Title: A TQM Implementation in North West Motor Welding Company

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Author(s): E. Buescher, F. Rivera and C. W

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E. Buescher, F. Rivera, C. Jones
J. Alvarez, E. Kangas, A. Uslu, R. Markle

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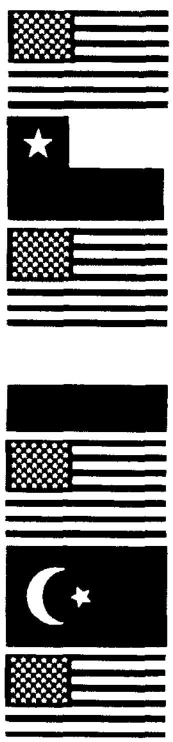
TQM I
GROUP PROJECT

A TQM IMPLEMENTATION IN NORTH WEST MOTOR WELDING COMPANY

BY

QUALITY TEAM



ED BUESCHER

FERNANDO RIVERA

CLIFFORD W. JONES

JOHN ALVAREZ

ERIC KANGAS

AKIN USLU

RICK MARKLE

FOR
DR. RICHARD F. DECKRO

EXECUTIVE SUMMARY

NorthWest Motor Welding is experiencing a severe problem in warranty claims from customers. An analysis of the warranty data has revealed that a high percentage of these claims, both in dollars and in number, were generated by just three cylinder head types within the Caterpillar rebuild line. The Quality Team performed an analysis of factors that might be causing this situation. The team recommended five potential solutions for consideration:

- Temperature controlled cooling process
- Serialization of heads for tracking and process control
- Temperature control ovens for heating and welding of cracks in heads
- Temperature measuring devices, for measuring the heads during welding and cool down
- Standardization of weld process

None of these potential solution, by themselves, will generate a complete solution. The team feels that a combination of these efforts will achieve success. We strongly recommend adopting all five alternatives.

Table of Contents

I. INTRODUCTION

The NorthWest Motor Welding Co. specializes in industrial diesel engine repair and overhaul. The diesel engine components that require rebuilding are usually received as individual items through a core exchange program common in the automotive industry. For reasons that will become clear later in this document the team decided to focus on the cylinder head rebuild process. The cylinder heads received are ordinarily referred to as raw core. The raw cores are inspected upon receipt and necessary repairs are determined. Common types of repairs that are necessary include welding cracks in the combustion surface and remachining the cylinder head to rebuild specifications. This process takes place in a mixed job shop and an assembly line environment at one of the plant locations in the Portland area.

Warranty claims have been a significant cost area in the overall financial picture of the company. Past attempts to reduce this cost area have seen some success in the short run, but have not been very successful in the long run. Once management attention is deflected toward some other area of the company, the process tends to return to previous levels of warranty claims. No long term solution to this problem has been found.

The management personnel of NorthWest Motor Welding have not had any formal training in Total Quality Management tools and techniques. While they are familiar with the term and have read about this area in periodicals, no collective practical experience exists. None of the non-management personnel have had any experience either. The President and Shop Foreman were receptive to attempting some new ideas to solve this problem area. This project will attempt to provide some analysis of the problem and recommend solutions to reduce the size of the warranty claims.

II. BACKGROUND

A. Problem Definition

NorthWest Motor Welding Company is determined to reduce the number of warranty claims generated by its customers. The team has analyzed the major warranty claims information and warranty cost information through the use of Pareto Analysis techniques. Copies of the Pareto Charts are included in Appendix A, at the end of this report.

The results of this analysis indicate that the majority of the warranty claims are generated by the Cylinder Head Rebuild Facility. This holds true whether we are analyzing the information by number of claims or by costs. As the charts in Appendix A indicate, the Cylinder Head Rebuild Facility accounts for approximately 85 percent of the warranties when considering the number of warranties recorded over the last year (Appendix A, Chart 1). When considering the costs associated with warranties, the Cylinder Head Rebuild Facility accounts for 75 percent of the total warranty costs over the last year (Appendix A, Chart 2). These results clearly indicate that focusing our attention on the Cylinder Head Rebuild Facility would hold the greater opportunity for significant cost and quantity of claims reduction.

Next we selected out the warranty information pertaining only to the Cylinder Head Rebuild Facility and reanalyzed the information. The recorded defect code for each warranty was grouped into five problem areas; valves, cracks, assembly, machining, and shipping. A Pareto analysis was again conducted on this subset of the data, both by number and by cost (Appendix A, Charts 3 and 4). The valve grouping had the highest quantity and cost with the cracks grouping just slightly lower in number and cost. A discussion with the

Cylinder Head Shop Foreman revealed that the shop had recently changed rebuild processes concerning valve seats and valves on the Cummins Diesel Line that had significantly reduced the number of valve related defects. Based in this information the team decided to shift its focus on valves to the next most significant problem area, the cracks.

One of the team members suggested we also analyze the data by grouping the information by original manufacturer; Caterpillar, Detroit Diesel, and Cummins Diesel. The results of this Pareto analysis are depicted in Appendix A, (Charts 5 and 6). When considering the number of claims, Cummins Diesel registered a clear majority with over 50 percent of the claims. When considering the cost of the claims, Caterpillar was slightly ahead in costs. A discussion with the Shop Foreman revealed that many of the warranty claims for the Cummins Line were the result of leaking injector copper sleeves. The process for inserting the new sleeves during the rebuilt process had been modified through the use of a new insertion tool. This had eliminated the warranty claims for the leaking injector copper sleeve problem. Based on this information the team decided to focus on the Caterpillar Line.

Selecting out the warranty information on the Caterpillar products produced the Pareto Charts depicted in Appendix A, (Charts 7 and 8). These two charts clearly indicate that within the Caterpillar Line, cracks are the most prevalent problem, both in terms of quantity and cost. On the basis of the above analysis the team decided to focus their efforts toward finding ways to reduce the number of warranty claims due to cracks on the Caterpillar Rebuild Line.

Within the warranty information on the Caterpillar products, selecting the data on cracks by type of cylinder head produced the chart that is depicted in Appendix A, (Chart 9). From this data the greatest number of warranty claims are from three types of cylinder heads; 343, 3306, and 3406. Selecting these three cylinder heads provides a project size that is possible given the time and resource constraints that the team must work within.

B. Rebuild Process

The cylinder head rebuilding process consisted of four basic segments: (1) cylinder head preparation, (2) welding, (3) machining, and (4) assembly. All of the operations except for welding are performed in the main shop area. Welding is done in a separate room. The flowchart in Appendix B provides a pictorial diagram of the process broken down into steps.

Preparation consists of inspection and disassembly, which are often done in conjunction with each other. Inspection is done using magnetic particle powder and applying an electric field to local areas of the head. Cracks interrupt the field which affects the dispersion of the powder, thereby indicating the location of the crack. Any cracks that are found are marked with a heat resistant white paint.

Disassembly consists of removing valves, rocker arms, springs, valve seats and guides, injectors, fuse plugs, and other miscellaneous removable components. The head is then cleaned in a hot tank with an alkaline solution.

If no cracks are found and the head meets dimensional specifications, it is sent directly to pressure test and finish machining. However, in most cases the heads are cracked and/or dimensionally out of specification. When this is the case, a determination is made as to the feasibility and cost effectiveness of repair. If it is not practical or cost effective to repair, the head is scrapped. This evaluation is often made during the disassembly and inspection operation. However, the material weldability and extent of the cracks sometimes can not be accurately assessed until the welding process.

Heads that need to be welded are prepared by machining out the injector nozzle area since it is often badly eroded. The injector nozzle area will be filled in with a plug during the preparation phase of the welding process. Cracks are not ground out since it is faster and easier to burn them out with a welding torch.

When a head has been selected for welding it is then placed in a brick oven for preheating. Preheating is accomplished with gas torches impinging flame directly on the head through the opening in the oven. Welders usually determine if the head is hot enough to weld by burning pure acetylene gas over the head. If the acetylene gas burns clean, without soot, the head is ready for welding.

Welding cast iron is difficult because of the high carbon content. Since carbon prevents good metal bonding, carbon plugs are placed into the ports and openings on the head to prevent molten metal from flowing into them. The head must be properly fluxed to remove impurities from the metal. While fluxing the welder heats the metal until it is molten. Cast iron welding rods are also preheated and then used as filler material. The most critical part of welding is a good bond between the filler and parent material. This is especially difficult with cast iron. If a good bond is not achieved the material often cracks. The welder completely bonds the weld puddle with the surrounding parent material and further fluxes the material to remove impurities.

During the welding process the welder is preheating another head in a separate oven. The second head is then welded while the first one is cooling. A third head is then placed in the oven for preheating and the cycle repeats. When the heads are completely cooled the slag must be removed. The slag is burned off with a torch because it is easier than grinding.

The head is then sent to sandblast for cleanup. From there it goes to rough machining where the welded passages are drilled and reamed to slightly undersize, and the welded surfaces are rough machined. Cracks are sometimes detected during these operations and, depending on the severity, will dictate the rework method. Severe cracks require rewelding. Less severe cracks are repaired by arc welding, pins, or a fiberglass crack filling compound.

Once the head is acceptable from rough machining it is sent on for finish machining, where the head is surface ground to specifications. Excess material in passages is removed by hand grinding. New fuse plugs for the water passages are installed and sealed. The head is then pressure tested for leaks in a water bath using high pressure air. If the leaks and/or cracks are small a fiberglass filling compound is used for sealing. Large cracks require welding and or installation of a pin to prevent crack propagation.

When the head passes the first pressure test it is then sent to have the valve seats installed. The valve seat area is machined to the final dimensions. The cylinder head is then sent back for a second pressure test. The valve seats are installed at the pressure test station. If the cylinder head passes the second pressure test the valve seats are ground. From there it goes to final inspection for an overall magnetic particle inspection. If the head is acceptable then it is alkaline cleaned and sent to assembly if the product is to have the valves installed. If the valves are not to be installed, the cylinder head is prepared for shipment.

During assembly the valves and valve train components are then assembled on the head. A vacuum test is performed to verify proper valve seating and sealing. Once the cylinder head passes the vacuum test it is prepared for shipment.

The above discussion outlines the general rebuild process on the Caterpillar rebuild line. The steps can be catergorized into four basic segments; (1) cylinder head preparation, (2) welding, (3) machining, and (4) assembly.

Reference to the flowchart in Appendix B provides the same information in diagram form.

C. Welding

1. Preheat Cycle

The preheat cycle involves heating the cast iron cylinder head from ambient temperature to a working temperature of 1250° F. This is accomplished through use of gas torches that are aimed at both ends of the cylinder head. According to the welders, the placement of the torches are critical so that the head does not heat too rapidly in an isolated area thus causing cracking due to stress buildup. The welders mentioned that different types of heads require different torch placement. The welders theorized that the design of the head, especially the thickness of the water cooling jacket, influences the preheat cracking problems.

This procedure was discussed with Bill Fuller[1], a ESCO Corporation metallurgist. Mr. Fuller commented that direct placement of the torches on any cast iron workpiece could result in warpage and eventually lead to stress that leads to cracking and warpage. He mentioned that the underlying cause for stress induced cracking is a result of having too high of a thermal (linear) expansion in a localized area. Machinery's Handbook lists the coefficient of thermal expansion of cast iron to be 6.55×10^{-6} inch per inch per degree Fahrenheit.[2] Applying this information to the large cylinder heads, which are about forty inches in length, means that they could expand by 0.31 inches when heated to a temperature of 1250 degrees Fahrenheit.

[1]Bill Fuller, an interview between Ed Buescher and Bill Fuller on Feb. 24, 1994 at ESCO Corp., Portland, OR.
[2]__________, Machinery's Handbook, Twenty-Second Edition, Industrial Press, Inc., New York, NY, July 1985, p. 2274.

$$6.55 \times 10^{-6} \text{ in/in/*F} \times (1250 - 70 \text{ *F}) \times 40 \text{ in.} = 0.44 \text{ inches}$$

Therefore, when attempting to preheat a cast iron workpiece, the goal should be to heat the entire cylinder head gradually and uniformly to the desired weld temperature. This method will minimize local stresses in the cylinder head.

Mr. Fuller mentioned that many industries that specialize in welding cast iron use a convection type oven to preheat and cool the workpiece instead of using the gas torches that NorthWest Motor Welding employs. An efficient type of convection oven is a recirculating oven. This oven works on the principle of heating the air and uses a fan to blow the hot air past the workpiece to promote uniform heating and a controlled temperature. A benefit of heating the cylinder head by air instead of by direct flame is that the entire head reaches the working temperature at the same time, thus reducing the stresses in the workpiece. This oven could also be employed to cool the head uniformly.

A disadvantage of this type of oven is that it needs to be insulated from the outside environment. Therefore, the welders would need to wear insulated gloves that are attached to the oven. This may make the cylinder head more difficult to weld.

The principle benefits derived from preheating cast iron result from slower cooling of the weld zone, particularly at the low temperatures in the martensitic transformation range. The presence of martensite in cast iron is undesirable because it has a low ductility and therefore poor ability to withstand thermal stresses. Slow cooling thus promotes complete austenitic transformations at high temperatures, permits hydrogen to diffuse out of the weld joint, and lowers the internal stresses set up during cooling.

Hydrogen may be introduced into the base metal from the flux or from any material that is left in an open container in the workshop. The primary source of hydrogen is moisture. This is the reason why arc welders place their weld rods in a heated container. The heated container keeps moisture from soaking into the coating on the weld rod and becoming trapped in the weld area. A hydroscopic material has an affinity for water and thus absorbs moisture readily. Hydrogen cracks in weldments result when hydrogen levels increase. This is a condition where the molten weld pool holds a greater concentration of hydrogen that it could hold as a solid at ambient temperature. Since hydrogen is more soluble in molten cast iron than solid iron, it will attempt to escape from the supersaturated solution during the cooling period. If the excess hydrogen does not escape, it becomes trapped within a discontinuity in the metal and within a hardened area, cracking may result.

The effects of preheating are:

a. It eliminates or decreases the danger of cracking by lowering the temperature differences between the unaffected base metal and the weld metal.
b. It minimizes hardness zones adjacent to the weld because it minimizes the formation of martensite.
c. It holds stresses to a minimum.
d. It decreases distortion.
e. It increases the rate of diffusion and escape of hydrogen from the weld joint.

2. Welding Cycle

After the cylinder head reaches the desired working temperature of 1250° F, the welding process begins. The welder uncovers the first area to be welded by removing the insulating material from the top of the cylinder head.

Only the area to be welded, usually one cylinder, is uncovered at this time. This keeps the head from cooling in other areas.

a. Torch Tip Selection

The first step involves the selection of the proper tip for the oxyacetylene torch. Different sizes of tips are available to the welders and the diameter of the tip influences the amount of heat that can be applied to the cylinder head. Initially the welder assesses the extent of the cracks by burning out the cracked areas with an oxyacetylene welding torch. After the metal is cut back removing the cracks it is easier for the welder to assess whether it is feasible and cost effective to weld repair. Bad heads are scrapped at this point.

b. Installing Carbon Plugs

Tapered plugs are added to the exhaust port and the intake plugs if these areas do not require welding. Straight carbon rods are placed into the bolt holes and other areas that are in the immediate vicinity of the weld zone. The use of these plugs, although necessary, may cause the base metal to absorb high levels of carbon in the valve seat area. This could lead to hard spots and cause cracking during the installation of the valve seats.

c. Cleaning the Base Metal

The welder then ignites the torch and begins to heat the base metal until the impurities start to glow. Then as the base metal starts to melt, the application of flux enables the impurities to float out of the weld pool in the form of a slag. The cleaning process is crucial to successful welding of cast iron. Cast iron is porous when compared to other metals and this allows for oil and other impurities to soak into the head during its service life. All of these impurities must be removed before the process of adding filler material can begin.

d. Installing Cast Iron Plugs in Valve Guides

Sometimes cast iron plugs have to be inserted into the cylinder head. These plugs are required is a large amount of metal has been removed from the cylinder head valve guide area. This process reduces the amount of welding that has to be performed to rebuild the area.

e. Addition of Filler Material

The addition of filler metal is accomplished through use of a high nickel filler rod. The composition of the filler material is very important and should be screened to ensure that it is of the proper chemistry. Improper filler material selection could result in poor bonding to the base metal. Care should be taken to keep the filler rods clean and free from grease and other impurities. All of these impurities could end up in the finished weld. The filler material is added to the weld area in the process of welding the cylinder head. The surface of the weld should rise to a level slightly above the old surface height. This ensures that enough metal is present during the machining processes performed later in the process.

3. Cooling Phase

The cool down process should be monitored to allow uniform cooling of the cylinder head. The welder accomplishes the controlled cooling by gradually reducing the torch heating. The cylinder head is covered and allowed to cool in the oven until the surface is no longer red. As discussed above, if the cooling takes place too rapidly, hydrogen and carbon will not have sufficient time to precipitate out of the weld zone. This could cause cracking. Also, during cooling it is important to allow the head to cool uniformly to prevent any warpage that might occur.

D. TQM Literature Search

The literature that does apply to the processes under discussion is limited. The type of articles found vary in scope from those dealing with the broad TQM theory explanation and its implications for the welding industry to those articles that focus on repair welding processes. An example of the former is "Statistical Process Control" written by Papritan and Helzer.[3] An example of the latter is "Repair Welding: How to Set Up a Shop" by C. MacCocaire.[4]

In the article, "Welding Myths Put to Rest,"[5] Western states that throughout his years spent training, qualifying, certifying welders, and working as a welder or inspector he has found that a surprising number of myths have been formulated and passed around the industry as fact. His research has shown that adequate research has been done that disproves many of these myths. However, this research is written on an engineering level. This level is often difficult to comprehend for many of the welders who have learned their trade through on-the-job training without a technical education. Some of the common myths of welding are:

- A weld can be restarted without cleaning.
- Time constraints do not affect weld quality.
- The way I was taught to weld 10 years ago is still good enough today.
- It might not look good but it will hold.
- Our shop does not do much critical work, and our welders do not need to be certified.
- Repaired welds are not as good as once-made welds.

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[3]J.C. Papritan and S.C. Heltzer, "Statistical Process Control for Welding," Welding Journal, March 1991, v70 n3, pp. 44-48.
[4]C. MacCocaire, "Repair Welding: How to Set Up a Shop," Welding Journal, August 1991, v70 n8, pp. 54-56.
[5]J.W. Western, "Welding Myths Put to Rest," Welding Journal, March 1991, v70 n3, pp. 75-77.

A coordinated effort to train the welders in proper welding techniques should take care of these myths. The research highlights the need to present the information in a clear way that is understandable to the welders.

In the article, "What Are the Causes of and Solutions to Weld Quality Conflicts?"[6] Holdren states "as long as welds have been evaluated, there have been conflicts among those responsible for the design, production, and examination of those welds." In this article the author suggests the following categories for grouping weld quality conflicts:

- human factors
- poor understanding of quality requirements
- inexperience of inspection personnel
- lack of inspection methods

Of these categories, Holdren states that the human factors are the main reason for the generation of quality conflicts.

The author of this article also provides some important observations on welding quality:[7]

- The quality of the resulting weld is heavily dependent upon the skill of the individual welder.
- Visual weld quality requirements should be expressed graphically instead of trying to specify the necessary details through the use of text to avoid mistakes introduced by human judgment in the quality inspection.

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[6]R.L. Holdren, "What Are the Causes of and Solutions to Weld Quality Conflicts?", Welding Journal, August 1993, v72 n8, pp. 57-65.
[7]Holdren, pp. 57-65.

- All of the people involved in the welding process: welder, designer, foreman, inspector, etc., must understand the quality requirements of the process.
- Inspection techniques are being improved to include the use of new technology, such as computer, robots, etc.,and individuals using this equipment must be highly skilled.
- Performance of effective visual examination before, during, and after welding will reveal 80-90 percent of those weld discontinuities that would be detected later by some more expensive and sophisticated nondestructive examination method.

MacCocaire has stated that maintenance shop welding has gained a bad reputation because the welder is often left with the responsibility of attempting repairs without the proper information to perform the job.[8] This particular image is further supported by the fact that there is a lack of expert information. Companies that have developed successful procedures over the years are not inclined to share this information. The article further states that all the weld repair processes should include the following steps:

a. non-destructive testing.

b. base metal identification.

c. heat treatment selection.

d. process and weld selection.

e. welding techniques, which will vary according to the process.

Glickstein has written about the application of the computer to the welding process.[9] Among the various uses cited is the use of a computer to monitor

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[8]MacCocaire, pp. 54-56.

[9]S.S. Glickstein, "Unique Ways to Apply the Personal Computer to Welding - Part I," Welding Journal, June 1992, v71 n6, pp. 79 - 82.

- Start of the welding stage
- Immediately after welding
- Start of the cooling stage
- End of the cooling stage

2. Rebuild Processes

Data collection on the cylinder head rebuilding process was recorded by shop personnel at each operation downstream of welding that could uncover or observe a defect. All Caterpillar Line team members were provided with defect repair maps for each of the three Caterpillar cylinder heads under evaluation (see Appendix D). On each defect repair map were places to record the employee, date, welder, serial number, operation were the defect was found, and what they identified as the cause of the defect, and drawing on which to record the defect location.

The purpose and importance of the maps were explained to the Caterpillar Line team members in a group meeting. Surprisingly, most of the sheets included entries for each requested item of information (see Appendix E).

The initial two weeks of data collecting went well. The lead inspector was ill the following week and data collection virtually came to a standstill. Collection never really gained momentum despite follow up requests. It was obvious that when the support or incentive to collect data was not present the process stopped. This was another indication that if management does not fully support the effort, the process of improvement is easily sidetracked by production pressures. One of the employees made the comment when asked where his data was: "Since you got rid of Juan (welder trainee responsible for many defective heads) we haven't had any bad ones to record."

B. Process Control

The following charts describe the flow process of welding and the overall process of rebuilding the cylinder heads:

WELDING FLOW PROCESS CHART

DETAILS OF METHOD	State	Distance in feet	Quantity	NOTES
INSPECTION OF HEAD; USE MAGNETIC CRACK DETECTOR	□		1	If needed turnover the head, to check other side
DRIVE THE PLUGS; IF NOT POSSIBLE SENT BACK TO	○		1	
INSERT CARBON RODS	○		1	Select the proper diameter
PLACE THE HEAD IN OVEN	○		1	Check the hooks, keep off the hot bricks; check supports
LIGHT THE TORCHES TO HEAT HEAD	○		1	
WAIT FOR THE RIGHT TEMP.	○		1	Wait for the right temp.; check the color
POSITION AND PREPARE THE HEAD FOR WELDING	○		1	Control the temp. do not wide open the welding area
TURN ON THE ACETYLENE AND STRIKE THE TORCH FOR	○		1	Obtain the right mix of acetylene and oxygen
WELDING PROCESS	○		1	Experience
(w p for void fillings) WELD THE PLUGS IN THEIR HOLES	○		1	Don't let the plug fall during process
CHECK FOR BROKEN PARTS AND FILL THEM	□		1	
MOVE THE HEAD TO COOLING TANK	⇨	16	1	Slow cooling is critical
MOVE THE HEAD OUT OF THE COOLING TANK	⇨	10	1	
USE THE TORCH TO CLEAN EXCESS OF FLUX	○		1	Do not heat up the head
IF WARPED SEND TO THE PRESS	□		1	
USE THE HOIST AND HAND TRUCK TO MOVE THE HEAD TO NEXT STAGE	⇨	25	1	

□	INSPECTION
Δ	STORAGE
O	OPERATION
⇨	TRANSPORTATION

CATERPILLAR CYLINDER HEADS REBUILD ASSEMBLY LINE

FLOW PROCESS CHART

DETAILS OF METHOD	State	Distance in feet	Quantity	NOTES
RECEIVING	△	45	1	
INSPECTION AND DISASSEMBLY	□ ⇨	12	1	Decision for operation
HOT TANK	□ ⇨	27	1	To make the disassembly easier
TEAR DOWN	○ ⇨	18	1	Recheck for cracks
CUTDOWN FOR WELDING	○ ⇨	22	1	Remove the cracked area completely
WELDING	○ ⇨	35	1	Experience
SAND BLAST AND CLEANUP	○ ⇨	31	1	Clean the parts thoroughly
MACHINE TOP AND SIDES	○ ⇨	24	1	Stay in tolerances; do not apply too much pressure on parts
MACHINE COMBUSTION SURFACE	○	11	1	Stay in tolerances
MACHINE MANIFOLD	○ ⇨	Same Loc.	1	
HAND GRINDING	○ ⇨	14	1	
PRESSURE TEST	□ ⇨	10	1	Check for cracks
SURFACE GRINDING	○ ⇨	15	1	

DETAILS OF METHOD	State	Distance in feet	Quantity	NOTES
SURFACE TOPDECK	○		1	Tolerances are extremely important
FINISH MACHINE WORK	○		1	
PRESSURE TEST	□ ⇨	9	1	Check for cracks
GRIND VALVE SEATS	○ ⇨	26	1	Tolerances are extremely important
FINAL INSPECTION	□ ⇨	37	1	Check the head thoroughly
WASH	○ ⇨	13	1	Clean the head completely; remove all residues
ASSEMBLY	○ ⇨	16	1	Apply the right torque
VACUUM TEST	□ ⇨	10	1	Check for cracks
SHIPPING PREPARATION	△	29	1	
□	INSPECTION			
△	STORAGE			
○	OPERATION			
⇨	TRANSPORTATION			

IV. IDENTIFICATION OF KEY PROBLEM AREAS

A. Data Analysis of The Defect Repair Maps

In order to track the defects that occur along the processing line, we have implemented a 'Defect Repair Map' (See Appendix E). We have been able to collect only 13 sheets, concerning the defects. The following table shows the number of cracks and other defects per welder:

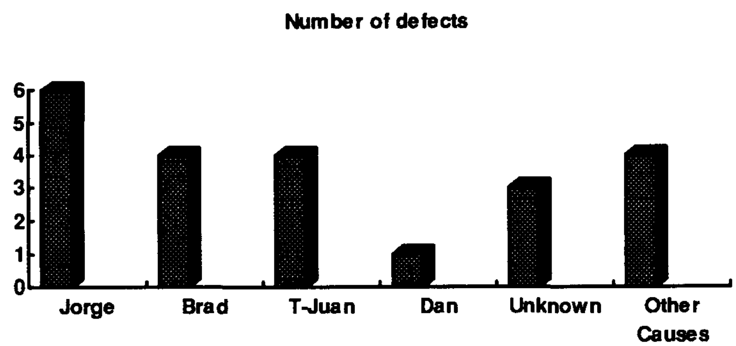
DAILY DEFECT TRACKING LOG
CAT Heads 343,3306,3406

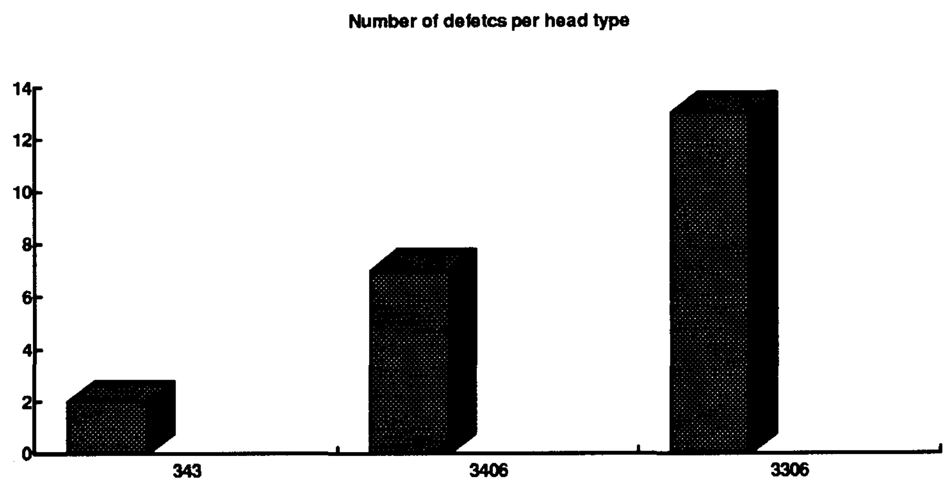
Number of recorded defective heads:	18
Total head repaired:	48
Approx defect rate:	37.50%

	CAUSE OF CRACK	343		3406		3306		Total
		#OF DEFECTIVE HEAD	#OF DEFECT	#OF DEFECTIVE HEAD	#OF DEFECT	#OF DEFECTIVE HEAD	#OF DEFECT	
WELDER	**Jorge**			2	3	2	3	*6*
WELDER	**Brad**			1	1	2	3	*4*
WELDER	**T-Juan**			3	3	1	1	*4*
WELDER	**Dan**					1	1	*1*
WELDER	**unknown**					2	3	*3*
	other	2	2			2	2	*4*
	total		2		7		13	22

Type of Head

The following two graphs illustrate the analysis of the data collected to this point in time.





B. Employee Discussions

1. Welding

Group members were present at the operation on a weekly basis, asking questions, learning the process, and showing interest in their work helped to develop a rapport with the shop personnel. Structured group meetings were held with the welders on one occasion, and with the Caterpillar Line team members on one occasion. Discussions were held with management usually on a weekly basis.

The first meeting was held with the welders to explain the purpose of the project in order to help determine what the problems were with the welding process and to help correct them. The welders opened up and presented numerous ideas that could be contributing to bad welding.

Of interest were the significant changes to the welding chambers that occurred sometime in the past. They went from an enclosed oven with a uniform, shielded bottom flame heating of the cylinder head to a crude oven consisting of bricks stacked with openings for large gas burners that directly impinged flame on the ends and/or sides of the heads. The cooling process following welding consisted of placing individual hot cylinder heads under separate metal covers and then insulating them with sand.

The current process is somewhat different. The hot cylinder heads are placed in a metal cooling box after welding. Subsequent heads are stacked on the previously cooling heads in the metal box. The process has no temperature controls and it is entirely up to what the welder decides to do as to when to start, stop, and move the heads.

Other areas of observation by the welders were:

- welding rod material changed from time to time
- weldability of different heads varied significantly
- there were some trainees and it takes a long time to train someone to properly weld cast iron
- there are no recognized authorities on welding cast iron and all training and information was passed on by word of mouth and on the job training
- some of the trainees had a language barrier problem

The welders were enthusiastic about applying new technology in an attempt to improve the welding process, such as using temperature monitoring devices, to verify proper welding temperatures. They were also very supportive in demonstrating the process of welding.

2. Rebuild Line

A meeting was held with the Caterpillar Line team from the machine shop area. The purpose of the project was explained to them. Defect repair maps were provided to each of them and they were asked to record defects and rework they observed in process.

They were quite open in describing chronic problems. Changes in the welding ovens and welder training were mentioned. They also noted that the hardness of the weld material had a significant impact on the machinability of the welded areas. This was a welder dependent phenomena. Some of the heads would warp during the weld process requiring rework. Machining the valve seat locations should have been done in steps of 0.010" until clean up, yet some machinists would start at the maximum size 0.030" to reduce machining time. The pressure test was more severe than would be encountered in service. Production demands prevented them from taking the time to assure proper equipment operation. Cutters were not properly sharpened and they were not even sure they were cutting the correct size holes.

Unfortunately, management was unable to allow any more group meetings. It became readily apparent that moving product was of higher importance.

3. Shop Foreman

A meeting was held with the shop foreman to review the results of the data collected. It was pointed out that most of the recorded problems were the result of cracks, likely induced during the welding process.

The solutions proposed by The Quality Team were reviewed with the shop foreman, except for the 'Replace the Foreman' option. He indicated that they have already started on the team option and had organized the welders *and* machinists as a team by product line with 1 lead over the entire team.

Additionally, they were in the process of developing a plan for profit sharing by team based on team performance. It was evident that he realized the benefits of a team. However, a team still had to be developed from the work groups.

V. PROPOSED SOLUTIONS

A. Alternatives

The Quality Team created a set of eleven alternatives to address the warranty problems related to cracks in cylinder heads. In order to show management the size of this problem the team started a program to monitor internal rejections due to cracks in the heads not fixed during the welding process. These alternatives were:

1. Temperature controlled ovens for heating and welding of cracks in heads.
2. Temperature measuring devices, for measuring the heads during welding and cool down.
3. Serialization of heads for tracking and process control
4. Standardization of weld process
5. Temperature controlled cooling process
6. Training program for welders
7. Tool maintenance and calibration
8. New Foreman for the shop, who will address the crack problem from a TQM perspective
9. Team organization for the shop based on the type of head
10. Profit sharing for employees based on performance of teams created in solution 9
11. Feedback to the employees in the form of meetings, newsletters, etc.

Each of the alternatives will be analyzed using the following seven criteria. These criteria were chosen to help the team understand each of the alternatives and to provide good justification for choosing the solutions we selected.

1. What specific problem does this solution address?
2. How does it address the problem identified in criteria 1?
3. How will the company measure the improvement in quality by implementing this solution?
4. How long before any improvement in quality can be measured?
5. Is the solution within resource constraints (man hours, equipment, training, funding, etc.)?
6. Is this a good TQM solution to the head crack problem?
7. How will the company implement this solution?

1. Temperature control ovens for heating and welding of cracks in heads.

- What specific problem does this solution address?

Cracks caused by the uneven heating of the head during the weld process. NorthWest Motor Welding management believes this is the major cause of cracks in the whole process.

- How does it address the problem identified in criteria 1?

The current method used in heating the cylinder heads has no temperature control or monitoring of the temperature. The temperature of the cylinder head during the weld process could vary as much as 100 degrees Fahrenheit. This varying of the temperature may be causing cracks in the head.

The form of heat used may also be causing the cracks. They are using from 2 to 5 open flames aimed at different points along the sides of the head to heat it and maintain the heat during the weld. A temperature controlled oven could heat the cylinder head evenly and keep the temperature constant throughout the welding process.

- How will the company measure the improvement in quality by implementing this solution?

Comparing the number of heads returned because of warranty claims and internal rejections before purchasing the ovens to the number after purchasing the new ovens.

- How long before any improvement in quality can be measured?

Due to the amount of time required to choose an oven and having the welders trained in their use, it could take 9 to 12 months before the new process stablizes and internal rejections can be measured. The warranty claims could take 12 to 24 months before enough data is collected for good analysis.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

This will be one of the most expensive of the possible solutions. The welding shop will need to purchase a couple of special ovens that will heat the heads evenly during the complete welding process. Using this oven the welders will show that these ovens do make a difference. After the data shows an improvement in quality because of these new ovens, management then will purchase enough for all welders. Estimated cost ranges from $50,000 to $150,000 each.

- Is this a good TQM solution to the head crack problem?

This solution addresses a process not a person, so it does make a good TQM solution. The solution will have measurable base data (when collected) and result data to compare it to. We should be able to tell if this solution made any real improvement in quality. The team believes there is a 61% chance that this solution will fix the warranty crack problem.

- How will the company implement this solution?

The first step would be to start serializing all heads (solution 3), so tracking can be implemented. A good baseline of data needs to be collected. Then a couple of ovens needs to be purchased and used for a set period of time. At different points along this period the warranty and rejection data will be analyzed to see if any improvement can be seen. At the end of the period if a reduction in cracks has occurred, then all welding stations will get there welding ovens.

2. Temperature measuring devices for measuring the heads during welding and cool down.

- What specific problem does this solution address?

The lack of good baseline data due to the lack of equipment to get good reliable data.

- How does it address the problem identified in criteria 1?

It makes the collection of base data possible and may address a problem in the method used to heat or cool the heads.

- How will the company measure the improvement in quality by implementing this solution?

This solution will help in making good choices in the future about heating and cooling temperatures used on heads.

- How long before any improvement in quality can be measured?

No quality improvement will be measured with this solution, but baseline data will start to be collected immediately.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

The collection of data in the Weld shop is needed to implement any TQM solution to the cracked head problem. The cost will be a couple of temperature measuring devices estimated of $1000.

· Is this a good TQM solution to the head crack problem?

Data collection is a very important part of implementing TQM. The team believes there is a 43% chance management will implement this solution and start data collection (process control).

· How will the company implement this solution?

The first step would be to start serializing the heads (solution 3), so tracking can be implemented. To collect a good baseline the welders will need to take measurements of head temperatures at different points throughout the weld process. All this data will need to be collected, analyzed, and stored for approximately one year to find out if any of these heads had warranty problems.

3. Serialization of heads for tracking and process control

· What specific problem does this solution address?

The lack of good baseline data due to the lack of equipment to get good reliable data. Coupled with solution 2, NorthWest Motor Welding can start getting good baseline data for use in analyzing the problem and to help solution to implement.

· How does it address the problem identified in criteria 1?

This makes the collection of base data possible and the company would be able to track all heads through the weld process and in the field.

· How will the company measure the improvement in quality by implementing this solution?

NorthWest Motor Welding will not directly be making improvements in quality with this solution, but will be collecting baseline data to be used to make a choice about which solution they should implement in the future.

- How long before any improvement in quality can be measured?

  No quality improvement will be measured with this solution, but baseline data can start to be collected immediately.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

  Yes, all that is needed is someone to enter the serial numbers into a database and stamp each head. Estimated cost is $1000.

- Is this a good TQM solution to the head crack problem?

  Data collection is a very important part of implementing TQM. The team believes there is a 49% chance that management will implement this solution and start data collection (process control).

- How will the company implement this solution?

  The first step would be to start serializing heads, so tracking can be implemented. All serialized head will be tracked in a database so analysis of the data can be carried out.

4. Standardization of process

- What specific problem does this solution address?

  It will start process control in the weld process. This solution will get everyone welding using the same steps and methods. It will address the couple of welders who may be doing their jobs differently and not knowing that this maybe the cause of cracks.

- How does it address the problem identified in criteria 1?

  Reduction of variances in the welding processes.

· How will the company measure the improvement in quality by implementing this solution?

The company would compare the number of heads returned because of warranty and internal rejections before standardization to the number after standardization.

· How long before any improvement in quality can be measured?

Due to the amount of time required to analyze the process, it could take 12 months before internal rejections can be measured. The warranty claims could take 12 to 24 months before enough data is collected for good analysis.

· Is the solution within funding constraints (man hours, equipment, training, etc.)

This method requires a large number of meetings with the team of welders to analyze and decide on the best procedures for NorthWest Motor Welding weld processes. Due to the hourly cost of having welders in meetings, the cost is estimated in the $20,000 to $100,000 range.

· Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution, because it takes team work to develop the correct procedures that all welders can live with. The team believes there is a 49% chance this solution will start process control. The team also believe there is a 39% chance that this solution will help with the cracked head problem.

·How will the company implement this solution?

The shop will need to have team meeting of welders to develop the procedures and training classes on the procedures and TQM would be given. Control charts and check lists will be developed for the welding process.

5. Temperature controlled cooling process

· What specific problem does this solution address?

Many of the welders feel that it is the way the heads are cooled that causes the cracks. The heads are placed in a large metal tank to cool together. There is no temperature control on the tank. Therefore, as each head is placed in the tank the temperature will rise some and then cool back down.

· How does it address the problem identified in criteria 1?

It stops the uneven cooling of the heads, which is believed to cause cracks.

· How will the company measure the improvement in quality by implementing this solution?

Comparing the number of heads returned because of warranty and internal rejections before temperature controlled cooling tanks to the number after temperature controlled cooling tank.

·How long before any improvement in quality can be measured?

Due to the amount of time required to choose and acquire the cooling tanks, it could take 6 to 12 months before internal rejections can be measured. The warranty claims could take 12 to 24 months before enough data is collected for good analysis.

· Is the solution within funding constraints (man hours, equipment, training, etc.)

This will depend on the method and equipment chosen. The estimated cost is in the $50,000 to $150,000 range.

· Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution as it addresses the methodology not the workers. It can be measured and the workers believe in the solution to the problems in the process. The team believes there is a 67% chance that this solution will help with the cracked head problem.

· How will the company implement this solution?

The weld shop will have team meeting with all the welders to pick the correct cool down methodology and equipment. The chosen equipment will be purchased and used.

6. Training program for welders.

· What specific problem does this solution address?

This alternative addresses the lack of process control in the welding process.

· How does it address the problem identified in criteria 1?

It will reduce the variances in the welding processes.

· How will the company measure the improvement in quality by implementing this solution?

Comparisons will be made of the number of heads returned because of warranty and internal rejections before training and to the number after training.

- How long before any improvement in quality can be measured?

Due to the amount of time required to analyze the process, design training classes, and get all welders through the classes; it could take 12 to 15 months before internal rejections can be measured. The warranty claims will take 12 to 24 months before enough data is collected for good analysis.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

This method requires a large number of meetings with a team of welders to analyze and design the training courses for NorthWest Motor Welding weld process. Due to the hourly cost of having welders in meetings and training classes, the cost is estimated to be a base cost of $80,000 and about $4,000 per welder.

- Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution. It takes team work to develop the correct training program that the welders and management can live with. The team believes there is a 50% chance this solution will start process control. The team also believe there is a 51% chance that this solution will help with the cracked head problem.

- How will the company implement this solution?

Team meeting with all the welders will be held to develop the training program. After the material has been agreed on, the course will need to be designed. The final step will be to have all welders go through the classes.

7. Tool maintenance and calibration.

- What specific problem does this solution address?

The incorrect size or poor maintenance of equipment could be causing the cracks in the rebuild process.

- How does it address the problem identified in criteria 1?

This solution requires all the equipment to be calibrated and working correctly.

- How will the company measure the improvement in quality by implementing this solution?

We will measure the number of heads returned because of head cracks and compare this number to the number before maintenance and calibration.

- How long before any improvement in quality can be measured?

Due to the amount of time required to calibrate all equipment and set up a routine of periodical calibration, it could take 9 to 12 months before internal rejections can be measured. The warranty claims could take 12 to 24 months before enough data is collected for good analysis.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

To have all equipment tested, would cost between $5,000 and $10,000. To replace all equipment that cannot be fixed, the cost is estimated to be in the $100,000 to $200,000 range.

· Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution as it addressees the process and not the employees. The team believes there is a 73% chance this solution will start process control. The team also believes there is a 10% chance that this solution will help with the cracked head problem.

· How will the company implement this solution?

The company will purchase the equipment and hire the expertise to calibrate all equipment in the shop. If any equipment needs replacing it will be replaced.

8. New Foreman for the shop.

· What specific problem does this solution address?

This addresses business as usual vs. change in management to get the TQM process going. The current Foreman was not hired for the job and has no TQM experience or training. The team feel that a Foreman that is motivated to implement TQM will help out the company.

· How does it address the problem identified in criteria 1?

There is a lack of committed leadership in the shop Foreman position.

· How will the company measure the improvement in quality by implementing this solution?

We will measure the number of heads returned because of head cracks and compare this number to the number before the new Foreman is hired.

- How long before any improvement in quality can be measured?

Due to the amount of time needed to find the correct Foreman and the time for the Foreman to get up to speed in the shop, it could take 6 to 12 months before internal rejections can be measured. The warranty claims could take 9 to 12 months before enough data is collected for good analysis.

- Is the solution within funding constraints (man hours, equipment, training, etc.)

The only cost will be the Foreman's salary and benefits. It will run between $50,000 to $100,000. There will be other costs related to what every TQM project he/she decides to implement.

- Is this a good TQM solution to the head crack problem?

This is hard to call. On one hand the team is saying that the Foreman is the problem, but on the other hand all the team is saying that's the leadership need more experience in TQM. The team believes there is a 46% chance this solution will implement TQM in the shop. The team also believe there is a 16% chance that this solution will help with the cracked head problem.

- How will the company implement this solution?

The company would find and hire a new Foreman and let him/her run the shop the best way he/she knows.

9. Team organization for the shop based on the type of head.

- What specific problem does this solution address?

Lack of communication within the shop.

· How does it address the problem identified in criteria 1?

The allows the employees to work in teams to address the problem within each process.

· How will the company measure the improvement in quality by implementing this solution?

We will measure the number of heads returned because of head cracks and compare this number to the number before working in teams was implemented.

· How long before any improvement in quality can be measured?

Due to the amount of time it takes to get teams working as teams, it could take 6 to 12 months before internal rejections can be measured. The warranty claims could take 12 to 15 months before enough data is collected for good analysis.

· Is the solution within funding constraints (man hours, equipment, training, etc.)

To have this solution work, there would need to be training in team process and TQM. There also will be the cost of having employees in meetings and not producing goods. Estimated cost to be $50,000 to $100,000 per team.

· Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution. It moves some of the decision making down to the workers and gets communication within a process started. The team believes there is a 24% chance that this solution will help with the cracked head problem.

· How will the company implement this solution?

The company will divide up the shop into teams based on each type of head that they work on. Each team will go through a set of classes on team process and TQM. The teams will then evaluate their own processes and give recommendations to management on how to improve their own product.

10. Profit sharing for performance

· What specific problem does this solution address?

Lack of motivation within the shop.

· How does it address the problem identified in criteria 1?

This will focus the employee on doing a better job. If the quality goes up, the employee will feel the benefit in his/her wallet.

· How will the company measure the improvement in quality by implementing this solution?

We will measure the number of heads returned because of head cracks and compare this number to the number before the profit sharing.

· How long before any improvement in quality can be measured?

It would take 2 months before internal rejections can be measured. The warranty claims could take 12 months before enough data is collected for good analysis.

· Is the solution within funding constraints (man hours, equipment, training, etc.)

The cost would be directly related to the improvement of quality. The estimated cost is $5,000 to $15,000, which will be made back by the reduction of warranty claims.

· Is this a good TQM solution to the head crack problem?

The team believes there is a 29% chance this solution will improve the process in the shop.

· How will the company implement this solution?

The company will set up a quality level for profit sharing

11. Feedback to the employee in the form of meetings, newsletters, etc.

· What specific problem does this solution address?

The lack of information that is not getting to the employees.

· How does it address the problem identified in criteria 1?

This puts information into the hands of the workers so that they can feel they are part of the team.

· How does the company measure the improvement in quality by implementing this solution?

We measure the number of heads returned because of head cracks and compare this number to the number before feedback procedures are started.

· How long before any improvement in quality can be measured?

It would take 6 to 12 months before internal rejections can be measured. The warranty claims could take 12 months before enough data is collected for good analysis.

· Is the solution within funding constraints (man hours, equipment, training, etc.)

This solution will cost the time of a person getting the information and putting into a form that everyone can read. The employee productivity is lost due to spending time in meetings. This alternative has an estimated cost of $50,000.

· Is this a good TQM solution to the head crack problem?

Yes, this is a very good TQM solution. It puts information into the hands that can use it. The team believes there is a 29% chance this solution will improve the process in the shop.

·How will the company implement this solution?

Someone will be designated to make a monthly news letter and distribute it to all employees. The company's upper management will start having monthly meetings with all employees.

C. ANALYSIS

After analyzing each of the alternatives the team found out there were three major sets of solutions. The first set had to do with the collection of data and standardizing of the welding process. The second set is related to attacking the problem directly. The third group has to do with setting up TQM in the shop.

Data collection and standardization	**Attacking the problem**	**Setting up TQM**
Temperature measuring devices, for measuring the heads during welding and cool down.	Temperature control ovens for heating and welding of cracks in heads.	New Foreman for the shop, who will address the cracks problem from a TQM perspective.
Serialization of heads for tracking and process control	Temperature controlled cooling process	Team organization for the shop based on the type of head.
Training program for welders.	Tool maintenance and calibration.	Profit sharing for employees based on performance of teams create in solution 9.
Standardization of weld process		Feedback to the employee in the form of meetings, newsletters, etc.

During the initial discussion of the alternatives the team rated the alternatives as shown in the following table. Each solution was related to the three categories the team setup. The rating was based on the chance of success of each alternative.

Solutions	1	2	3	4	5	6	7	8	9	10	11
Data collection and standardization	0%	43 %	49 %	49 %	0%	50 %	72 %	0%	0%	29 %	29 %
Ranking		**4**	**3**	**3**		**2**	**1**			**5**	**5**
Attacking the problem	61 %	0%	0%	39 %	67 %	51 %	9%	16 %	24 %	0%	0%
Ranking	**2**			**4**	**1**	**3**	**7**	**6**	**5**		
Setting up TQM	0%	0%	0%	0%	0%	67 %	0%	46 %	25 %	0%	0%
Ranking						**1**		**2**	**3**		

The team then did a weighting analysis of all 11 alternatives. Each team member had a total of 10 points for each of the following criteria to give to an alternative. The criteria was broken down into two sets, effect on quality, and acceptance by people involved. All criteria within a set was weighted and then each set was weighted against the other. The following table show the weighting and ranking of the alternatives.

Weighting			Alterative (Team Selection W eighted Selection)																					
Group weights	Weights by groups	Criteria	1		2		3		4		5		6		7		8		9		10		11	
	44%	Effective in reducing rework	17	7.48	7	3.08	17	7.48	10	4.40	11	4.84	1	0.44	5	2.20	4	1.76	4	1.76	2	0.88	2	0.88
	56%	Effective in reducing cracks	17	9.52	7	3.92	5	2.80	5	2.80	17	9.52	4	2.24	6	3.36	0	0.00	4	2.24	4	2.24	1	0.56
	100%			17.00		7.00		10.28		7.20		14.36		2.68		5.56		1.76		4.00		3.12		1.44
39%				6.63		2.73		4.01		2.81		5.60		1.05		2.17		0.69		1.56		1.22		0.56
	64%	Acceptance by management	1	0.64	9	5.76	13	8.32	9	5.76	7	4.48	8	5.12	4	2.56	4	2.56	8	5.12	1	0.64	7	4.48
	23%	Acceptance by employees	13	2.99	7	1.61	6	1.38	1	0.23	18	4.14	3	0.69	8	1.84	0	0.00	3	0.69	7	1.61	4	0.92
	13%	Acceptance by team	10	1.30	6	0.78	17	2.21	9	1.17	6	0.78	4	0.52	2	0.26	0	0.00	6	0.78	2	0.26	2	0.26
	100%			4.93		8.15		11.91		7.16		9.40		6.33		4.66		2.56		6.59		2.51		5.66
61%				3.01		4.97		7.27		4.37		5.73		3.86		2.84		1.56		4.02		1.53		3.45
100%																								
		Weighted Total	9.64		7.70		11.27		7.18		11.33		4.91		5.01		2.25		5.58		2.75		4.01	
		Alterative Ranking	3		4		2		5		1		8		7		11		6		10		9	

C. Proposed Solutions

The top five alternative are as follows:

1. Temperature controlled cooling process
2. Serialization of heads for tracking and process control
3. Temperature control ovens for heating and welding of cracks in heads.
4. Temperature measuring devices, for measuring the heads during welding and cool down.
5. Standardization of weld process

These five are proposed solutions that the team will present to the management of NorthWest Motor Welding. Pros and cons for each of the solution will be discussed so that management can make a sound decision on which solution to implement.

Solution 1.

alternative 5: Temperature controlled cooling process

PROs		CONs
This is a problem that the welders believe to be a cause of cracks in the heads		No hard data showing this solution will fix the problem
The cooling method has chanced over the years and the quality of the product reduced.		This solution will take a long time to show any improvements.
Team believes this has the highest chance of improving the quality.		A high capital cost to implement.
		Funding is low within the company, so acceptance by management will be low

Solution 2.

Alternative 3: Temperature control ovens for heating and welding of cracks in heads.

PROs		CONs
Controls the heat processes		No data to support that there is a problem in the heating method used.
The team believes this solution has the highest chance of improving the quality		Highest cost of all the solutions
		Funding is not there at this time for this project
		Least likely of all solutions to be accepted by management.

Solution 3.

Alternative 1: Serialization of heads for tracking and process control

PROs		CONs
Start data collection for future analysis		Does not improve the quality.
Low cost to implement		Hard to get employees to see a reason for it.
Easy to implement		Hard to get management to see a reason for it.

Solution 4.

Alternative 2: Temperature measuring devices for measuring the heads during welding and cool down.

PROs		CONs
Start data collection for future analysis		Hard to get employees to see a reason for it.
Low cost to implement		Hard to get management to see a reason for it.
Easy to implement		
May improve the quality		

at 20 to 25%)[14] and no breakdown by type of internal defects. The only measurement they had was of the warranty levels. Unless critical areas are measured, it will be difficult to evaluate progress and determine whether or not your program is actually producing changes necessary for lasting quality improvements.[15] To accurately track rework levels and determine defect causes, the cylinder heads would need to be assigned a unique serial number. In this way information could be recorded at each operation and a problem history could be developed. Continuous efforts to start a serialization program did not prove successful since management was more interested in the short term production shipments.

NorthWest Motor Welding management professed they never pressured the workers to sacrifice quality in order to meet production. The message that 'production was top priority' came across clearly, even though it may not have been stated as such. It is clear management actions express their priorities much louder than their words.[16] As Crosby puts it: "Workers perform like the attitude of the management."[17] It is important that what is proclaimed matches the beliefs and actions of management since any discrepancies are quickly picked up. "In some companies there are many forces which seek to have as much product shipped as possible. There are pressures that discourage care in manufacturing and assembly."[18]

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[14]This estimate is based on the general estimate listed for manufacturing businesses in Evans and Lindsay, p. 53.
[15]Ludeman, pp. 52-57.
[16]Thomas J Peters and Robert H. Waterman Jr., In Search of Excellence. Lessons From America's Best-Run Companies, New York, NY, Warner Books, Inc., 1982, pp. 73-75.
[17]Phillip B. Crosby, Quality if Free: The Art of Making Quality Certain, New York, NY, McGraw-Hill, 1979, p. 273.
[18]August B. Mundel, Ethics in Quality, New York, NY, ASQC Quality Press, Marcel Dekker, Inc., 1991, p. 103.

The quality problems at NorthWest Motor Welding were not due to lack of effort on the part of the workers. They were constantly striving to produce as they understood that if they did not, they may not have a job, since the shop was non-union. Additionally the company was not financially strong. Deming observes that most of the trouble comes from the system, which is the responsibility of management. It certainly applied in this situation.[19]

The workers wanted to do better, as was evidenced by their interest in reviewing problems and collecting data. In order to solve the problems they needed the proper systems, training, and equipment. Management must show the employees that management is improving things such as better incoming supplies, statistical tools, better maintenance and training.[20] Further, Steele alleges that adequate support is essential to address the priority areas, assure speedy results, and get the employees to do things right the first time.[21] When management not only clearly states, but backs it up with action, that they will not get any new equipment, it certainly does not help quality improvement efforts when the employees know that the equipment they have is inadequate to do the job correctly.

The welders were physically separated from the rest of the shop and this, coupled with the fact that many of the problems occurred in welding, lead to the syndrome of the "welders" against "the rest of the shop." Blaming the welders for the bad welds was very counterproductive, since many of the weld quality and crack problems were due to factors beyond their control, such as inadequate training and equipment. Including the welders as part of each product team, Caterpillar, Detroit, or Cummins, is an appropriate team building

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[19]Deming, p. 67.
[20]Deming, p. 68-69.
[21]Jack Steele, " Inplementing Total Quality Management for Long- and Short-Term Bottom-Line Results," National Productivity Review, Summer 1993, v12 n3, p. 438.

effort. As Ozawa suggests the TQM system will only work when there is a total, unified effort by all the employees in the company, and the employees see themselves as part of the bigger picture.[22] Teams would involve them as part of the overall picture and enhance their ability to collectively solve problems. Common commitment and accountability are essential for a team to produce collective performance, instead of just a collection of individual performances.[23]

B. Processes within The Quality Team

"The Quality Team" could have been more appropriately named "The Quality Workgroup" at the start of this project if one applied criteria according to Katzenbach and Smith.[24] We were a group with individual accountability assigned to individual work products. As the project went through the difficult phase of trying to collect data with little support from NorthWest Motor Welding it became apparent that the scope of the project was changing. This uncertainty coupled with the frustration of little progress against a finite time schedule caused a great deal of stress among the members. None of the members were personally against one another. However, during the process of discussing plans and ideas, some of the members were not treated as fairly as they probably should have been and they may have taken some of the discussions personally.

If any one factor was overriding in group discussions it was always the urgency to meet timelines. This is not the best way to operate, yet it was a constraint placed on the team that had to be dealt with.

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[22]Masayoshi Ozawa, Total Quality Control and Management: The Japanese Approach, Tokyo, Japan, JUSE Press Ltd., 1988, p. 7.
[23]Jon R. Katzenback and Douglas K. Smith, "The Discipline of Teams," Harvard Business Review, v71 n2, Mar/Apr 1993, p. 112.
[24]Ibid., p. 113.

In the end, once we had shared some common experiences, we were beginning to function more like a team. However, to function as a truly effective team it would have taken much more time and experience together.

It is interesting to compare how the team perceived each option would be accepted by management as compared to how management actually rated them for acceptance. Clearly an outside judgment on what will be accepted is not always accurate, and as such feedback should be elicited from those involved. Feedback from the shop workers would have also provided some insights, but due to production pressures was not available.

APPENDIX

Appendix A	Pareto Charts 1 to 9
Appendix B	Flowchart of the Caterpillar Line Processes
Appendix C	Welding Data Collection Forms
Appendix D	Defect Repair Maps for Caterpillar Cylinder Heads
Appendix E	Completed Weld Maps
Appendix F	Foreman's Estimate of Solution Adoption
Appendix G	Team Log
Appendix H	Team Member Comments