Prevention of Reservoir Interior Discoloration

Federal Manufacturing & Technologies

K. F. Arnold

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Black Belt Project

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Contents

Section

Abstract

Summary

Discussion

Scope and Purpose

Prior Work

Activity

Measurement Phase

Analysis Phase

Improvement Phase

Control Phase

Summary of Tools Used

Summary of Results

Attachment A

Attachment B

Attachment C

Attachment D

Attachment E

Illustrations

Figure

1 Weld Color Specimen

2 Typical Passthrough Chamber on GTAW Welder

3 Typical GTAW Glove Box Chamber

4 Reservoir Mock-up for Passthrough Experiment

5 Photographs of Coloration and Spotting Produced at Three Levels of Oxygen

6 Effect of Oxygen Level on Color Related to Cleaning Method

7 Run Chart of Oxygen Data Grouped by Shift and Day

8 Summary of Oxygen Plotted Against 15 ppm Specification

9 Process Capability for Oxygen Plotted Against 15 ppm Specification

Table

Number

1 Organizational Impact

Abstract

Contamination is anathema in reservoir production. Some of the contamination is a result of welding and some appears after welding but existed before. Oxygen was documented to be a major contributor to discoloration in welding. This study demonstrates that it can be controlled and that some of the informal cleaning processes contribute to contamination.

Summary

Problem Description

The problem is discoloration and spotting on the interior of the reservoir in the Heat Affected Zone (HAZ) detected after structural girth welds by Gas Tungsten Arc Welding (GTAW). The presence of spots and color on the interior, known as Foreign Material (FM) of this critical product is not acceptable unless the chemistry and the source of the material is known. Consequently, product must be destroyed for surface analysis to verify the source of the FM. Borderline cases now wait for weeks for disposition by the design agency representative.

Solution Strategy

The solution strategy was to utilize the six sigma plus tools to develop a solution to the coloration and spotting on the interior of reservoirs. The approach was to follow the DMAIC (Define, Measure, Analyze, Implement, Control) flow. The definition process begins with a problem statement and extends to the thought process map and the process map. The goal in this phase is to make a rough cut on identification of the critical inputs (x's) that affect the critical outputs (Y's). The measurement phase is where you observe the process and determine the capability of the process and the normal variation of the output variables. At this time you also must determine if your measurement systems are capable of detecting the level of variation you expect to encounter. In the analysis phase the FMEA (Failure Modes and Effects Analysis) is developed from the process flow diagram. The design of experiments (DOE) are developed based on the critical x's identified by the FMEA and the other work. These experiments are executed and the responses are measured. The results of the designed experiment will quantify the effect of the inputs (x's) on the output (Y's) of the process. Further DOEs may be required to fully define which x's are critical to the output of interior coloration. Once collected, the data is analyzed using the PGA (Practical Graphical and Analytical) approach. First just look at the numbers; then chart the numbers; then perform regression to divine the predictive equation. Then comes implementation where the changes are put in force. A control plan will be put in place to provide performance metrics and corrective actions should anything go wrong.

Summary of Six Sigma Tools

The first step was to perform a literature search, which is a form of benchmarking. This search was to establish if weld coloration was a problem in the industry. The search turned up several documents

suggesting that coloration was a problem. These papers discussed causes of coloration and how it may be prevented. The cause of the problem is due to manganese in the alloy and oxygen in the cover gas. To eliminate all color, one would have to remove all manganese and oxygen from the equation. Due to the fact that our alloy is fixed, we are restricted to manipulating oxygen. Of great interest was the paper "*Reference Color Charts for Purity of Purging Gas in Stainless Steel Tubes*" by J. Vagan Hansen, Report 94.34, Revised May 1998. This paper included color photographs that illustrate the color that will result if product is welded in the presence of small amounts of oxygen (ppm levels).

The first tool was process mapping, which was used to map the passthrough process in detail. Passthrough is the process of taking a part from factory air through to the controlled argon (oxygen-free) atmosphere in the glove box. A thought process map was used to help give direction, continuity, and history to the project. The cause and effect diagram is used as a technique to generate thought from the team to outline all factors that may affect the outcome of the weld. Failure Modes and Effects Analysis (FMEA) was used by taking information from the process map and rating it as to the effect on the outcome of the specific process step. Results of the FMEA provide guidance on which inputs (x's) appear to be critical to the outputs (y's and Y's). Design of Experiments (DOE) were used in two cases--first to establish how well the passthrough removed oxygen from the interior of the product and then to correlate weld coloration to ppm of oxygen in the weld chamber. Results of the DOEs were analyzed by the Practical, Graphical and Analytical (PGA) approach, first using practical analysis by just looking at the raw data, then graphing the data and using Multivary charts in order to visualize the difference. This was followed by regression analysis. A run chart was used for trend analysis to establish if the oxygen level can be maintained at the new level of 15 ppm. A Pareto analysis was utilized to develop the organizational impact based on the number of borescope rejects for spots and coloration.

Results and Conclusion

As a result of this project it has been shown that oxygen is a critical input to the coloration from the GTAW process. If the level of oxygen can be controlled below the 15 ppm level, weld coloration will be nonexistent and spot coloration will be significantly reduced. If this low level of internal coloration is sustained, and rejects for this cause are minimized, we will have eliminated one of the needs for the interior aqueous clean (after weld). Elimination of this final cleaning step would further reduce manpower and the potential for contamination of clean product.

As a result of this work and implementation of these findings, the savings associated with scrap, rework, and laboratory analysis will total approximately \$50,000/year. This does not include the intangible reduction in flow time resulting from the reduced need to hold discrepant product for design agency review.

Discussion

Scope and Purpose

The purpose of this report is to document the impact that the welding environment has on contamination of stainless steel assemblies.

Prior Work

No previous work has been performed on this topic although some of the contamination studies are

related to the welding process.

Activity

Measurement Phase

Process Description

The output of the GTAW process is a structural girth weld on a high-pressure vessel that will contain a highly reactive gas.

In general, two symmetrical shells are machined from a forging. These shells are produced using a group of meticulously evaluated process materials (tools, chemicals, polishing agents, etc.). Each process material is carefully evaluated and tested to prove that it can be removed with the qualified aqueous cleaning. This evaluation is required to preclude contamination of the final cleaned and welded assemblies. Once machining is completed, the shells are cleaned by the qualified aqueous cleaning method, inspected, and packaged in clean nylon bags. The two clean components then go to tack welding where (in some cases) the clean parts are removed from the bags and wiped down with a polyester wipe and alcohol from a polyethylene bottle. Once the shells are tacked together, the tacked areas are brushed to remove discoloration and rinsed with alcohol from the polyethylene bottle.

The tack weld subassemblies are then put into the glove box passthrough chamber where atmospheric oxygen is (supposed to be) removed before passing into the argon atmosphere. Once in the argon-filled and oxygen-controlled glove box the parts are welded by the Gas Tungsten Arc Welding (GTAW) process. This process uses a tungsten electrode to create an arc that heats the metal while wire is fed into the molten weld puddle. In these structural welds the part rotates several times while approximately 40 feet of weld wire becomes part of the joint. The temperature of the part and the weld exceeds 1500 degrees F. Any oxygen present in the argon atmosphere (parts per million range [ppm]) will cause oxidation and coloration. The presence of any spot, either organic or inorganic, will also cause discoloration.

Once the weld is complete, the part is allowed to cool and then brought back out through the passthrough. The part is then cleaned and borescope inspected. During the borescope inspection if any spots or great contrast of color is observed in the product, the parts are rejected. The rejected product must wait for customer disposition though the borescope unless one is sectioned for analysis and the material is proven to be caused by welding.

TMAP

The thought process map is a formalization of a technique used frequently over the years. The old method was a list of questions that is constantly updated as new information is collected. The TMAP is a graphical approach to the earlier listed questions. The first question in the TMAP was "Is there color in the weld?" Then the flow moves on to the question of oxygen concentration and how does this concentration correlate to the color of the weld. One of the related questions was "Can we predictably produce color at will?" This question was answered as a part of a designed experiment. The thought process map is included as Attachment A.

Process Map

As one of the most important tools in the box, process mapping is essential to understanding the problem at hand. Initially there was an implied process map that we will call the Ideal passthrough process. As the team worked the problem, we discovered that there was actually a process well defined and documented. The process map is contained as Attachment B.

Cause and Effect Diagram: Fishbone

This tool was extremely useful and helped the team visually identify all areas that the team believed may be potential sources of weld coloration and oxygen. This tool was helpful in clearly identifying the fact that there was a difference in opinion among the experts on the level of oxygen that would cause weld coloration. This discussion also led to the discovery of the glove box operation guide.

Residual Gas Analysis (RGA) Measurement Study

The Nicolet Residual Gas Analyzer (RGA) was utilized to measure the presence of oxygen and other gasses that were present in mock reservoirs after passthrough processes of varying efficiency. The analysis of this experiment is not complete due to the fact that the RGA has been inoperative for several months. Initial results did indicate that there is a problem with the capability of the RGA to detect small (10-50 ppm) variations in the amounts of oxygen in the mock reservoirs.

This problem is an indication of the level of control we must have to control the appearance of color in the weld zone. We are required to control levels of oxygen so low that even state-of-the-art equipment like the RGA cannot discriminate between the expected variations of these trace gasses.

Weld Color Measurement Study

The second measurement study was performed on the weld color rating system used to categorize the weld coloration on the Cap 3 weld. The Cap 3 weld specimens were laser marked into radial grids. These grids were numbered from 1 to 6 and then this sequence was repeated. There are 12 radial cells in each part. Each of these radial cells is divided into three areas. The cell layout and numerical assignment are illustrated in Figure 1.

Figure 1. Weld Color Specimen. Grids Marked on Cap 3 Weld Specimen for Contaminate Placement.

For the measurement study a representative group of three parts was chosen. Within these parts there were 36 cells that were measured. There is only one inspector so the study was done at two different times in a manner that the operator had no recollection of the last rating of a given cell. Analysis of the measurement system indicates that the majority of the variability is due to the process (oxygen) and only a small amount of variability is due to the measurement system. This measurement system is highly capable of discriminating between color variations caused by oxygen levels of 20, 60, and 100 ppm.

Analysis Phase

FMEA

The Failure Modes and Effects Analysis is a powerful tool for identification of the critical x's that influence the critical Y's of the process. The FMEA also is effective in prioritizing future black belt activities. The FMEA was input and the team rated each item for severity, probability, and how easily the system can detect each failure (each rated from 1 to 5). After all the steps of the passthrough process were collected and rated, the list was sorted by RPN. This sorted list provides a Pareto analysis of the operation steps that have the largest impact on the process output of color.

The key input activities were

1. Evacuation of the passthrough to 50 microns
2. Verification that the oxygen level did not rise over 15 ppm
3. Verification that oxygen level is less than 50 ppm

Corrective actions include reducing the level of oxygen allowed from 50 ppm to 15 ppm. This also includes training of all operators on the negative impact interior color has on customer confidence in

our product.

Passthrough DOE

This first experiment was to determine the ability of the passthrough process to remove oxygen from the interior of a reservoir before it is placed into the glove box chamber for welding. This experiment considered three factors at two levels. The factors were passthrough vacuum, time at vacuum, and number of argon rinses. The experiment was designed to that it could be replicated on different equipment so the results could be blocked by welder and/or operator. Figure 2 illustrates a typical passthrough chamber. Figure 3 illustrates an overall view of a typical GTAW welding glove box chamber. Figure 4 illustrates the mock-up reservoir with valve in place.

Although the analysis for the experiment was not complete at this writing, the results of this experiment indicated that the passthrough process is extremely robust in removing oxygen from the interior of tack welded reservoir assemblies. This finding resulted in a significant change in direction in the project. To this point the team believed that the oxygen source was due to an inefficient passthrough. Based on the partial results of this experiment, the focus was shifted to the oxygen level in the glove box.

Figure 2. Typical Passthrough Chamber on GTAW Welder

Figure 3. Typical GTAW Glove Box Chamber

Figure 4. Reservoir Mock-up for Passthrough Experiment

Cap 3 Weld Color DOE

The second design of experiments utilized a weld specimen left over from a discontinued product line. In this experiment, the goal was to establish what effect different levels of oxygen have on coloration and what colors are present at the different levels. The weld for this experiment was a Tungsten Inert Gas (TIG) weld without cover gas and with no fill wire added. Relatively speaking, this is a low heat input weld compared with the GTAW girth weld that is the focus of this project. This experiment was a general linear model with three levels of oxygen and two methods of cleaning. The parts were also marked in a grid so that various cleaning residues could be placed on the weld specimen before welding. This was to evaluate if the dried cleaning residues could be seen before welding or after

welding and the effect of oxygen level on spot coloration.

Ten parts were included in this experiment. The two cleaning methods were the qualified reservoir "aqueous cleaning" and an "alcohol wipe down." The aqueous cleaning process uses a heated Oakite NST detergent (mixed in a 3% solution) and de-ionized water solution in an ultrasonically agitated tank, followed by a cascading rinse in heated de-ionized water. The alcohol wipe down is a manual cleaning process performed by the welding operator at the workstation. The operator wears cleaned latex gloves and wipes the part with a polyester wipe wetted with approved alcohol from a polyethylene bottle.

The levels of oxygen were set at 20, 60, and 100 ppm. The parts were contaminated in a systematic fashion with six cleaning residues known to be potential contaminants at the time of welding. Each part was contaminated with a given material in the same location. Three drops of the contaminant were placed in each of 12 radially located grids at three distances from the weld. In the 12 radial grids, the contamination was repeated twice (six contaminants) to block potential interaction (or confounding) of results due to location of contaminant relative to heat input (differences due to weld start/stop and overlap area).

The contaminants were (in order of placement location on part)

1. Oakite NST detergent mixed 3% with de-ionized water.
2. Tap water.
3. Alcohol from polyethylene bottle (8µ g/ml hydrocarbon) with glove and wipe; agitated.
4. Alcohol from original glass container.
5. KCD wiping solution from polyethylene spray bottle.
6. Alcohol from polyethylene bottle (8µ g/ml hydrocarbon) with glove and wipe; not agitated.

This experiment indicates that oxygen level has a statistically significant effect on the coloration and spotting of the weld. The cleaning method did not have a statistically significant effect on coloration. Spotting was consistent with certain materials. The color of the spots became darker as the oxygen level increased. Observations of spots before and after welding indicated the contaminated alcohol (from polyethylene bottle with 8 g/ml plasticizer present) was practically invisible before the weld but became visible after welding. Figure 5 illustrated the coloration and spotting of specimens welded at three levels of oxygen content. Figure 6 is a chart indicating graphically the effect welding oxygen level on the color of the parts cleaned by aqueous or alcohol wipe. As the oxygen level increases so does the color of the alcohol wiped product relative to aqueous cleaned product.

Summary of Analysis

This has been the richest portion of the project, leading to new levels of understanding of the process. The results are conclusive and indicate that if we weld at the design agency specified level of 50 ppm we will get parts with coloration that will cause product to be scrapped or remain on hold until review by the design agency. This could also result in the sectioning of units that may exhibit black spots due to oxidation of inorganic contaminants such as tap water spots.

Based on regression, the following equation describes the relationship of the factors to weld coloration. The lower the color rating, the better.

$$\text{Color rating} = 23.2 - 1.68 (\text{Clean method}) + 0.819 (\text{Oxygen level})$$

The equation is solved by substituting a coded value from the experiment for clean method (-1 or +1) and the actual oxygen level (16, 60, or 100) that yields a minimum color rating. In this case, clean method should be +1 so that 1.68 will be subtracted from 23.2, and in the second case oxygen level should be 16 so that 13.1 is added to 23.2, as shown here.

$$\text{Color rating} = 23.2 - 1.68 (+1) + 0.819 (16 \text{ ppm})$$

$$\text{Color rating} = 34.6$$

Coded values for cleaning are Oakite NST (+1), alcohol (-1). For oxygen the actual values are 16 ppm, 60 ppm, and 100 ppm.

The data for this analysis is included in Attachment D.

Based on this predictive equation, it is clear that to minimize the color rating the plus level for clean (Qualified Aqueous: Oakite NST detergent and water and the lowest level of oxygen will result in the lowest possible color rating.

Welded at 100 ppm

Welded at 60 ppm

Welded at 16 ppm

Figure 5. Photographs of Coloration and Spotting Produced at Three Levels of Oxygen

Improvement Phase

As part of the improvement phase we have incorporated a reduction in the level of oxygen that can be present in the glove box during welding. The maximum allowable operational oxygen level has been reduced to a maximum of 15 ppm in welding work instructions.

Validation

The results of the weld color DOE were validated on a reservoir with a GTAW girth weld. The designed experiment was based on a relatively low heat Tungsten Inert Gas (TIG) weld. This validation confirmed the conclusions developed on a different weld schedule in a different machine with a different operator and followed the predictive equation developed from the DOE. The product was cleaned with the qualified aqueous cleaning process and welded at < 1.0 ppm (0.4 ppm) oxygen. The entire lot was inspected and had very little coloration. The only color present was a tiny straw colored line that was just visible. The unit in question was S/N 1459 and product was welded on 11/4/00.

Results and Conclusions

The result is that the general requirement oxygen levels for GTAW welding will be reduced to 15 ppm. This level of oxygen has been unofficially adopted by many of the reservoir welding engineers as good operating procedure, but was not standardized for all product.

This level of oxygen was held on the lean glove box for a representative period with no oversight and resulted in a very high process capability. This indicates that we will be able to sustain the low level of oxygen required to make colorless welds.

Control Phase

Control will consist of specific work instructions that will advise the welding operators to stop welding if the oxygen level in the glove box exceeds 15 ppm. The operator will also be instructed to inform the welding process engineer if abnormal coloration is observed on the exterior of the bottles. The operator would then complete a Non-Conformance Report (NCR) citing the welding process as the cause of coloration. The information on the NCR can be used to support the position that we know what the residue is because we know when and where it happened.

The training for glove box operation was modified to include a statement on the problems with coloration on the interior of product and the problems this creates with customer confidence.

The glove box operation manual will be updated to reflect the changes in training and the levels of oxygen allowed. Both the training and the glove box operation manual need to address how to find and repair holes in the glove box gloves.

Trend Analysis

Oxygen Data Analysis

As a part of the control phase the sustainability of the improved process must be documented. For this purpose a strip chart recorder was connected to the oxygen meter on the lean cell glove box. The operators were instructed not to weld if the oxygen level was above 15 ppm. This strip chart recorder was set to run continuously for a period of six days. This data collection period covered all shifts, weekends, and overtime. This covered downtime periods to active production.

Graphical analysis indicates that the greatest variation is generally between days, and in general there the data trended upwards from Wednesday to the highest value on Monday. The highest variability within a day appears to be those days that there was welding activity. A general upward trend of the data is indicative of leaks in the gloves. Leaks in the gloves were repaired on first shift Monday, causing some of this variation. This data is presented in Figure 7, which is a run chart grouped by day and shift.

Potential variables that cause the day-to-day, shift-to-shift variation are the frequency of use of the system, the leaks in the gloves, the operating pressure of the argon in the box, and the effectiveness of the passthrough operation in preventing oxygen from entering through the door. Even though there is some variation that appears to be out of control, the bottom line is that for practical reasons the maximum level that is reached is 8 ppm, which is well below the existing 50 ppm specification. The 8 ppm maximum is also well below the self-imposed limit of 15 ppm, effectively confirming that the system is easily capable of keeping oxygen levels below 15 ppm in the glove box. Figures 8 and 9 illustrate the capability of the system to maintain the 15 ppm level of oxygen under normal operational circumstances.

This data set is included as Attachment E.

Summary of Tools Used

Process mapping was used to map the passthrough process. A thought map was used to provide direction, continuity, and history for the project. This was followed by the cause and effect diagram and the Failure Modes and Effects Analysis (FMEA). The FMEA distilled operation from the process map into ratings. Design of Experiments (DOE) were used in two cases. First to establish how well the passthrough removed oxygen from the interior of the product, and second to correlate weld coloration to ppm of oxygen in the weld chamber. Results of the DOEs were analyzed by the Practical, Graphical and Analytical (PGA) approach, first using practical analysis by just looking at the raw data, then graphing the data and using Multivary charts in order to visualize the difference. This is followed by regression analysis. A run chart was used for trend analysis to establish if the oxygen level can be maintained at the new level of 15 ppm. Pareto analysis was utilized to develop the organizational impact based on the number of borescope rejects for spots and coloration.

Summary of Results

Business Impact

Currently the plant actively produces a significant number of reservoir components with GTAW girth welds. These estimates are based on actual borescope inspection logs for approximately two years (1998 – 1999). During this time the reject rate for the cause of staining, weld coloration, or black

spots near the weld is on average 62 units per year. Of the 62 rejects at borescope we have successfully reworked 47 units and scrapped 15 units for destructive testing. The 15 scrapped units are destructively tested so that we may gain "line of sight" access to the stain or discoloration. Highly sensitive surface analysis techniques are used to determine the composition of the discolored area. Table 1 outlines the itemized costs based on an average of 62 units per year rejected at borescope for weld coloration or black spots in the weld area. The scrap value (base material and labor) is based on average cost for all full-up reservoir assemblies (with a GTAW girth weld). The remaining 47 units are reworked and accepted as-is or accepted by a Specification Exception Release (SXR). A Proposed Reportable Savings form has been submitted and approved for an annual savings of \$50,978 as a result of the findings of this project.

Table 1. Organizational Impact

Activity	Hours required	Frequency per year	Hours per year	Rate per hour	Dollars per unit	Cost per year
Reject paperwork	0.2	62	12.4	22.02		\$273
Re-clean	2	62	124	20.33		\$2,521
Re-inspect	0.9	62	55.8	22.02		\$1,229
Section rejects	3	15	45	24.34		\$1,095
Engineering action NCR SXR	1	62	62	33.51		\$2,078
Surface analysis	23	15	345	32.17		\$11,099
Documentation	35	15	525	33.51		\$17,593
Scrap Value		15			846	\$12,690
SXR		24			100	\$2,400
						\$50,973 Total/year

The results of this project will yield an annual savings of approximately \$50 K/year. This is in addition to reducing the flow time for reservoir production as well as freeing up some overburdened resources in cleaning and laboratory analysis.

Effect of Oxygen Level on Color Rating and The Relationship to Cleaning Method

Figure 6. Effect of Oxygen Level on Color Related to Cleaning Method

Run Chart with subgroups on Shift

Number of runs about median:	2.0000	Number of runs up or down:	8.0000
Expected number of runs:	10.4737	Expected number of runs:	12.3333
Longest run about median:	10.0000	Longest run up or down:	4.0000
Approx P-Value for Clustering:	0.0000	Approx P-Value for Trends:	0.0066
Approx P-Value for Mixtures:	1.0000	Approx P-Value for Oscillation:	0.9934

Figure 7. Run Chart of Oxygen Data Grouped by Shift and Day

Report 1: Executive Summary

Figure 8. Summary of Oxygen Plotted Against 15 ppm Specification

Report 2: Process Capability for Oxygen

Figure 9. Process Capability for Oxygen Plotted Against 15 ppm Specification

ATTACHMENT A

ATTACHMENT B

ATTACHMENT C

Cause and Effect Diagram

FISHBONE DIAGRAM FOR PASSTHROUGH – ELIMINATING WELD COLOR

Process/Product Failure Modes and Effects Analysis (FMEA)

Process or Product Name:	GTAW Passthrough	Prepared by: K. F. Arnold	Page ____ of ____
Responsible:		FMEA Date (Orig) 6/5/00	(Rev) 11/08/00

Process Step Input	Failure Mode	Failure Effects	SEV	Causes	OCC	Current Controls	DET	RPN	Actions	Resp.	Actions Taken	SEV	OCC	DET	RPN
Evacuate to 50 microns	Discoloration of weld	Scrap	5	Too high oxygen content in part	3	TP MO 605 training	1	15	Training on adverse effects of colors	Weld process engineer	11/22/2000				0
Evacuate to 50 microns	Discoloration of weld	Scrap	5	Allowed oxygen into chamber through	3	TP MO 605 training	1	15	Training on adverse effects of colors	Weld process engineer	11/22/2000				0
Verify O2 did not rise over 15 ppm	Discoloration of weld	Scrap	5	Read oxygen meter too fast	3	Glovebox manual	1	15	Specify a time period	Weld process engineer	11/22/2000				0
Verify O2 did not rise over 15 ppm	Discoloration of weld	Scrap	5	Operator overlooks step	3	Glovebox manual	1	15	Reinforce in traveler instructions	Weld process engineer	11/22/2000				0

Color data sheet.xls

Run order	Run	Body serial	Cap Serial	Clean	O2	color	Spot	color1,1c	color	Spot	color1,2c	color	Spot	color1,3c	color	Spot
1	3	3	x013	NST	16	50	10	60	50	10	60	25	0	25	25	0
2	6	6	x030	Alcohol	16	50	30	80	25	50	75	25	0	25	25	0
3	7	7	x033	Alcohol	16	50	10	60	50	30	80	25	10	35	25	0
4	2	2	x007	NST	60	100	40	140	100	50	150	50	0	50	50	0
5	5	5	x020	Alcohol	60	100	20	120	100	50	150	50	0	50	50	0
6	9	17	x050	NST	60	75	30	105	100	50	150	50	0	50	50	0
7	10	19	x055	Alcohol	60	100	50	150	100	50	150	50	0	50	50	0
8	1	1	x001	NST	100	100	30	130	100	50	150	75	0	75	75	0
9	4	4	x017	Alcohol	100	100	40	140	100	50	150	75	40	115	75	0
10	8	8	x034	NST	100	100	30	130	100	50	150	75	20	95	75	0

Color data sheet.xls

Run order	Run	Body serial	Cap Serial	Clean	O2	color1,4c color	Spot	color1,5c color	Spot	color1,6c color	Spot	color2,1c color
1	3	3	x013	NST	16	25	0	25	0	25	10	35
2	6	6	x030	Alcohol	16	25	10	35	0	25	10	35
3	7	7	x033	Alcohol	16	25	0	25	0	25	10	35
4	2	2	x007	NST	60	50	0	50	0	50	30	80
5	5	5	x020	Alcohol	60	50	0	50	0	50	30	80
6	9	17	x050	NST	60	50	10	60	0	50	30	80
7	10	19	x055	Alcohol	60	50	10	60	0	50	50	100
8	1	1	x001	NST	100	75	40	115	0	75	40	115
9	4	4	x017	Alcohol	100	75	40	115	0	75	50	125
10	8	8	x034	NST	100	75	20	95	0	75	30	105

Color data sheet.xls

Run order	Run	Body serial	Cap Serial	Clean	O2	Spot	color2,2c	color	Spot	color2,3c	color	Spot	color2,4c	color	Spot	color2,5c
1	3	3	x013	NST	16	50	75	25	0	25	25	0	25	25	10	35
2	6	6	x030	Alcohol	16	10	35	25	0	25	25	0	25	25	10	35
3	7	7	x033	Alcohol	16	20	45	25	0	25	25	0	25	25	0	25
4	2	2	x007	NST	60	20	70	50	0	50	50	0	50	50	10	60
5	5	5	x020	Alcohol	60	50	100	50	0	50	50	0	50	50	10	60
6	9	17	x050	NST	60	50	100	50	10	60	50	0	50	50	0	50
7	10	19	x055	Alcohol	60	50	100	50	10	60	50	0	50	50	0	50
8	1	1	x001	NST	100	50	125	75	30	105	75	40	115	75	30	105
9	4	4	x017	Alcohol	100	50	125	75	30	105	75	30	105	75	30	105
10	8	8	x034	NST	100	50	125	75	0	75	75	0	75	75	40	115

Color data sheet.xls

Run order	Run	Body serial	Cap Serial	Clean	O2	color	Spot	color2.6c	Total	Average
1	3	3	x013	NST	16	25	0	25	440	37
2	6	6	x030	Alcohol	16	25	0	25	445	37
3	7	7	x033	Alcohol	16	25	0	25	430	36
4	2	2	x007	NST	60	50	0	50	850	71
5	5	5	x020	Alcohol	60	50	0	50	860	72
6	9	17	x050	NST	60	50	0	50	855	71
7	10	19	x055	Alcohol	60	50	0	50	920	77
8	1	1	x001	NST	100	75	0	75	1260	105
9	4	4	x017	Alcohol	100	75	0	75	1310	109
10	8	8	x034	NST	100	75	0	75	1190	99

rawdata7days.xls

Date	Day	time	Oxygen	Shift
10/31/2000	Tuesday	15:46	1	2
10/31/2000	Tuesday	16:46	1	2
10/31/2000	Tuesday	17:46	1	2
10/31/2000	Tuesday	18:46	1	2
10/31/2000	Tuesday	19:46	1	2
10/31/2000	Tuesday	20:46	1.5	2
10/31/2000	Tuesday	21:46	1.5	2
10/31/2000	Tuesday	22:46	1.5	2
10/31/2000	Tuesday	23:46	1.5	3
11/01/2000	Wednesday	0:46	1.5	3
11/01/2000	Wednesday	1:46	1.5	3
11/01/2000	Wednesday	2:46	1.5	3
11/01/2000	Wednesday	3:46	1.5	3
11/01/2000	Wednesday	4:46	1.5	3

11/01/2000 Wednesday	5:46	1.8	3
11/01/2000 Wednesday	6:46	1.8	1
11/01/2000 Wednesday	7:46	1.9	1
11/01/2000 Wednesday	8:46	2	1
11/01/2000 Wednesday	9:46	1.9	1
11/01/2000 Wednesday	10:46	1.9	1
11/01/2000 Wednesday	11:46	1.9	1
11/01/2000 Wednesday	12:46	2	1
11/01/2000 Wednesday	13:46	2	1
11/01/2000 Wednesday	14:46	2	1
11/01/2000 Wednesday	15:46	2	2
11/01/2000 Wednesday	16:46	2	2
11/01/2000 Wednesday	17:46	2	2
11/01/2000 Wednesday	18:46	2	2
11/01/2000 Wednesday	19:46	2	2
11/01/2000 Wednesday	20:46	2	2
11/01/2000 Wednesday	21:46	2.2	2
11/01/2000 Wednesday	22:46	2.2	2
11/01/2000 Wednesday	23:46	2.2	3
11/02/2000 Thursday	0:46	2.5	3
11/02/2000 Thursday	1:46	2.5	3
11/02/2000 Thursday	2:46	2.5	3
11/02/2000 Thursday	3:46	2.5	3
11/02/2000 Thursday	4:46	2.6	3
11/02/2000 Thursday	5:46	2.6	3
11/02/2000 Thursday	6:46	2.5	1
11/02/2000 Thursday	7:46	2.5	1
11/02/2000 Thursday	8:46	2.5	1
11/02/2000 Thursday	9:46	2.5	1
11/02/2000 Thursday	10:46	2.5	1
11/02/2000 Thursday	11:46	2.5	1
11/02/2000 Thursday	12:46	2.6	1
11/02/2000 Thursday	13:46	2.7	1
11/02/2000 Thursday	14:46	2	1
11/02/2000 Thursday	15:46	1.9	2
11/02/2000 Thursday	16:46	2.4	2
11/02/2000 Thursday	17:46	2.8	2

rawdata7days.xls

11/02/2000 Thursday	18:46	2.8	2
11/02/2000 Thursday	19:46	2.8	2
11/02/2000 Thursday	20:46	2.8	2
11/02/2000 Thursday	21:46	2.8	2
11/02/2000 Thursday	22:46	2.9	2
11/02/2000 Thursday	23:46	3	3
11/03/2000 Friday	0:46	3	3
11/03/2000 Friday	1:46	3.1	3
11/03/2000 Friday	2:46	3.2	3
11/03/2000 Friday	3:46	3.2	3
11/03/2000 Friday	4:46	3.2	3
11/03/2000 Friday	5:46	3.4	3
11/03/2000 Friday	6:46	2.5	1
11/03/2000 Friday	7:46	1.3	1
11/03/2000 Friday	8:46	2	1
11/03/2000 Friday	9:46	2.3	1
11/03/2000 Friday	10:46	2	1
11/03/2000 Friday	11:46	2.4	1

11/03/2000 Friday	11:46	2.4	1
11/03/2000 Friday	12:46	2.6	1
11/03/2000 Friday	13:46	2.9	1
11/03/2000 Friday	14:46	3.5	1
11/03/2000 Friday	15:46	3.5	2
11/03/2000 Friday	16:46	3.5	2
11/03/2000 Friday	17:46	3.6	2
11/03/2000 Friday	18:46	3.6	2
11/03/2000 Friday	19:46	3.8	2
11/03/2000 Friday	20:46	4	2
11/03/2000 Friday	21:46	4	2
11/03/2000 Friday	22:46	4	2
11/03/2000 Friday	23:46	4	3
11/04/2000 Saturday	0:46	3.9	3
11/04/2000 Saturday	1:46	3.8	3
11/04/2000 Saturday	2:46	3.7	3
11/04/2000 Saturday	3:46	3.6	3
11/04/2000 Saturday	4:46	3.6	3
11/04/2000 Saturday	5:46	3.8	3
11/04/2000 Saturday	6:46	4	1
11/04/2000 Saturday	7:46	4.2	1
11/04/2000 Saturday	8:46	4.3	1
11/04/2000 Saturday	9:46	4.3	1
11/04/2000 Saturday	10:46	4.3	1
11/04/2000 Saturday	11:46	4.3	1
11/04/2000 Saturday	12:46	4.3	1
11/04/2000 Saturday	13:46	4.4	1
11/04/2000 Saturday	14:46	4.4	1
11/04/2000 Saturday	15:46	4.5	2
11/04/2000 Saturday	16:46	4.6	2
11/04/2000 Saturday	17:46	4.7	2
11/04/2000 Saturday	18:46	4.9	2
11/04/2000 Saturday	19:46	5	2
11/04/2000 Saturday	20:46	5.2	2
11/04/2000 Saturday	21:46	5.2	2

rawdata7days.xls

11/04/2000 Saturday	22:46	5.2	2
11/04/2000 Saturday	23:46	5	3
11/05/2000 Sunday	0:46	4.9	3
11/05/2000 Sunday	1:46	4.9	3
11/05/2000 Sunday	2:46	4.9	3
11/05/2000 Sunday	3:46	4.8	3
11/05/2000 Sunday	4:46	4.8	3
11/05/2000 Sunday	5:46	4.8	3
11/05/2000 Sunday	6:46	4.8	1
11/05/2000 Sunday	7:46	4.9	1
11/05/2000 Sunday	8:46	4.9	1
11/05/2000 Sunday	9:46	4.9	1
11/05/2000 Sunday	10:46	4.9	1
11/05/2000 Sunday	11:46	4.9	1
11/05/2000 Sunday	12:46	4.9	1
11/05/2000 Sunday	13:46	4.9	1
11/05/2000 Sunday	14:46	4.9	1
11/05/2000 Sunday	15:46	4.9	2

11/05/2000 Sunday	16:46	4.9	2
11/05/2000 Sunday	17:46	4.9	2
11/05/2000 Sunday	18:46	4.9	2
11/05/2000 Sunday	19:46	4.9	2
11/05/2000 Sunday	20:46	5	2
11/05/2000 Sunday	21:46	5	2
11/05/2000 Sunday	22:46	5.5	2
11/05/2000 Sunday	23:46	6	3
11/06/2000 Monday	0:46	6.1	3
11/06/2000 Monday	1:46	6.2	3
11/06/2000 Monday	3:46	7	3
11/06/2000 Monday	4:46	8	3
11/06/2000 Monday	5:46	8.2	3
11/06/2000 Monday	6:46	8	1
11/06/2000 Monday	7:46	8	1
11/06/2000 Monday	8:46	8.2	1
11/06/2000 Monday	10:46	2	1
11/06/2000 Monday	11:46	2.7	1
11/06/2000 Monday	12:46	2	1
11/06/2000 Monday	13:46	3	2
11/06/2000 Monday	14:46	3.8	2
11/06/2000 Monday	15:46	5	2
11/06/2000 Monday	16:46	6.3	2
11/06/2000 Monday	17:46	6.5	2
11/06/2000 Monday	18:46	6.2	2