floor actively implementing all changes derived so far into his boat and applying SPC principles to as many parts as possible for his boat.

9 Aug. 91. - Mr. Walton joins me in lamination to observe the building of his boat. As work progresses we discuss the methods, solutions, and directions indicated by analysis to date. Everything goes well until the second skin layer of the starboard hull section, then for some unknown reason the associates mix three lbs. less resin than experimental procedures call out. Naturally the team comes up short and needs to draw a make-up bucket, but this time 6 lbs is drawn instead of 3 and they complete the hull section with only 1.5 lbs of scrap. At this juncture, John Walton begins expressing doubts about experimental procedures and worries about starved laminates. Worse still, is the accidental dripping of two drops of sweat wicked into the fabric by one of the team members which produce two 4" diameter fish\eyes inside his hull.

Murphy's Law has take root and the progression is from bad to worse. I tell him that he will see where the extra resin has gone once the part goes under vacuum and tell the team leader to get a heat lamp to help evaporate the moisture out of the laminate once it is under vacuum. But the crisis is not over yet, because of John Walton's presence the workers are nervous and working more carefully i.e. slower in order to do a good job. Ambient air temperature has increased and operations sequence time run long, the sample test patch has jelled indicating the part should be under stable vacuum by now but the team is working a brand new bag which naturally has leaks and therefore they are having problems reaching acceptable vacuum. John is now convinced that his hull is trashed, in spite of my reminder that part cure more

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slowly under vacuum and show him satisfactory liquidity through the bag. Five minutes overdue the team achieves stable vacuum and I point out to him two areas in the hull with excessive bleeder cloth saturation, this is where the extra resin went.

His skepticism on this point abates but he still has reservations about the integrity of his hull. Specifically he wants to know what went wrong in the process. Our discussion moves into the human factor, and I use this occurrence to emphasize the need to pre-impregnate the fabric both from the point of consistency and operation time sequence as shown form the direction that analysis was previously leading toward. His reservations are entirely extinguished in spite of the multiple crisis (or perhaps because of it) subsequently when 100% tap-out of his hull draws the remark from the craftsman that this is one of the best hulls ever produced. He asks Wayne to implement experimental procedures as soon as they are validated and begin research on purchase of a pre-impregnator.

15 Aug, 91. Final entry. Overview training with the Section Heads has revealed some skeptics, some believers, but mostly people willing to give it a try. Most of the supervisors are sold on SPC base on the evidence of results but have mixed feelings (natural human resistance to change). My thanks to Wayne for the experience, and Harold, Pedro Alex, Brian and Julio for the cooperation rendered to me on the floor.

Cost Savings Analysis

T-30 resin @ $0.87 per lb
Catalyst @ $14.50 per lb.
Carpet @ 10.35 per lin. ft.
Manpower @ $11.00 per hour

Waste reduction:

Resin

10 lbs per float hull X 2 floats per boat= $17.40 per boat

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30 lbs per main hull= $23.93 per boat

25 lbs per main deck= $21.75 per boat

Catalyst

at 1% of resin weight savings= $180.75 per boat

Carpet
at 5% of lin. ft. = $5.20 per boat

Man-hours
10 min. X 4 on float hulls= $8.00
10 min. X 5 X 2 on main hulls= $19.00
10 min. X 5 on main decks = $9.16
20 min. X 2 on hull carpet = $8.00

Direct Savings = $293.19 per boat X 250 boats per yr. = $73,297.50

Rework reduction-man-hour savings
Carpet: 10 hrs per week = $110.00
Floats 3
Hulls 3 20 hours per week= $220.00
Main Decks 3

$330.00 X 52 = $17,600 per yr. indirect labor

Warrantee reduction
@ 30 void repairs/70 gross repairs per yr. avg. cost per repair = $2037.26 (info provided by Sales Dept)

30 X 2037.26 = $61,117.80/132 boats per yr. = $463.01 $463.01/10 yr. warrantee = $46.30 per boat warrantee cost (voids)

50% reduction in voids = $46.30 X 132 = $6111.60 per yr.

Total = $97,013.50 per yr. Savings"
So states Mike's report.

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(This estimate is extremely conservative in that it does not take into account the excitement of a happy customer who enjoys a boat without problems, having to stock extra material to handle warrantee work, added burden to staff and associates to manage warrantee and rework, etc.)

Please consider this is the result of a part-time associate performing SPC in a start-up situation. Using conventional proportional formula projections it is easy to see that we have an excellent opportunity to gain enormous leverage through this tool. Few tools offer the potential payback or ROI as do TQM and related tools.