

CERTIFIED WELDING SUPERVISOR MANUAL FOR

Quality and

Productivity

Improvement



American Welding Society



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CERTIFIED WELDING SUPERVISOR MANUAL for QUALITY and PRODUCTIVITY IMPROVEMENT

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Dedication

Several years ago on the Gulf Coast, a group of dedicated men in the shipbuilding industry were concerned about the lack of well-trained welding supervisors. If welding supervisors did not have the appropriate knowledge and skill levels, how then could the welders being supervised achieve improved quality and productivity levels? To this end, those dedicated men became the catalyst that advanced the Certified Welding Supervisor Program to where it is today. Most likely, this manual would not have become a reality when it did without their support, their initial efforts as a Beta Test Site, and their feedback during program development. For that reason, this manual is dedicated to Ron Pierce of Welding Engineering Services Company and Tom Bender, Jackie Morris, and Lavon Mills of Bender Shipbuilding & Repair Company.

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Preface

In 2000, the American Welding Society (AWS) initiated the establishment of a Certification Program for Welding Supervisors. First, an AWS committee drafted the B5.9:2000, *Specification for the Qualification of Welding Supervisors*, which was followed by the AWS QC-13, *AWS Standard for the Certification of Welding Supervisors*. This groundwork was done by AWS, which recognized that the position of welding supervisor was one of the most under-trained positions in all of manufacturing, construction, and fabrication—particularly in the area of optimizing the quality and productivity of personnel under the supervisor’s direction. AWS saw an industry need and responded.

Welding supervisors are found in every industry that uses welding as a core process in the manufacture, construction, or fabrication of their products. The role they play is often one of organizing production paperwork and ensuring that parts are available to the welders. In many cases, welding supervisors have little or no welding experience, knowledge of welding science, or training in how to support their welders. This situation has resulted in years of missed opportunities in many companies to improve welding quality while also increasing productivity.

Significant improvements can be made through the efforts of a well-trained welding supervisor, who knows what factors influence welding quality, and how monitoring welders can achieve that quality. At the same time, through training, a welding supervisor can understand all of the complimentary factors in welding operations that lead to maximized productivity.

This manual takes a comprehensive approach to present the welding supervisor, planner, engineer, or other management personnel with the most useful technical welding information combined with the most effective management principles, concepts, and techniques to apply this welding knowledge.

Sample questions are included in each section of this manual to help students gauge their understanding and confidence level. When this program is completed, the welding supervisor will have the working knowledge to direct, support, and instruct welders to improve both quality for the customer and productivity for the company.

This manual has been developed by AWS to support welding supervisors in one of the most challenging and rewarding careers in industry. Those candidates who successfully complete this program will be prepared to take the AWS Certification Test. More importantly, they will be better prepared to make one of the most important contributions that any employee can offer—helping their company to be more competitive in the global marketplace by improving manufacturing performance. This is a challenge that all companies now face.

Acknowledgments for Course Materials

The material for this Certified Welding Supervisor's Manual for Productivity and Quality Improvement was developed for AWS by Barckhoff Welding Management Corporation, a thirty-year-old welding management consulting firm.

This manual has been copyrighted by the American Welding Society (AWS), and Barckhoff Welding Management holds and retains prior copyrights for much of its material.

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Chapter 1—MANAGEMENT SYSTEMS FOR THE WELDING SUPERVISOR

Introduction

In manufacturing and construction companies that use welding as a core process, welding supervisors hold a unique position. To begin to understand the welding supervisor and his duties, it is important to understand his unique position.

Most companies have supervisors. They may be called team leaders or managers, but their role is the same. A supervisor provides workers their assignments, makes sure they have the tools, materials, and training to do their work, provides support, and monitors them throughout their work shift. The result of effective supervision is each worker is efficient and produces only quality work. With effective supervision, production workers achieve higher levels of productivity and quality.

With the day-to-day pressures of getting production out, how a supervisor should function and the results expected are lost. In many production environments, supervisors, including welding supervisors, are expediting parts, chasing paperwork, filling out unnecessary reports, and performing other non-supervisory duties, which take them outside of their assigned department. This leaves production workers unsupervised for long periods of time. This results in lack of communication and support, leaving welders with the feeling that they are on their own. Problems that they encounter must be handled with the hope that the results will be acceptable.

In many cases, welding supervisors have limited understanding of the technical aspects of welding and, therefore, are unsure of their ability to provide direction and support to the welders. This situation has unwittingly limited the amount of daily support the welder receives. Company management may not realize the detrimental affect when welding supervisors are not properly trained or assigned to perform essential duties, which can lead to improved quality and productivity on each shift.

Any training course for welding supervisors should address a welding supervisor's need both for technical and managerial training to develop the skills to perform his job in the most professional manner. This leads to improved results in both quality and productivity. This Certified Welding Supervisor Manual for Quality and Productivity Improvement recognizes that the welding supervisor has an important role in the operations of any company that does welding.

To fully understand and appreciate his role, the supervisor must first understand some of the different management systems currently used by manufacturing companies.

The management systems used by companies are numerous and varied. To maintain a manageable review of these systems, this manual will consider only

those systems that are most widely used and have the most impact on welding operations.

The systems that will be reviewed are:

1. **No System–System.** Some companies do not have a comprehensive management system, but instead follow an undocumented “way of doing things.” Their No System has evolved over the time that the company has been in existence. This system exists in a wide variety of companies and may describe the approach used in your company.
2. **Lean Manufacturing.** This management system brings a variety of techniques and tools to all types of manufacturing companies, including welding companies. Lean Manufacturing is a broad-based management system that has been designed for all types of manufacturing environments. The primary focus of Lean is to reduce or eliminate waste or non-value added steps in all processes, including design, administration, and sales.
3. **Total Quality Management (TQM).** This is a management system that focuses on all the measures necessary to meet the quality requirements of a customer. This system has evolved over many years and is manifested in a number of different ways. TQM is a system that extends beyond manufacturing and incorporates all functions involved in assuring that the customer gets the quality product or service that he expects.
4. **Total Welding Management® (TWM).**¹ Total Welding Management is an approach to improving welding operations that uses the Barckhoff Welding Management System® and The Barckhoff Method®² to focus on the critical company functions, key results areas, and welding goals to achieve improved quality and productivity. It was developed for companies that do welding, but has been successfully applied in other production environments. A principle of TWM is to align the organization to serve the welder with the tools needed to achieve consistently high levels of quality and productivity.

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No System– System

This system, although it has little documentation or specific training, is considered a management approach. Companies that use this approach can be easily identified by the way they conduct day-to-day operations. They rely heavily on what was done in the past and often learn expensive lessons from their failures. What they do in the future is defined primarily by what worked or did not work in the past. In many cases practices are defined in negative terms of what not to do.

When it comes to training new personnel, the veterans conduct “on the job training” that consists of both useful practices as well as the transfer of bad habits. This training can perpetuate a pattern of performance that is similar to the performance the company experienced in the past. With this management system, it is difficult to make improvements, as most of the learning comes from correcting mistakes of the past.

In order to survive, companies using the No System–System management approach emphasize the need to be productive and to get out the shipments. This can lead to a belief among manufacturing personnel that productivity and output are more important than quality. Even if this is not true, the lack of a management approach and supporting system that defines the needs of both quality and productivity leaves the impression that getting out shipments is the foremost concern of management.

Companies using this No System–System tend to be slow to react to change and slow to make improvements, since only costly mistakes are likely to move them into a new direction.

Companies with this type of management system pose a challenge along with a level of frustration to a new manufacturing supervisor. The challenge starts when a new supervisor begins his duties. In most cases the supervisor he is replacing or the manager he will be working for usually trains the new supervisor. New supervisors, not exposed to a quality/productivity approach, learn to focus primarily on making sure that parts are always available to meet production schedules. New supervisors receive little formal training on how to technically support their welders. As a result, many end up as glorified expeditors, spending the bulk of their time making sure that production is not interrupted. They have very little day-to-day contact with their employees and therefore have little impact on either the quality of the welds made or on increasing the productivity of the welders.

Lean Manufacturing

Lean Manufacturing is a management system that has received much attention in manufacturing companies in the past several years. Lean started to gain popularity in the U.S. after the Japanese automaker Toyota demonstrated its success. The introduction of Lean Manufacturing is viewed as a management paradigm shift. It represents a cultural change in the way companies are managed in all aspects. The paradigm shift comes from the concept that everyone in the company must focus on eliminating waste in all operations, from sales

and design through production. When applied to welding, Lean would review each welding operation with the goal of eliminating the steps that do not contribute to making quality parts efficiently. Lean is a continuous improvement process that never ends. After more than twenty years of dedicated effort, Toyota acknowledges that they have only achieved about 10–15% of their total potential improvement.

Lean Manufacturing achieves results by focusing on several core concepts and tools:

1. **Just-in-Time (JIT) Production.** This concept requires a company to produce products only when customer orders exist. JIT requires that a company rethink its traditional approach to high volume continuous production and develop systems that are cost effective and responsive to low volume and high variety demand. JIT results in a steady flow of parts. The right parts arrive at the right time, in the right place, and in the right quantity to keep production moving on schedule. When carried out properly, JIT results in shorter customer lead times, improved quality, a minimum amount of work-in-progress inventory, and less finished goods. Lean considers any inventory as waste that needs to be eliminated from all parts of a business.
2. **Quality Principle.** This principle requires quality to be built into the design of each part and into each production process. It prevents defective parts from moving from one workstation to the next. For welders this means inspecting their own work and assuring that they correct any defects found. The supervisor is notified if this cannot be done. In Lean organizations, this quality principal is extended to all functions, and gives everyone both the responsibility and the authority to halt production for any observed quality defect. Everyone accepts responsibility for quality.
3. **Full Utilization of Team Members.** Lean Manufacturing holds the fundamental belief that all members of an organization can contribute to all aspects of the business. Continuous training and development is a cornerstone of Lean. Lean utilizes cross training and defines the responsibilities of a team or department. This concept supports a team or department in solving problems and taking responsibility for the workmanship of what they produce. Through training and utilizing the potential of each employee, everyone is more committed to the goals of the organization and develops the additional skills to increase their contribution.
4. **Muda.** Muda is the Japanese word for waste. In Lean Manufacturing, the elimination of Muda is considered the highest principle. All activities, training, analysis tools, controls, and management systems in Lean are used to focus on improving everyone's ability to eliminate waste. Waste in Lean is defined as any non-value added step or process. In a Lean organiza-

tion, waste in every function is viewed as an opportunity to improve and reduce costs. Lean analysis tools such as Value Stream Mapping and Process Flow focus on identifying waste. Lean companies train all employees in these basic tools so that they can all contribute to elimination of Muda.

5. **Pull.** In Lean Manufacturing plant layouts, process flows and systems are designed around the concept of pulling materials through the factory rather than the traditional approach of pushing materials through based on a production schedule. In traditional systems, detailed schedules for each department and supplier are developed to support the production schedule. With Pull, schedules for supporting departments are determined by the demand of the final operation. Parts are replenished by both internal departments and outside suppliers. Kanban, JIT, and other tools are used to accomplish this. The Pull system supports the Lean concept of elimination of waste, as nothing is produced until it is needed by the customer.

Lean Manufacturing uses a variety of tools, techniques, and methods to support its concepts and achieve its higher-level goals. Some of the more common ones include:

- *Kanban*—Kanban is the communication process used to ensure that parts are available when they are needed for subsequent manufacturing operations. It is generally a visual message or signal that is sent to a supplying department or outside supplier to communicate how many and when the next batch of parts is needed for production. Many companies with and without Lean Manufacturing use this replenishment process.
- *Single Piece Flow*—This is the system that allows a company to cost effectively build only parts when needed. It requires a great deal of focus on manufacturing throughput, where quick change set ups will allow for economical production runs of as little as one part. The focus is on eliminating the waste of inventory and having production resources making parts that are needed now.
- *Takt Time*—This is an approach to manufacturing planning that begins by establishing a rate of required production output based on customer demand. Production capacities and production rates of all parts and processes are established based on the output rate required to meet customer demand. Once the Takt time for the end product is established, the production rates and allowed production times for each part can be established. These become the output standards for component parts and operations.
- *Standardized Work*—This is used to determine the method and sequence to make the parts in the most efficient manner. Standardized work units for component parts must support the overall Takt time required to support the final production rates.

- *Kaizen*—A technique used by a team or department to make improvements in a process or series of processes. A Kaizen event is usually conducted with all team members over a few days and then the improvements are made and implemented immediately. This is an intensive effort to reorganize an activity to achieve higher efficiency, better quality, and lower costs. The basic premise for this technique is to achieve continuous improvement. It is done using a very intense, tight time frame.
- *Poka-Yoke*—This is a technique that is used to design processes and equipment for processes to prevent the possibility of error. Common applications include the detection of missing parts or the prevention of incorrect assembly. Poka-yoke is often referred to in Lean as mistake proofing. It is used to improve quality by reducing the possibility of error through process design.
- *Visual Control*—This technique involves the use of lights and/or audible signals that highlight a problem at a workstation. They are used to get a quick reaction to solve a problem so that quality productive work can resume.
- *Teaming*—This is the technique of forming teams of six to eight people with the responsibility to meet a specific quality, production, or safety goal of the company. Teams are formed only after adequate training and often assigned to work on specific improvement projects. An hourly employee often leads these teams, and they stay together until the project has been completed and implemented.

For welding supervisors there are several positive things that result from the implementation of a Lean Manufacturing system. They include:

1. An approach to standardizing the process times for each welding operation, which gives the supervisor standards by which to evaluate productivity.
2. The use of process control and monitoring equipment to detect missing parts and incorrect assemblies. This helps improve the quality of input parts for welded assemblies.
3. A welder inspecting his own work and not allowing defective parts to move on helps define many of the inputs and outputs to and from the welding workstation.
4. Lean Manufacturing also introduces the concept of 5S to the workstation, which can be used as an organizing and housekeeping system.

The 5S system consists of the following sequence of steps:

1. *Sort*—remove from the workstation any item that is not needed.

2. *Straighten*—arrange items in the workstation so that they are easy to find and use. Mark and label items to aid in identification and for ease of future location.
3. *Sweep*—clean the workstation thoroughly, paint if necessary, and replace all worn and nonfunctioning items.
4. *Schedule*—set up a schedule to see that the first 3Ss – sort, straighten, and sweep are continued and do not become just one time events.
5. *Sustain*—monitor the repetition of these procedures until they become habit.

The result of the 5S approach is a neater, better organized, and more attractive work area. This helps set the environment that leads to better productivity. The 5S approach to layout represents a series of steps that are applied to each specific area, such as a welding workstation. How the 5S principles are applied by the welding supervisor with the welders depends on the knowledge and experience of both in building the best environment for the welder.

One of the drawbacks to using the 5Ss and other Lean principles in welding operations is that many company and supervisory personnel have little technical training either in welding or in the Lean principles to effectively implement them. Without specific training, attempts at Lean Manufacturing are likely to fail. Lean is a general company-wide system for managing and improving all processes. It does not specifically focus on any one manufacturing technology such as welding.

Total Quality Management (TQM)

The system of TQM grew out of the need to ensure quality in day-to-day manufacturing. As pointed out in the No System–System, quality is often ignored in the day-to-day push to get product out the door.

TQM traces its origins to the 1960s when Japanese companies desired to improve quality in order to compete in world markets. The Japanese started their journey to quality by listening to W. Edwards Deming, an American trained statistician and quality teacher. Deming was a pioneer in the field of applying statistical approaches to measuring quality and designing techniques for controlling processes and predicting when deviations were leading to out of control conditions. These techniques are practiced today by many companies in the U.S. as Statistical Process Control.

TQM begins with an understanding of what the customer wants, and then creates a quality system that will ensure that the customer receives the product that fulfills his requirements. TQM does this by focusing on three goals:

1. **Quality of Design.** A product must be designed to meet the customers' needs.

2. **Quality of Conformance.** Takes the design and any standards that are needed, and puts in place the measurements and controls to ensure that the specifications are met.
3. **Qualities of Performance.** The performance of the product and customer satisfaction with the product are measured and any shortcomings corrected.

TQM achieves these goals through the quality assurance function in a company. They develop and implement the quality system to ensure the quality of design, conformance, and performance. As part of the TQM system, reports of the quality measures go to the Quality Department. This data provides facts for the correction of deficiencies that occur during various production processes. This feedback provides the opportunity for continuous improvement of processes and quality.

In some companies, there is not a strong link between TQM and productivity. This is often due to the perception that there are few opportunities to improve both quality and productivity. This has been disproved, especially in welding. As an example, the reduction in welding defects results in a marked savings in welders' time to make repairs. That time can then be used to make more production welds, thus increasing productivity.

A TQM management system tries to integrate the following organization functions:

1. Marketing
2. Management
3. Product Design
4. Process Control
5. Production
6. Training
7. Quality Assurance

Although TQM can take a number of different forms in an organization, there are some characteristics that are common to successful TQM companies. They include:

- The culture of the organization changes—this is seen most notably at the supervisory level by better training and a deeper understanding of the importance of quality and how quality is achieved.

- Greater welder involvement in more aspects of the business by using the welders as a source of ideas for continuous quality improvement.
- Use of incentives, such as gain sharing or other profit sharing, to reward all employees for improved results.
- Improving customer satisfaction with the quality of the product. A willingness to make changes that answer customer concerns about quality without blaming employees.
- Elimination of rigid constraints that were put in place as a result of earlier problems or failures. Band-aid solutions are eliminated and replaced by an effective quality system.
- Greater use of technology and more flexibility in solving problems and addressing quality issues.
- Better cooperation with suppliers to improve the quality of materials supplied.
- Measurable progress in recording, analyzing, and reporting quality improvement, and providing more emphasis where needed for further improvement.

The welding supervisor sees that a company that follows the TQM system shows a definite focus on quality. A TQM company has the support of management and the rest of the organization to achieve and sustain the quality of not only welding, but also of all the materials and parts that are used in welded assemblies. The drawback of TQM for the welding supervisor is that it is not welding specific. It only identifies the need to put in place measures, procedures, and methods that will improve quality but does not provide the technical detail required to achieve welding quality.

TQM does not include the technical specifics of the science of welding and welding processing required to define what form the procedures and methods should take or how specific values are determined. The supervisor also does not see in TQM what training is necessary to raise the level of knowledge and skill of the welders to meet the quality needs of the TQM system. Although improved quality does help improve productivity, the TQM system itself does not specifically address productivity in any meaningful way to aid the supervisor in trying to increase productivity while improving quality. For companies doing welding, TQM needs to be supplemented by a system, which is focused on improving total welding operations so that higher levels of quality and productivity can be achieved.

Total Welding Management (TWM)

Total Welding Management¹ (TWM) is a system for managing welding operations that leads to the achievement of high levels of quality and productivity. It is the only management system that provides the detail required for every function and person involved in welding. TWM offers a comprehensive organization wide approach to long-term sustainable improvement.

The control system within TWM is designed to assure that all welding related activities are carried out in a correct, safe, timely, and efficient manner, and results in the production of cost effective quality products every time.

TWM is based on the Barckhoff Welding Management System[®], which is the model that provides the framework of TWM to plan and control all welding related activities in a company. This model represents a systematic approach for the development of a company's specific welding management system.

TWM encompasses much more than the welding supervisor's responsibility, but by reviewing the total system, supervisors will better understand their role in achieving the company's goal of quality weldments at the lowest cost.

TWM uses a three-phased process of evaluating, planning, and improving all of the welding-related activities in a company referred to as the Barckhoff Method[®].

The Method encompasses product design, material procurement, process design and control, quality assurance, parts preparation, fitup, and final assembly to meet specifications without defects.

TWM using the Barckhoff Method[®] applies proven technical, organizational, and management principles to welding as they have been applied to other manufacturing processes such as machining and assembly.

TWM has three distinct characteristics:

1. It combines the art, science, and technology of welding with tested and proven management principles and includes the four critical organizational functions, which impact welding (Four Critical Functions).
2. It associates five defining responsibilities (Five Key Results Areas) for each of the Four Critical Functions, resulting in twenty different Key

1. Total Welding Management and Total Welding Management System are both copyrighted (2005) by Jack R. Barckhoff, P.E. In this chapter and throughout this manual, the use of Total Welding Management or TWM, and Total Welding Management System or TWMS refers to copyrighted Total Welding Management System. Copyright laws protect any reference to this system. "Total Welding Management" is also the title of a book written by Jack R. Barckhoff, P.E., copyrighted and published by the American Welding Society (AWS). In this book, all of the principles and concepts of Total Welding Management (TWM) are detailed.

Results Areas that collectively represent all of the welding-related responsibilities in a company.

3. It is a systematic approach in which a six-step process (Six Managerial Steps) and cost reduction goals (Five Welding Do's or Goals) are applied to the Five Key Results Areas of each of the Four Critical Functions to identify and quantify opportunities to improve productivity and quality.

The Four Critical Functions are:

1. Design Engineering
2. Manufacturing Engineering
3. Manufacturing Operations (including Supervisors)
4. Quality Assurance

The Five Welding Do's (Goals) are:

1. Reduce Weld Metal Volume
2. Reduce Arc Time Per Weldment
3. Reduce Rejects, Rework, and Scrap
4. Reduce Work Effort
5. Reduce Motion and Delay Time

Welding supervisors, as part of their daily responsibilities, focus on these five goals.

The Five Key Results Areas for Manufacturing Operations are:

1. Personnel Training and Qualification
2. Material Input
3. Equipment Performance
4. Method and Procedure Application
5. Work Center Control

These Key Results Areas of Manufacturing Operations affect and are affected by welding supervisors more than any others. The other Critical Functions also have Key Results Areas related to achieving the Five Welding Do's.

The Six Managerial Steps are:

1. Information Gathering and Analysis
2. Planning and Goal Setting
3. Training
4. Implementation and Fine Tuning
5. Measurement and Control
6. Reporting

These six managerial steps are used both to implement TWM and provide the framework for the management system.

The Barckhoff Method[®] has three phases to TWM:

1. **Phase I—Survey and Evaluation.** The improvement of welding operations begins with benchmarking current conditions and performance. Gathering data as well as conducting interviews at all levels in the organization helps establish the baseline.

The Six Managerial Steps and the Five Welding Do's are used to evaluate each of the Five Key Results Areas within each of the Four Critical Functions to find opportunities for improving productivity and quality.

This data is then analyzed. From the summarized results, improvement goals are established and projects prioritized. Potential savings are reported in both man-hours and dollars.

2. **Phase II—Management Planning and Goal Setting.** Management reviews the Phase I findings, recommended actions, and potential productivity and profitability gains. Projects are then prioritized. Resources are assigned, schedules agreed to and then a Gantt chart is developed. This serves as the roadmap for TWM.
3. **Phase III—Implement and Sustain.** In this phase, the company develops and implements a customized welding management system and pursues the objectives selected in Phase II. Teamwork and team building are stressed as knowledge is instilled in welders and others through training.

Five Welding Do's (Goals)

These Do's represent the five major goals that any welding company needs to focus on to gain significant improvement in both welding quality and productivity.

1. **Reduce Weld Metal Volume.** The intent of this goal is to eliminate waste by reducing the volume of weld metal to the minimum necessary to be consistent with the joint application and specification requirements. Designers should minimize the volume of weld metal required and avoid over-specifying weld sizes. Welders should not deposit welds larger than required by the design specifications. Although this goal directly affects arc time, it is considered separate from arc time because it is distinct from weld process deposition rate.
2. **Reduce Arc Time Per Weldment.** This goal centers on the deposition rate capabilities of the welding process and the welding technique used. The specified volume of weld metal should be deposited in the least amount of arc time.
3. **Reduce Rejects, Rework, and Scrap.** This goal focuses on eliminating or correcting any situation that tends to result in the production of unacceptable welds. The achievement of this goal results in minimizing or eliminating the costs and unproductive labor hours associated with rejects, rework, and scrap. This results in both weld quality improvement and a reduction of weld costs for repairs.
4. **Reduce Work Effort.** Work effort refers to the degree of difficulty, fatigue, and hazard associated with welding. The focus of this goal is to minimize or eliminate characteristics of work habits; methods, environment, equipment, tooling, and workplace that tend to increase the difficulty of work effort.
5. **Reduce Motion and Delay Time.** This goal includes all time elements associated with a welding operation except for arc time. The focus of this goal is to minimize or eliminate all characteristics of work habits, methods, environment, equipment, tooling, and the workplace, that tend to increase time, produce excess motion or repeat time, or cause the welder delay time.

Four Critical Functions and Key Results Areas

There are four distinct support functions required to produce a weldment or welded product. The Barckhoff Method[®] defines them as the Four Critical Functions. They are Design Engineering, Manufacturing Engineering, Manufacturing Operations and Quality Assurance.

Key Results Areas make up the major portion of a Critical Function's responsibility as related to welding. They are defined as follows:

- **Design Engineering**

Key Results Areas are:

1. **Material Selection.** Identifying, evaluating, and choosing between combinations of base metal and filler metal
2. **Weld Size Determination.** Determining the proper size of weld for a specific type of joint and specific application.
3. **Weld Joint Selection.** Selecting and applying the appropriate type and geometry of weld consistent with welding economics and quality.
4. **Manufacturing Review.** Reviewing and appraising weldment design to ensure economic manufacturing consistent with specifications and manufacturing capabilities.
5. **Weldment Specification.** Development, review, and release of the documents that define, describe, and explain the welding requirements for each weldment.

- **Manufacturing Engineering**

Key Results Areas are:

1. **Workmanship Standards.** Specifying or providing welding production requirements to meet quality and quantity standards.
2. **Welding Process Selection.** Choosing and specifying the most efficient and effective process for a welding application.
3. **Equipment and Tooling Selection.** Choosing and specifying welding equipment, fixtures, jigs, and positioners for a welding process and application.
4. **Method and Procedure Development.** Determining the most effective combination of welding materials, welding process, and technique characteristics, consistent with production and quality requirements to satisfy in-service conditions.
5. **Work Center Planning.** Organizing efficient and effective work center layout, workflow, process sequencing, motions, and accountabilities to enable the welder to meet or exceed productivity and quality requirements.

- **Manufacturing Operations**

Key Results Areas for the welding supervisor are:

1. **Personnel Training and Qualification.** Instruction and qualification of welders and other manufacturing personnel in the use of the work methods, procedures, fixtures, and equipment in accordance with the work center control plan.
2. **Material Input.** Controlling the shape, size, dimensions, surface condition, and composition of materials entering all welding workstations.
3. **Equipment Performance.** Insuring all equipment's capability to perform to its intended purpose.
4. **Method and Procedure Application.** The use of equipment, tooling, process, and techniques to meet standards, specifications, and procedures.
5. **Work Center Control.** Auditing and monitoring the welder, work methods, procedures, materials, equipment, and tooling in accordance to plan and correcting variances.

- **Quality Assurance**

The Key Results are:

1. **Policy and Accountability.** Statements of acceptable standards, behavior, and organization responsibilities relating to quality.
2. **Quality Standards.** Definitions and descriptions of acceptable quality levels.
3. **Quality Procedures.** The means and methods for measuring quality.
4. **Inspect, Measure, Report.** The process of translating technical measurements into meaningful management reports.
5. **Corrective Action.** Procedures that describe the actions to be taken to correct variances from standards, specifications, or other requirements applicable to a part, product, or process.

Six Managerial Steps Defined

In a TWM system, to properly develop, implement, and control a welding management system project and effectively solve any welding problem, the following Six Managerial Steps as described below are applied.

- **Step 1—Information Gathering and Analysis.** This step is used for collecting, recording, and analyzing facts and information necessary to build the foundation for the project. This step also provides the basis for evaluating the project's performance after its implementation. Personnel working in this step must be knowledgeable in the operations surveyed and with the resultant data.
- **Step 2—Planning and Goal Setting.** In this step, the total project is developed and the goals are established. Assignments are made and schedules are determined. All necessary methods for insuring the development and implementation of the program are established. The necessary control methods for insuring maintenance of the implemented project and measurement of project performance are also developed.
- **Step 3—Training.** In this step, all personnel who will control, use, or work on the project are trained in the detail of their functional responsibility, how the overall program works, what the goals are, and when the project is to start.
- **Step 4—Implementation and Fine-Tuning.** In this step, the project is put into action. It is closely monitored to insure that all necessary details are covered. When required, on the job follow-up training is conducted.
- **Step 5—Measurement and Control.** This is the step that audits, monitors, and collects data regarding project performance. Essential data must be reported to insure the continuing success of the project.
- **Step 6—Reporting.** In this step, all measurements are analyzed for comparison to goals and the results reported to management and others responsible for taking corrective actions. Timely feedback of critical information is essential to reverse undesirable trends and avoid unwanted change.

When implemented, TWM results in a closed-looped management system that includes all aspects of welding, and ensures both proper control as well as continuous improvement of welding operations.

Before we summarize the advantages of each of the four systems reviewed above, a brief discussion of both Six Sigma and ISO would be appropriate as welding supervisors may encounter them.

- **Six Sigma.** Six Sigma is a methodology and set of tools used to evaluate processes for the purpose of reducing variation to reduce costs and improve quality. The tools used by Six Sigma can be quite analytical and involved and require specialized training.

With completion of formal Six Sigma training, formal levels of proficiency are granted from Green Belt to Black Belt. Companies such as General Electric, under the leadership of Jack Welch, have trained thousands of Black Belts. This training in their estimation has result in significant annual cost reductions through the application of Six Sigma tools and methodologies. Savings have come from reducing process variation both internally and with suppliers.

Six Sigma tools can be used in both TQM and TWM systems to support improvement programs. These tools can also be used with the No System System but without a formal structure, results would be limited.

- **ISO.** ISO represents the formal documentation of a company's quality system to defined national and international standards. ISO requires formal, periodic external audits to assure that a company's documented quality procedures are followed. Many companies are required to maintain ISO certification by the industry or customers they serve. ISO international standards include ISO 9000, 9001, 9002, and 1400. ISO is a natural extension of TQM, as it provides the structure for formal documentation required for an effective TQM system and provides the formal certification and independent outside audit.

TWM supports ISO as it provides complete documentation with the TWM system for all welding-related operations. A No System–System would have difficulty meeting any ISO certification requirements as there is little formal documentation followed in the No System–System.

Table 1 will help highlight some of the strengths and weaknesses of the management systems reviewed. The characteristics included in the comparison show how each system supports quality improvement, productivity improvement, continuous improvement, and whether each system provides generalized or detailed welding specific information for improvement.

Table 1.1—Comparison Chart

	No System	Lean	TQM	TWM
Quality	No	Yes	Yes	Yes
Productivity	Yes	Yes	No	Yes
Welding Specific	No	No	No	Yes
Continuous Improvement	No	Yes	Yes	Yes

Conclusion

A welding supervisor could work for a company using any one of the above management systems. Only one has been found to provide the detailed technical and managerial information required to achieve lasting welding quality and productivity improvement. For this reason, this manual is written using the Total Welding Management System to prepare welding supervisors for their very important role in manufacturing.

This does not mean that a welding supervisor who has learned the concepts and principals of TWM will not be able to apply them in other environments. He will find that this detailed technical and managerial knowledge will fit very neatly with and enhance other systems of management. It will definitely enhance the quality and productivity where there is no company manufacturing system at all.

A welding supervisor is not expected to be involved in all of the activities of TWM. The purpose of introducing TWM is to provide a better understanding of how other parts of the organization function and to show how the supervisors' role forms an integral part of the management system.

The most important knowledge that a welding supervisor should come away with after having studied this manual is their new found ability to:

- look at the situation that exists in their department and evaluate whether it is the most appropriate way to perform the welding tasks, based on this manual; if not to understand what actions need to occur to correct the situation.
- then take those things that should and can be changed, and have the confidence and knowledge to effect change without fear or doubt.
- evaluate the changes that have been made through monitoring of those improvements to verify that they have achieved the desired result, and then to continue to refine and improve upon the result.

In this manual, it will become clear that supervisors play a very important role in any management system. This is true, especially in the Critical Function of Manufacturing Operations and the Key Results Areas of Personnel Training and Qualification, Material Input, Equipment Performance, Method and Procedure Application and Work Center Control. Throughout the remainder of this manual the welding supervisor's role will be detailed along with the technical information required to fulfill his important role in the quality and productivity of his welding operations.

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“Total Quality Management for Engineers,” Mohamed Zairi. 1991. Woodhead Publishing Limited, Abington Hall, Abington, Cambridge, England.

“Implementing World Class Manufacturing,” Larry Rubrich & Madelyn Watson. 1998. WCM Associates, Fort Wayne, Indiana.

“Total Welding Management,” Jack R. Barckhoff, P.E. 2005. American Welding Society, Miami, Florida.

Review Questions

1. Many companies have supervisors doing which of the following?
 - A. Supporting the welders activities
 - B. Checking the quality of parts
 - C. Expediting parts and pushing productivity
 - D. Playing cards
 - E. None of the above
2. Which management approach relies on welders teaching welders on the job?
 - A. Total Welding Management
 - B. No System–System
 - C. Lean Manufacturing
 - D. Total Quality Management
 - E. Total Quality Welding
3. In the Lean Manufacturing System, which is not a concept?
 - A. Muda
 - B. Pull
 - C. Quality Principal
 - D. Just-In-Time
 - E. Quality of Conformance
4. In the workstation approach using 5S, which of the following are part of that system?
 - A. Sort
 - B. Straighten
 - C. Schedule
 - D. Sustain
 - E. All of the above
5. The TQM System approach relies on which of the following to achieve the goals of this system approach?
 - A. Quality of Effectiveness
 - B. Quality of Efficiency

- C. Quality of Repair
 - D. Quality of Performance
 - E. Quality of Training
6. Which if any of the following may be characteristic of a TQM System approach?
- A. Use of incentives
 - B. Kanban
 - C. Improving customer satisfaction
 - D. A and C
 - E. Takt time
7. The TWM System approach which of the following is not one of the 5 Welding Do's Goals?
- A. Reduce Nonconformance
 - B. Reduce Arc Time Per Weldment
 - C. Reduce Work Effort
 - D. Reduce Weld Metal Volume
 - E. Reduce Motion and Delay Time
8. For a welding supervisor which of the Key Results Areas are most important?
- A. Welding Process Selection
 - B. Method and Procedure Application
 - C. Material Selection
 - D. Weldment Specification
 - E. Quality Standards
9. Which of the Six Managerial Steps is essential for sustainability?
- A. Information and Goal Setting
 - B. Measurement and Control
 - C. Reporting
 - D. Implementation and Fine Tuning
 - E. Training

Answers

1. C
2. B
3. E
4. E
5. D
6. D
7. A
8. B
9. C

Chapter 2—REQUIREMENTS OF A WELD

Introduction

Welds must meet a variety of requirements to provide a safe and economical structure or weldment (see Figure 2.1). Requirements for welds can be specified in several different ways:

- Company design and quality requirements
- Codes and specifications
- Customer requirements and/or expectations

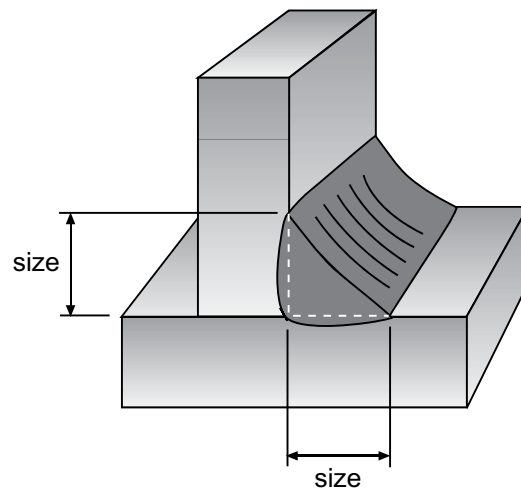


Figure 2.1—Requirements of a Fillet Weld

Requirements for a Fillet Weld

These requirements need to be well thought out and properly documented for shop use. Formulating these requirements into a welding workmanship standard along with weld sample boards and mock-ups is best way of doing this. Quality cannot be a matter of opinion but should be defined by requirements that mean the same to all those involved in welding operations. The quality requirements should be both observable and measurable, and need to be effectively communicated to the shop floor.

Quality requirements for shop use are specified by:

- Welding workmanship standards
- Weld sample boards

- Weld mock-ups

Weldment mock-ups and sample boards are effective communication tools. Mock-ups can be a replica of the actual products being produced or a representation of typical welds. Mock-ups show how the parts fit together, where the welds are placed, acceptable weld appearance and even weld sequence, if appropriate. They provide a visual display of the weld bead and joint requirements (see Figure 2.2).

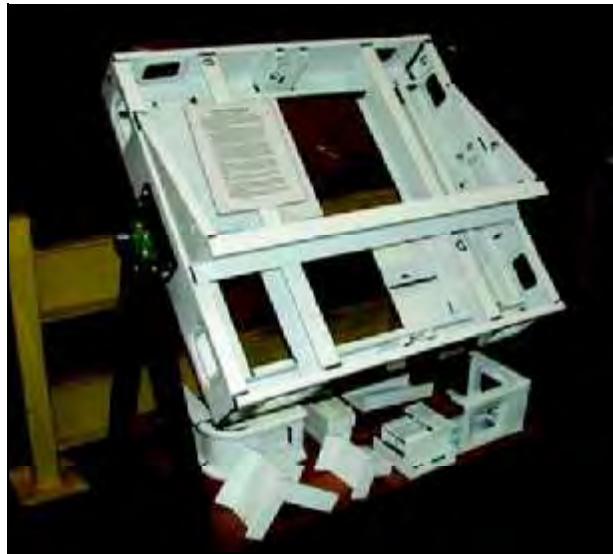


Figure 2.2—Weld Mock-Ups

Sample boards on the other hand, represent acceptable and unacceptable welds from a visual inspection perspective. Company expectations in terms of weld quality are effectively communicated with weld sample boards (see Figure 2.3). In essence, mock-ups and sample boards are the visual representations of the welding workmanship standard.

Requirements for welds can include:

- Size
- Length
- Profile and appearance
- Weld soundness

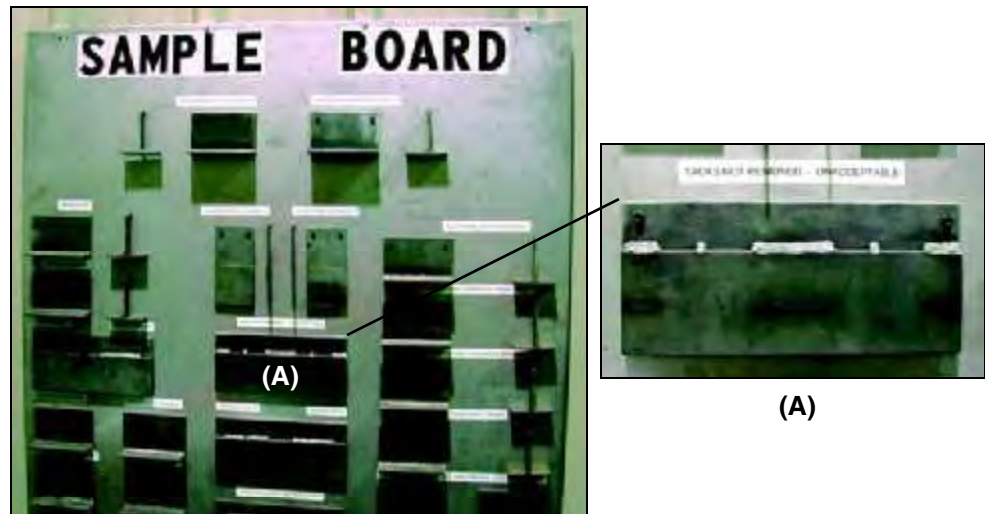


Figure 2.3 Sample Board

- Mechanical properties
- Leak tightness
- Corrosion properties and/or chemistry requirements

Objectives

This chapter has the following objectives:

1. Learn the terms and definitions commonly referred to in welding
2. Understand how weld size is specified
3. Know how to use a welding gage
4. Understand the difference between a weld discontinuity and a defect
5. Learn the types of defects encountered in welding

Weld Terminology

It is important to define the terminology used in the industry before discussing welding requirements in detail. Figure 2.4 describes parts of a weld. Root of joint vs. root of weld is shown in Figure 2.5.

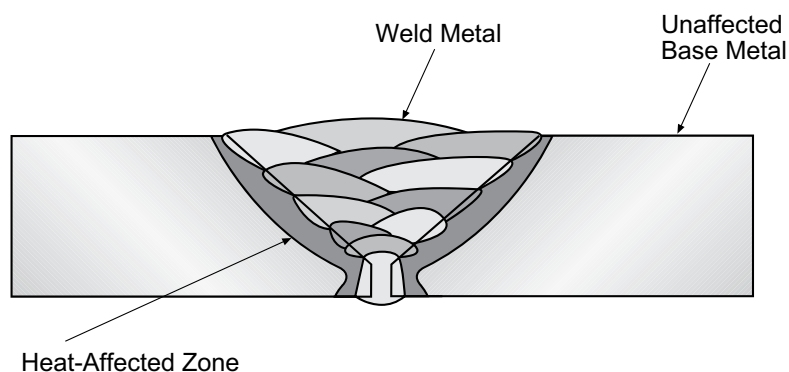


Figure 2.4—Parts of a Weld

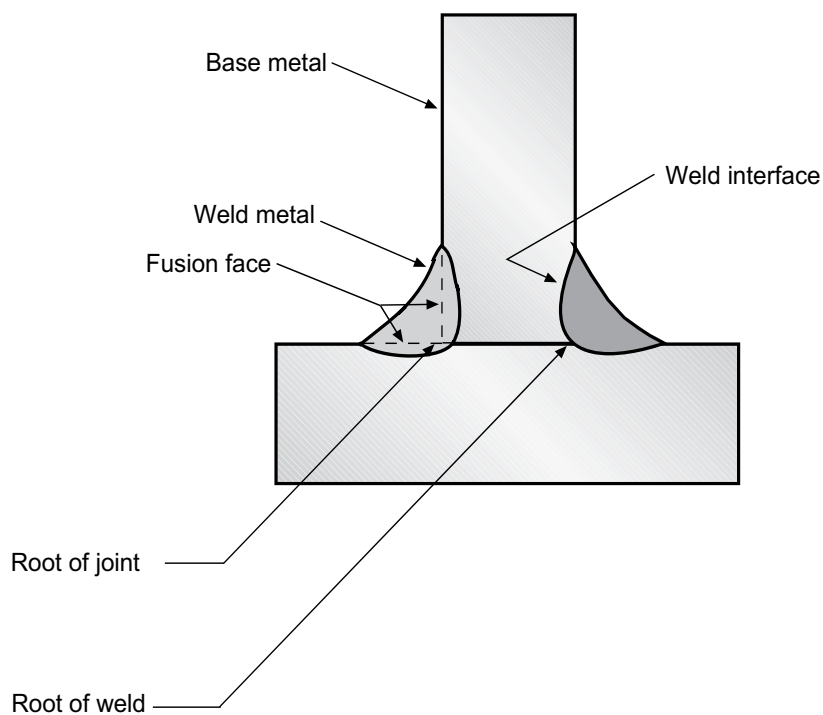


Figure 2.5—Root of Joint vs. Root of Weld

Weld size and throat for flat, convex, and concave profile fillet welds are shown in Figures 2.6–2.8.

Terminology for groove welds is illustrated in Figure 2.9.

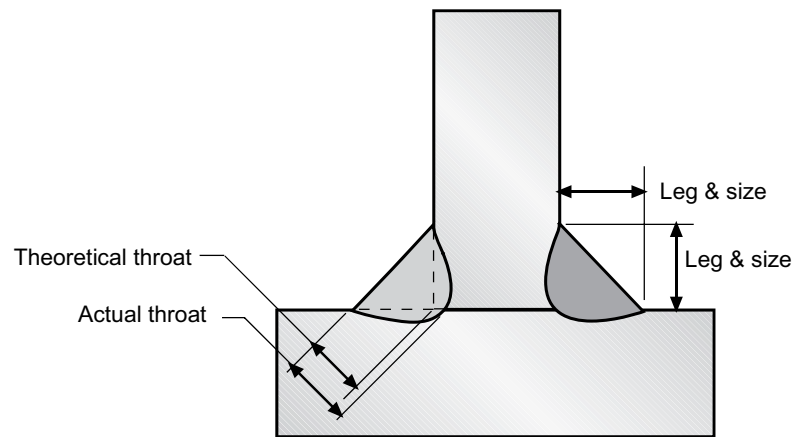


Figure 2.6—Weld Size and Throat for a Flat Profile Fillet Weld

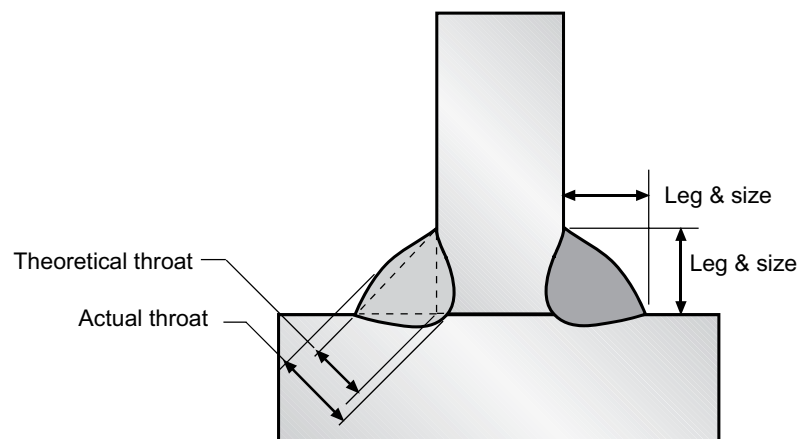


Figure 2.7—Weld Size and Throat for a Convex Profile Fillet Weld

Weld Failure

How do welds fail? To understand how welds are sized we first need to know how welds fail when overstressed. Which is the most likely failure plane for the simple T-joint shown in Figure 2.10? Make a note of your answer. The most likely plane of failure will become evident as you read the next few pages.

Weld Size

The requirements of a weld are shown in Figure 2.11. Weld size determines the strength of a weld. When a plate is loaded in tension as shown in Figure 2.12, the load is transferred from one part to the next by the connecting welds. Before the designer can correctly design the weld, he or she must first understand how the joint will fail. Both the base metal and weld metal must be designed to carry the intended loads.

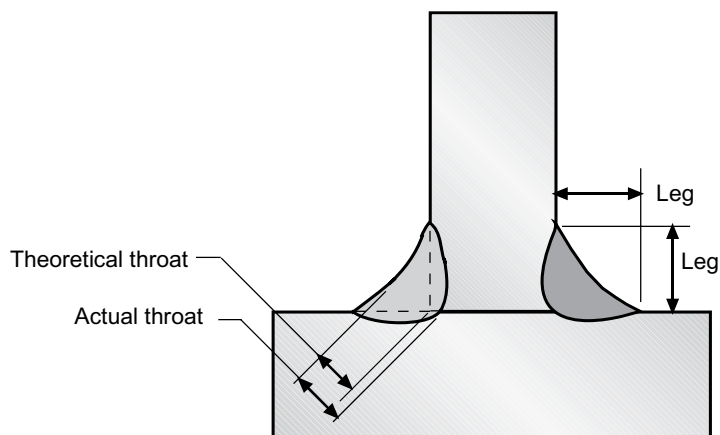


Figure 2.8—Leg Size and Throat for a Concave Profile Fillet Weld

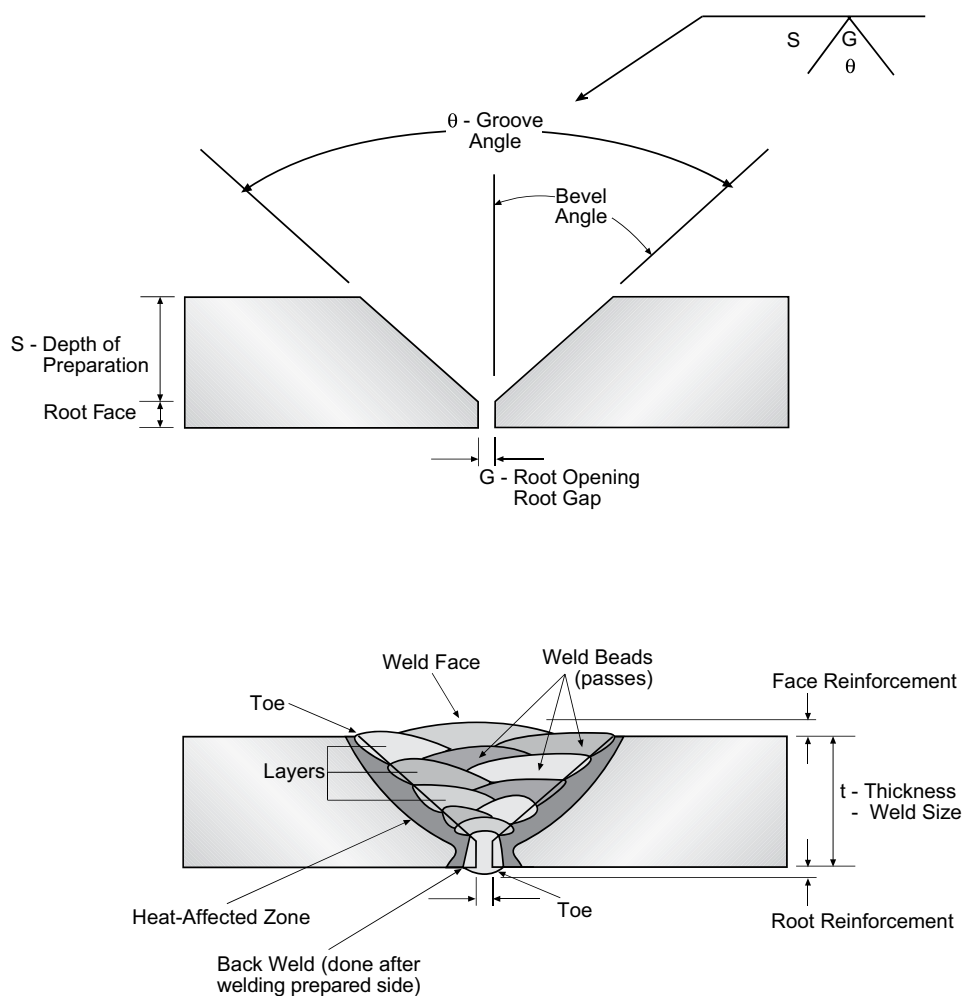


Figure 2.9—Terminology for Groove Welds

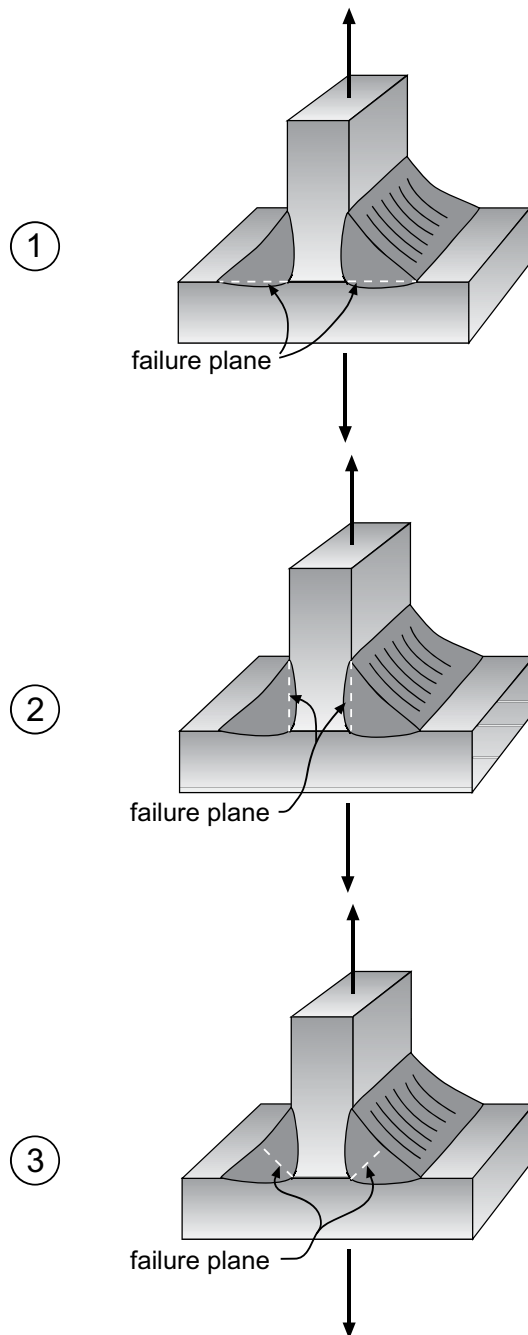


Figure 2.10—Examples of Failure Planes in Simple T-Joints

For a fillet weld, failure will occur through the weld throat, which is the shortest distance from the root of the weld to the weld face. The weld throat is, in fact, the weakest part of the weld (see Figure 2.13). Hence, the answer to the question posed for Figure 2.10 is the # 3 failure plane.

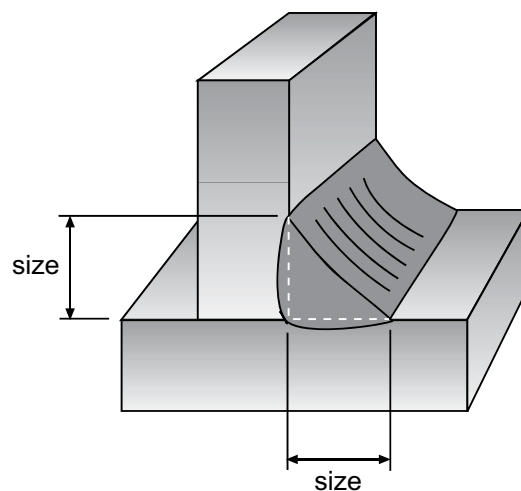


Figure 2.11—Weld Leg Size is Used to Specify the Strength of the Fillet Weld

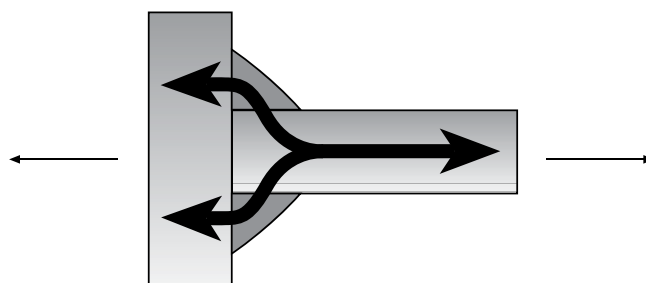


Figure 2.12—Welds are Used to Transfer Load

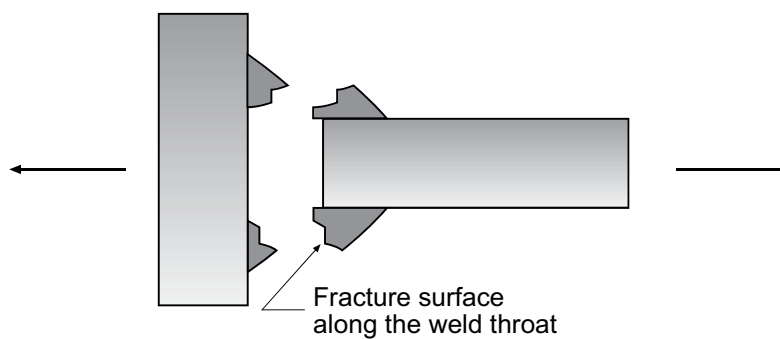


Figure 2.13—Fracture Surface Along Weld Throat

When designing a fillet weld, the engineer works with weld throat but specifies leg size in accordance with our standards. Similarly, when the shop determines the size of a weld by its leg size, it is really trying to ensure that the weld throat is adequate. Caution must be exercised when measuring the size of concave weld because the leg will not be representative of the throat (see Figure 2.14).

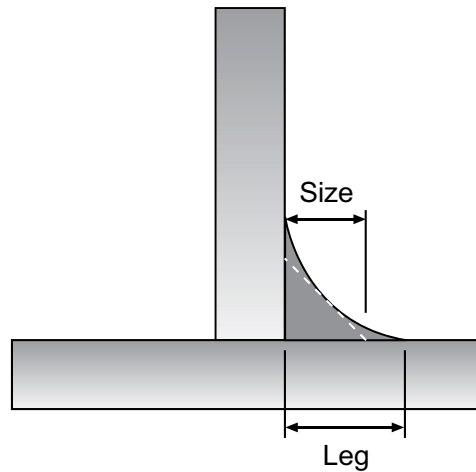


Figure 2.14—In Concave Welds, Leg Size is Not Representative of Throat

A typical gage for measuring the size of a fillet weld is shown in Figure 2.15.

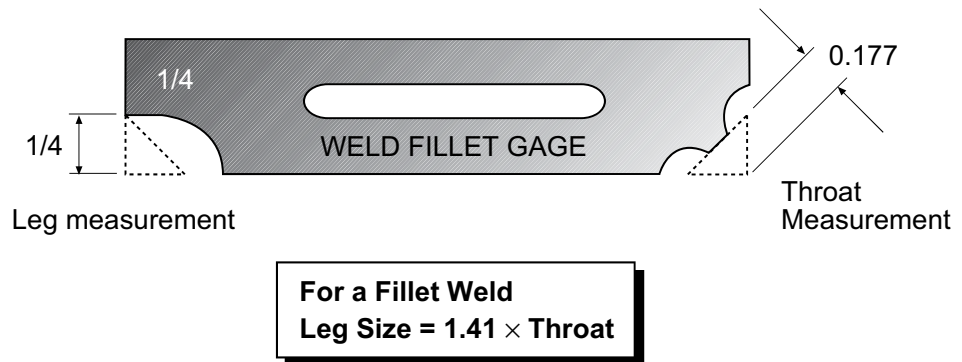


Figure 2.15—Typical Weld Fillet Gage

Proper use of a fillet gage to measure the size of a weld is shown in Figures 2.16 and 2.17. Examples of the proper use of a weld gage are shown in Figure 2.18.

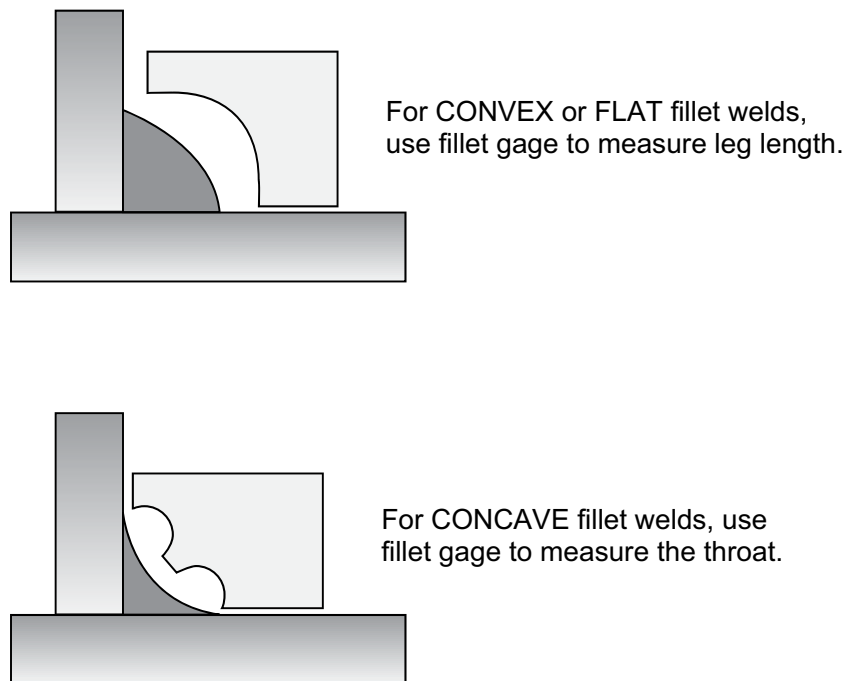


Figure 2.16—How to Use a Fillet Gage



Figure 2.17—Closeup of a Fillet Gage

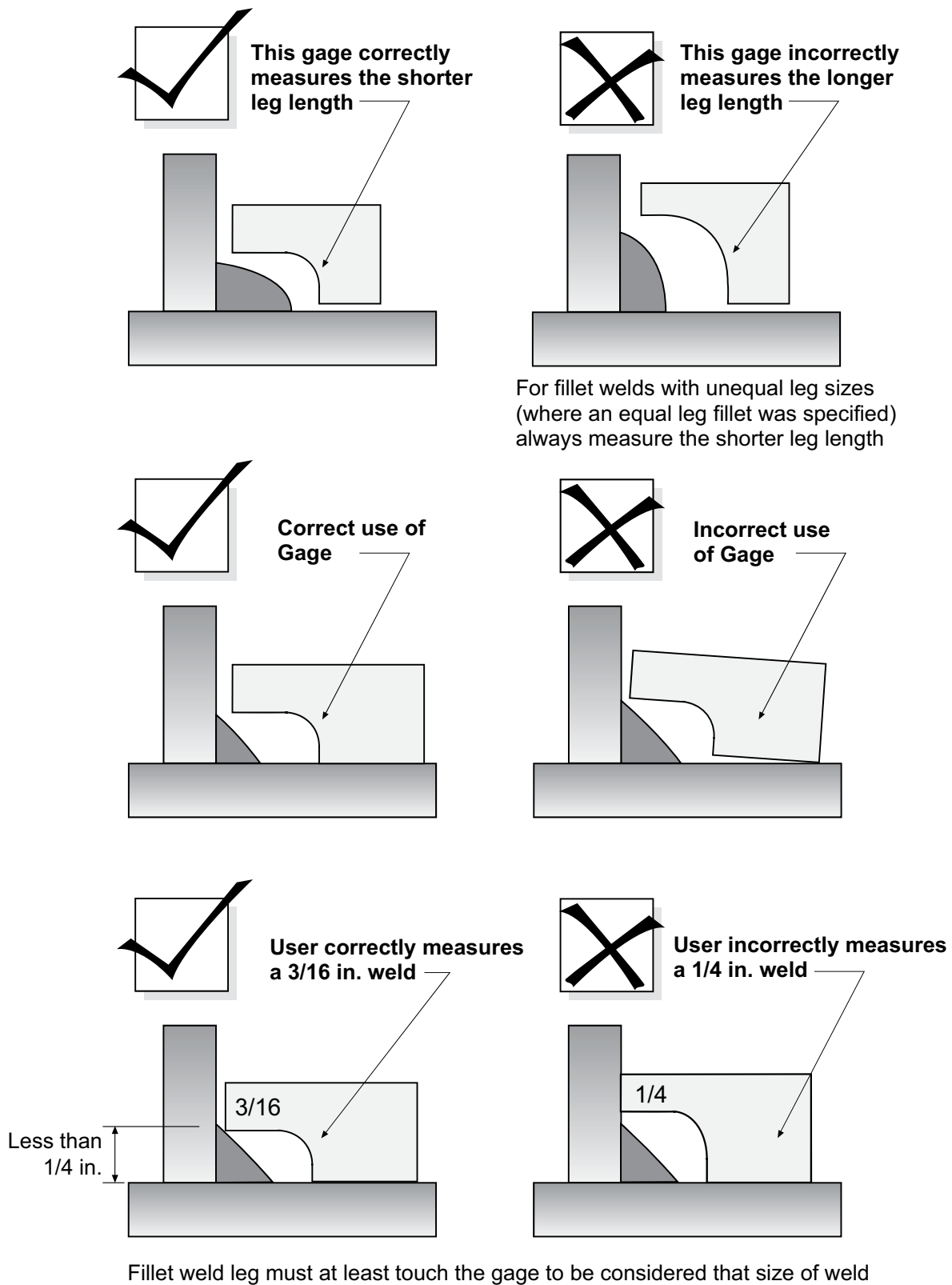


Figure 2.18—Examples of the Proper Use of a Weld Gage

Gaps between the base metals in a fillet welded connection present a special problem. As shown in Figure 2.19, a gap can reduce the weld throat. This reduction of weld throat lessens the load carrying capacity of the fillet weld.

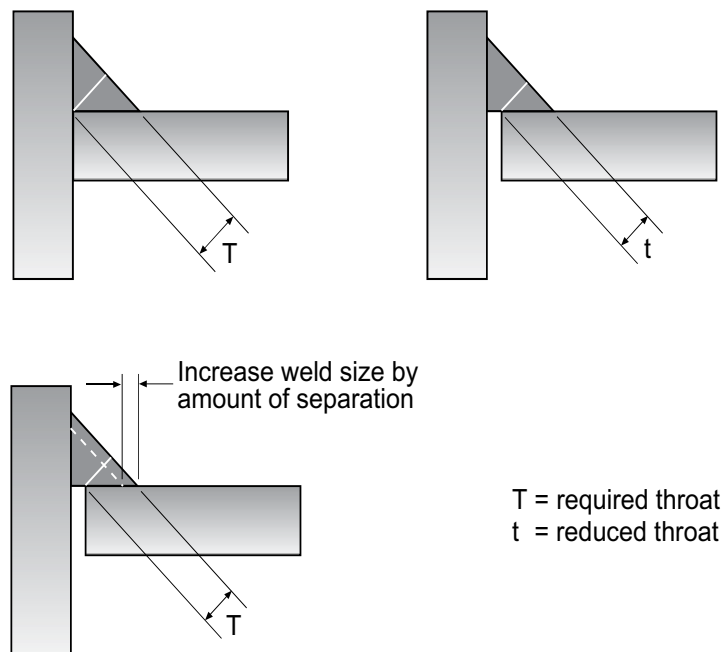


Figure 2.19—Gaps Between Base Metals Can Reduce Weld Throat

Example

When the gap is 1/16 in. or greater the weld size must be increased by the amount of gap (see Figure 2.20).

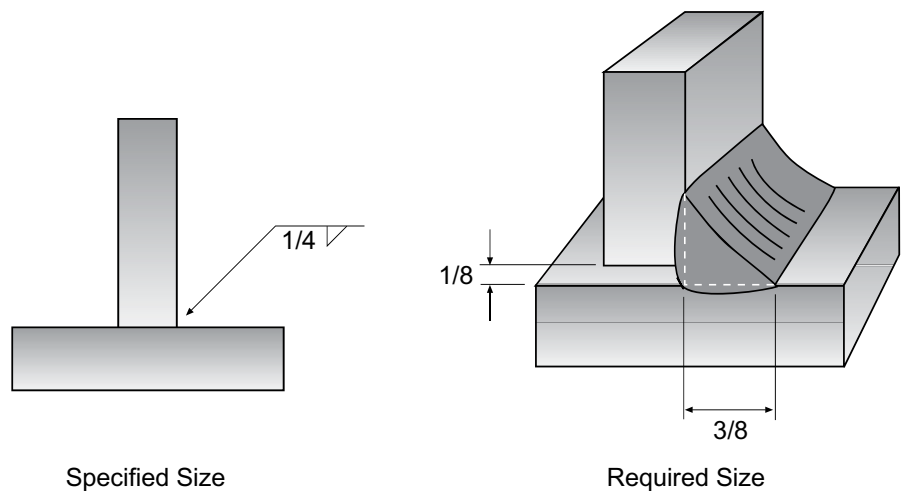


Figure 2.20—Increasing Weld Size by Amount of Gap

Welders should also be knowledgeable about the costs of overwelding. As shown in Figure 2.21, the adjacent sidebar small changes in weld size can make a big difference in weld volume and costs

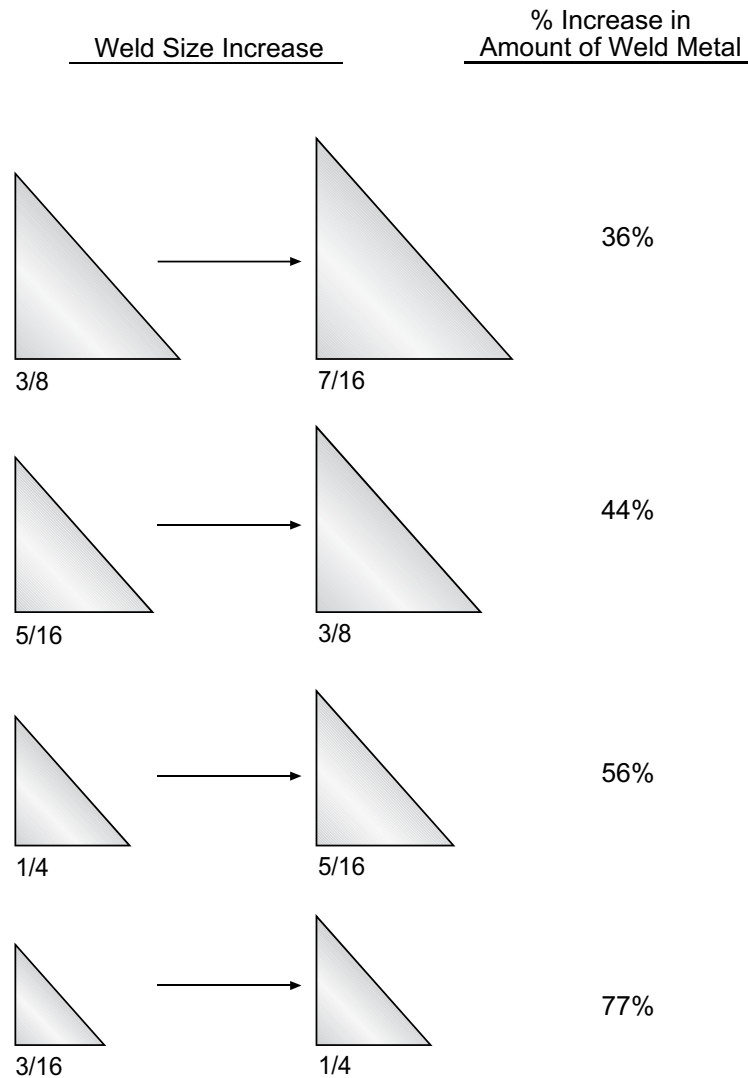


Figure 2.21—Cost of Overwelding

A very common overwelding problem, which can result from an incorrect transverse electrode angle, is a horizontal leg that is larger than required. As shown in the table in Figure 2.22, weld volume and costs are significantly affected by this type of problem.

Excessive convexity can also lead to unnecessary extra costs. Welding position, shielding gas, and other essential welding variables can affect the amount of convexity (see Figure 2.23).