

TOTAL WELDING MANAGEMENT

Total Welding Management is a system focused on improvement. It includes management principles, and a planning process with a structured approach. When adopted by a company, it can improve welding quality and productivity, thus helping the company to become more competitive and more profitable.

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TOTAL WELDING MANAGEMENT

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The Barckhoff Welding Management System and the Barckhoff Method

Introduction

This book is not about teaching welding. It is a completely new paradigm for managing a business involving welding.

In this book, I will share a system that marries the science of welding technology with sound management principles to form a Total Welding Management System.

Whether it is a manual, robotic, or fully automated welding operations, the same principles and concepts of The Total Welding Management System and The Barckhoff Method will apply.

It has evolved from over 40 years of experience in working with companies that do welding.

The implementation of this management system has resulted in significant cost savings for most companies. Savings per welder has ranged from \$10,000 to \$35,000 annually. Typical annual savings have been \$15,000 to \$25,000 per welder per year. As an example, a company with 50 welders can typically expect savings of \$750,000 to \$1,250,000 per year. This management system has been applied to many companies and over a broad variety of products.

Construction machinery, industrial fans, commercial lawn mowers, ships and barges, storage tanks, hospital equipment, truck bodies and rail cars represent some of the products to which the system has been applied. It has also been applied to small, medium, and very large companies. In any company where welding is an important part of the business, *Total Welding Management* can help deliver improved profitability.

Over more than the past thirty years, survey results of the welding operations of many companies have shown productivity gains of typically 20% to 50% using the Total Welding Management System.

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2. A method to identify, quantify, and harvest the total potential for welding improvement in your company
3. A structure to manage improvement projects to assure results
4. The focusing of key company resources to service the welder for welding quality and productivity improvement
5. A management reporting and control system to identify deviations from performance standards so that Corrective Action can be taken as required
6. A process for continuous improvement in weld quality and productivity
7. Managerial, technical, and welding skills training for everyone involved in the welding management system.

The Total Welding Management System incorporates all of the tools and management processes required to make your welding operations the best in the world.

Let's begin by reviewing the background of its development.

From college, I started my career as a sales engineer with The Lincoln Electric Company, a supplier of welding equipment and consumables. During my first year, I went through an extensive training program to prepare for this role. The training program consisted of

1. The science and theory of welding
2. Welding application engineering
3. Welding methods engineering
4. Extensive practical experience welding on the shop floor using a variety of welding processes and methods

This training program, coupled with my engineering education from Ohio State University gave me the foundation to begin a career in welding.

At The Lincoln Electric Company, Mr. James F. Lincoln developed a value-added cost reduction sales strategy. This approach involved providing customers with technical services at no charge to help them reduce their cost of welding. His idea was cost-reduction selling to improve the sale of welding equipment, consumables and welding supplies. This approach offered customers a much greater return on equipment and consumables purchased than the competition.

As a young sales engineer attempting to deliver promised additional

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As I began to teach these principles, welders better understood the science behind the welding arc and how to control bead shape, size, and quality. This also helped reduce training time. Once they understood the theory of welding, I quickly discovered that they were able to learn and apply new welding processes much faster.

At that time, many managers and engineers looked at welding as an art or a mystery. This was different than their view of other manufacturing processes. For example, in machining they understood material feed rates, cutting speeds, metal removal rates, and how to control with precision, the removal of metal. They did not understand the variables of the welding process nor how to control various filler metal deposition rates with the same precision.

Early in my career, I came to realize that there was 'gold in them thar weld nuggets' and saw welding quality and productivity improvement as the biggest opportunity many welding companies had to improve their bottom line profitability.

From these experiences I began to see my job as something much greater than selling welding equipment and consumables. I saw, in many companies, an opportunity to transform welding from a process that was often out of control and not understood, to one that was managed.

From these early experiences, I developed a passion for welding management. Since that time, I have dedicated my life to helping companies get control of their welding operations.

My efforts began on the welding floor, but today The Total Welding Management System includes all aspects of welding from design through quality assurance.

My early experiences as a sales engineer were frustrating. I worked with welders on the shop floor, teaching them the science of welding and getting some improvements. The personal satisfaction of working with welders willing to learn and improve touched my soul. Improvements came quickly and they were eager for more.

Since I had to work with many companies in my capacity as a sales engineer, I would leave one to work with another. Upon my return, I would find that improvements I had made were not maintained. Welders would fall back into old habits, even though most of them had been very receptive to learning and changing the way they viewed welding. When I

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Because of my passion for welding improvement, I left The Lincoln Electric Company after twenty years to form Barckhoff & Associates, Inc., a welding management, consulting, engineering, and training company. This allowed me to commit full time to the further development of the principles, concepts and systems for welding management and help companies improve their welding operations.

This book will lay the foundation for understanding the Total Welding Management System to manage your welding operations for quality and productivity improvement.

Some companies have been very successful in applying the principles of the Total Welding Management System. They have improved their company's profitability through significant savings in welding costs. Others have been moderately successful, gaining improvements of 10% to 30% in productivity. Some have failed to achieve the full potential savings. This book will show you how to plan for and achieve success as well as explain why some have succeeded when others have not achieved their potential.

The Total Welding Management System provides the way to plan and control your welding operations. To illustrate relative unit cost differences between welding operations that are in control and those that are not, I have included Figure 1. This figure shows how the total unit costs of welding change over periods of time between planned and controlled welding operations and those that are not. As more of the variables that affect welding are controlled, total unit costs of welded products are reduced. This figure also demonstrates how costs are reduced as improvement actions are taken and a welding management system is put in place. The opportunity for cost reductions by gaining control of your welding operations is significant.

The Total Welding Management System not only reduces manual welding costs but also prepares your welding operations for automation and robotics by putting in place the basic automation requirements. These include consistency, repeatability, and control of product output. These principles apply not only to arc welding but also to other forms of metal joining, such as resistance welding, soldering, and friction welding.

The primary focus of this book is to

1. help take the mystery out of the welding process and move it to an engineered science in your company,

CHAPTER 1

My challenge was to work with top managers and show them that welding was not solely an art but a combination of science and art. It could be managed but needed their understanding and leadership. Engineering and welding skills were out of balance in many companies. Welding had to be brought under more engineering control. There had to be more of an engineered science approach to welding.

Company owners or presidents would often spend \$100,000 on a machining center to reduce a part cycle time by 5%. The same executives, however, would be reluctant to spend a few thousand dollars to improve their welding operations. As an example, by investing perhaps \$10,000 to upgrade a welding fixture and doing some welder training, productivity could improve by 20%. An investment in welding typically yields a much shorter payback time than larger capital investments such as new machining equipment.

Some companies would spend \$200,000 for a new computer system including training, to improve shop scheduling and reduce inventory, but would not invest in training to improve welding quality and productivity. Improvements in welding generally do not take a lot of capital investment. In fact, most welding savings require little or no capital investment. Only when a company is in control of its engineering and manufacturing disciplines, is it ready for capital investments such as welding automation and robotics.

I talked with many company executives about how they could increase the productivity in their welding operations. The productivity of each welder could be improved by 30% to 50% by putting in place a management system that could achieve typical annual savings of \$15,000 to \$25,000 per welder. The responses I got were varied.

Some executives would respond with enthusiasm, "You tell a very convincing story." Many would ask for more detailed information. Others would say, "That sounds like a great program. Why don't you contact my welding department manager?" or, "Why don't you send me some information and I will have my engineer give you a call?"

Others responded, "The management system sounds like exactly what we need—our welding operations are not very productive and we do have a number of quality issues," or, "Our welders are a different breed...I am not sure that they can be managed using a system of management—they must be managed carefully," and "Welding is more

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welding once they were told how this knowledge would benefit them. Most had never been properly trained to understand the physics and chemistry of welding. As an example, they did not understand the molten pool and welding variables necessary to control the weld bead shape, so they could not make judgments to change welding parameters to improve weld quality, and produce more linear inches of weld per minute, with less physical effort.

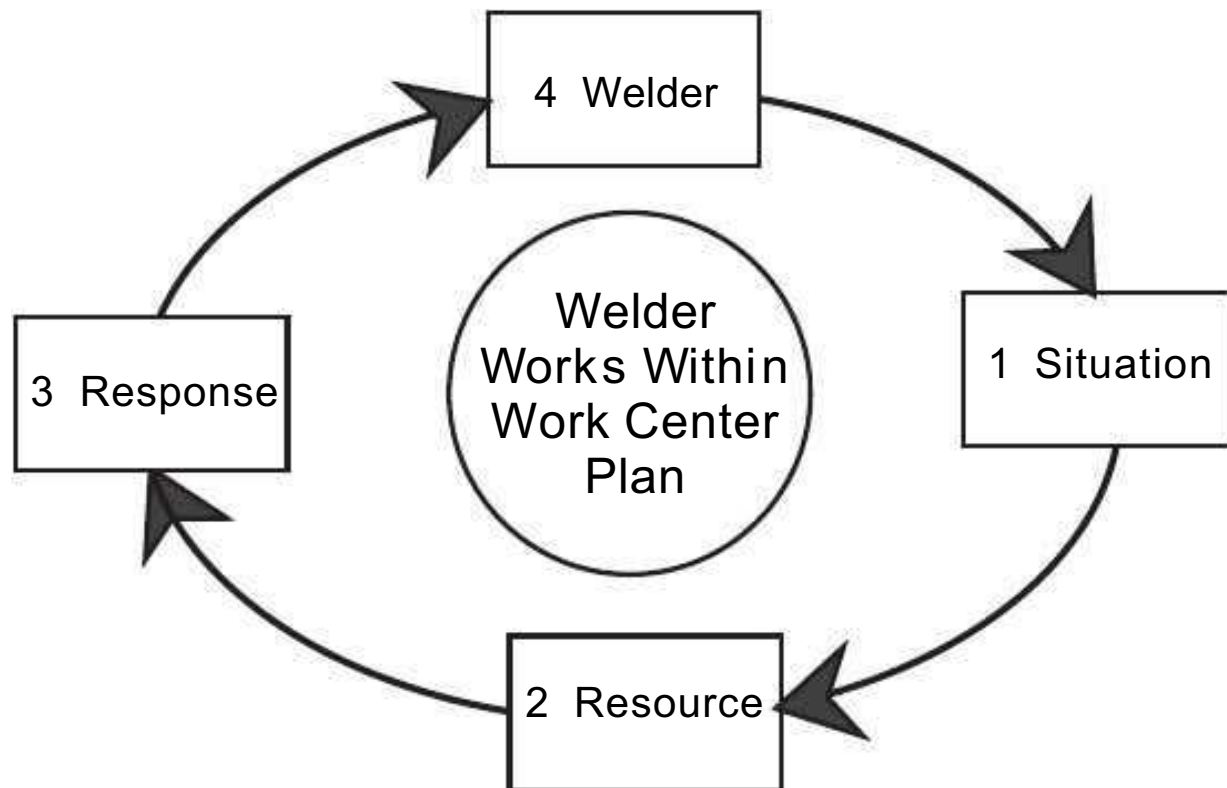
I found that both welders and supervisors were hungry and eager for knowledge. They wanted to learn and improve to make a better, more consistent product. In too many cases, no one showed them how or provided them with the technical and management support required for continuous improvement.

Proper support of the welder includes training, good weldment design, consistent component parts, good fixtures and welding equipment, and a timely response when there is a deviation from planned production output or weld quality. Support of the welder is the heart of the Total Welding Management System.

Control of your welding operations is essential for long-term quality and productivity improvement. Figure 2 illustrates how management control principles are applied to welding in The Total Welding Management System. TWM can be viewed as a Closed Loop System and is used as a management process to correct variances from an established Work Center Plan that is developed to support the welder.

For example, when there is a deviation from or interruption to planned performance such as equipment malfunction, in a closed loop system the welder reports the situation or deviation to his supervisor. The supervisor contacts the resource (in this case. maintenance), which responds by troubleshooting and/or replacing the equipment within an agreed to specified response time so that welders production can resume at its planned rate of output. This is the essence of an effective management system with feedback and rapid response to assure continued levels of planned quality and productivity.

As I made the transition from a sales engineer to a welding management consultant, I initially experienced a lot of frustration as I worked with companies that were doing welding. I knew that I



Welder reports problem or deviation from plan (1–Situation)
Appropriate Resource (2) responds with corrective action (3–Response)
Production resumes quickly and effectively to the plan (4–Welder)

Figure 2. Total Welding Management Closed Loop Feedback System

The messages that came through most frequently from company executives were:

1. *The welding process can't be controlled, like machining or other manufacturing processes.* There is a lot of craftsmanship and art to welding. Results are highly dependent on the skills of each welder. Modern machining equipment with CNC controls in contrast is not dependent on an operator, once the job has been tooled, programmed, set up, and the machine takes over.
2. *Welders can't be managed.* They are craftsmen, independent, proud of their work, and know the best ways to weld. It's dirty work so you can't push them. Welders are in short supply so we don't want to upset them by telling them how to do their job or forcing them to change.
3. *My welders are productive.* They are always welding, fitting up parts, grinding, or hammering parts together. They are always

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metals being joined, the welding process, proper filler materials, control of the components, and control over the process. We can now use the science of welding as the basis of a welding control plan.

Proof of this is the fact that some companies have gone to robotic or fully automatic welding. If the welding process was not completely known and predictable, a robot could not do it. Many welding operations have tried robotic welding and failed. In most cases, it was because the company had not done its homework in preparation for the robot. The engineering and manufacturing basics were not in place such as:

1. prints with proper fabrication and weld specifications,
2. component parts made to specification to produce consistent material fitup,
3. properly designed welding fixtures that hold component parts in the same position every time and provide easy access to all weld joints,
4. the right process and qualified welding procedures with defined limits for the welding variables, and
5. a workmanship standard with a monitoring and auditing process control system to assure consistent production.

These are the same requirements for cost-effective manual welding. What you would do to install a robot, you should also do for a current manual welder. By doing so, you benefit in two ways:

1. return significant profits to your bottom line with little or no capital investment, and
2. prepare your manufacturing and engineering disciplines with the base they need for automation and robotics.

There have been instances where presidents of companies mandated to manufacturing engineering to purchase and install a welding robot at the cost of a quarter of a million dollars, only to see the robot eventually taken out of service. The basics were not in place. Welders can adjust for out-of-control situations, robots cannot.

Since we have completed the evolution of welding technology, how are welders performing today? Are they applying this body of technical knowledge to produce the most cost effective and consistent weldments? The answer, even from our most recent surveys is that consistent and cost effective welding performance is still an exception rather than the rule.

Many companies are not applying the science of welding that is now

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Many supervisors continue to look at welding as an art and not a science. Therefore, they have no way to monitor and control it. You cannot control an art—you can control a scientific process.

Many of the welding processes observed on the shop floor are either not the best welding process for the application or the welding procedure used for the welding process selected was not correct. This often results in quality problems and poor welder productivity. The welding process must be the right process for the application, and the right welding procedures must support it. We still have a long way to go to get the knowledge of welding into every welding organization.

Welder Support

Let's now turn to the concepts of welder functional support and the control system.

Working with other functional departments such as design engineering, manufacturing engineering, and quality assurance, I also often found a lack of understanding of the welding process and welding management. These departments many times did not fully understand how their function affected the welder and the final product. Many had little empathy for the welder and little interest in helping.

As part of my cost reduction selling effort, I would work with these departments to teach them what they needed to know to support the welder. An emphasis was put on how important it was to control all the variables involved in welding from product design, joint design, welding process selection, welding procedure development, material fitup, equipment maintenance and fixturing to production and quality control.

Through proper training and a good monitoring and auditing support system to support the welders through the transition period, many companies made significant weld quality and productivity improvements.

The design engineers have to design sound economic welds with proper parts tolerances to produce good material fitup of welded components.

The Fabrication Department has to manufacture all weldment components to design dimensions and within tolerances so they would fit properly in the final weldment.

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The welding equipment has to be maintained in good condition to deliver consistently the proper arc stability and weld bead shape.

Manufacturing Operations has to deliver all parts required on time and to proper print specifications to the welding workstation so the welder could complete work on time.

Manufacturing Engineering has to provide the welder with work methods and application welding procedures to produce quality parts in a productive manner.

The welding supervisor has to make sure the welder has everything needed. This includes training, proper welding documentation, such as prints, workmanship standards, work methods with proper weld sequencing and welding procedures, and welding equipment so he could be effective in consistently meeting quality and quantity output standards for each weldment.

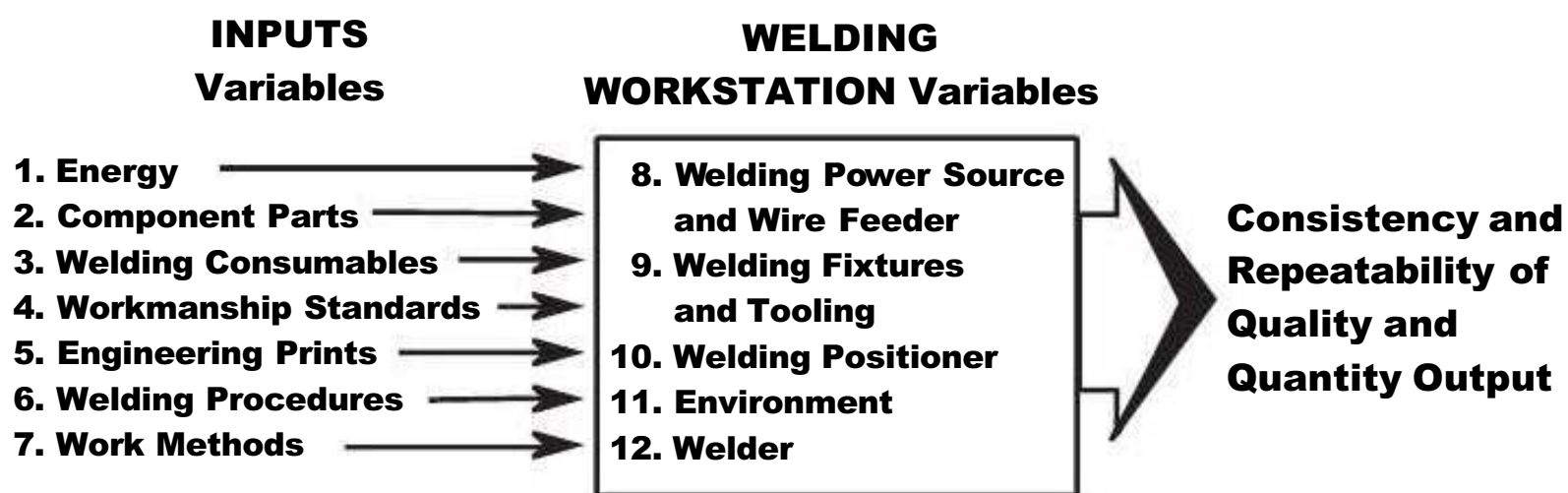
Work Center Control

The starting point for good management of welding is a control plan to ensure that such things as engineering prints, component parts, equipment performance, work methods and welding procedures conform to specifications and standards and result in finished weldments conforming to design requirements. It is the road map that the welder must follow to assure consistent quality and productivity of every weldment, every time.

Figure 3 illustrates the Work Center Control Plan consisting of seven inputs numbered 1–7, which come into the welding workstation as inputs, and five components numbered 8–12, which are within the welding workstation. Together these twelve items represent the variables of Work Center Planning and Control. Each of these variables must be qualified and controlled to a specification and a standard for each job that is put into the workstation, including the welder.

Figure 4 gives, in more detail, examples of situations, resources and responses to deviations from a plan. Target response times are developed as part of the initial planning process. In this process goals are established for the time allotted to return a workstation to planned welding quality and productivity. Situations, resources, response plans are also developed for the lead person, supervisor, manager, maintenance

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A good work center plan consists of qualified input variables, equipment that meets specification requirements including a well layed out workstation with a trained and qualified welder.

Figure 3. Work Center Control Plan

monitoring of the welder's application of the process welding variables and techniques and work-in-process are essential to consistently meet time and quality standards.

This means that personnel at all levels and across all departmental functions of responsibility must be qualified to do their job. Training in this context is much broader than qualifying a welder to meet a specific welding standard or code requirement.

One effective control method for welder training is to select and train company Internal Welder Trainers. The responsibility of these individuals is to:

1. train and qualify new hires for the shop floor.
2. upgrade and maintain the knowledge and skills of the current welders plus, troubleshoot welding technical problems.
3. function at times as the right arm of the supervisor working with the welder on the job as needed.
4. help maintain the company welder certification program.

Often they also function as welding technicians. Properly used, they have been very effective in improving weld quality and productivity.

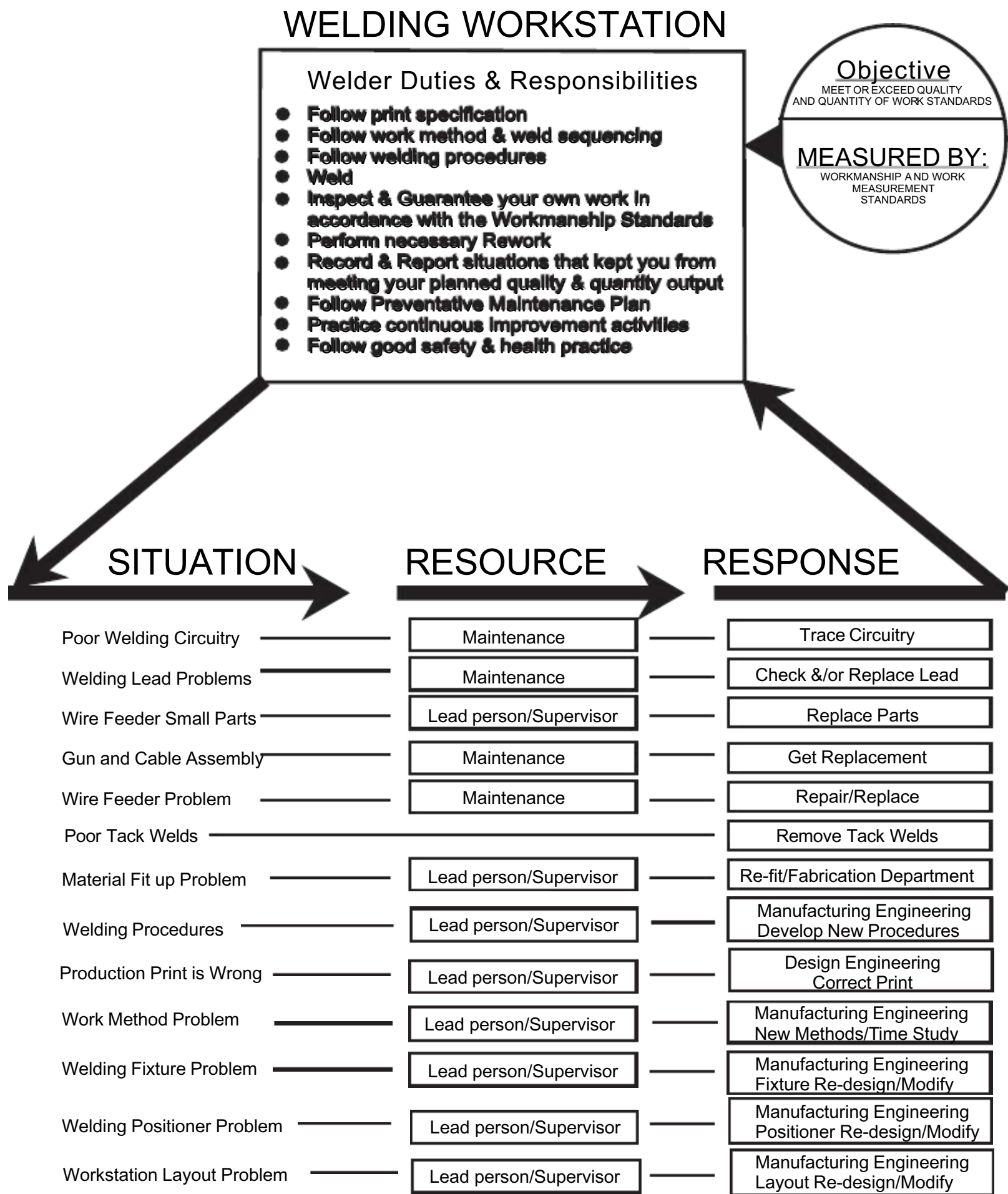
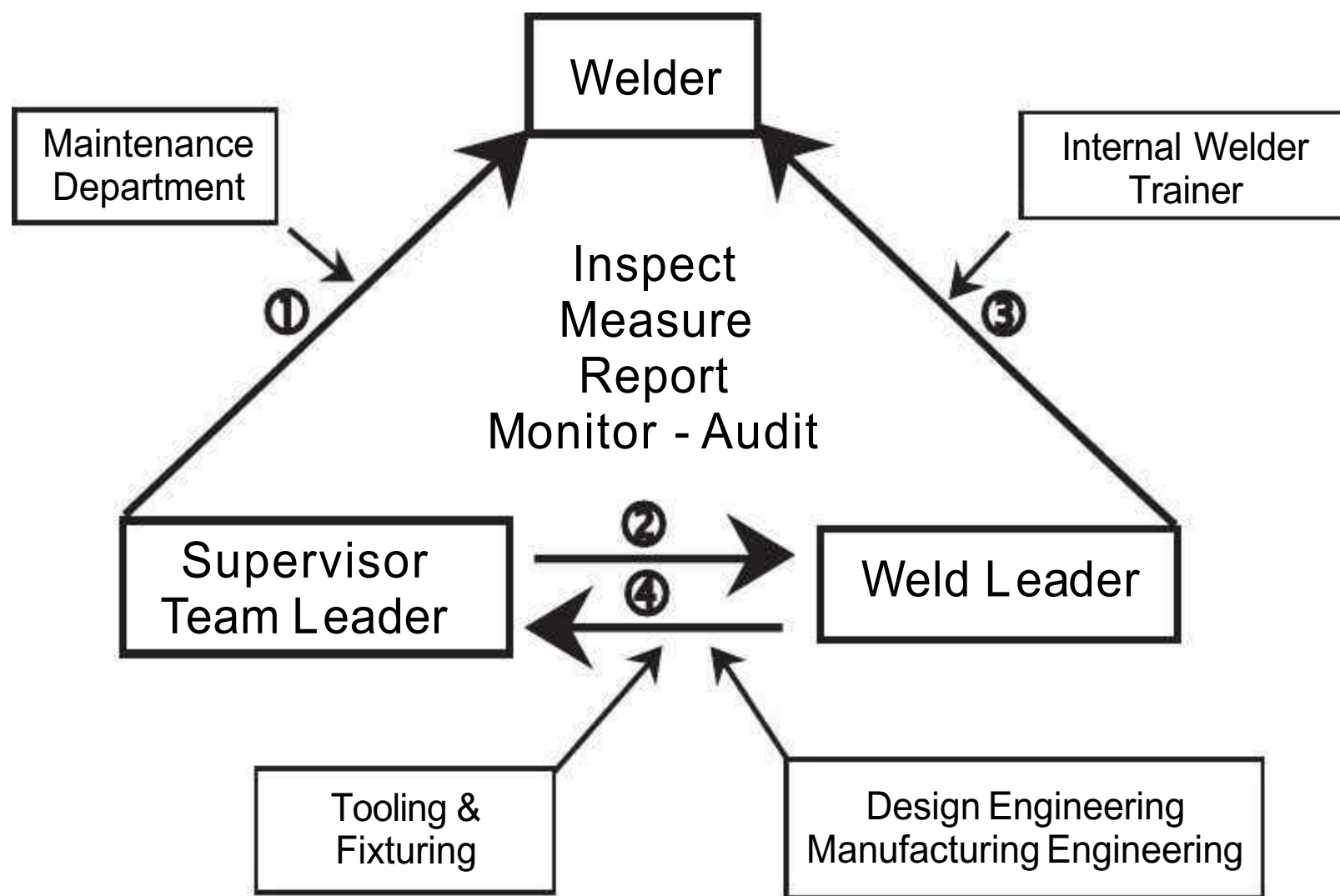


Figure 4. Welder Support System

Figure 5 illustrates how the Welding Team Support System within and

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1. Supervisor monitors welder
2. Supervisor sends weld leader for problem solving to the welder
3. Weld leader works with welder
4. Weld leader reports results to supervisor

Figure 5. Welding Team Support System

The CEO provides the direction and resources for the key support departments of Design Engineering, Manufacturing Engineering, Manufacturing Operations, and Quality Assurance to build a total welding management system to support the welding supervisors, welding crews, and welders.

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These values, along with the ten principles of the Total Welding Management System detailed in Chapter 3, provide the framework for building an effective Upside Down Organization.

Organizations that are successful in being the most cost effective in producing quality-welded products view the welder at the top of the organization chart. Support functions work together to assure that everything is done from design engineering to manufacturing engineering, and through manufacturing operations and quality assurance to support the welder.

Where this organization principle is practiced, companies are very successful in achieving improved weld quality and productivity. Welder attitudes significantly change to being more positive in the Upside Down Organization. Where this principle is not believed and practiced, there will always be welding issues that do not get resolved, resulting in a company's failure to meet competitive quality and productivity standards.

For the Welder Support System to be effective, the job description for each function must assure that every element required to make the welder successful is completed on a timely basis. This starts with the CEO and includes the functional departments of design engineering, manufacturing engineering, manufacturing operations, and quality assurance.

Five Welding Do's

In Total Welding Management, these four functional departments are defined as the Four Critical Functions. Executive management must assure that each of these four functions is properly focused on the Five Welding Do's and serving the welder to improve weld quality and productivity. The Five Welding Do's are the major goals of any welding improvement program. They define major items that affect weld quality and productivity and become the focus for improvement activity. The Five Welding Do's are:

1. Reduce weld metal volume.
2. Reduce arc time per weldment.
3. Reduce rejects, rework, and scrap.
4. Reduce work effort.

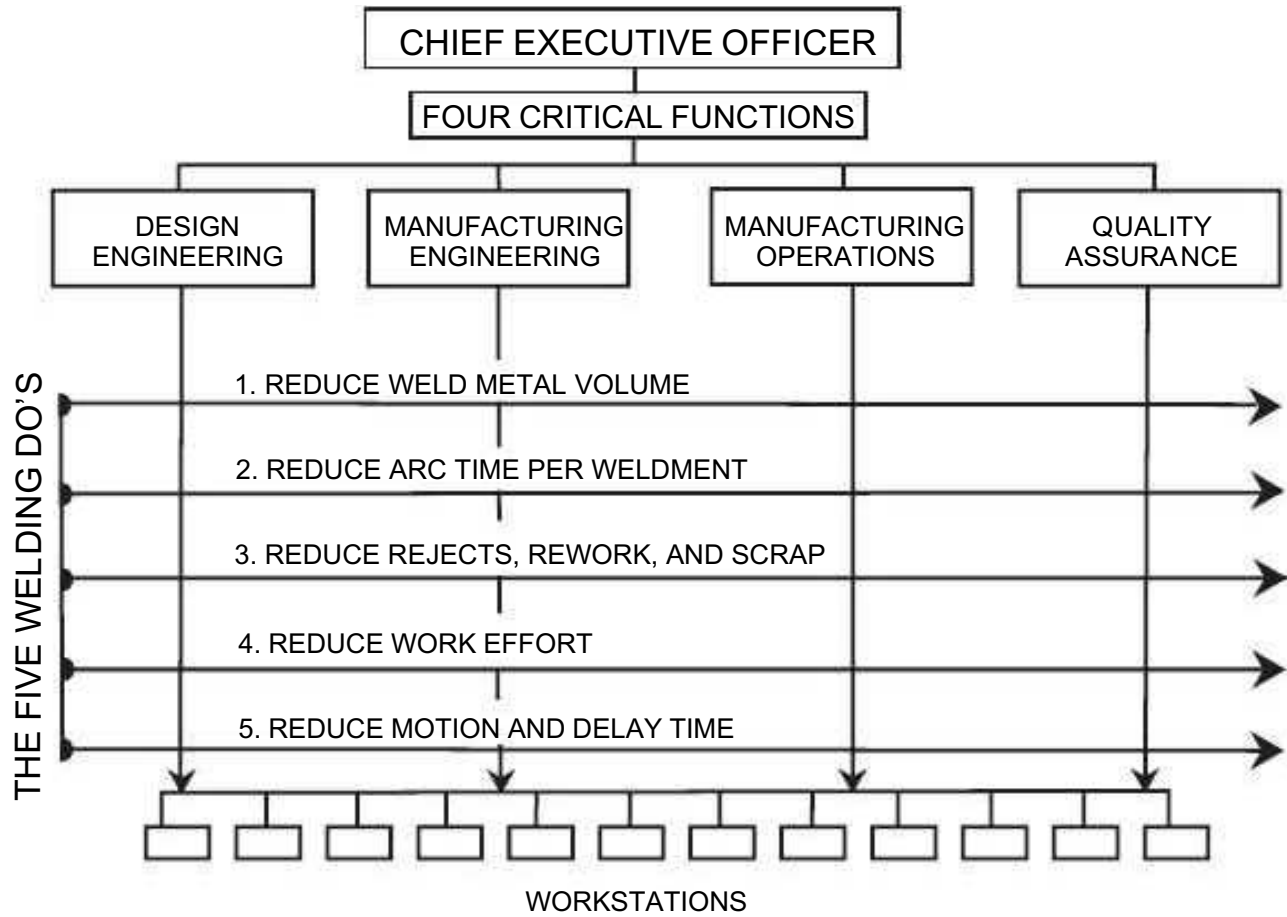


Figure 7. The Five Welding Do's and the Four Critical Functions

cover, in detail, how each of the Four Critical Functions affect the Five Welding Do's.

Top Management Leadership

The key to success is getting all the Critical Functions to work together to support the welder. Since this is not done by many companies today and represents a major change in management's approach, it takes top executive leadership and support to make it happen effectively. Without top executive leadership, effective change will not occur. The old saying is, "If nothing changes, nothing changes." Top management must set the direction, expectations, and provide hands-on leadership during this critical transition of management approach and organization focus. After the transition period and with the support system in place with monitoring, auditing and management reporting, top management involvement can be reduced.

The Upside Down Organization, with top management leadership and support, is a key principal and cornerstone of the Total Welding Management System. The reason it is so important is that to combine the science of welding with the management of welding requires a new approach to welding management. Now that welding can be looked at as an engineered science, this new management approach is possible.

Recap

Let's now recap the key points of this Chapter.

1. Given proper product design, weld joint design, correct parts, good welding fixtures, correct welding process and procedures, the right equipment, good process and procedure control, efficient workstation layout, planned work methods with weld sequencing, and trained welders, weld quality and productivity can be improved significantly.
2. Most welding support functions in the past have not been integrated to serve the welder, and therefore, the results on the shop floor have been less than optimal in terms of quality and productivity. Tearing the walls down between the Four Critical Functions of design engineering, manufacturing engineering, manufacturing operations and quality assurance, and uniting

Chapter 4

The Method: A Three-Phased Approach to Identify and Harvest Profit Improvement Opportunities

The Method is the structured process for implementing the Total Welding Management System that results in improvement in weld quality and productivity. It helps position a company for improved profitability. It also represents the “how to” of Total Welding Management. The Method consists of three steps or phases.

Four Critical Functions

Before we discuss in detail each of the three phases of The Method, let's present the Welder Support System as the core concept behind organizing and managing welding operations effectively.

As introduced in Chapter 2, to be successful in improving weld quality and productivity, welders need support from key functional departments. The most important departments that must support the welder for his success are referred to in TWM as the Four Critical Functions:

1. Design Engineering
2. Manufacturing Engineering
3. Manufacturing Operations
4. Quality Assurance

Let's look at the role of each of these functional areas and examine how they impact the welder's quality and productivity.

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has to develop the weldment specification including the weld acceptance criteria to meet product design and quality requirements.

If the Design Engineer does not have adequate weld design knowledge, then the weldment that the welder is given to make will not be produced in the most cost-effective way. A thorough knowledge and understanding of weld design and welding processes is essential for the Design Engineer to serve the welder properly.

Manufacturing Engineering

Manufacturing Engineering is the bridge between Design Engineering, Manufacturing Operations and the welder.

To effectively serve the welder, Manufacturing Engineers must understand how to develop the acceptable and unacceptable weld quality standards in the form of Workmanship Standards. These are developed from the weldment specification issued by Design Engineering.

Manufacturing Engineering must understand how to select the proper welding process and welding procedure for each welding application. They must also know how to select the proper welding equipment, tooling and fixtures.

They are responsible for the development of the Work Center Plan, which includes workstation lay out, material flow, work methods, time standards, and proper weld sequencing to minimize unnecessary warpage and distortion.

An additional responsibility is to develop a maintenance plan to assure equipment is reliable and delivers consistent results.

The Manufacturing Engineering must have the technical knowledge and the practical experience with all the welding processes and equipment used by the company in order to effectively serve the welder.

Manufacturing Operations (Production Management)

Manufacturing Operations must assure that all weldment component parts are made per the engineering print specification so that they come together with the proper material joint fits.

Manufacturing Operations is the focal point to assure that every welder in every workstation has the right parts in the right quantity, at the right time and of the right quality. This helps assure consistent welder

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performance, work methods and welding application procedures, and control of the work center plan developed by Manufacturing Engineering.

With focus on the concept of holding each welder responsible for his own quality, Manufacturing Operations through the shop floor supervisors is responsible for conducting routine quality and productivity monitoring to assure that all work is being done to print specifications, workmanship standards, work methods, and welding procedures. The supervisor is also responsible for assuring, with Quality Assurance, that all deviations are properly documented and corrective action taken.

In essence, Manufacturing Operations serves the welder by assuring proper workstation layout, equipment, component parts, documentation guidelines and training are provided and followed so that the welder can be most productive.

Quality Assurance

An effective quality system is welder focused. Each welder is given the tools required, i.e., prints, equipment, tooling, process sheets and measuring equipment to assure parts are made right every time. Welders are responsible for following the guidelines of print specifications, workmanship standards, and process welding procedures provided by Manufacturing Engineering and for checking their own work with the tools developed by Manufacturing Engineering.

Quality Assurance is responsible to set up the quality system, conduct audits, and review documentation when there is a deviation from specifications or standards.

Quality Assurance is responsible with Manufacturing Engineering and Manufacturing Operations for having the right systems and controls in place to assure that all components for each weldment are always made to print specification. They are also responsible to assure that quality control checks are made so that all welds are made per the design requirements.

Quality begins with proper specifications from Design Engineering, correct welding processes and fixturing from Manufacturing Engineering

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In order to provide visual quality guidelines to the welders and supervisors, many companies design and build a Quality/Process Center in the welding production areas which consists of:

1. A workmanship sample board that shows the common types of welds used, with examples of different acceptable and unacceptable welds for easy reference.
2. Welding quality and production mockups of common weldments to show examples of various types, sizes of welds, and locations of welds used.
3. A display of engineering prints, process prints with weld sequencing and welding symbols, work methods, welding procedures, and the maintenance plan for easy reference.

The intent is to provide the welder, welder trainer, and supervisor examples of each welding standard along with all the information needed to produce a weldment and control the process in each workstation to produce cost-effective weldments.

These Quality/Process Centers have also been used to show customers how quality is controlled for their specific products.

From the above-defined roles for each of the Four Critical Functions, it is apparent that each greatly influences the welder's quality and productivity. A significant portion of what determines how productive a welder can be is in the control of the Four Critical Functions. This is why it is so important for the success of Total Welding Management that each are adequately trained in the welding aspects of their discipline and work together to support the welder and thereby the success of the company.

The Welder Support System becomes as important as the welder or operator for improving weld quality and productivity. A strong support system needs to be put in place before significant improvements can occur. The support system has to come first in any total welding management system.

Many support function managers do not understand their role in a successful welding improvement program. Executive managers are the only ones with the authority to pull together all the support departments and focus them on welding improvement by supporting the welder. It is, therefore, essential that top management bring together all of the support department managers with a common goal of supporting the welder for

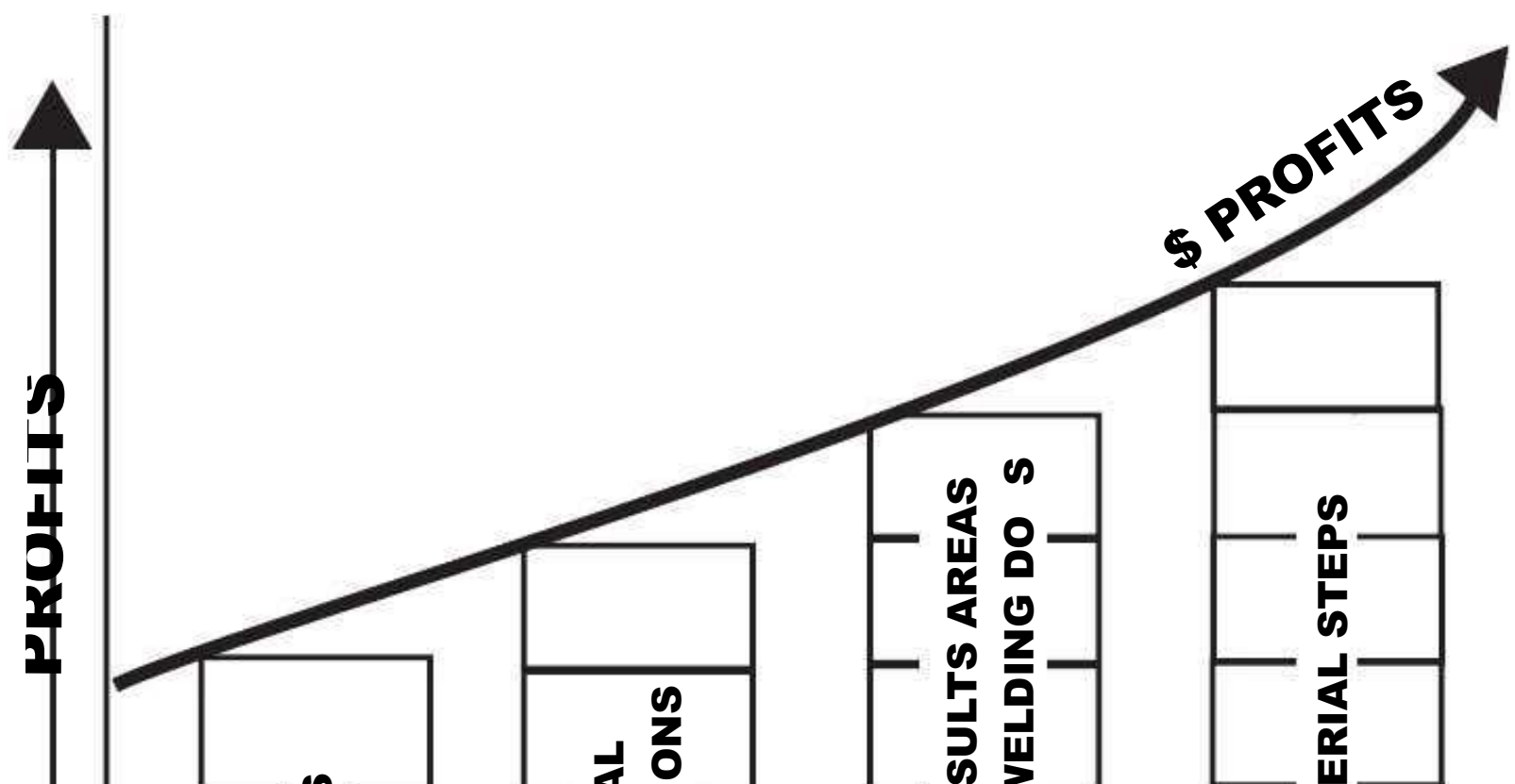
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process to identify, quantify, harvest and maintain weld quality and productivity improvements.

The Method is the path to Total Welding Management and does the following:

1. identifies and quantifies all the potential welding improvement opportunities in dollars and hours with supporting details along with actions required to achieve those saving opportunities. (Identify opportunities),
2. evaluates the opportunities identified, gets the management team buy in, and develops a plan to get results. (Plan for success) and,
3. gets the results by implementing the plan and putting a management system in place to assure that results are sustained. (Harvest and maintain results).

As the 3-4-5-6 step Method is applied to a company's welding operations profit improvement results as illustrated in Figure 10. The Method includes Three Phases, The Four Critical Functions with Five Key Results Areas for each, the Five Welding Do's as goals, and the Six Managerial Steps. This is why the process is referred to as the 3-4-5-6 Method. Each of these steps will be explained, in detail, in subsequent Chapters.



CHAPTER 4

The Method:

- has three phases detailed later in this chapter,
- focuses on the Four Critical Functions as outlined earlier in this chapter,
- uses the methodology of Five Key Results Areas with each of the Welding Do's as goals to evaluate potential improvements across the Four Critical Functions as covered in Chapter 7 and,
- incorporates Six Managerial Steps as the foundation for managing results as discussed in Chapter 9.

As Total Welding Management is implemented, your company, using The Method profits potential from welding improves.

The following three phases of The Method represent the steps or systematic approach to achieve improved weld quality and productivity.

Phase I—Survey and Evaluation

This phase answers the questions, Where is your company now in terms of welding quality and productivity? What are the biggest potential opportunities for improvement? What are the potential dollars and hours of savings for each opportunity? What actions are required to harvest the savings from each opportunity? A systematic process, which is reviewed in Chapter 8, is used to gather the data required to answer these questions.

Phase II—Management Planning and Goal Setting

This phase is management driven and sets specific goals and plans based on the opportunities identified in Phase I. How do we as a management team work to get the improvements? Where do we begin? What is our plan? What actions are required by whom to get the improvements identified? What are the priorities? What resources are required? How long will it take? When do we start to realize savings? In this phase the management team develops the plan to achieve the agreed to results. This is where the hard work of implementation planning begins.

Phase III—Implement and Sustain

This phase starts with detailing how your team will work together in a planned way to build the management and technical knowledge base about all aspects of welding for each functional area.

Training of welders, managers, supervisors, internal welder trainers, and functional personnel is a key part of this phase. Training on what

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management system that is put in place. This is the doing step of The Method and done well, yields the results management seeks. This is why this third Phase is called Implement and Sustain.

The three phases of The Method provides the framework for weld quality and productivity improvement. They represent the structure around which the ten principles are applied to implement Total Welding Management. The Method represents an organization change process. The change represents the way that welding and welding management moves from what it was to Total Welding Management.

To effect change, education, training, and teamwork are essential. In welding management three types of training are required: managerial, technical, and skills.

Training

To begin the change process, senior management, the managers of the Four Critical Functions and selected other managers critical to the process are trained as the initial core group. Many of this core group then typically serve on the Welding Steering Team for implementation of the Total Welding Management System project. This training should be in the welding management concepts and principles as well as welding management. This group also is trained in a sampling of the subjects that will be taught to the Four Critical Function personnel involved in the Total Welding Management System.

The balance of training for the Four Critical Function personnel should include the following:

- Training of the technical support personnel including design and manufacturing engineers and quality assurance in the technical aspects of welding.
- Training of several people in welding technology and techniques needed to train the remaining welders. These individuals become your Internal Welder Trainers and technicians.
- Training of the maintenance personnel to troubleshoot and maintain all equipment in 'as new' condition.
- Training of all the managers and supervisors in the Total Welding Management System including The Method, the four management concepts, the ten principles, the Five Welding Do's,

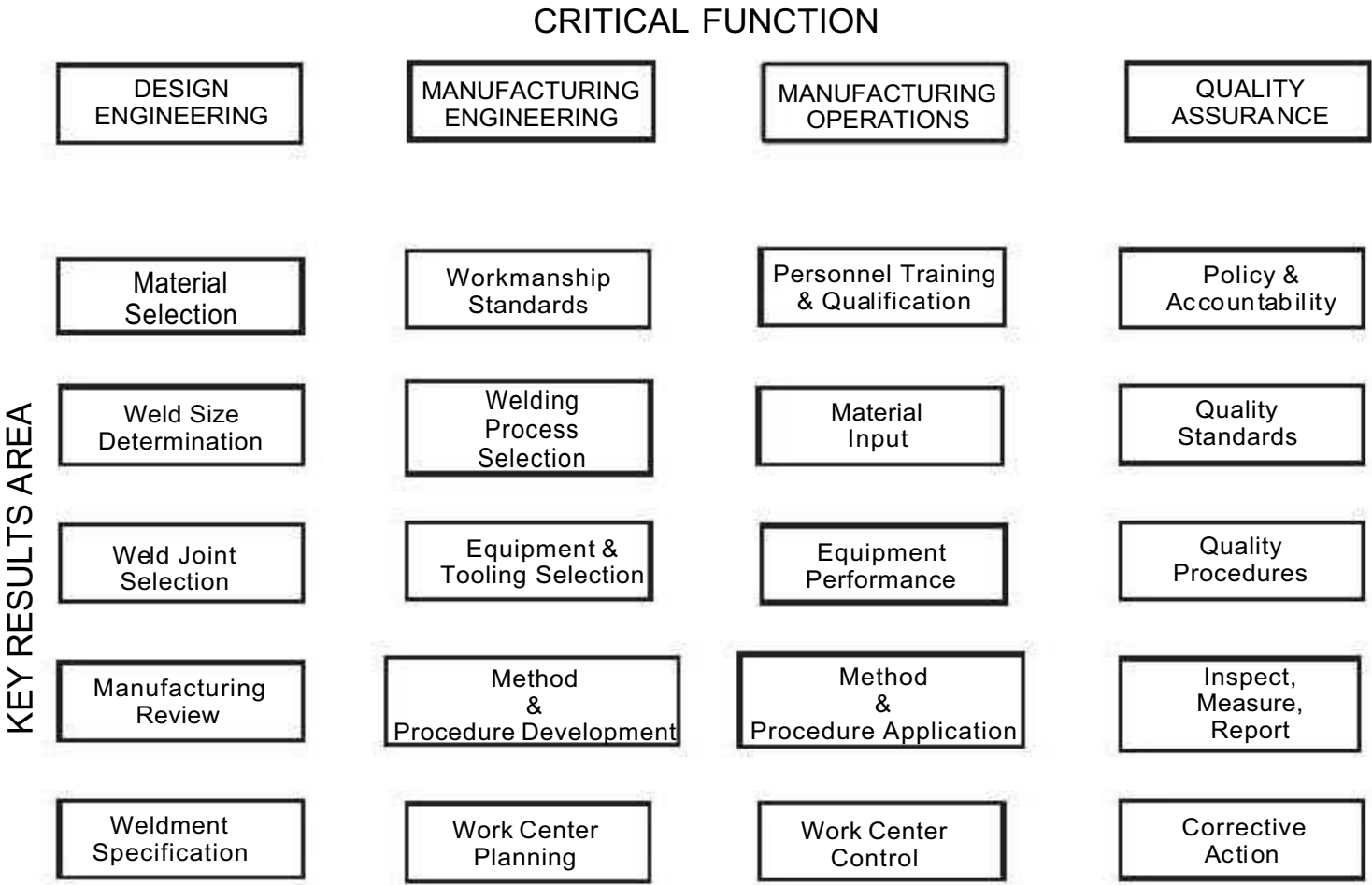


Figure 13. Critical Functions with Corresponding Key Results Areas

2. **Weld Size Determination.** What is the right size weld and length given the materials selected and structural design requirements? Does the Design Engineer select weld sizes by guesstimation, rule of thumb, or calculation and how the weld joint will react under various types of loading?

Under specifying a weld size or length can result in potential weld failures.

Over specifying a weld size can lead to higher welding costs, as well as, potential weld failure. The optimum weld size and shape for each design requirement results in the most cost-effective and reliable welds.

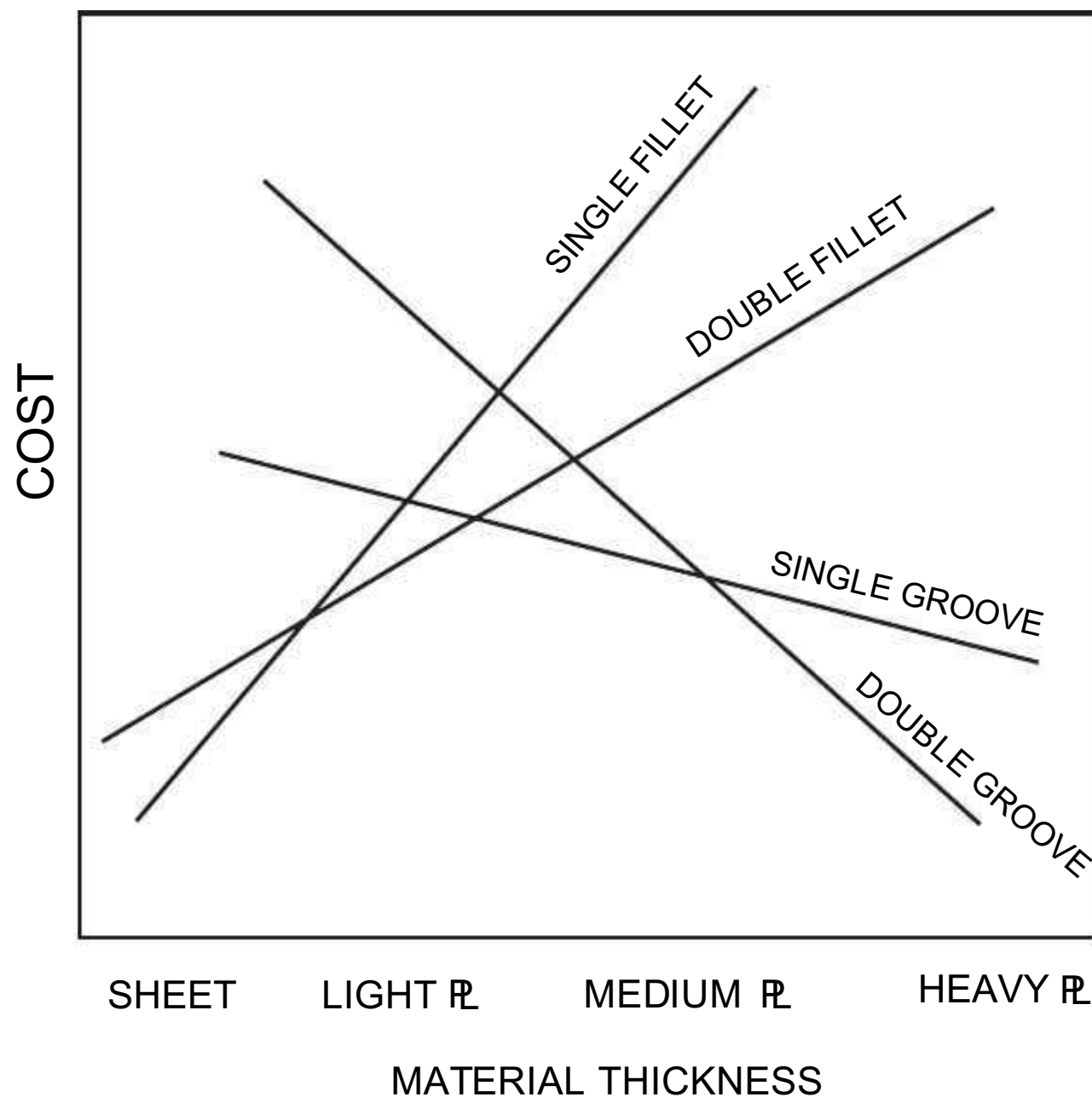
3. **Weld Joint Selection.** What is the best type of weld joint for each application—butt, corner, tee, edge, or lap? What is the best weld—a bevel, a V-groove, fillet or lap? The selection of weld joint and weld type affects weldment costs. As an example, a small fillet weld can be more cost effective than a groove weld, but a larger fillet weld may be less cost effective than a groove weld.

A design engineer needs to understand when to apply the fillet weld and when to apply the groove weld. Specifying the wrong one can either add extra welding time, increased material preparation and fabrication time and possibly cause base material shrinkage and distortion.

Figure 14 illustrates how costs vary by type of weld and material thickness. As an example, for light gage materials, such as sheet metal, the single fillet weld is the most cost effective. As the material thickness increases, groove welds become more appropriate and cost effective.

4. **Manufacturing Review.** With proper knowledge of the welding processes and the capabilities of his company's specific manufacturing equipment, the Design Engineer is better equipped to specify a weld that is right for the application and can be made cost effectively with the best welding process accessibility and material fitup. He also has the responsibility to keep up-to-date with equipment changes in the shop as they can change process availability and capability.

The Design Engineer has the responsibility in the design



**Figure 14. Relative Cost Comparison—
Fillet Welds vs. Groove Welds**

specific weld joint selected. There are usually several types of weld joints or welding processes adequate for a given design. The Design Engineer who knows what his shop is capable of makes a big contribution towards improving welder quality and productivity.

The Design Engineer further needs to be aware of the proper welding gun or torch accessibility needed to produce a quality weld at good productivity levels. This knowledge helps to reduce welder work effort and fatigue.

A weldment specification includes engineering drawings of the welded assembly and of all components including welding symbols. These specifications define dimensions and tolerances; weld sizes, critical dimensions, material fitup, and any specific testing requirements, as well as, the acceptable weld criteria including such variables as surface finish, degree of undercut allowed and minimum and maximum weld sizes. All the information required to define the final weldment and assure that it can be made to meet design requirements should be contained on the engineering drawings or in the welding specification document. This information is the result of the Design Engineer's review of the design drawings for the weldment and an understanding of its application.

It is a good practice prior to the engineering release of a new or revised design that the Design Engineer meets with the design team made up of Manufacturing Engineering, Manufacturing Operations, and Quality Assurance to review the drawings to assure that all the parts and the final weldment can be made to print specifications and fit together for optimum welder productivity.

This gives Manufacturing Engineering, Manufacturing Operations, and Quality Assurance an opportunity to raise issues in manufacturing that might make it difficult and/or costly to produce the weldment. Design Engineering can then evaluate changes recommended prior to release and often head off quality, productivity, and cost issues.

From the above discussion we can see that Design Engineering starts the process of cost effective welding through design both for function and manufacturability. Without proper consideration for manufacturing capability and welder productivity, weldment designs will end up costing more than they should. Design Engineering is the first step to improving welder quality and productivity, leading to lower weldments costs.

Manufacturing Engineering

Top Management's Role

Now that they understand how the Four Critical Functions impact the quality and productivity of the welders, executive management often ask the following questions:

1. How do I get each of the Four Critical Functions to see their jobs as serving the welder on the floor?
2. How do I get them to work together?
3. What role should I, as president or CEO, play in leading the company to work together to get the quality and productivity improvements in our welding operations?

Some of the answers to these questions are found by adopting the concept of the Upside Down Organization introduced in Chapter 2. Company presidents and CEOs should look at themselves at the bottom of the organization chart rather than at the top. Then, get their department managers to see themselves as serving the welders and welding crews who are now at the top of the chart. To date, I have never encountered a CEO or president who has disagreed with this concept.

The Upside Down Organization begins with the recognition that without production employees, in this case welders and operators, customers for whom we design and sell our products will never get what they want. The more a company can focus on helping and getting its production employees to do the best job possible in producing products for customers, the odds of delivering consistently what they want are greatly improved.

Top management must take the lead and bring their managers together to support the welder. Once top management leads their managers through this new way of looking at their organization, the stage is set for significant improvement in welder quality and productivity.

This change in top management's mindset, leadership, and management approach has paid off with increased profits in many companies.

The only way to make the Upside Down Organization work is for the president, CEO, or general manager to understand and provide the leadership to make it happen. It takes hands-on, informed and committed leadership from the top to create this new environment and new

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must come first. Without it, significant sustainable welding quality and productivity improvements that could be obtainable and sustainable are not possible.

Welder Support System

Before we move on, let's expand a bit more on the Welder Support System and who is being supported to improve quality and productivity.

In traditional companies, when we look at welding on the shop floor, where profits are gained or lost, we see a welding supervisor who is on the firing line everyday coordinating production activities to get jobs completed on time. We see the welder who is doing his best, often with limited technical and shop support.

In some companies with large welding projects such as barges or other large structures, there are welding crews consisting of 8–20 welders working on a project as a team.

In my experience with project or construction type production such as the fabrication and building of barges, ships, bridges and rail cars, a welder-welding crew-supervisor organization structure is commonly used. In Total Welding Management, the Four Critical Functions then serve the welding crew.

The floor team consisting of the welding crew, weld leader and supervisor are the core group responsible for delivering quality, cost effective weldments. This concept of the welding triangle is illustrated in Chapter 2, Figure 5. It is the support of the welder; weld leader, supervisor, and welding crew that comprise the components of the triangle that the Four Critical Functions must serve together to achieve a high quality and productive welding operations.

Recap

Let's summarize what we have learned about the Welder Support System and the Four Critical Functions:

1. The functions of Design Engineering, Manufacturing Engineering, Manufacturing Operations and Quality Assurance together form the Four Critical Functions for effective welding management. Each independently must be knowledgeable and competent in all technical aspects of their work as it relates to the

- crew, and welding supervisor determines a company's success in improving weld quality and productivity. This group taken collectively is referred to as the Welder Support System.
3. Traditional organization structures with separate islands of functional responsibility will not lead to significant improvements in welder quality and productivity unless top management can find a way to get the Four Critical Functions to work together to support the welder. For example, if Design Engineering continues to throw the prints over the wall to Manufacturing Engineering and Manufacturing Operations, opportunities to improve quality and productivity are limited.
 4. The Upside Down Organization with the welders and operators at the top, the Four Critical Functions below as support, and top management at the bottom providing leadership resources, direction and expectations is the structure that has been proven to deliver the best results in welder quality and productivity improvement. This new way of looking at organization structure gets the Four Critical Functions to work together and focus on serving the welder for greater quality and productivity. The walls between functional departments that once existed come tumbling down. They now have a common goal of working together to serve the welder.

The next Chapter will expand on the use of the Five Welding Do's as goals and the Key Results Areas for each of the Four Critical Functions. When the Key Results Areas are used with the Four Critical Functions, they serve as the basis of identifying and quantifying the opportunity for profit improvement in your welding operations.

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The Five Welding Do's

This chapter will expand the concept of the Five Welding Do's as major goals to improve welding operations. The Five Welding Do's, used in combination with the Four Critical Functions, form the basis for identifying and quantifying welding improvement opportunities in each company and form the data structure for the Survey and Evaluation phase of The Method, which is covered in Chapter 8. They were introduced in Chapter 2 and are shown in Figure 7.

This chapter will:

1. Expand on the Five Welding Do's as goals to improve weld quality and productivity.
2. Show how each of the Four Critical Functions and each of their respective Key Results Areas influence each of the Five Welding Do's in weld quality and productivity.
3. Give examples of how the Four Critical Functions and the Five Welding Do's are used to quantify savings potential as they are analyzed with their respective Key Results Areas.
4. Introduce the Four Critical Functions and Five Welding Do's as the basis for Phase I of The Method—Survey and Evaluation.

During my years working with welders on the shop floor, I kept coming back to five basic goals that, when pursued, always led to welding improvement.

The Five Welding Do's

These five major goals then formally became the Five Welding Do's that helped identify opportunities for welding quality and productivity

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Reducing nonproductive or wasted hours in each of these Five Welding Do's will increase the welding operating factor, resulting in more arc-on time to achieve reduced product cycle times. Another way to look at the Five Welding Do's is to view them as ways to eliminate waste throughout a company's welding operations.

Figure 7 in Chapter 2 shows the relationship between the Five Welding Do's and the Four Critical Functions and their respective Key Results Areas. As can be seen from the figure, each of the Four Critical Functions influences and determines the degree of success in each of the Five Welding Do's. Examples of this are given later in this Chapter.

Let's now look at the process of welding through the welder's eyes. The Five Welding Do's can be used to provide insight into how weld quality and productivity can be improved in any operation by using them in conjunction with observations of jobs being welded on the shop floor. Looking at each of the Five Welding Do's in more detail, we see how they can reduce overall welding costs with this type of focus.

1. **Reduce Weld Metal Volume.** One of the most persistent problems I have encountered on the shop floor has been overwelding. The mind set "the bigger the weld, the better the weld" has been ingrained in design and manufacturing engineers, inspectors, supervisors and welders for a long time.

This misconception comes from a lack of understanding of how weld strength is determined and how ineffectual the making of oversized welds can be. From a design standpoint, there is a correct weld application and size for each weld joint. Overwelding adds labor costs and can contribute to shrinkage and distortion of the welded assembly, possibly rendering the assembly unacceptable. More is not always better in welding.

Often in the past, weld size determination was thought of as a judgment call by engineering based on past practices and guesstimation with little solid engineering or good manufacturing practices in welding. This practice is still followed in some companies.

Reducing weld metal volume and improving weld joint quality and productivity requires proper weld joint design and sizing by Design Engineering. Correct component parts specification and tolerances to ensure proper material fitups and

Example 1 on page 73 quantifies the cost impact of overwelding. As the fillet size of a weld decreases the volume of the weld metal decreases, reducing the arc time per weldment. As this example illustrates, reducing the fillet weld size from 1/4 inch to 3/16 inch reduces weld metal volume by 78%. In the example, this would result in an annual cost savings per welder of \$7,700 based on a 25% operating factor.

The intent of this example of the goal of reduced weld metal volume is to eliminate waste by reducing the volume of weld metal to the minimum necessary to be consistent with the weld joint application and specification requirements. In other words, designers should minimize the volume of weld metal required and avoid specifying or requiring welds that are larger than necessary. Welders should not deposit welds larger or longer than required on the engineering print.

Although this goal directly affects arc time, it is considered separate from the goal of Reduce Arc Time per Weldment because it is a distinct item apart from the welding process and more related to design.

2. **Reduce Arc Time Per Weldment.** To reduce arc time per weldment, you must select the proper welding process, electrode type and size, and shielding gas for the welding application and weld size specified to result in the fastest linear inches of travel speed.

Weld joint position, clean parts, good material fitup, and weld joint accessibility are also contributing factors to reducing arc time per weldment.

This goal is complimentary to goal 1, Reduce Weld Metal Volume. Once a specified weld metal volume and the greatest metal deposit rate have been determined with the other factors in control, you have:

- a. reduced arc time per weldment, and
 - b. increased your welding operating factor.
3. **Reduce Rejects, Rework, and Scrap.** Anytime there is a weld quality issue that resulted from a part not meeting print specifications, the part or the complete weldment has to be reworked or even scrapped if it cannot be made to conform to

Manufacturing Operations

Manufacturing Operations and its production support departments, which include scheduling, inventory control; maintenance, fabrication, and purchasing also play a critical role in the success of each welder by how they focus on the Five Welding Do's.

Some of Manufacturing Operations key responsibilities include assuring that all welders are trained and qualified in the welding processes and procedures used, and assuring that all weldment component parts required are delivered to the welding workstations on time and within design specifications. They are also responsible to assure that all equipment, tooling and fixtures are maintained in good working order, that the welder applies all defined processes properly, and that all variables within the workstation are properly controlled in accordance with a Work Center Plan developed by Manufacturing Engineering.

Manufacturing Operations, in carrying out their major responsibilities, can affect the Five Welding Do's of reduced weld metal volume, reduced arc time per weldment, reduced rejects, rework and scrap, reduced work effort and reduced motion and delay time.

A few examples:

- If all component parts are not delivered on time to start a weldment, delays will occur, resulting in lower welder productivity.
- If component parts are not made per print specifications, poor material fitup, rework and extra labor hours will result.
- If equipment is not maintained properly, breakdowns or malfunctions will occur, resulting in lost welder time and/or poor weld quality.

Quality Assurance

Quality Assurance is responsible, in consultation with top management, for setting the company quality policy and making sure everyone follows it. They also set specific quality standards for each weldment based on design and process requirements, document quality procedures that are to be followed for each job, inspect, measure, and provide feedback on deviations from specifications. They also coordinate corrective actions when there are

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transferred to Manufacturing Operations and specifically to the welder and monitored by the supervisor.

Quality Assurance also impacts the Five Welding Do's. If quality standards are not established for each job and monitored throughout the welding process, rejects, rework, and scrap will result. If consistent weld quality standards are not documented and well understood by all Four Critical Functions, overwelding, weld failures, and poor quality and weld cosmetics can occur.

It is now becoming clear how the Four Critical Functions within a company focusing on the Five Welding Do's can deliver profit-making improvements. As the Four Critical Function personnel become aware of the Five Welding Do's and how their decisions impact weld quality and productivity, they will make better decisions in Design Engineering, Manufacturing Engineering, Manufacturing Operations, and Quality Assurance. The result will be greater welding profits through improved quality and productivity.

Survey and Evaluation

Now that we understand the relationship between the Four Critical Functions and the Five Welding Do's, the next logical questions would be: Where do I start the improvement? Design engineering? Tooling? Fixturing? Production Scheduling? Maintenance of welding equipment? Documenting quality standards? Workstation lay out? Where do I start and how much can I expect to save as I work on each item?

To answer these questions, Phase I of The Method—Survey and Evaluation, was developed. Phase I identifies and quantifies the improvement potential for each of the Four Critical Functions across the Five Welding Do's within the Key Results Areas.

The survey data is gathered through a formal in-plant review of all aspects of your welding operations. Actual welding jobs being processed on the shop floor are observed and data measurements made and recorded. The results are reviewed and analyzed, and then summarized into a comprehensive and detailed report to management.

The survey touches all aspects of welding. It begins when all the base raw material for a weldment enters the plant, and proceeds through its operations. All steps beginning with weld design through the fabrication,

THE FIVE WELDING DO'S

Functions is used in conjunction with the Five Welding Do's and Five Key Results Areas to quantify potential savings opportunities. They represent examples of specific jobs observed as they were being welded.

The cells in the following examples refer to the matrix of the Four Critical Functions with the Five Welding Do's across their specific Key Results Areas. This will be explained in more detail in Chapter 8.

Example 1. Cell 1-2

Function	Design Engineering
Welding Do	Reduce Weld Metal Volume
Key Result Area	Weld Size Determination
Observation	Specified a 1/4-in. fillet weld on 1/4-in. base Material. Over specified weld—only a 3/16-in. fillet weld was needed.
Savings Potential	3/16-in. fillet weld = 0.0656 lb/ft (weight) 1/4-in. fillet weld = 0.117 lb/ft (weight) Difference = 78% (1/4-in. vs. 3/16-in. fillet weld) Weld Process: • GMAW, 0.045-in. diameter E70S-3 electrode @ 250 amperes= 7.5 lb/h. deposited. • 2000 hours @ a 25% operating factor = 500 hours of arc time available. • 1/4-in. weld – 500 hours × 7.5 lb/h/0.117 lb weld per foot = 32,051 ft. of weld deposited. • 3/16-in. weld—(32,051 ft. of weld × 0.0656 lb weld per foot)/ 7.5 lb weld metal deposited = 280 hours. Savings: 500 h (1/4-in. weld) – 280 h (3/16-in. weld) = 220 hours. 220 hours × \$35/h = \$7,700.
Action	Change weld size specification and instruct welder.

Example 2. Cell 5-9

Function	Manufacturing Engineering
Welding Do	Reduce Motion and Delay Time
Key Result Area	Method and Procedure Development

THE FOUR CRITICAL FUNCTIONS AND THEIR FIVE KEY RESULTS AREAS

To give Manufacturing Engineering a complete picture of what is required, the engineering specifications must be clear and complete. Anything less could result in rejects, second-guessing, added costs, and potential failures.

Manufacturing Engineering

Manufacturing Engineering is the bridge between Design Engineering and Manufacturing Operations. Manufacturing Engineering takes the weldment specification from Design Engineering and defines the “what and how to” for Manufacturing Operations. The Key Results Areas are:

1. **Workmanship Standards** include providing welding production requirements to the shop personnel to meet the quality standards for each weldment. Manufacturing Engineering takes the weldment specification and identifies all critical requirements and outlines the general workmanship standards that would apply. Examples are surface finish of weldment, allowable weld porosity, weld spatter, degree of undercut, overlap, and weld size limits. These workmanship standards define for each weldment what is an acceptable and unacceptable weld.

To do this properly, Manufacturing Engineering must have knowledge of the application of the weldment, its critical characteristics, and of what is practical on the shop floor. Being overly stringent on the workmanship standards leads to unnecessary added costs. Being lax leads to rejects, rework, and potential weld failures.

2. **Welding Process Selection** includes choosing and then specifying the most efficient and effective welding process or processes for each weldment based on the weldment specification of the design and knowledge of the shops capabilities. This is where the Manufacturing Engineering’s knowledge of the equipment and capability of the shop pays off in improved welding quality and productivity.
3. **Equipment and Tooling Selection** is the step where the welding equipment, fixtures, jigs, and positioners for the weldment are

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Workstation layout, material flow, weld sequencing and welder body motion are established first, followed by work methods development. Work methods provide the elemental breakdown of the complete labor work cycle time with or without time standards. This step involves determining the most efficient and effective combination of welding materials, welding process or processes, welding variables and technique characteristics consistent with quality and production requirements to satisfy in-service conditions. This is also where the welding variables for the selected welding process are defined and refined to form the basis of the welding procedures.

5. **Work Center Planning** involves a combination of the above four Key Result Areas, and defining all the variables both coming into the workstation and those within the workstation, assuring that each is qualified to an acceptable standard to enable the welder to meet or exceed quality and productivity expectations. A well-organized workstation leads to minimum welder fatigue and wasted body motion. A poorly organized workstation leads to lost time, welder frustration and increased fatigue, all leading to higher costs.

From the Five Key Results Areas for Manufacturing Engineering, we see that each can have a dramatic impact on welding quality and productivity. To apply them requires that Manufacturing Engineering understands the weldment design requirements as well as the capabilities of production.

Manufacturing Operations

Manufacturing Operations is responsible for directing and coordinating all the activities involved in producing the product. These responsibilities begin with employee hiring and training and go through managing and controlling what goes on in each workstation to assure all standards, specifications, procedures and work methods, and instructions are followed.

The Five Key Results Areas for Manufacturing Operations are:

1. **Personnel Training and Qualification** focuses on the most important factor in any business—its people. Great people make

THE FOUR CRITICAL FUNCTIONS AND THEIR FIVE KEY RESULTS AREAS

Screening includes an assessment for any skills that might be lacking for the work required. Training and coaching employees may be required as they take on new assignments and require new skills.

In order to ensure that welders are actually qualified and maintain their qualifications, many companies have adopted either formal certifications such as AWS certification or developed their own in-house certification program. Many companies are now recertifying their welders on an annual basis. This assures that welder's skills are maintained and any need for skills upgrading or remedial training is formally identified.

Another important consideration in ongoing welder qualification and training is the issue of eyesight. As we age, our eyesight changes. With age, a welder's ability to view the molten weld puddle may deteriorate, requiring the use of corrective lenses. It is a good practice to conduct vision tests on welders each year. The welding industry now has available corrective eyewear that can be used quite effectively under the welding hood.

Design Engineering, Manufacturing Engineering, and Quality Assurance are also responsible for training and qualifying their personnel as required.

As part of the Total Welding Management System, welder training is designed around teaching welding concepts and performance rather than just skills training. The Method and the concept of the Upside Down Organization involves teaching the employee the science of welding rather than just technique training or just telling or showing. Through experience, I found "training only" produced about 10% to 30% of the potential improvement. Employees involved in the complete training process, as in The Method, far exceed those results in improved weld quality and improved productivity.

2. **Material Input** assure all component parts that go into the welding workstation are right. All materials must meet design specifications. This Key Results Area focuses on controlling the shape, size, surface condition and dimensions of all parts entering each welding workstation. If all parts coming into the welding workstation are right and delivered on time, the welder

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to be conducted to assure the specific equipment can consistently perform as required. A good preventive maintenance program to keep equipment in good working order is necessary.

Equipment performance also includes fixtures, jigs, positioners, and any other items used by the welder in the workstation. It would also include any mechanized automatic welding equipment, as well as robotics and full automation systems.

4. **Method and Procedure Application** assures that the use of welding equipment, fixtures and tooling, welding processes and techniques are applied by the welder to meet specifications and standards and that the proper welding procedures are followed. Is each welder doing what has been documented as being required to produce the weldment effectively?
5. **Work Center Control** addresses putting in place the tools to track the progress of production as well as a quick response system to handle situations such as equipment breakdowns, and quality and production issues. Anything that causes deviations or delays is handled as part of the Work Center Control system.

This Key Results Area focuses on implementing the work plan established by Manufacturing Engineering and controlling it. It includes monitoring and auditing the welder as well as the work methods, materials, equipment, and tooling in accordance with the Work Center Plan and correcting variances from the plan when they occur to keep production flowing with minimal lost time.

Manufacturing Operations Key Results Areas bring Design Engineering and Manufacturing Engineering together on the shop floor with qualified and trained personnel, specifications, procedures, work methods, standards, good operating equipment, and a shop management system that assures high welder quality and productivity. If any of these Five Key Results Areas are overlooked or if not done effectively, welder performance and results will suffer.

Quality Assurance is the fourth critical function. Quality Assurance performs an audit function in the company to assure that all the principles and procedures of the welding management system are followed.

THE FOUR CRITICAL FUNCTIONS AND THEIR FIVE KEY RESULTS AREAS

managers. It outlines general company-wide quality standards, responsibilities, company quality values, and general procedures on how quality issues will be handled.

Effective quality policies are written in clear concise language, well communicated, understood and practiced by all employees. The lack of a quality policy invites confusion, differences, inconsistency, and conflict regarding quality standards, responsibilities, and procedures. A quality policy is the framework for a company's quality system.

2. **Quality Standards** for a company flow from the company quality policy and any specific quality requirements of the industry served. For example, if a company is producing pressure vessels then part of the company quality standards would include the testing and documentation requirements for pressure vessels.

Quality Standards also encompasses all the quality information in the TWM system as well as the productivity information and the structure within the TWM system. It is this all inclusive Quality concept in TWM that sets the management requirements for all data that supports not only the traditional approach to quality, but also includes all information aspects of TWM to assure that the system is functioning properly and providing the performance and exception information that management needs to manage the system on a day-to-day basis.

The company quality policy clearly defines the responsibilities and accountabilities of each of the Four Critical Functions. The Quality Standards then include all the documentation, monitoring, auditing and reporting requirements to assure that the policy is being followed and the TWM system is maintained.

3. **Quality Procedures** define how the Quality Standards for both quality and productivity are to be verified through inspection, monitoring and auditing. The Quality Procedures also define the specific reports that management receives to report both deviations from the standards and the overall performance of the TWM system.

At the operating level on the shop floor, the Quality

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procedures documented on the shop floor for everyone's use, many quality problems are eliminated.

4. **Inspect, Measure, Report** is the actual carrying out of the Quality Procedures by the welders, supervisors, auditors and heads of the support functions. The welders as they inspect their own work report quality data and other issues on the 'welder shift sheet.' The supervisor, through the use of the Summary Log and observations on the shop floor, monitors quality and initiates corrective action as required. The auditors prepare summary quality reports to management from the quality data provided by the shop floor as well through as procedural audits, to advise management on the overall conformance within the company to the TWM Management Plan which includes the use of the Quality Procedures. This reporting provides management with an ongoing appraisal of the overall health of their TWM system. If from and of the data reported, management action is required, they can then initiate it based on this factual data. This overall reporting data is also used by members of the management team to initiate any corrective actions required within their scope of responsibility. This process of management reporting is essential to keep the TWM system performing.
5. **Corrective Action** closes the loop by assuring that when there are quality issues on fabricated components or weldments, they are properly analyzed to cause and corrective action to be taken quickly and effectively.

In many organizations responsibility for quality has truly been transferred to the welder and monitored by the supervisor. Welders record the quality data as outlined by the quality assurance standards and the supervisor leads the effort for corrective action when deviations to specifications are found.

In the Total Welding Management System, welders record on a Daily Shift Report any variable that prevented them from meeting the standard of quality and/or quantity output from their workstation. Corrective action for each specific variable is then assigned to one of the Four Critical Function personnel for resolution.

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Matrix

Figures 16–19 display a matrix for each of the Four Critical Functions with the Five Welding Do’s and each of their respective Five Key Results Areas. This matrix is used in the Phase I—Survey and Evaluation. It summarizes the potential improvement opportunities, which were identified during the survey from interviews and observations of the welding operations.

Five Key Results Areas	Five Welding Do’s				
	Reduce Weld Metal Volume	Reduce Arc Time per Weldment	Reduce Rejects, Rework, and Scrap	Reduce Work Effort	Reduce Motion and Delay Time
1. Base Material Selection					
2. Weld Size Determination					
3. Weld Joint Selection					
4. Manufacturing Review					
5. Weldment Specification					

Figure 16. Design Engineering—Matrix

Five Key Results Areas	Five Welding Do’s				
	Reduce Weld Metal Volume	Reduce Arc Time per Weldment	Reduce Rejects, Rework, and Scrap	Reduce Work Effort	Reduce Motion and Delay Time
1. Workmanship Standards					
2. Welding Process Selection					
3. Equipment and Tooling					

Five Key Results Areas	Five Welding Do's				
	Reduce Weld Metal Volume	Reduce Arc Time per Weldment	Reduce Rejects, Rework, and Scrap	Reduce Work Effort	Reduce Motion and Delay Time
1. Personnel Training and Qualification					
2. Material Input					
3. Equipment Performance					
4. Methods Application					
5. Work Center Control					

Figure 18. Manufacturing Operations—Matrix

Five Key Results Areas	Five Welding Do's				
	Reduce Weld Metal Volume	Reduce Arc Time per Weldment	Reduce Rejects, Rework, and Scrap	Reduce Work Effort	Reduce Motion and Delay Time
1. Policy and Accountability					
2. Quality Standards					
3. Quality Procedures					
4. Inspect, Measure, and Report					
5. Corrective Action					

Figure 19. Quality Assurance—Matrix

THE FOUR CRITICAL FUNCTIONS AND THEIR FIVE KEY RESULTS AREAS

company, are the input data to the first phase of the three phases of The Method to weld quality and productivity improvement. This phase is referred to as the Survey and Evaluation.

Examples

Let’s go through a few examples to demonstrate how the matrixes can be used to identify opportunities. This is similar to what we did in Chapter 6 but expanded to include the Five Key Results Areas for each of the Four Critical Functions.

Example One

Critical Function	Manufacturing Operations
Welding Do	Reduce Work Effort
Key Result Area	Personnel Training and Qualification
Observation	Two similar jobs were running on the shop floor in adjacent welding workstations. One welder would finish a weldment in 2.5 hours on average. The second welder would take 3.25 hours on average. In observing the slower welder, it was noted that he was welding the “hard way.” The second welder was not utilizing the welding fixture causing excessive handling of the weldment and out-of-position welding. Plus, he was using a lower wire feed speed than was in the documented welding procedures issued.
Situation	The second welder had not been trained on how to efficiently run the job and, therefore, was not making standard rate.
Consequence	Low productivity and increased cost of \$26.25 per weldment. 0.75 hours × \$35/hour. 1,200 weldments produced per year.

CHAPTER 8

- b. Phase II—Management Planning and Goal Setting establishes the goals, priorities, and action plans that begin the planning process.
 - c. Phase III—Implement and Sustain, provides the structure and management system to accomplish and maintain improvements and begins the journey to Total Welding Management and improved company profitability
2. The data for Phase I that identifies and quantifies improvement opportunities comes from observing welding on the shop floor, observing flow, layout, identifying actions to improve and quantifying potential savings. It also includes close examination and study of existing company engineering drawings, workmanship standards, work methods and welding procedures as well as interviews with various other critical function personnel at all levels to determine their present involvement and what they need to know and learn to support the welding operations.
 3. Figure 23 shows a sample data gathering form that can be used to record data from each workstation as observations are made of welding jobs on the shop floor. The observation data is summarized in a matrix of the Four Critical Functions, Five Welding Do's and Five Key Results Areas.
 4. The summary of the survey data also includes the major actions required to accomplish the savings potential in each of the Key Results Areas. This information is used for action planning in Phase II—Management Planning and Goal Setting to identify what actions are required to accomplish identified savings.
 5. The Potential Savings Summary, Figure 24, represents a summary, in graphical form, of the total company potential savings. This summary is helpful to management in identifying the greatest payback areas and provides data for a detail discussion of Phase II—Management Planning and Goal Setting.

Before we move into a detailed discussion of Phase II, we will spend some time in the next chapter explaining the Six Managerial Steps. They represent the very important foundation that underlies Phase II and III of The Method. The understanding, acceptance, and application of these six building blocks is essential to the success of your Total Welding

Chapter 9

The Six Managerial Steps

The Foundation of Total Welding Management

In Chapter 8 we presented the details of how to prepare a Survey and Evaluation to develop potential savings for your company from welding improvements. The input for the survey comes from a review of existing company documents, observations of jobs on the shop floor, and interviews with various managers and Critical Function personnel. We now know how to determine the potential savings from specific welding improvements. How do we now manage the process to get these results? The answer lies in the use of the Six Managerial Steps.

These steps represent the management process that is essential for success in developing and implementing a total welding management system to get the identified improvement results.

This chapter will:

1. Define the Six Managerial Steps to get from survey to results. These steps represent the bridge that ties together the three phases of The Method. They also provide the framework for the closed-loop management system that assures that improvement results will be maintained.
2. Show how the Six Managerial Steps are used in each of the three phases of The Method to build a plan for success.
3. Explain top management's critical role in leading an organization through the Six Managerial Steps to Total Welding Management.

The Survey and Evaluation phase of The Method identifies welding improvement opportunities along with the actions required to harvest them. In the Management Planning and Goal Setting phase your

CHAPTER 9

Figure 26 illustrates the concept behind the Six Managerial Steps. They form a closed loop system of plan, execute, and control. This system begins with an Input followed by an Action resulting in an Output and then Feedback to close the loop. Plan the improvement, execute or make the improvement, and control to assure that the improvement is maintained.

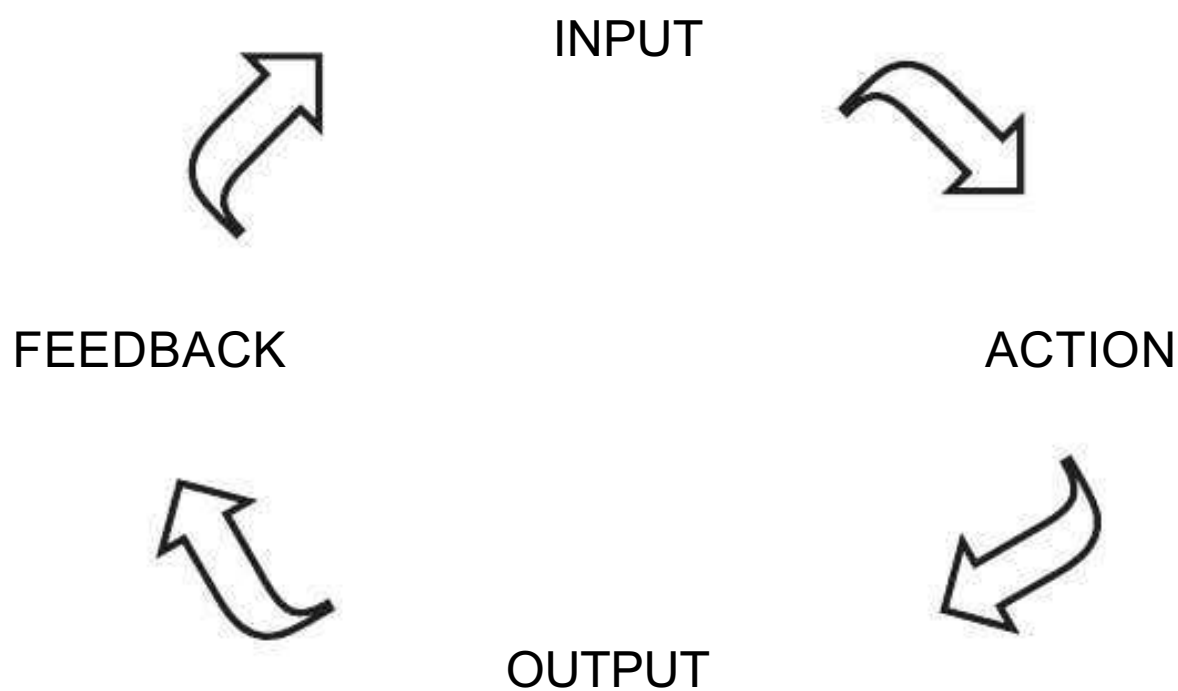


Figure 26. Six Managerial Steps as a Closed Loop System

The Six Managerial Steps to a successful welding management system are:

1. Information gathering and analysis
2. Planning and goal setting
3. Training
4. Implementation and fine tuning
5. Measurement and control
6. Reporting

To better understand each of the Six Managerial Steps, let's look at how each might be applied to the three phases of The Method and then to a specific improvement project. Recognize that the Six Managerial Steps

entire company. The result of this step is Phase I of The Method, Survey and Evaluation. The information is gathered through interviews with various levels of management, supervisors, and technical personnel in the Four Critical Functions, along with shop floor observations and measurements. The information gathered is then analyzed and summarized by the Five Welding Do's, Four Critical Functions and their specific Key Results Areas and represent potential savings in weld quality and productivity improvement. Figure 24, on page 105 of Chapter 8, illustrates this summarized survey information with potential dollar savings for each Welding Do. Once the data is gathered in Phase I, it is analyzed to determine which projects would provide the best payback for effort involved.

In Phase III the macro survey data from Phase I is again reviewed in detail and refined in a detailed micro sense for final project management and action planning. This is illustrated in the example in Figure 27—Information Gathering and Analysis.

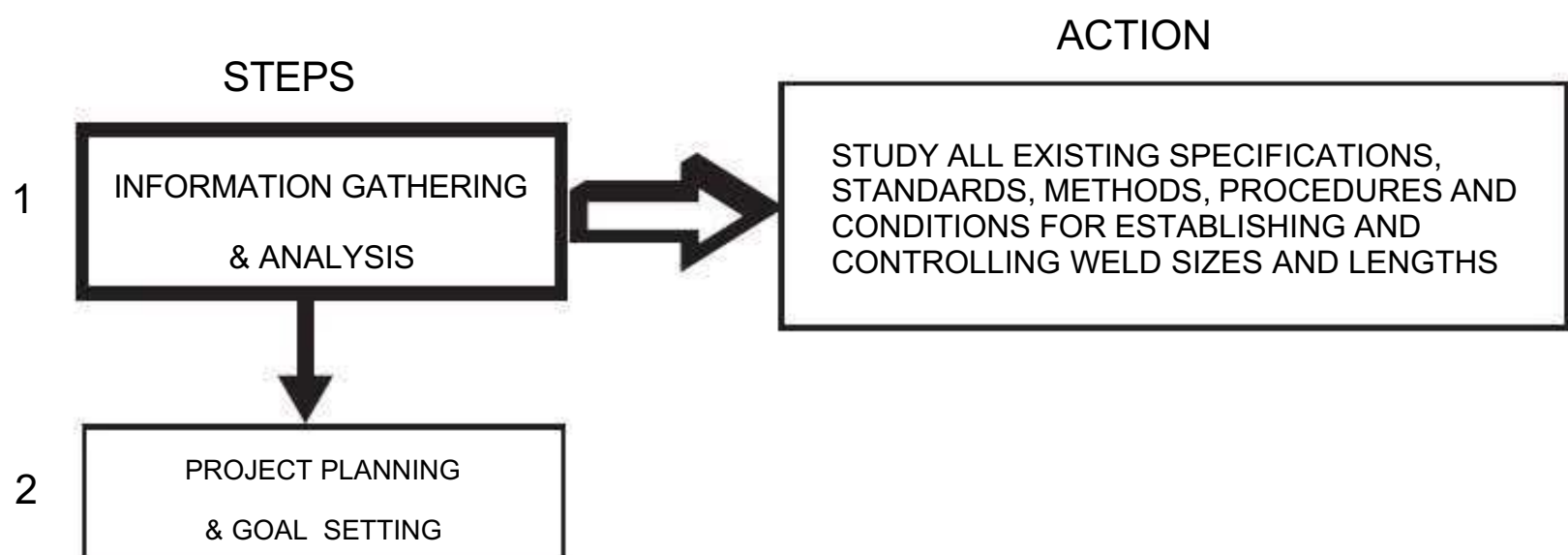


Figure 27. Step 1—Information Gathering and Analysis

Step 2—Planning and Goal Setting

CHAPTER 9

made and first cut planning for the company's welding improvement program are also made by top management along with the management team. In Phase III, the survey data is revised and in a micro sense, the project goals and objectives are finalized in detail from the additional data gathered. This is illustrated in Figure 28—Planning and Goal Setting.

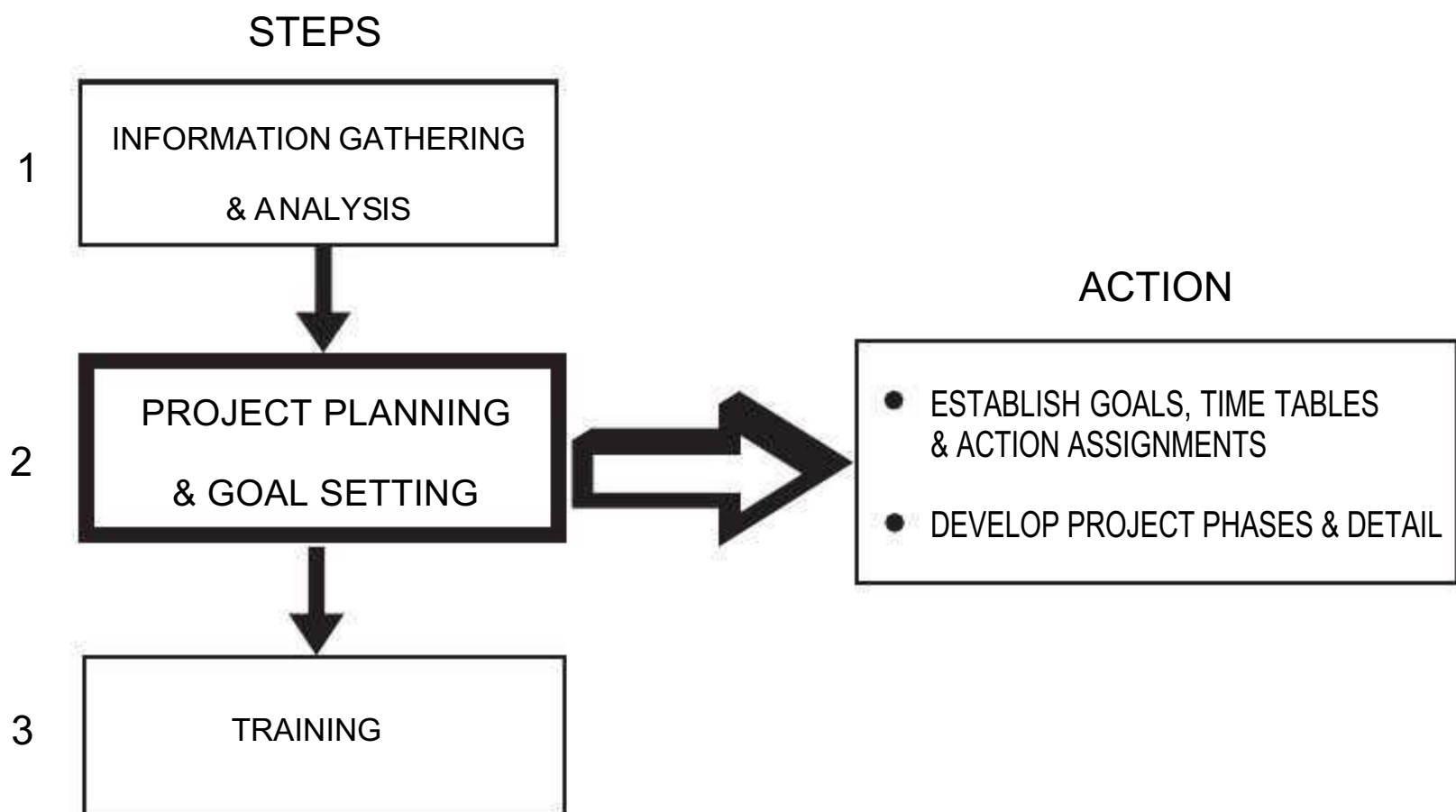


Figure 28. Step 2—Planning and Goal Setting

Step 3—Training

In this step, all personnel who will manage, use or work within the Total Welding Management System are trained in the management concepts and principles of the Total Welding Management System and the technical aspects of welding that affect their functional responsibility. They are also introduced to the overall company project goals and the project timelines. Training applies to personnel of each function and at all

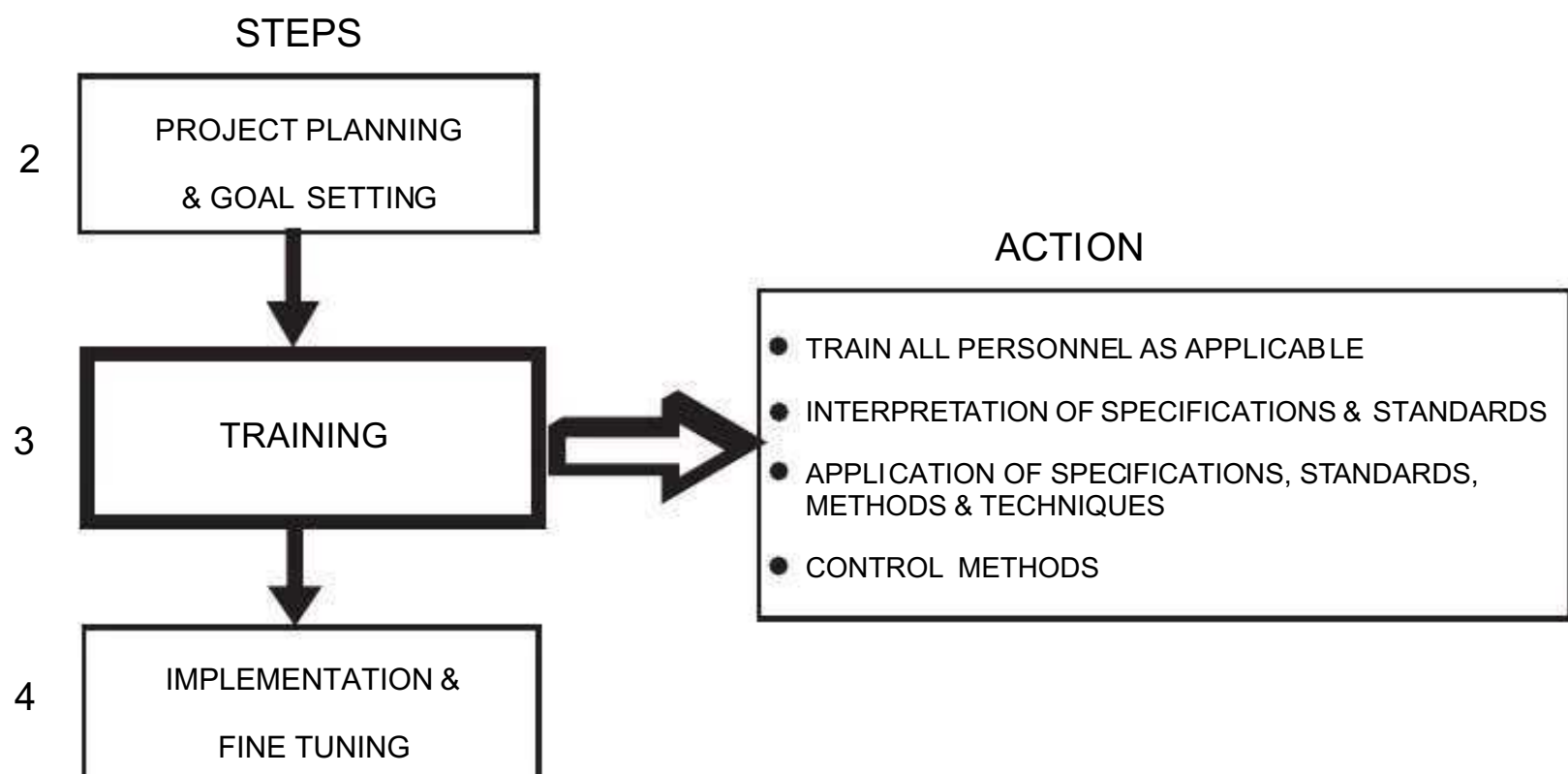


Figure 29. Step 3—Training

Step 4—Implementation and Fine Tuning

Once a specific project of the Total Welding Management System is implemented, it is closely monitored. When required, on the job follow-up training is conducted. It is unusual that any project is planned and executed perfectly the first time. Continual improvements are made as needed. This step is part of Phase III—Implement and Sustain, Figure 30—Implementation and Fine Tuning.

As an example of fine-tuning or continuous improvement, a specific project might involve lay out, material flow, weld sequencing, equipment, fixturing, the welding process, welding procedures, work methods and training of the welder. Once the project is implemented, any or all of the above may need to be fine tuned or modified until the project meets planned results.

Step 5—Measurement and Control

This is the step that inspects, measures, monitors, audits, and collects

PHASE II—MANAGEMENT PLANNING AND GOAL SETTING

The Management Planning and Goal Setting meeting was held about three weeks after the report was circulated, giving everyone time to review and prepare questions. Attendees at the meeting included company top executives and managers of the Four Critical Functions.

See Table 2 for a potential savings summary.

Table 2. Company B—Potential Savings Summary Chart
(See Figure 24 in Chapter 8)

Do's	Potential Savings
Reduce Weld Metal Volume	\$625,000
Reduce Arc Time per Weldment	\$350,000
Reduce Reject, Rework and Scrap	\$450,000
Reduce Work Effort	–0
Reduce Motion and Delay Time	\$600,000
Total Potential Annual Savings	\$2,025,000

The total savings potential for 100 welders represents \$20,000 per welder a year. This savings per welder falls within the typical range of \$15,000 to \$25,000 per welder annually found over many companies in a variety of different industries.

The detailed planning in this phase begins with the high-level savings summary chart. Figure 24, on page 105 of Chapter 8, shows in detail the potential savings across the Four Critical Functions for each of the Five Welding Do's crossing the Key Results Areas. This is a picture of the actions required to harvest the savings. For example, note in Figure 24, that when each Welding Do crosses a particular Key Results Area, it is marked with a bullet (•). Each cell area marked as such is reported with the data gathered and observed, and accompanied with a recommended action plan in the form of a project or projects in the Survey report.

As the management team analyzes the Survey and Evaluation report, projects are identified by looking at the recommendations for

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Key Results Areas to Reduce Weld Metal Volume, the first Welding Do (see Table 3).

Table 3. Summary of Critical Functions and Key Result Areas

Functions	Key Results Areas	Cell No.
Design Engineering	Weld size determination	1-20
	Weld joint selection	1-30
	Weldment specifications	1-50
Manufacturing Engineering	Workmanship standards	1-60
	Method and procedure development	1-90
Manufacturing Operations	Personnel training and qualification	1-11
	Material input	1-12
Various Functions	Inspect, measure, and report	1-19
	Corrective action	1-20

Table 3 is an example of how the Four Critical Functions must work together to accomplish one goal of reducing weld metal volume. All Four Critical Functions are essential for success. As each Key Result Area that needs attention is brought into control, the result of improved weld quality and productivity will follow. It is also an example of how welding improvement is a management system of process, procedures, controls, and feedback.

Keep in mind while going through this example that other Welding Do Key Results Areas for each critical function could be impacting results at the same time and, therefore, need to be analyzed together.

Before we review management's action plan for the reduction in weld metal volume goal, let's review the summary of the recommendations from the Survey and Evaluation (see Table 4).

**Table 4. Summary of Recommendations
from Survey and Evaluation**

PHASE II—MANAGEMENT PLANNING AND GOAL SETTING

**Table 4. Summary of Recommendations
from Survey and Evaluation (Continued)**

Weld Joint Selection	• Reevaluate weld joint design to reduce weld metal volume and tighten component parts tolerances to improve material fitups. <i>(Design Engineering)</i> • Assure materials are properly beveled to meet the required bevel angle tolerances. <i>(Manufacturing Operations)</i>
Weldment Specification	• Establish a written welding specification to address how weld sizes and weld joints will be assigned to engineering prints. <i>(Design Engineering)</i>
Workmanship Standards	• Develop a written Workmanship Standard document that specifies the acceptable/unacceptable weld criteria. <i>(Manufacturing Engineering)</i>
	• Design and build a physical sample board that shows the various types of welds and criteria. This will serve as a visual standard for their acceptable/unacceptable acceptable welds to meet weld quality requirements. This is generally accomplished by the Internal Welder Trainer. <i>(Manufacturing Engineering)</i>
Method and Procedure Development	• Develop written and qualified application production welding procedures with tight welding variable tolerances. Document and review with supervisors and welders. <i>(Manufacturing Engineering)</i>
	• Train welders in the essential welding variables to achieve consistently sized and shaped welds. <i>(Manufacturing Operations)</i>
Personnel Training and Qualification	• Develop qualification criteria for welders and consider a welder requalification program for when welders produce unacceptable weld quality. <i>(Manufacturing Operations)</i>
Material Input	• Produce fabrication department components parts to print specifications to permit good material fitups in the welding operations that, in turn, will reduce weld metal volume and, therefore, lost production labor hours. <i>(Manufacturing Operations)</i>
Inspect, Measure, and Report	• Supply weld fillet gages to all welders, inspectors and supervisors and train them in their use to measure weld

**Table 4. Summary of Recommendations
from Survey and Evaluation (Continued)**

Monitoring and Auditing	• Set up system for monitoring and auditing (Manufacturing Operations and Quality Assurance). • Implement a welding shift reporting system that will provide a way for welders to report problem situations occurring on their shift that cause unintended changes. The issues reported can then be passed on to the Four Critical Functions for corrective action. (<i>Manufacturing Operations</i>)
Corrective Action	• Correct root causes to prevent unwanted change. (<i>Manufacturing Operations and Quality Assurance</i>)
Reporting	• Summarizes measurements into meaningful report for management decision-making. (<i>Quality Assurance</i>)

The recommendations in Table 4 are the basis for action plans to reduce weld metal volume as well as address other overall issues that will lead to additional savings in other Welding Do's.

In Company B the Management Planning and Goal Setting meeting under the leadership of the company President, the following decisions and action plans were made regarding priorities, projects, and resources:

1. Priority Goal No. 1—Reduce Weld Metal Volume.
2. Savings Goal:
 - First year—75% of \$625,000 or \$470,000.
 - Second year and beyond—\$625,000/year based on the latest findings and recommendations and acceptance by the welding steering team.
3. Resources for this project would depend on the resources needed for all of the other project work assignments being done simultaneously with this project. For example, the Reduction of Arc Time per Weldment addresses some of the same Key Results Areas as the Reduction of Weld Metal Volume.
4. Project Team Leader to be senior welding or manufacturing engineer. Reports to senior management on a monthly basis.
5. Welding Steering Team review meeting—held twice a month to

PHASE II—MANAGEMENT PLANNING AND GOAL SETTING

The above is an example of an approach of how a Management Planning and Goal Setting process might be conducted. As you can see, Phase I of The Method begins with defining the opportunities for improvement which are then summarized in a Survey and Evaluation report. This report summarizes the potential cost savings opportunities from both wasted labor hours and filler materials by Welding Do's with their respective Key Results Areas and includes Recommended Actions for each critical function.

For example, one survey observation reported that several welders on one product line were using different welding parameters and depositing different fillet weld sizes. The management team recognized that corrective action of just a few Key Results Areas would save considerable wasted labor hours and filler materials. This was identified by the management team as "low hanging fruit" that could fall directly to the company's bottom line as increased profits with little effort to implement and no capital investment.

As another example, if it were observed that many welders were not using the proper welding procedures and techniques for a particular type of weld, then a welder skills training program would be an appropriate project. In Phase II the projects are identified, prioritized and laid out in detail on a Gantt chart.

Below are some additional examples of recommendations from another Survey and Evaluation.

1. Training should focus initially on the welding process variables and techniques that will achieve consistently sized fillet welds. By controlling wire feed speed, arc voltage and the other welding variables, the weld bead size and shape can be effectively controlled.
2. Shop floor control of weld metal volume should include corrective action for oversized welds. Grinding to reduce weld bead size is not appropriate; therefore a weld leader or an Internal Welder Trainer should work with the welders who produce excessive weld bead sizes to review the welder's techniques and applied welding procedures.

Chapter 12 of this book will present a complete case study of how a 150-year old company transformed itself to improved quality and productivity through the application of the principles and concepts of Total Welding Management. As stated by the five-generation family

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1. Management Planning and Goal Setting is the second phase of the three phases of The Method to Total Welding Management where the company management team does the detail planning from the data provided from the Survey and Evaluation for successful weld quality and productivity improvement. The quality of this step determines the degree of success in achieving potential improvements.
2. Since the planning and goal setting includes the Four Critical Functions and represents a major commitment of resources, top management must lead it. Change for improvement only happens with management commitment, involvement, and a plan. A complete detailed project plan with a project manager is both required.
3. The example of Company B demonstrates the process that top management and the management team goes through to evaluate the Survey results and recommendations, set priorities, agree on goals, identify needs and assign resources, develop action plans and set up to manage the improvement process through frequent project team meetings and management reports.

Now that we have learned how to evaluate the Phase I Survey and Evaluation Results, and how to complete the Phase II Management Planning and Goal Setting process, let's move on to making it happen, Phase III—Implement and Sustain. This is where the management team begins to learn the new way to manage projects as well as the entire welding process to achieve improved company profitability.

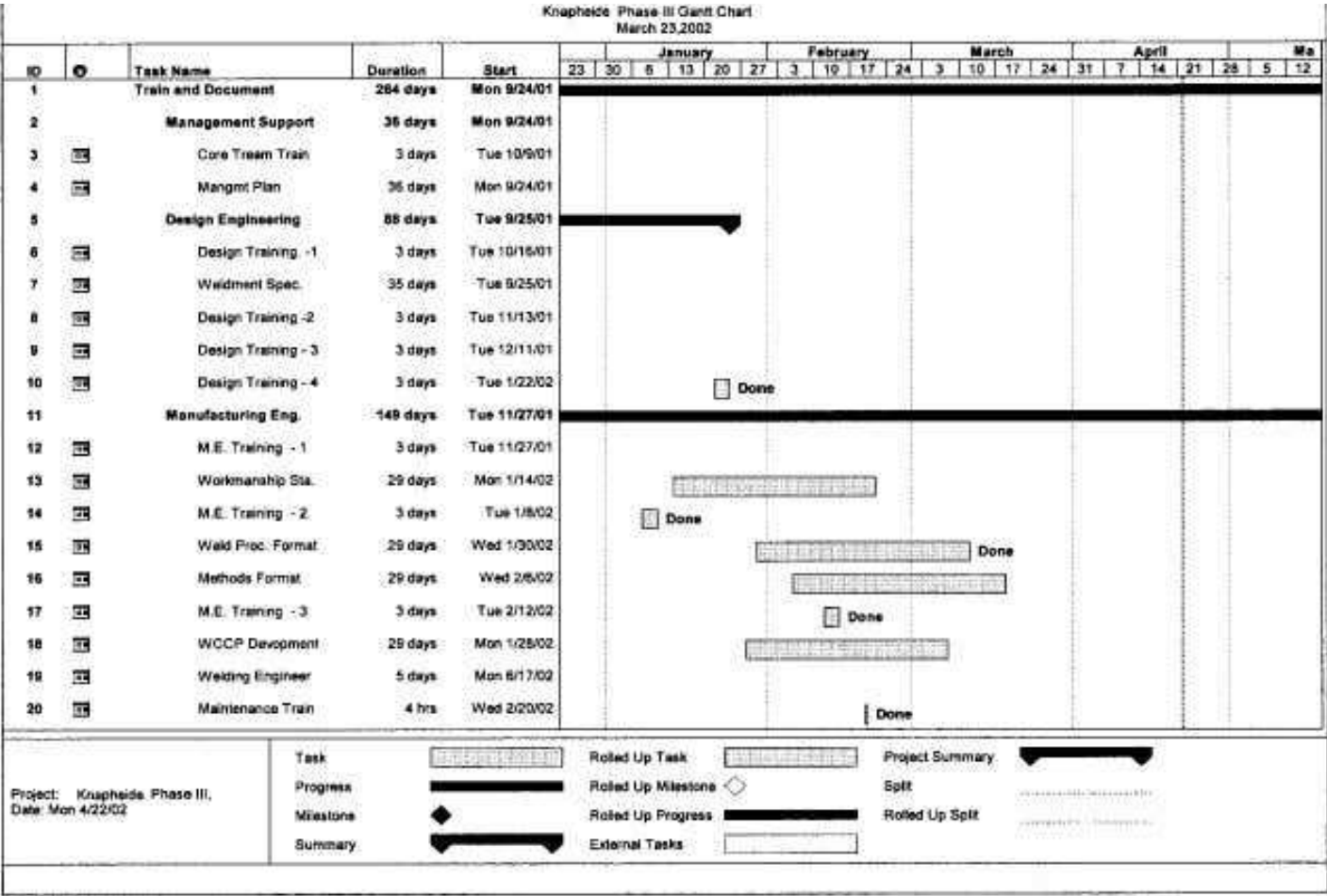


Figure 37. Integrated Project Plan

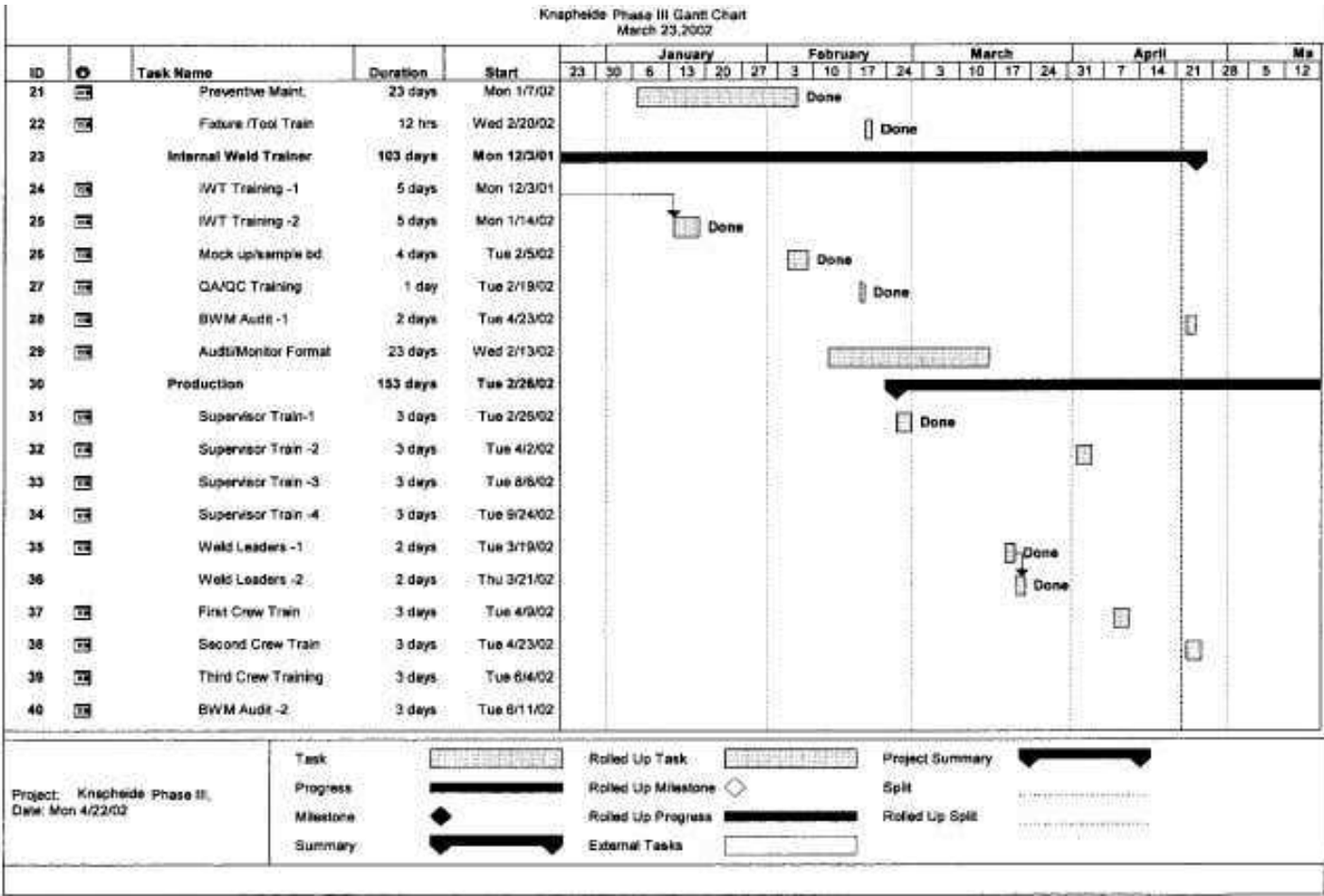


Figure 37. Integrated Project Plan (Continued)

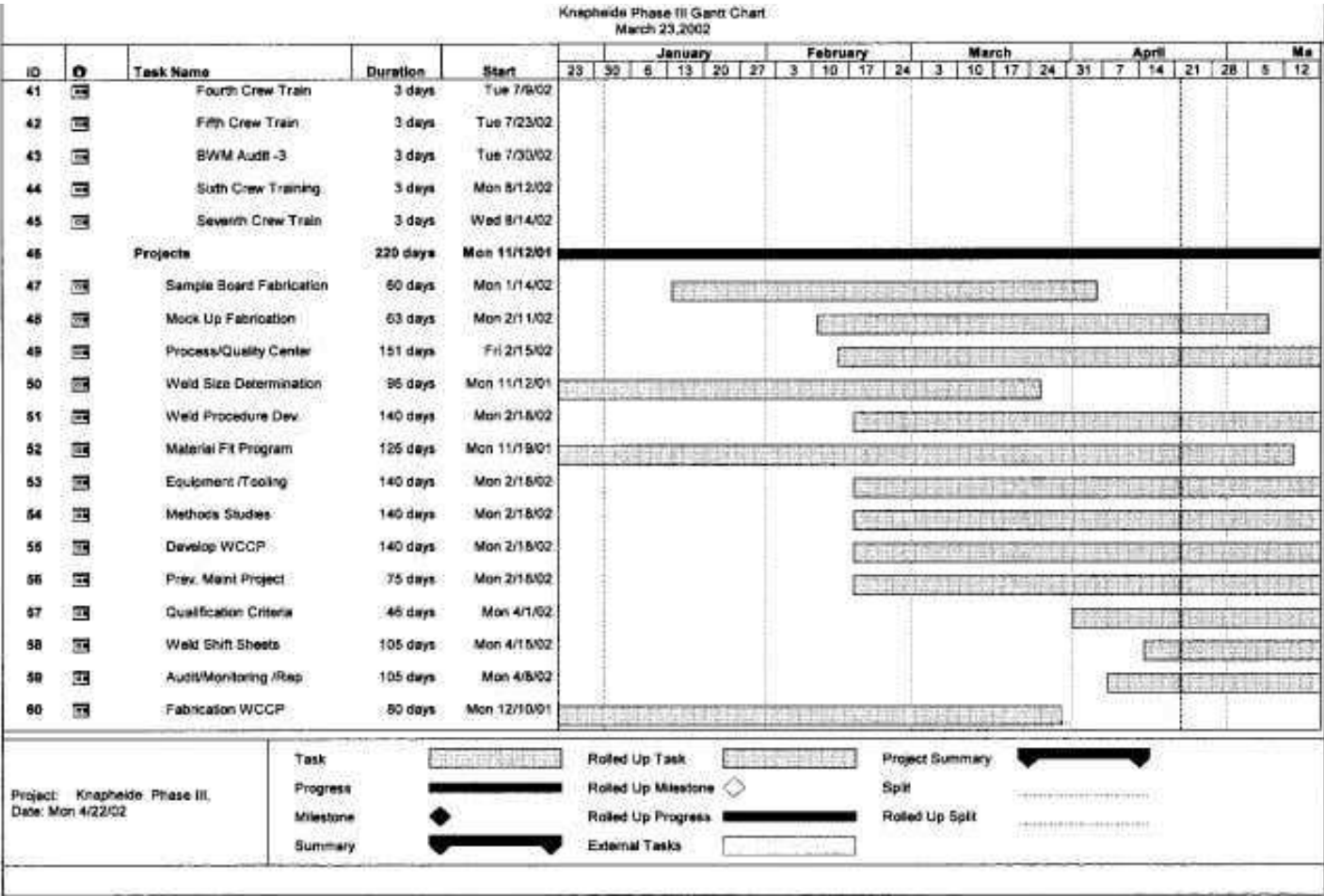


Figure 37. Integrated Project Plan (Continued)

following their welder training to implement the Knapheide Total Welding Management System and the Work Center Control Plan at the welder workstation.

To accomplish this complex task, every department and function that impacts the welding operations must be trained and documentation created to allow them to fulfill this role. All support activities must be developed and implemented before welder training begins so that when the welder training is completed, they will reenter a controlled environment in their welding workstations.

Pace

The second key point critical to achieving the first stage of implementation is pace. Pace is defined as the rate at which a company can provide the resources required to complete all the projects for the implementation of the Total Welding Management System. It is critical that the proper pace of any project be set so that expectations are realistic.

Total Welding Management requires training and development of documentation to achieve the goals of welding quality and productivity improvement. This training and documentation requires a significant amount of man-hours. The effective use of available resource man-hours directly impacts management, engineering, and production efforts. To prevent conflicts that may interfere or stop the development or implementation of the welding management system, training, development and implementation a pace must be agreed to, which takes into account the need for ongoing production demands during the project period. Even though this is a basic point, without a defined and communicated schedule with training dates and documentation completion dates all of these activities will slip because of a lack of advanced planning. Everyone involved in the TWM project must understand and support the agreed to sequence and pace of the project activities.

To recognize the importance of sequence and pace, at the end of Phase II, Barckhoff personnel developed a rough project Gantt chart, and subsequently presented it to the Knapheide management team. After some fine-tuning it became their roadmap to TWM. The chart showed the order in which training, documentation and project development was to

CHAPTER 12

Engineering, Manufacturing Operations, and Quality Assurance first, and then train the welding crews that consisted of the welders, welding supervisors and weld leaders. At Knapheide, the supervisors and weld leaders had been trained separately on what they 'needed to know' prior to attending the welder training sessions.

Because of production demands, the training was scheduled to minimize interferences with the production schedule. To this end management training was conducted first. The individuals participating in this training were the senior managers and department heads that would partially comprise the Welding Steering Team.

The Welding Steering Team was charged with carrying out all of the assignments contained in the Gantt chart plan and manage the Total Welding Management System project, both through implementation, and after to foster consistency and sustainability. The frequency with which they met varied with the project requirements of the plan. During the training, development and implementation phases they met once a week. The frequency gradually decreased until by the time Knapheide entered the sustainability phase, they were meeting once a month.

In the Knapheide project plan, the initial management and technical welding training was conducted for the following groups:

- Management Team
- Design Engineering
- Manufacturing Engineering
- Quality Assurance Personnel
- Internal Welder Trainers
- Maintenance Personnel
- Fixture Designers and Builders
- Supervisors
- Weld Leaders

Design Engineering

Following the training of the management team, the Design Engineers were trained in weld design. This was done in anticipation of the way system improvements would need to follow the flow of information. Since Design Engineering must begin the work on engineering drawings and specifications before the rest of the

Engineering training was conducted emphasizing the specific Five Key Results Areas of the Barckhoff Method that applied to Design Engineering.

Upon completion of the first weld design training class for Design Engineering, the participants began writing the weldment specification document. The purpose of this document was to define all product welding requirements not already contained on the engineering drawings. The requirements covered the different classes of welds and the acceptance criteria of each. This weldment specification contained the requirements for weld quality enabling the production department to clearly understand the difference between acceptable and unacceptable defective welds and to apply this knowledge in a practical sense to welds being made on a day-to-day basis. In addition to the writing of the weldment specification, members of the Design Engineering group began putting into practice the training they had received and began making drawing improvements as recommended in the Survey and Evaluation report.

Manufacturing Engineering

The training of the Manufacturing Engineering Group also followed the Key Results Areas as defined in the Barckhoff Method for the Manufacturing Engineers. Their training began before the last of the Design Engineering classes. This was done to maintain the pace of the training after the Design Engineering Group produced the weldment specification document. This document was then turned over to Manufacturing Engineering and was used as part of their training.

Manufacturing Engineering then incorporated the weldment specification into the workmanship standards for the company. This standard describes the workmanship, welding technique and quality requirements, and is used as a training document for the welder training, and also as a working document on the production floor. This document is then used along side the workmanship sample board and production mockups that were placed in a Weld Quality and Process Center located in every welding production department to serve as visual aides for defining weld quality and product output requirements.

Acknowledgments

This book would not exist without the opportunity that I was given beginning over 40 years ago to work with many companies that were producing many different types of welded products. Most important were the many welders, supervisors, engineers and managers I worked with in each of the companies during the process of developing the Total Welding Management System.

I am thankful for my association with James F. Lincoln and the opportunity of working under his system of Incentive Management that promoted the philosophy of 'The Actual Is Limited: The Possible Is Immense.'

Thank you to Walter E. Vuchnich for his encouragement to my commitment to the Total Welding Management System at a time when others had misgivings about it.

Thanks to Jack Eide and Robert Lockwood for their foresight and encouragement to form Barckhoff and Associates, Inc. in pursuit of my passion and commitment to Total Welding Management.

To Walter R. Edwards, P.E., who worked with me in the very early stages of developing the Total Welding Management System using the Barckhoff Method and to my former associates Gregory Krause, P.E. and John M. Menhart, P.E. for their participation in its early application.

To my associate Donald L. Lynn, P.E., who has served with me since 1990 in the advanced stages of development and application of the Total Welding Management System.

Thank you to Ray W. Shook, Executive Director, Andrew Cullison, Publisher and Ron C. Pierce, P.E., (Chairman of Welding Engineering Supply Co., Inc./Chairman of the AWS Foundation) and the American Welding Society's staff for their support of Total Welding Management.

To Clint Vogus and Dave Edwards for their help in the early drafting and proofing of the many revisions.

Dedication

I dedicate this book to the memory of my beloved mother who inspired me from early childhood to be industrious and make a difference; also, to the welders and supervisors that the principles of Total Welding Management support.

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Author's Notes

To clarify a few terms used in the book, note the following:

1. Recognizing that we live in a world where everyone has an equal opportunity in all professions, we use the words 'him' or 'his' when we are referring to the generic gender without prejudice.
2. The term 'shop floor' or 'welding shop floor' as used in this book refers to the area in a company where production takes place. Depending on the specific product manufactured, the shop floor could also be referred to as the welding floor, welding area, production area, welding department or welding and fabrication yard.
3. The use of TWM in this book refers to the system of Total Welding Management.

Weld. A localized coalescence of metals or non-metallic materials produced either by heating the material to the welding temperature, with or without the application of pressure, or by the application of pressure alone and with or without the use of filler metal.

Weld Axis Position. A line through the length of the weld perpendicular to and at the geometric center of its cross section.

Weld Bead. A weld resulting from a weld pass.

Weld Cycle Time. The total time and series of events required to complete all the steps involved in making a weld or weldment.

Weld Joint. The opening between two joint members in a weldment that provides space to contain weld metal.

Weld Joint Selection. This is one of the Five Key Results Areas for Design Engineering. It represents selecting and applying the appropriate type weld joint consistent with welding economics and quality requirements.

Weld Leader. A trained experienced welder that is used to train other welders, when requested by the supervisor, on the job and to assist in technical problem solving on the shop floor. His main responsibility is to weld.

Weld Metal. Metal in a fusion weld consisting of that portion of the base metal and filler metal melted during welding.

Weld Metal Volume. The specific amount of weld metal deposited in a given size weld, weld bead, or weld joint.

Weld Size Determination. This is one of Five Key Results Areas for Design Engineering. It represents determining the proper size of weld for a specific type of joint and application.

Welder. One who performs manual or semi-automatic welding.

Welder Support System. This refers to the Four Critical Functions taken as a group whose primary focus is to perform their jobs effectively so as to support the welder for weld quality and productivity

GLOSSARY OF TERMS

Welding Consumables. Those electrodes or materials that provide the filler metal to the weld.

Welding Crew or Team. Two or more welders and/or operators under the direction of a line manager such as a welding supervisor, foreman, lead person or a combination of all of the above.

Welding Cycle Time. The time represented by the complete series of steps involved in making a weld or weldment.

Welding Department. This refers to the department within a company that is responsible for welding. In most companies this falls under the responsibility of the Manufacturing Operations.

Welding Electrode. A component of the welding circuit through which current is conducted and terminates at the arc.

Welding Filler Metal. The metal or alloy added in making a weld joint that alloys with the base metal to form weld metal in a fusion-welded joint.

Welding Operator. A person who operates adaptive control, automation, mechanized or robotic welding equipment.

Welding Operations. All of the departments within a company that contribute to or support welding.

Welding Parameters. The welding variables within a welding procedure resulting in a deposited weld.

Welding Position. The relationship between the weld pool, joint, joint members, and the welding heat source during welding.

Welding Procedure. The detailed method, essential welding variables and practices involved in the production of a weldment.

Welding Procedure Specification. The document that provides the required welding variables for a specific weld application to assure repeatability by properly trained welders and operators.

Welding Process. A grouping of basic operational elements used in welding.

Welding Technique. The details of a welding procedure that are controlled by the welder or welding operator.

Welding Technology. This represents the documented body of knowledge about welding that is currently available. It is the science behind welding.

Welding Variables. The essential welding variables of a welding process that determine the weld or weld bead size and shape. Depending on the welding process, these variables could be amperage, wire feed speed, arc voltage, contact tip to work distance, transverse/work angle, travel angle, travel speed and orientation of the electrode/wire to the weld joint.

Welding Workstation. A designated work place with one welder or operator assigned to complete a specific welding operation.

Weldment. An assembly whose component parts are joined by welding.

Weldment Specification. This is one of Five Key Results Areas for Design Engineering. It involves defining, describing and explaining all of the welding requirements for a weldment. Design Engineering documents it in a Weldment Specification.

Wire Feed Speed. The rate at which wire is consumed in welding, arc cutting, or thermal spraying.

Work Center Control Plan. This represents the detailed plan (weldment specification, workmanship standards, welding process, work methods and welding procedures, equipment, techniques, etc.) for each weldment and is used to control quality and productivity.

Work Measurement Standards. The elemental breakdown of the welding cycle times to include motion, sequencing and time allowance for each element of the operation to build or fabricate a weldment. The standard also includes fatigue, delay, and personal time allowances.

Workmanship Standards. This is one of the Five Key Results Areas for Manufacturing Engineering. It represents providing the welding production requirements to shop personnel to meet the quality standards for each weldment (acceptable/non-acceptable).

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Five Welding Do's

25	34	41	43	49
63	65	66	70	77
87	88	91	104	108
111	120	127	138	147
165	173	178	181	

Four Critical Functions

13	25	36	37	40
47	49	59	60	65
66	70	72	75	77
85	87	89	91	104
106	111	120	125	130
132	138	142	147	171
173	176	181		

H

Hands-On Leadership

11	12	27	30	34
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I

Implement and Sustain

42	43	94	108	110
112	113	115	124	125
131	151	161	165	178
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Inspect, Measure, Report

71	74	86	88	95
128	129	136	179	

Internal Welder Trainer

21	31	42	43	56
125	129	131	156	158

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Key Results Area (*Cont.*)

77	86	87	91	104
106	108	111	118	120
121	125	127	135	157
173	176	177	179	183

M

Management Planning and
Goal Setting

42	94	106	108	109
111	120	121	123	124
126	127	130	136	142
150	178	179	182	

Q

Qualification

20	21	38	56	82
83	88	89	95	96
99	128	129	136	176
180	181			

R

Reduce Arc Time per Weldment

25	44	65	67	68
90	95	96	100	106
127	148	181		

Reduce Motion and Delay Time

25	44	65	69	73
87	95	106	127	148
161	181			

Reduce Rejects, Rework, and Scrap

25	44	65	67	74
87	88	91	95	148

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Reduce Weld Metal Volume (*Cont.*)

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Reduce Work Effort

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Total Welding Management
System (*Cont.*)

116	120	125	126	138
139	143	145	148	149
151	155	156	158	165
176	178	182		

U

Upside Down Organization

5	11	13	15	22
27	31	43	47	61
63	83	169	171	182

W

Welder Support System

15	20	22	25	36
37	40	44	45	47
62	63	70	183	

Welding Team

21	23	47	49	60
68				

Welding Technology

1	18	43	185	
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Work Center Planning and Control

12	13	15	20	28
56	69	170	173	